Carbon Sequestration in New York State:
A Decade of Research

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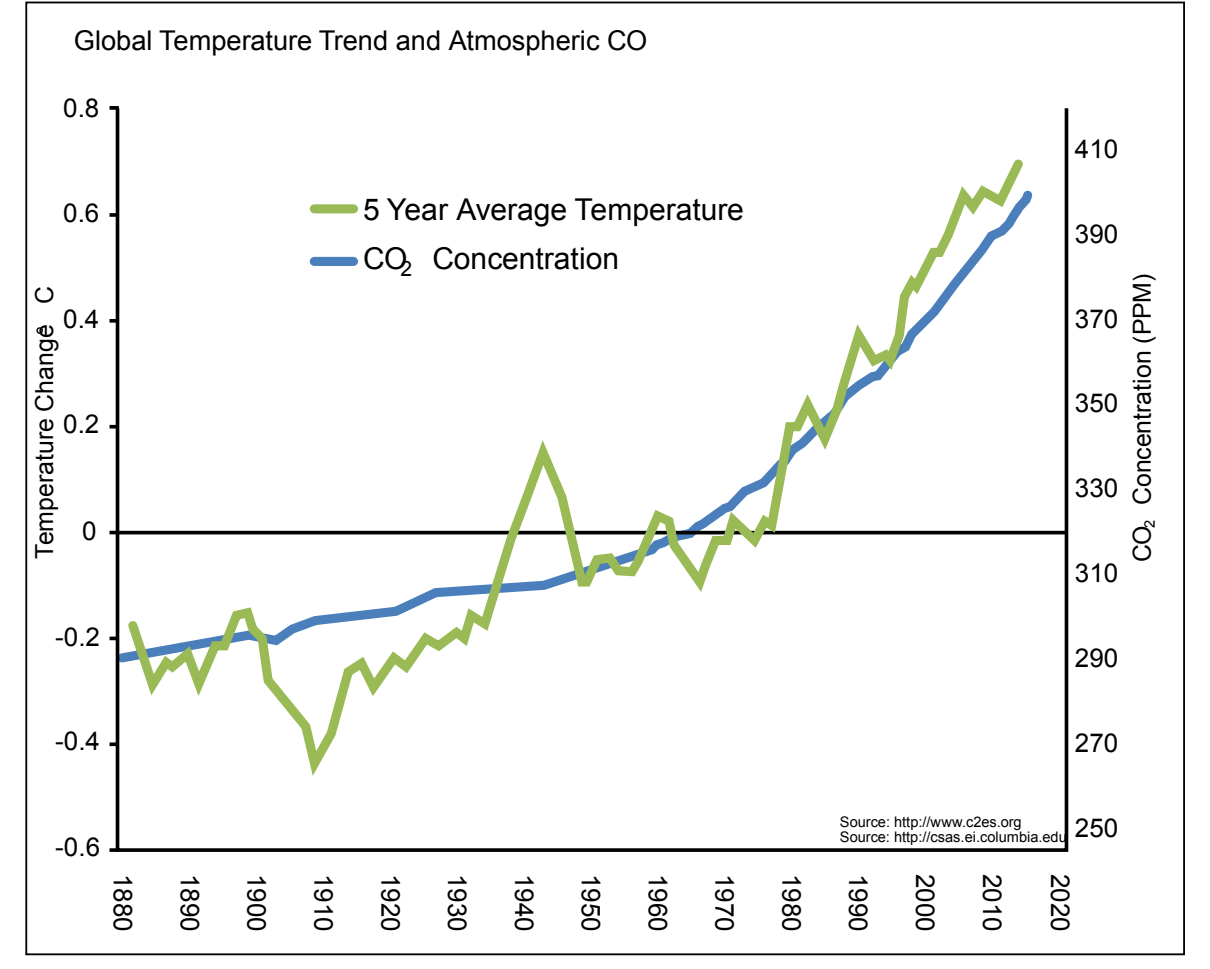
Abstract

The vast majority of scientists agree that global climate change is occurring, and that greenhouse gases such as carbon dioxide (CO_2) are a major contributor. The geologic sequestration of carbon dioxide has emerged as one of the leading methods for reducing the emission of greenhouse gases. Over the past ten years geologists at the New York State Museum and State Geological Survey have been involved in several projects that investigate the potential for sequestration of CO_2 in New York State. Sites of past and present projects include the Potsdam Sandstone in western NY, the Queenston Formation in central NY, the Newark Rift Basin in the tri-state area, and the Baltimore Canyon Trough south of Long Island. The geology of these areas is never simple and each study presents its own unique challenges which must be addressed through detailed scientific research. Although these projects are not all success stories, the data and analyses associated with each has added a wealth of knowledge to both the climate change community and overall geologic understanding of New York State.

CO_2 in the Atmosphere

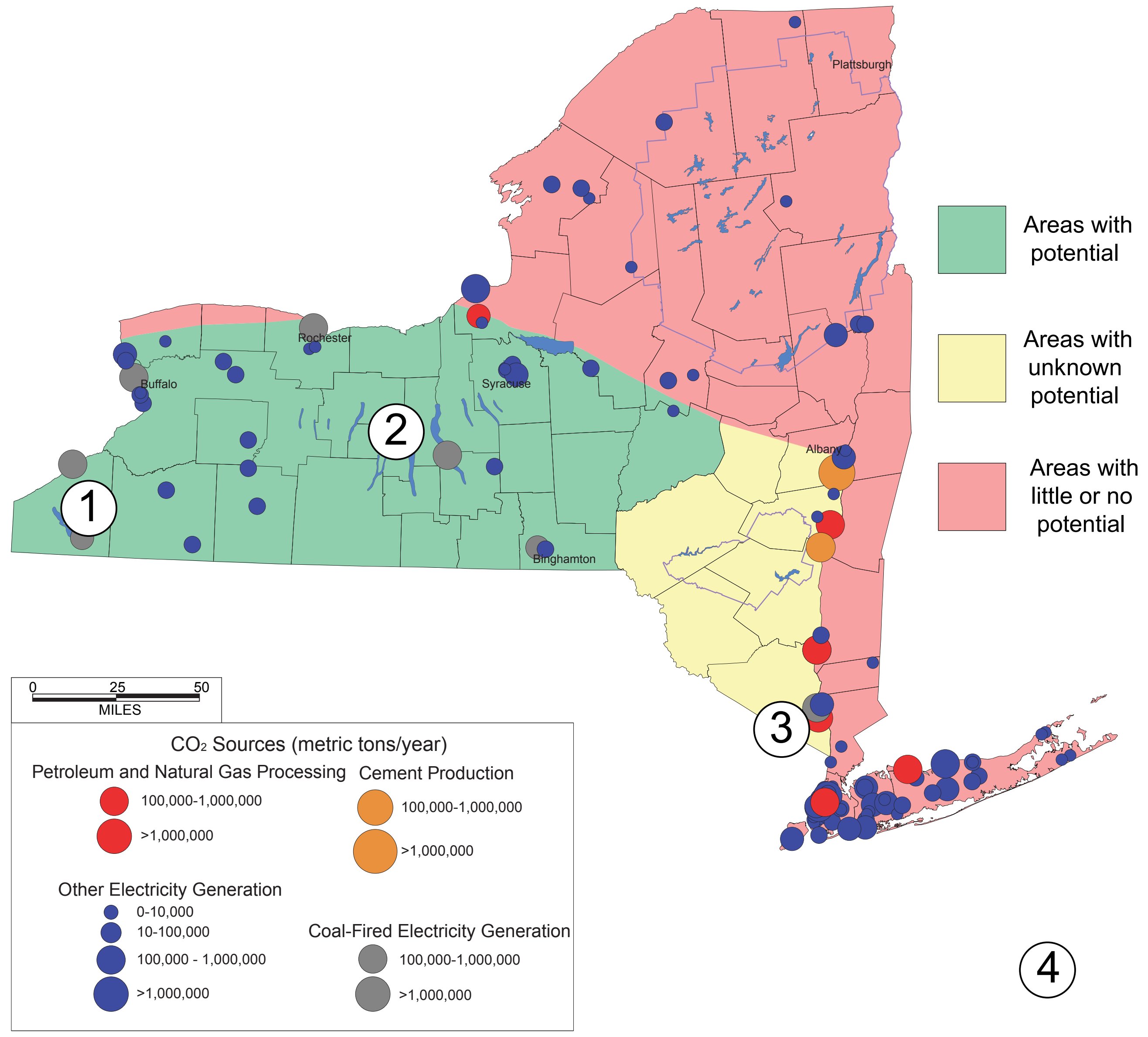


Source: http://www.c2es.org
Source: http://csas.ei.columbia.edu

The greenhouse gas carbon dioxide (CO_2) is a major contributor to climate change. It is released during combustion of fossil fuels such as coal. CO_2 levels in the atmosphere have increased significantly since the onset of the Industrial Revolution and atmospheric concentrations of CO_2 are now at their highest levels in 500,000 years.

Rising global temperatures have been documented and are projected to cause more frequent heat waves, droughts, severe storms, and other extreme weather events throughout the world. In New York State, climate change threatens natural resources, agriculture, human infrastructure, and public health.

CO2 Sources and Sequestration Potential in New York State



- 🟩 Areas with potential
- 🟨 Areas with unknown potential
- 🟥 Areas with little or no potential

CO_2 Sources (metric tons/year)

Petroleum and Natural Gas Processing
- ● 100,000-1,000,000
- ● >1,000,000

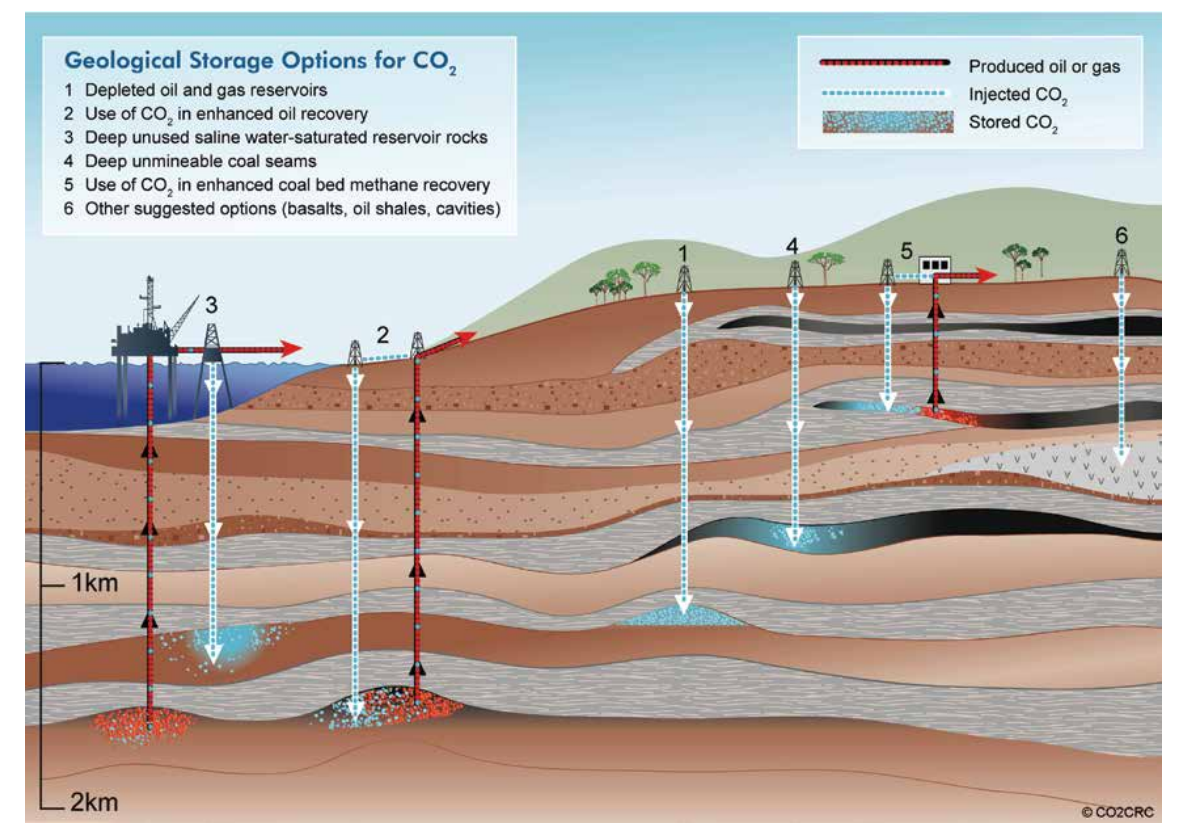
Cement Production
- ● 100,000-1,000,000
- ● >1,000,000

Other Electricity Generation
- ● 0-10,000
- ● 10-100,000
- ● 100,000 - 1,000,000
- ● >1,000,000

Coal-Fired Electricity Generation
- ● 100,000-1,000,000
- ● >1,000,000

How Do You Sequester CO_2?

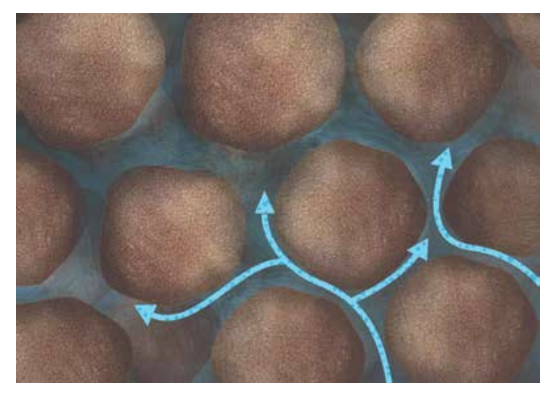
Carbon capture and sequestration is the process by which carbon dioxide is removed from the flue gases of large stationary sources, such as coal-burning power plants, and transported to a selected site where it is injected into deep underground reservoirs through specially designed wells. Since CO_2 is already a natural part of the Earth's system, once sequestered in the deep subsurface, it will eventually become a permanent part of the geologic environment through a series of natural processes.



Porosity

Porosity is a measure of the amount of space between the grains of rock. This space is typically filled with a salty fluid that is displaced by the injected CO_2. Rock units with porosities less than 5% are generally not considered suitable for sequestration.

Permeability

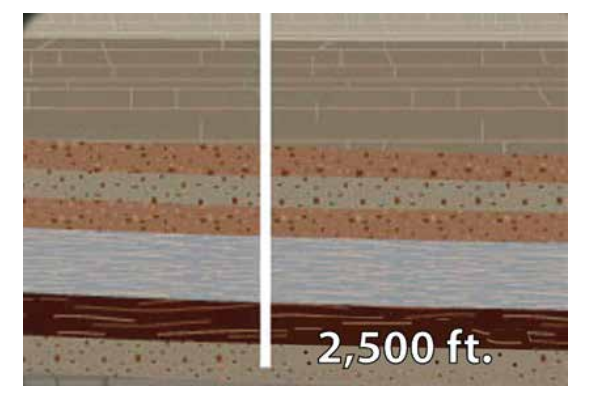


Permeability refers to how well the pores of a rock are interconnected. It is possible to have a rock with high porosity, but if the pores are isolated, the CO_2 will be unable to flow away from the injection site.

Cap Rock

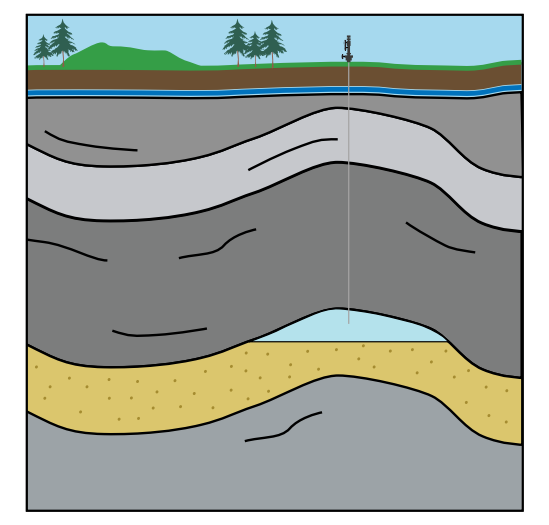
To be suitable for sequestration, a formation must also lie beneath layers of impermeable rock that will provide a "cap" or seal to prevent upward migration of the CO_2. Cap rocks can be any type of rock as long as it has low permeability and is free of open faults.

Depth



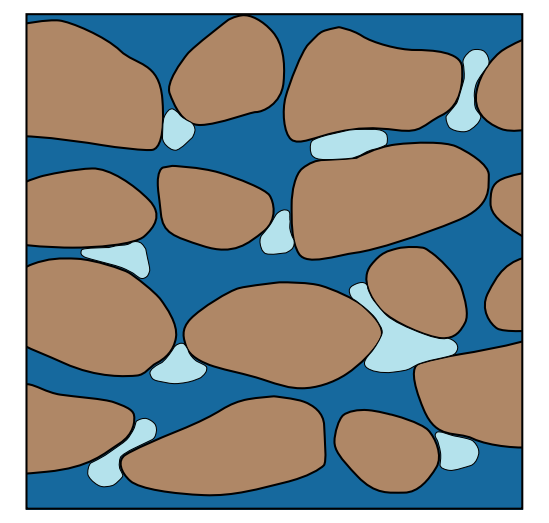
Much more CO_2 can be sequestered if it is kept as a supercritical fluid. To ensure that injected CO_2 remains in a supercritical state, sequestration reservoirs must be at least 2,500 feet below the ground surface. Below this depth, temperatures and pressures are high enough for stable storage of supercritical CO_2.

Structural Trapping



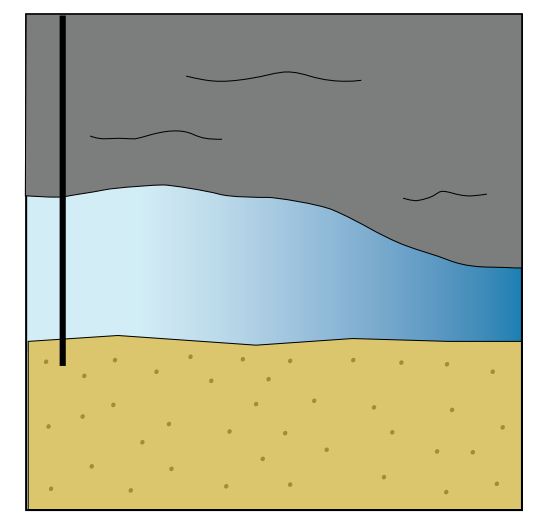
This is the most dominant of the trapping mechanisms. Once injected, the supercritical CO_2 can be more buoyant than other liquids that might be present in the pore space. The CO_2 will therefore migrate upward through the porous rocks until it reaches an impermeable layer of cap rock.

Residual Trapping



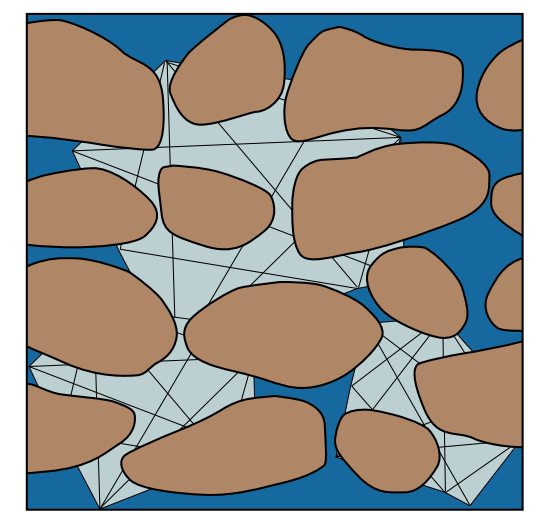
As the supercritical CO_2 is injected into the formation it displaces fluid as it moves through the reservoir rock. As it moves, some will be left behind as disconnected, or residual, droplets. The main difference between residual and structural trapping is that if the cap rock were removed, residually trapped CO_2 would not escape.

Dissolution Trapping



Over time, supercritical CO_2 dissolves in other fluids. This phase in the trapping process involves sequestered CO_2 dissolving into the salt water (or brine) already present in the reservoir. As CO_2 dissolves into the formation fluid it becomes more dense and will eventually sink to the bottom of the rock formation.

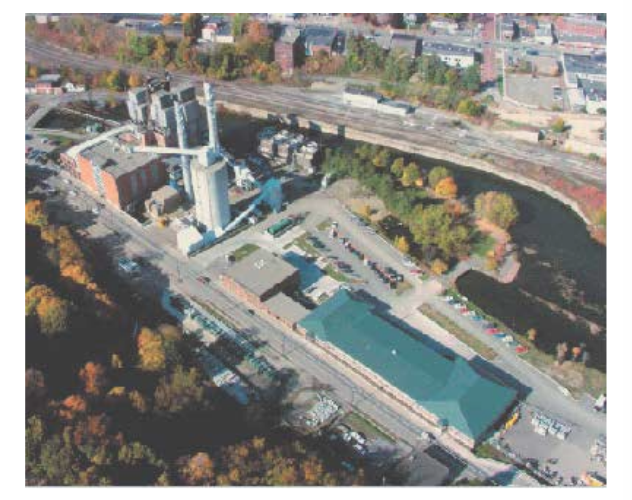
Mineral Trapping

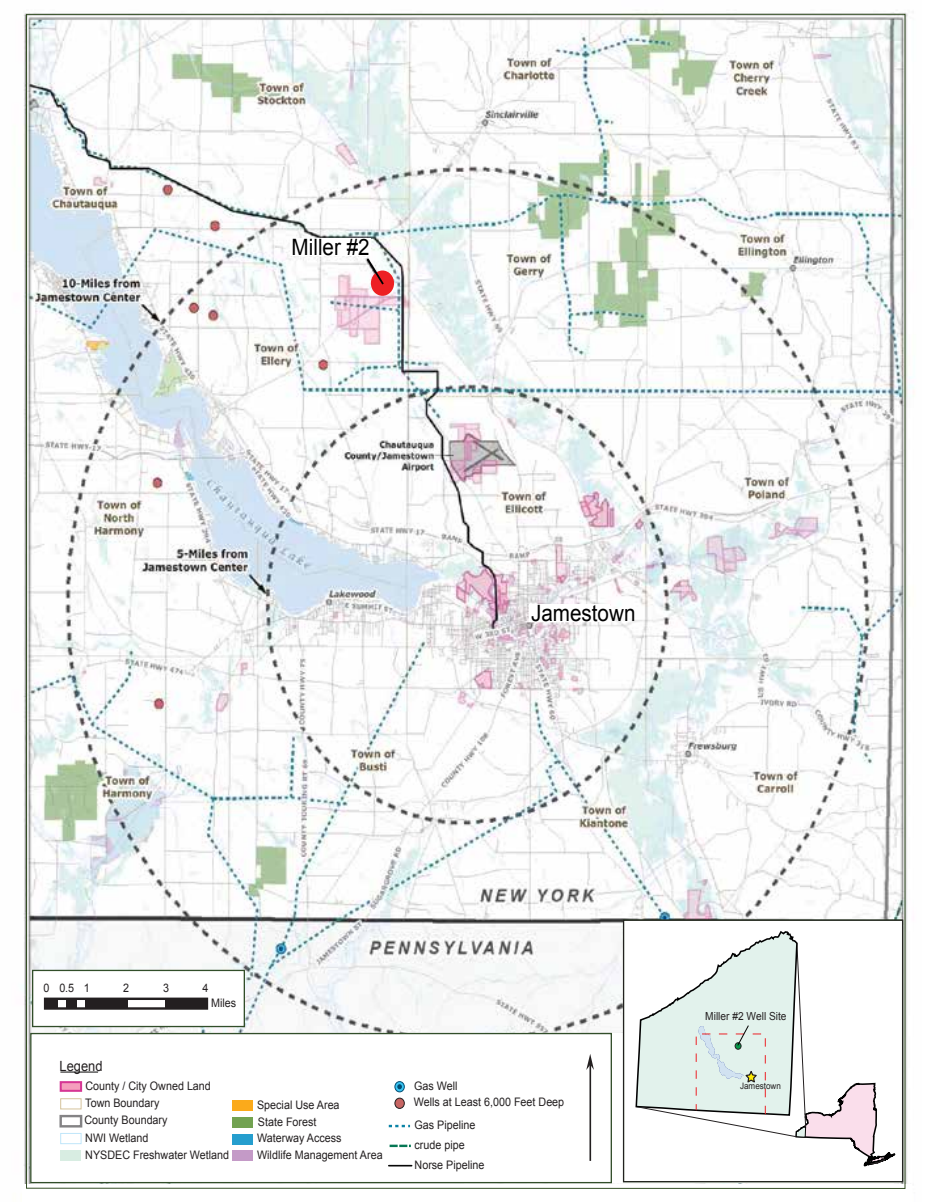


When CO_2 dissolves in water it forms a weak carbonic acid. Over time, this acid can react with the surrounding rock and precipitate new carbonate minerals. This process can be rapid or very slow depending on the chemistry of the rock and water in a specific storage site. This is the most secure form of trapping because it effectively sequesters CO_2 as a solid.

① Jamestown - Chautauqua County

In 2008, the Jamestown Bureau of Public Utilities (BPU) began a project to investigate the possibility of replacing their current coal-fired power plant with a new oxy-fuel combustion plant with near-site carbon capture and storage. Their intention was to sequester the CO_2 produced by the plant in the Rose Run and Potsdam Sandstones which are estimated to lie over 6,000 feet below the surface in the Jamestown area, Chautauqua, NY. As part of their site characterization, the Jamestown BPU partnered with Unbridled Energy to drill a well for the purpose of collecting rock samples and data for evaluation.



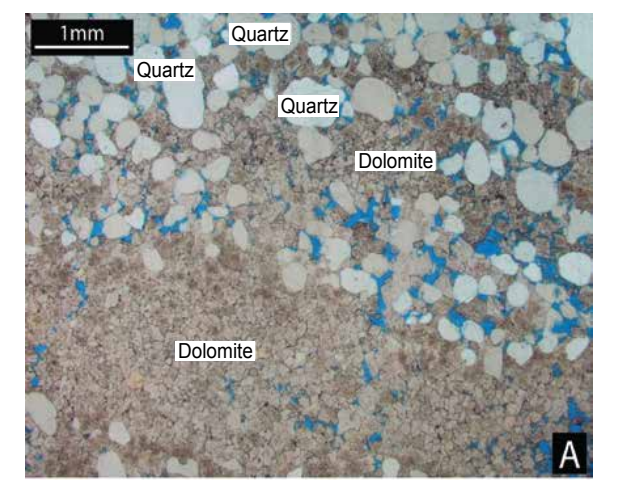


In April of 2009 the Miller #2 well (API#31-013-25737-00-00) was drilled roughly 8 miles north of the city of Jamestown. The well reached a total depth of 7,312 feet and captured over 150 feet of continuous core along with 50 rotary sidewall plugs. After analyzing the samples and well logs, it was determined that the Potsdam Sandstone was either not reached or absent at the site. The Rose Run, however, was sampled by the core and found to be approximately 180 feet thick.

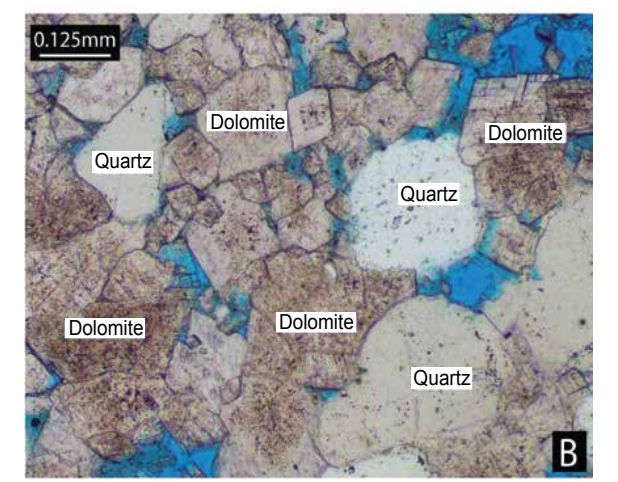
The core was described by geologists at the State Survey and samples were sent to a lab for porosity and permeability measurements. Thin sections were also made from the samples so that mineralogy and pore characteristics could be determined.

Lab results indicate that the Rose Run Sandstone has porosities as high as 5.6%, but the permeability measurements were lower than predicted with an average of 0.1 mD. After analyzing the core and thin sections, the survey geologists concluded that the Rose Run had undergone secondary mineralization. This means that the original porosity and permeability of the sandstone may have been much higher, but at some point in the formation's history, fluids passed through the rock and precipitated minerals like dolomite, which filled the pore spaces.

The lack of permeability at Miller #2 site has put the Jamestown project on hold, however several members of the team believe that mineralization at the drill site was a localized event and that there may be other areas near the city where the Rose Run is suitable for CO_2 sequestration.



1.5x optical zoom

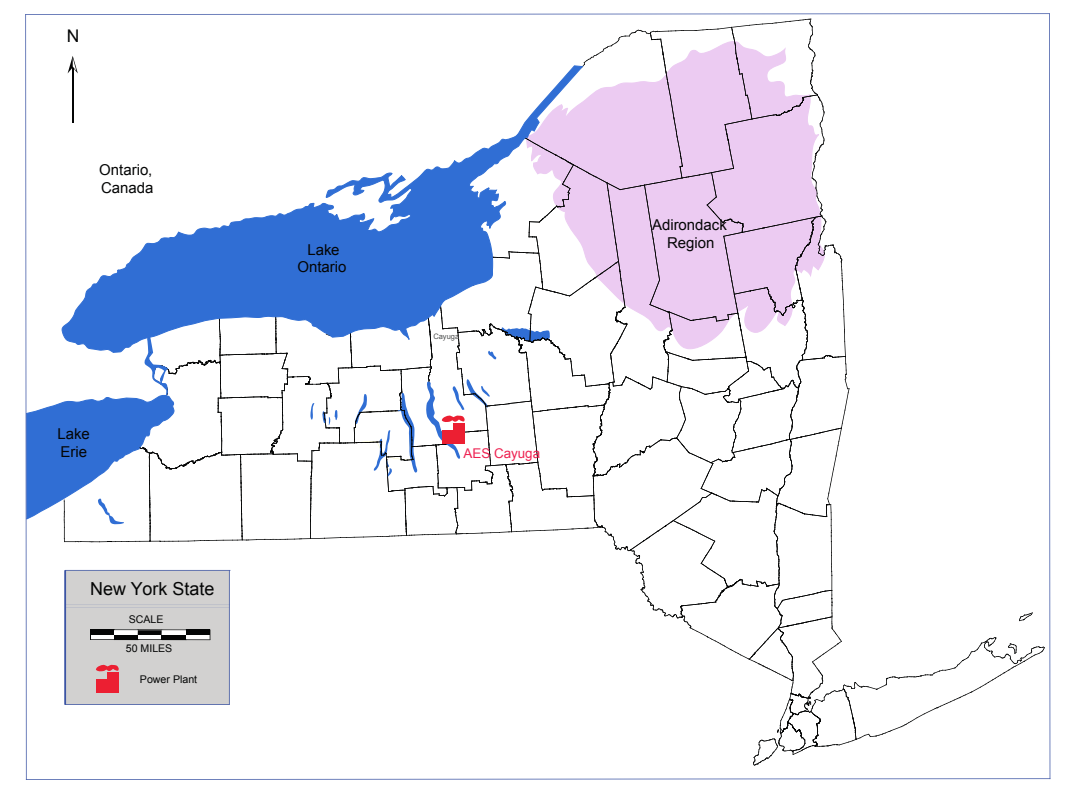


10x optical zoom

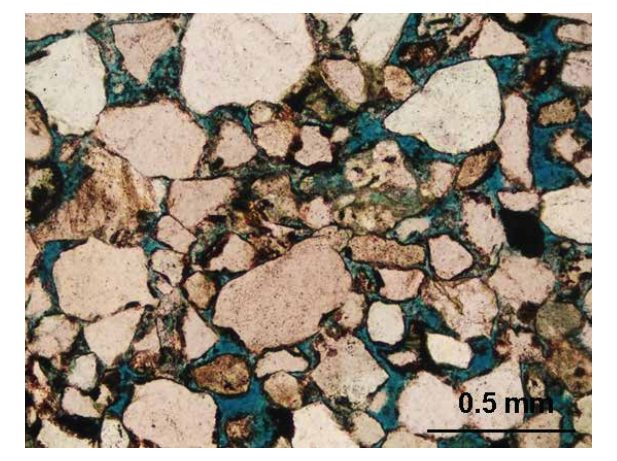
This thin section from the Rose Run Sandstone at 6,345 feet shows dolomite crystals (light brown) occupying the pore space (blue) between quartz grains (white to tan). This sandstone would have significantly higher porosity and permeability if not for the presence of dolomite.

② Cayuga - Central NY

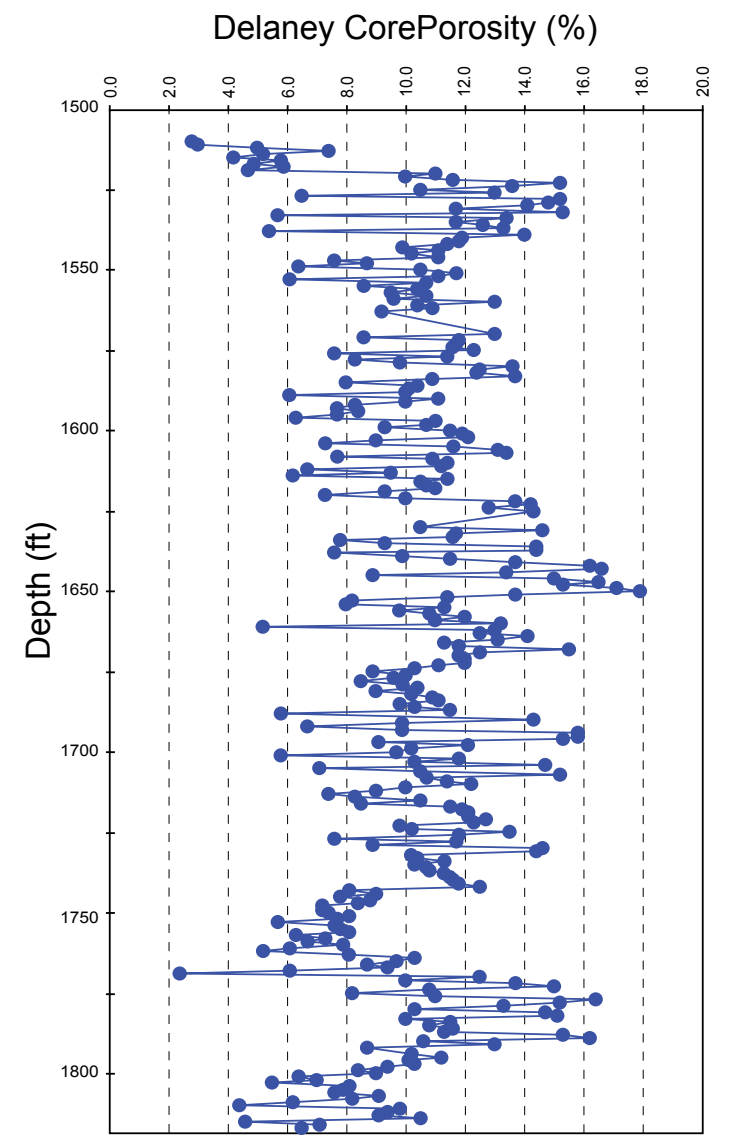
In 2010, Kathryn Tamulonis, a graduate student at Cornell University, completed a doctoral thesis in which she assessed the carbon sequestration potential of the Queenston Formation near the AES Cayuga coal-fired power plant in Tompkins County, central New York.

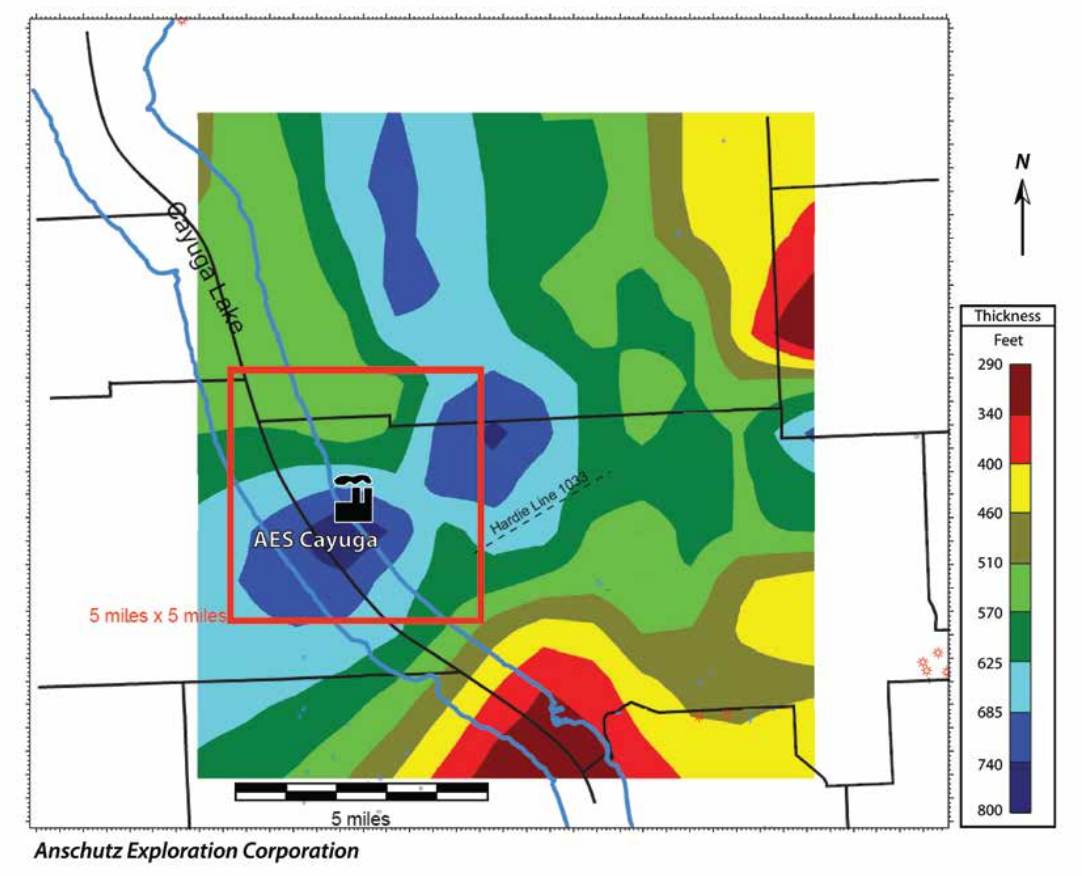


The Queenston is primarily a shale in most parts of the state, however in central NY, it occurs as a quartz sandstone with some dolomite deposited in non-marine, fluvial environments such as breaded streams.



With help from geologists at the New York State Survey, Dr. Tamulonis used the logs from nearby wells and samples from the survey's core collection to fully describe the reservoir qualities of the Queenston Formation in central NY. Porosity measurements taken from the Delaney core have a range of values from 2.5 to 18% with an average of about 10%.





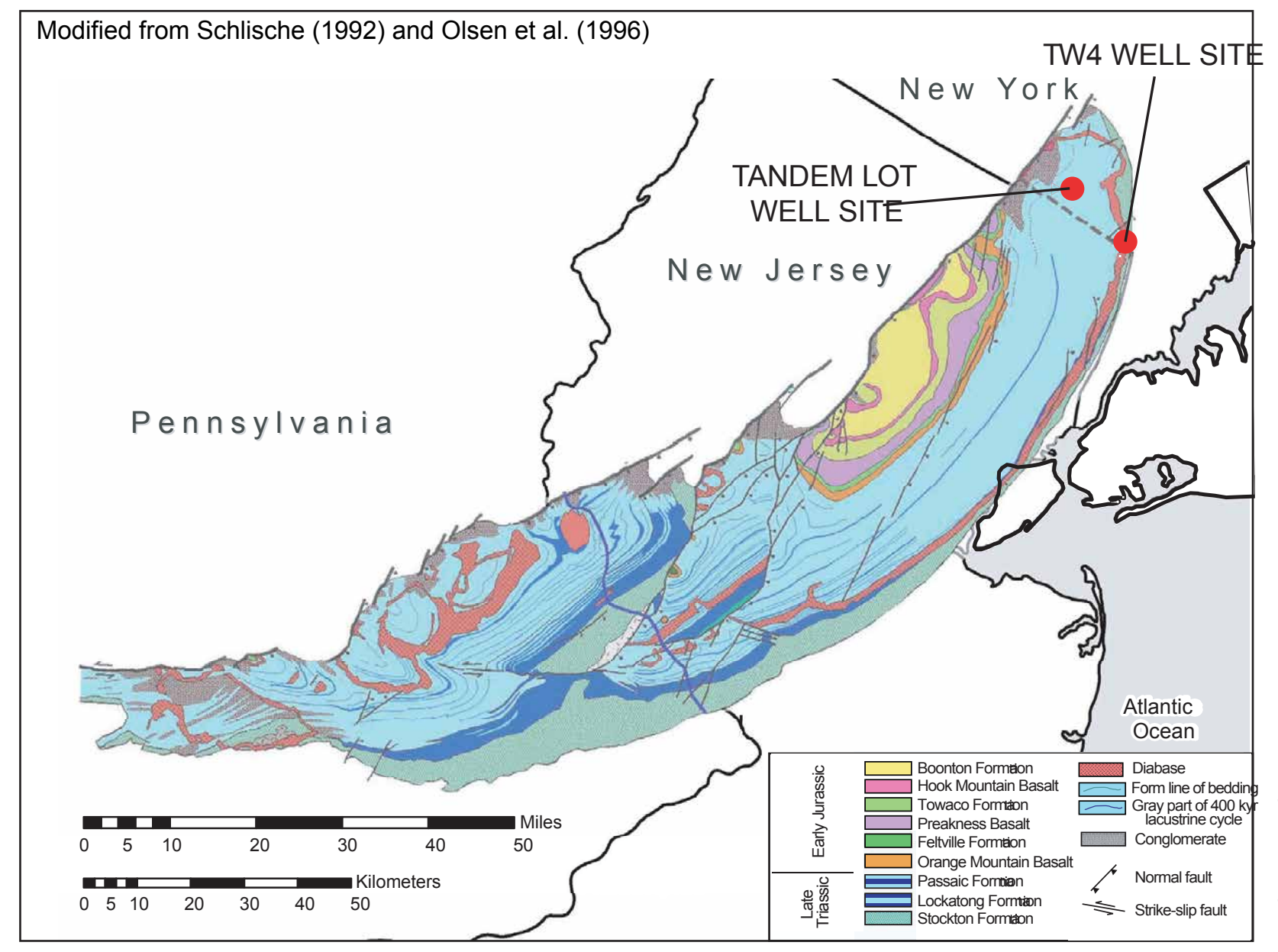
Anschutz Exploration Corporation

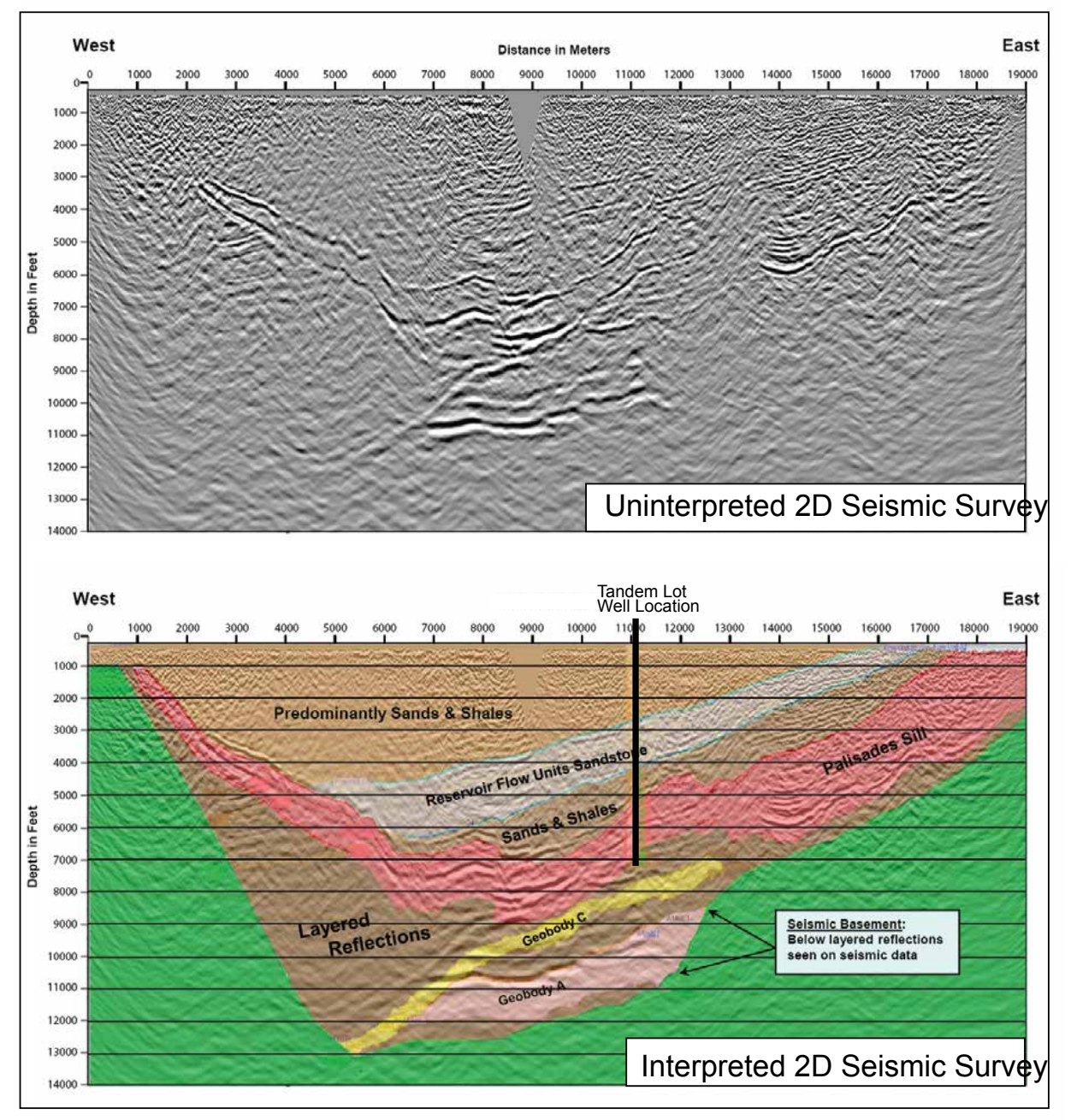
This high resolution isopach map based on seismic data indicates that the Cayuga power plant is located above an especially thick section of the Queenston sandstone (>700ft). Dr. Tamulonis has calculated that the 25 square mile area surrounding the power plant has the capacity to hold approximately 18 million tons of CO_2 which is equivalent to 8 years of output from the plant. Unfortunately the current cost of retro-fitting the Cayuga power plant with carbon capture technology is too high to be economically feasible without substantial government incentives.

③ Newark Basin (TriCarb Project)

The Newark Rift Basin is an elongate half-graben measuring 120 miles long and 30 miles wide at its widest point. It extends from eastern Pennsylvania, through northern New Jersey, and into south eastern New York. Similar to the Baltimore Canyon Trough (see MRCSP / Offshore), the Newark Basin formed during the breakup of Pangea and birth of the Atlantic Ocean. Over the next 35 million years the basin gradually filled with Triassic and Jurassic aged sediments. Later an igneous intrusion commonly called the Palisades Sill was intruded into the basin.

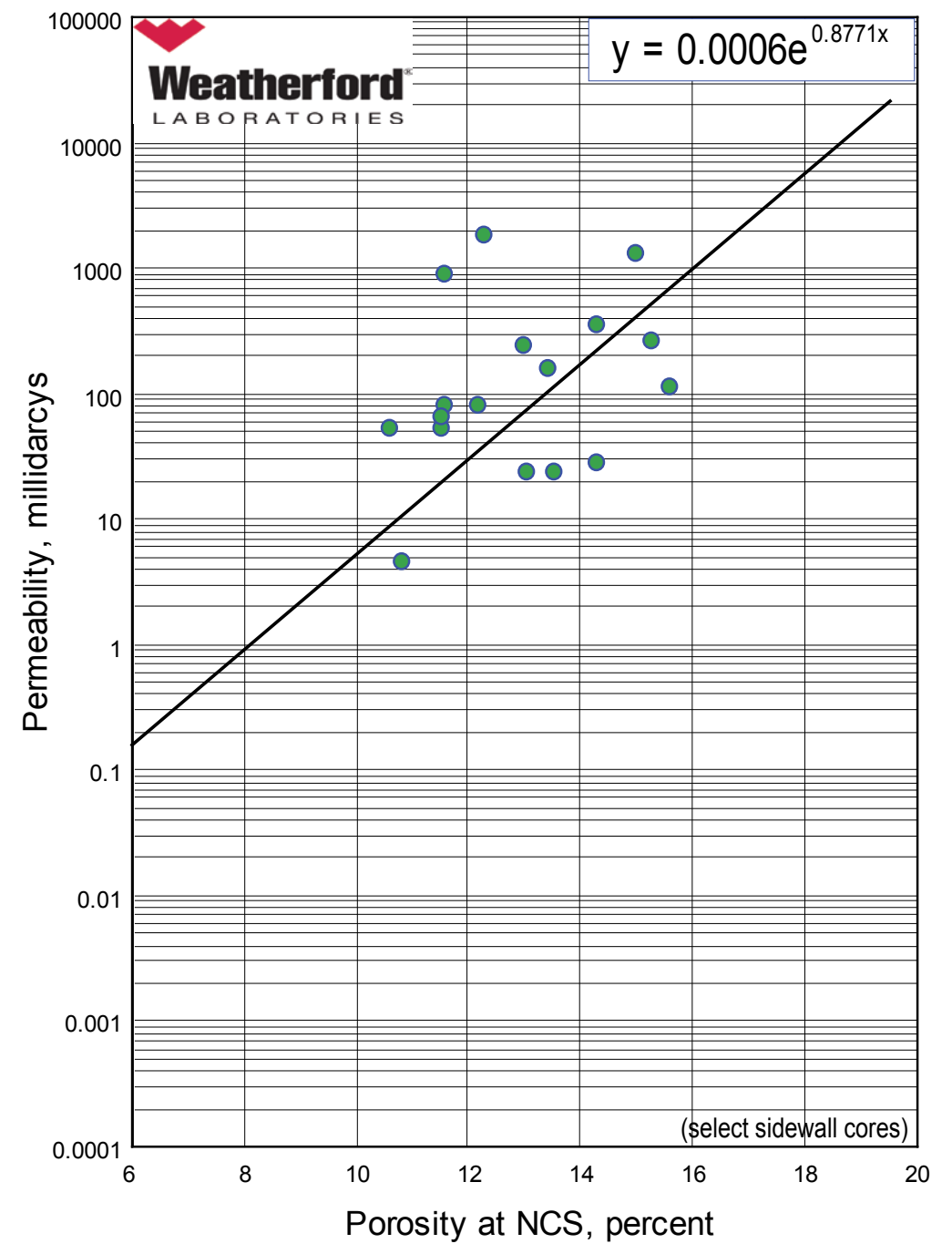
Modified from Schlische (1992) and Olsen et al. (1996)

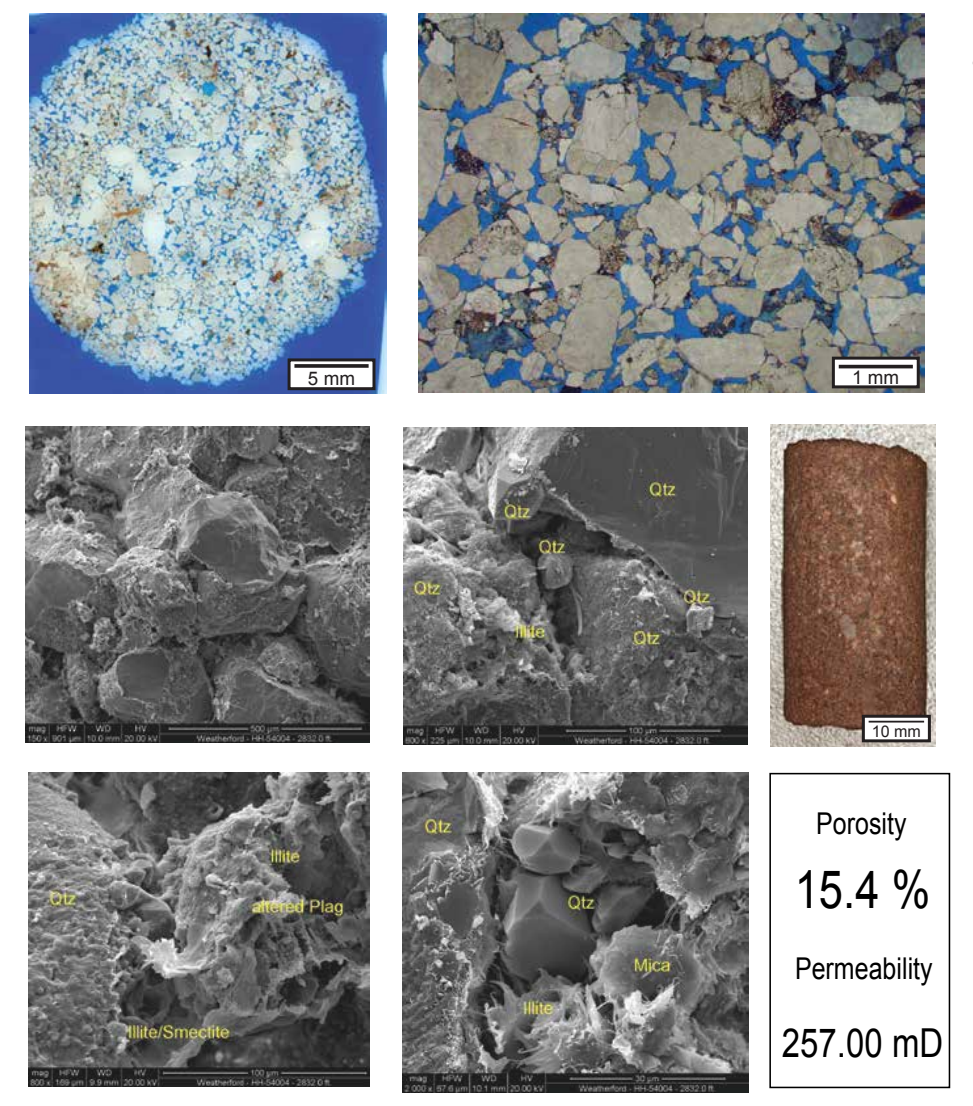




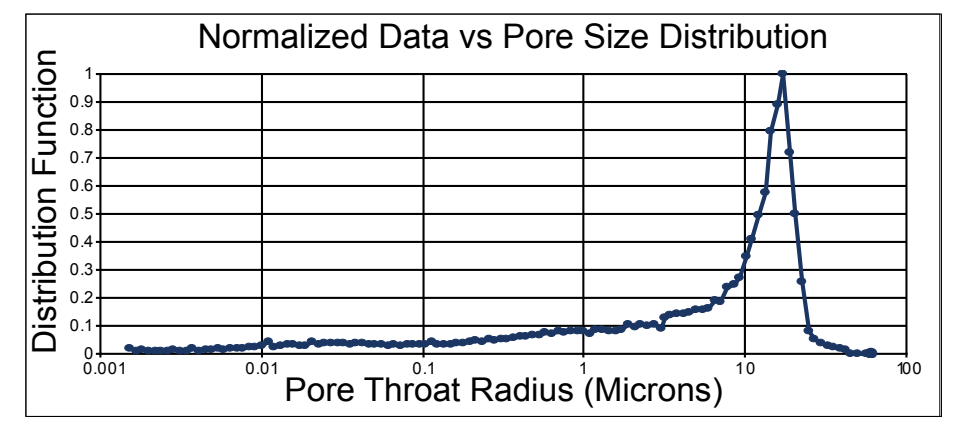
In October of 2011 the tandem lot well (API#31-087-27016-00-00) was drilled in Rockland County to a depth of 6,885 feet. As a result of that well, a 1,300 foot section of the Passaic Formation between 2,000 and 3,300 feet was found to have sandstones with between 10 and 17% porosity and permeabilities greater than 1,500 millidarcies. These qualities make the section an excellent reservoir, but because there is no cap rock between this zone and the 2,500 foot depth mark, supercritical sequestration would not be possible at the well site. However, the bedrock formations in the basin do not lie perfectly flat, and there may be other areas where this section, or similar sections, are deeper and possibly below the sill.

A total of 75 horizontal sidewall cores were collected from the Tandem Lot Well. Thin sections were made from each plug and porosity / permeability tests were conducted on most samples. 17 sidewalls were collected from the potential reservoir zone between 2,000 and 3,300 feet. Porosity values for these samples range from 10.9 to 15.7%, with an average of 13.0%. Permeability values are highly variable, but average 337 mD.





Porosity
15.4 %
Permeability
257.00 mD



This sample of the Passaic Formation was collected from the Tandem Lot Well at 2,832 feet. Laboratory measurement indicate that this sandstone has a porosity of 15.4% and a permeability of 257 millidarcies.

In August and September of 2013 a second well, TW4 (API#31-087-30000-00-00), was drilled on Columbia University's Lamont-Doherty campus to a depth of 1,803 feet. Over 1,000 feet of core was collected below the Palisades Diabase, the vast majority of which (>80%) appears to be reasonably porous sandstones. Porosity / Permeability measurments from 9 core samples average 12.7% and 9.4mD. This well is not deep enough to be an injection site, but the sandstone units at this site may be traced to deeper parts of the basin.

Lamont-Doherty Earth Observatory
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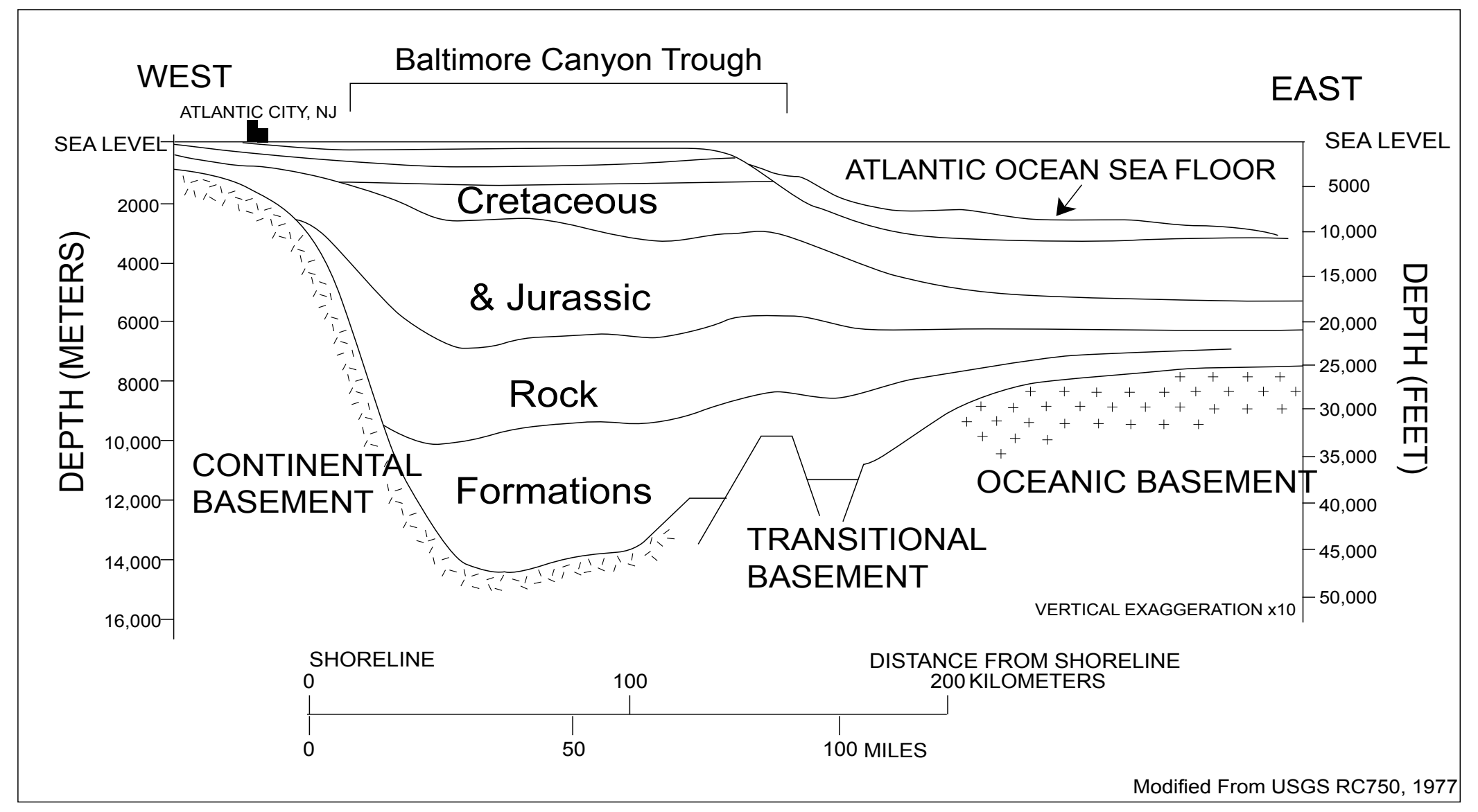
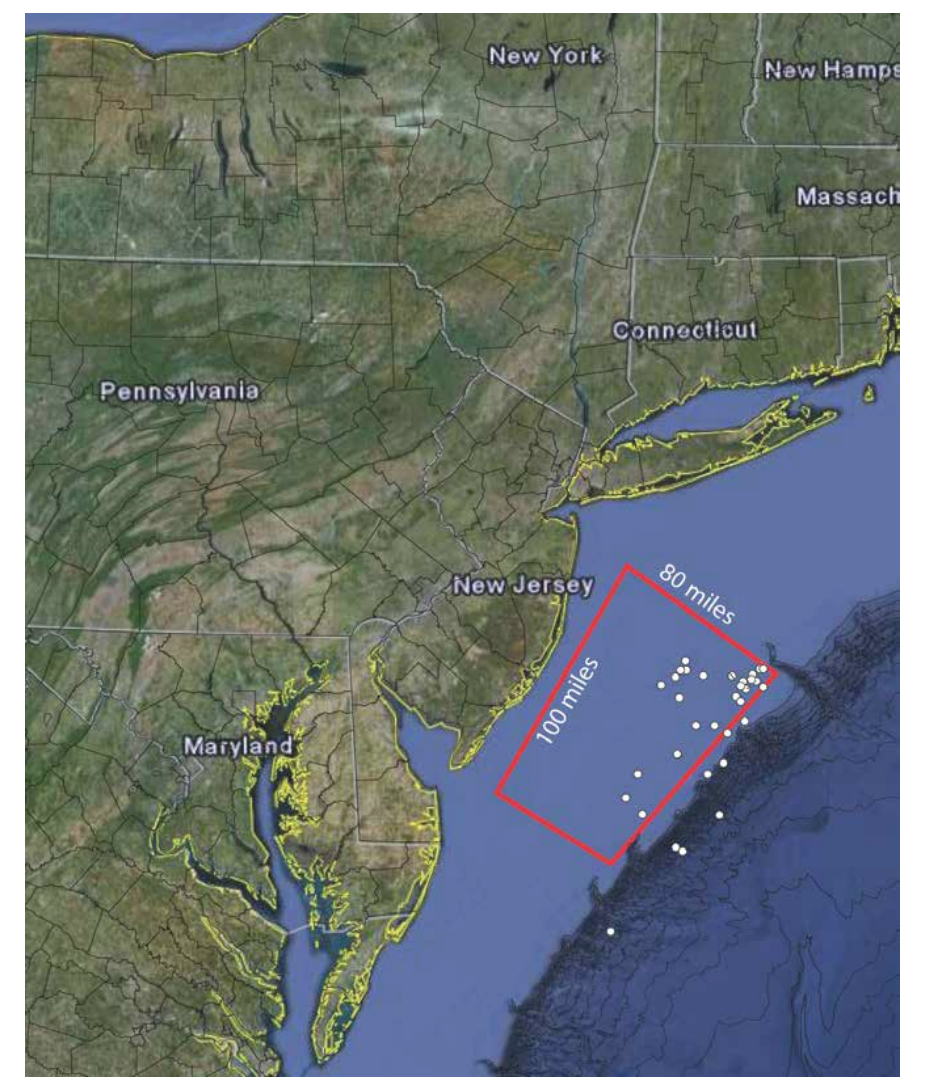
④ Offshore - Baltimore Canyon Trough

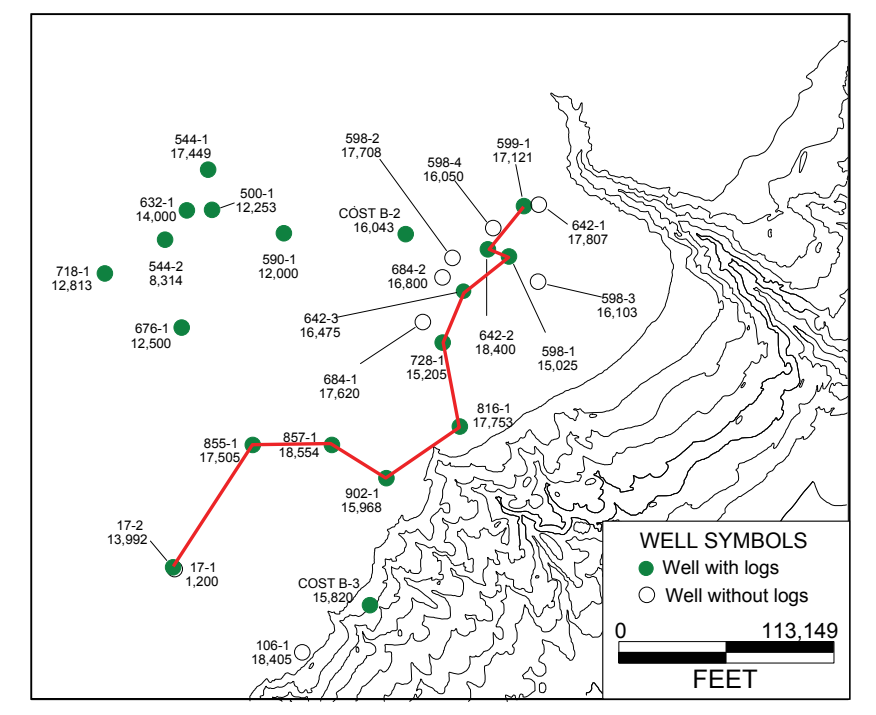
A large portion of the continental shelf to the south of Long Island and east of New Jersey is defined by a geological structure known as the Baltimore Canyon Trough (BCT). The BCT formed during the break up of the Pangea Supercontinent approximately 200 million years ago. As North America began to separate from Africa, a series of rift valleys formed along the eastern margin of the United States. As the rifting continued and the Atlantic Ocean grew wider, the BCT and other basins filled with sediments that later formed limestones, sandstones, and shales.

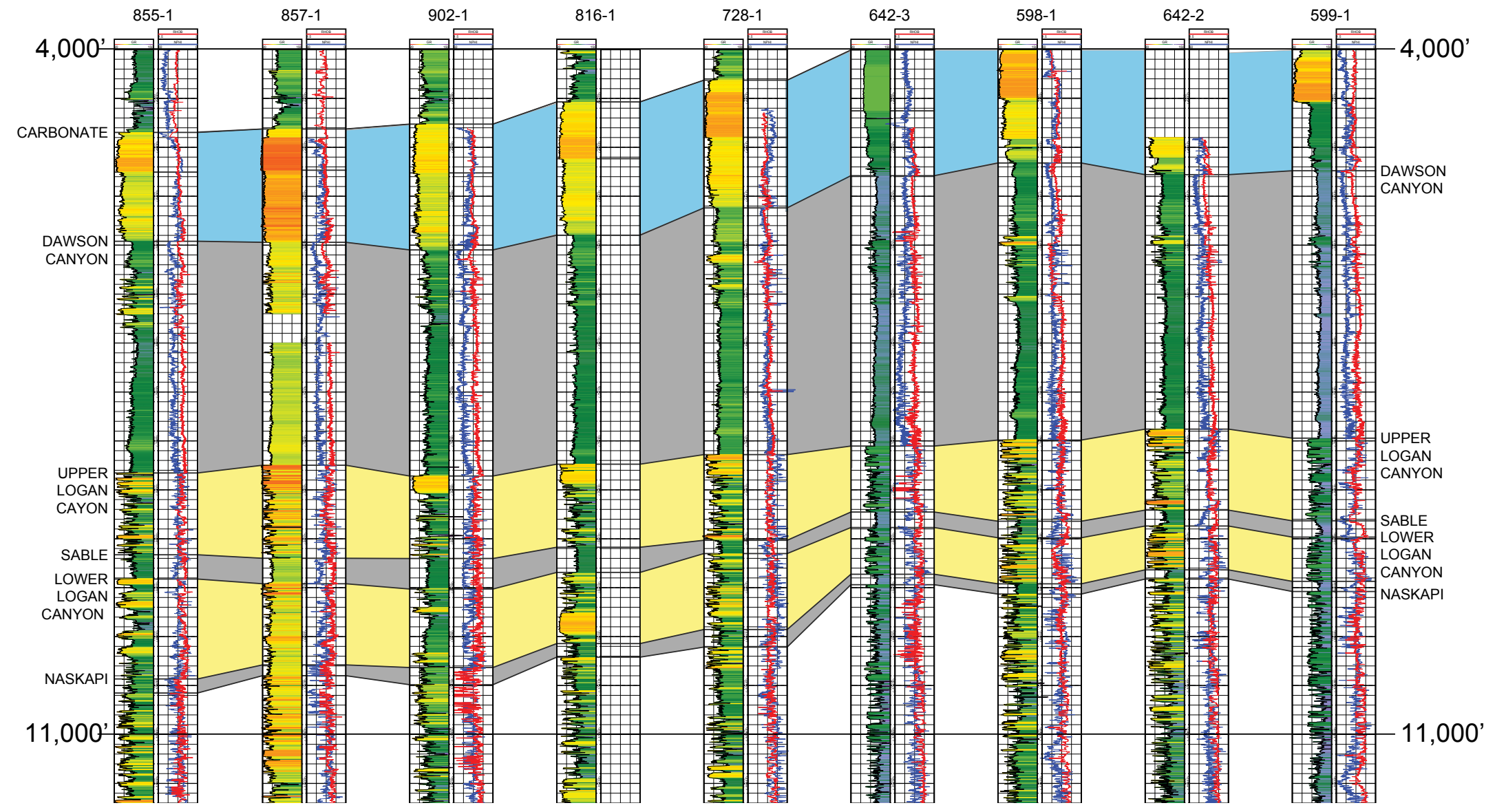


Modified From USGS RC750, 1977



Although the Midwest Region Carbon Sequestration Partnership has only been examining the BCT for a short time, geologists have identified three formations that appear to have excellent qualities for carbon sequestration. The Upper Logan Canyon, Lower Logan Canyon, and Mississauga Sandstones all occur at depths greater than 2,500 feet and have extremely high porosities and permeabilities in the places where they have been sampled. These formations are also overlain by thousands of feet of shale which would act as a "lid" by preventing upward movement of sequestered CO_2. The MRCSP offshore team, including the New York Geological Survey, is currently working to fully characterize both the sandstones and cap rocks to evaluate their full sequestration potential.





Southwest to Northeast cross section through 10 wells in the study area. There is a significant thickness (>1000 feet) of Upper and Lower Logan Canyon Sandstones overlain by the Dawson Canyon Mudstones. Well logs and limited sampling indicate that the Logan Canyon has porosities >20% and permeabilites of 100+ mD.

ACKNOWLEDGMENTS

The New York State Geological Survey would like to thank all of the sponsors of these research projects including: NYSERDA, The United States Department of Energy, Cornell University, The TriCarb Consortium, and The Midwest Region Carbon Sequestration Partnership (MRCSP). Without their help and funding, none of this research would have been possible.

NOTICE