

PS Preliminary Results from the TriCarb Deep Stratigraphic Well drilled into the Newark Rift Basin, Rockland County, New York*

Brian E. Slater¹, Langhorne Smith¹, Matthew P. Tymchak², and Daniel J. Collins³

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Abstract

The TriCarb Consortium for Carbon Sequestration (TCCS) is a partnership consisting of researchers from industry, academia, and government with a common interest in CO₂ sequestration. As part of their ongoing attempt to characterize the sequestration potential of the Newark Rift Basin, the TCCS oversaw the citing, permitting, and drilling of a deep stratigraphic well at the northern tip of the basin, in Rockland County, New York. This well penetrated the Late Triassic Passaic Formation as well as the full thickness of the Palisades Sill, reaching a total depth of 6,881 feet. Data acquired from this well includes over 150 feet of continuous core, 50 sidewall cores, and a full suite of wireline logs (PEX, ECS, HRLA, DSI, and FMI). Sample depths were chosen to acquire specimens from both potential cap rocks and porous intervals. Results from the laboratory analysis of these samples indicate that there are several intervals with porosities greater than 10% and permeabilities of over 100mD. Preliminary results from this well give good reason to believe that a significant amount of supercritical carbon dioxide could be sequestered in areas of the Newark Rift Basin.

Preliminary Results from the TriCarb Deep Stratigraphic Well drilled into the Newark Rift Basin, Rockland County, NY



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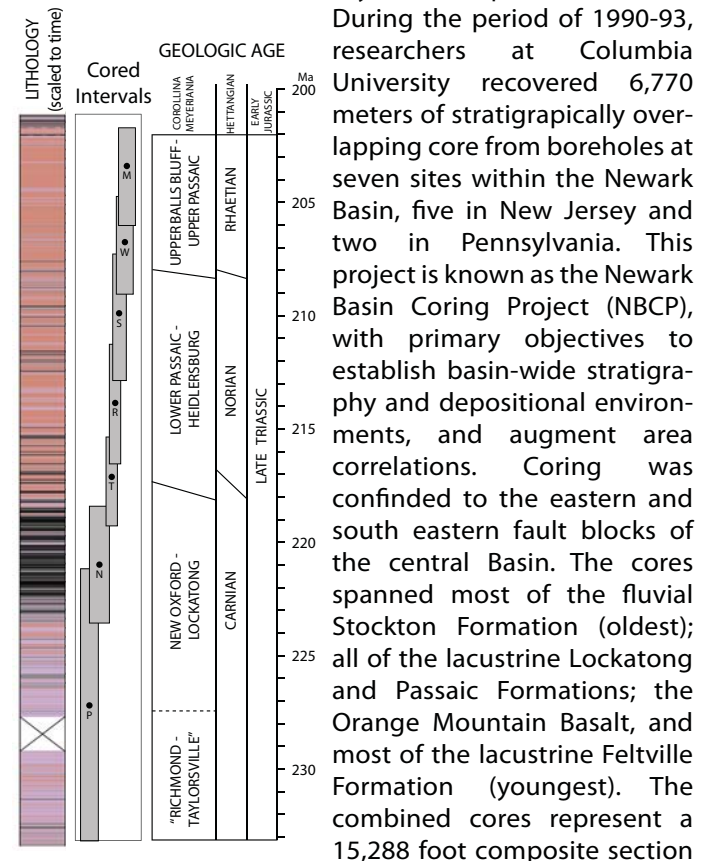


Abstract:

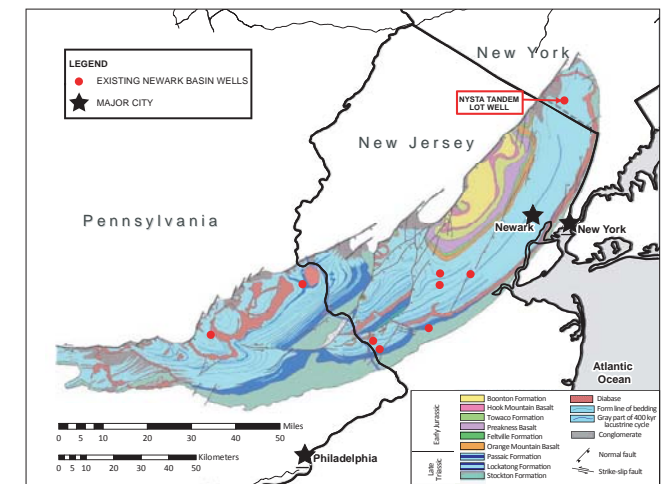
The TriCarb Consortium for Carbon Sequestration (TCCS) is a partnership consisting of researchers from industry, academia, and government with a common interest in CO₂ sequestration. As part of their ongoing attempt to characterize the sequestration potential of the Newark Rift Basin, the TCCS oversaw the citing, permitting, and drilling of a deep stratigraphic well at the northern tip of the basin, in Rockland County, New York. This well penetrated the Late Triassic Passaic Formation as well as the full thickness of the Palisades Sill, reaching a total depth of 6,881 feet. Data acquired from this well includes over 150 feet of continuous core, 50 sidewall cores, and a full suite of wireline logs (PEX, ECS, HRLA, DSI, and FMI). Sample depths were chosen to acquire specimens from both potential cap rocks and porous intervals. Porosity, permeability, and mineralogy analyses have been run on sidewall cores as well as samples from the whole core. Thin sections were also made from each sample and used to compliment core description and log interpretations. Preliminary results suggest that there are may be several intervals that meet the criteria for sequestration of supercritical carbon dioxide.

Background:

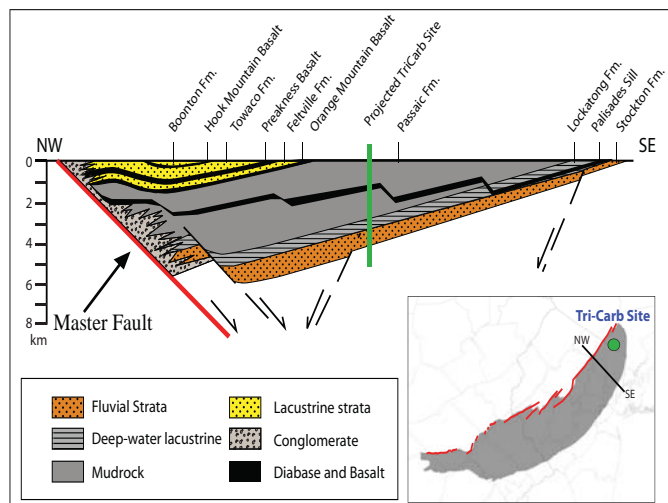
The Newark Basin is an elongate half-graben encompassing an area of more than 7,000 square km, extending from southeastern New York, through northern New Jersey, and into eastern Pennsylvania. The Basin is approximately 190 km long and 50 km wide at its widest point. It is bounded to the northwest by the Ramapo Fault Zone.



age rocks with individual core intervals ranging from 373 ft. to 4,015 ft. None of the cores were deep enough to penetrate the unconformity separating the basal Triassic Stockton from the underlying Paleozoic formations.



Geologic and structural map of the Newark Basin illustrating deep stratigraphic borehole locations and proximal CO₂ emitters. The Basin is an elongate half-graben and is approximately 190 km long and 50 km at its widest point, and is bounded to the northwest by the Ramapo Fault Zone. Modified from Schiliche (1992) and Olsen et al. (1996).



This cartoon of the basin geology highlights the master fault (red) on the northwest side. The cross section was taken near the northern end of the basin in New Jersey and shows the northwest-dipping strata along with the a projection of the approximate TriCarb well site in New York (green).

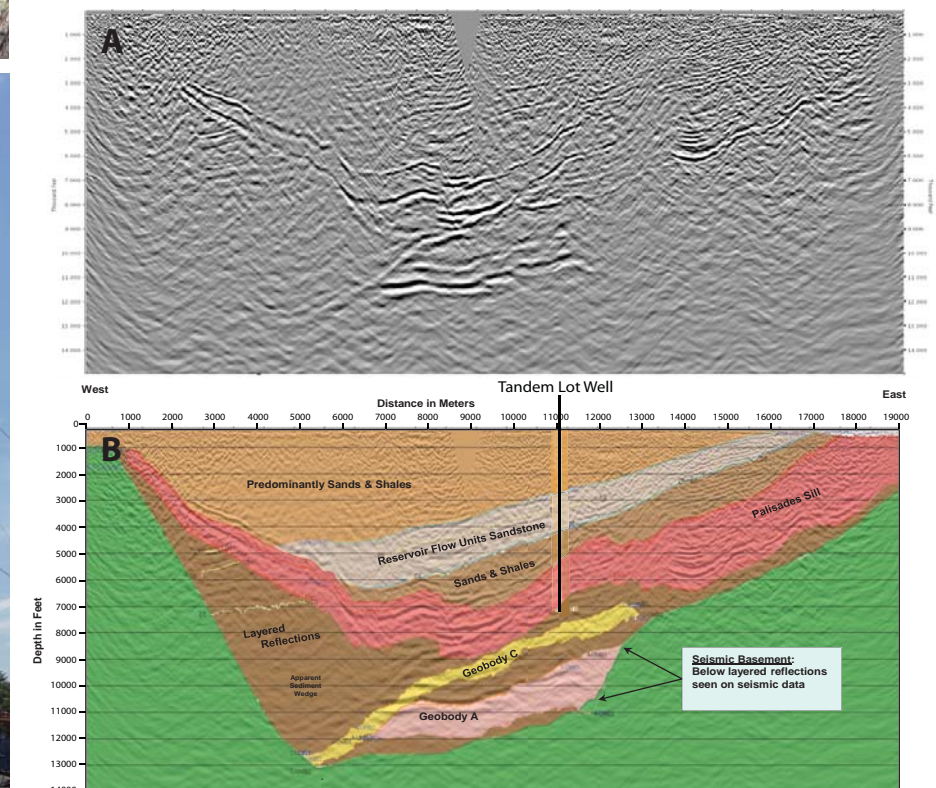
Siting and Drilling the Tandem Lot Well:



A photo of the Union rig #18 drilling the Tandem Lot Well in October of 2011. This well attracted a significant amount of attention from the general public as it was located in the clover-leaf of Exit 14 on I-287 only 20 miles from Manhattan

The Tandem Lot Well was sighted in the New York State Thruway Authority's (NYSTA) tandem truck lot adjacent to west-bound entrance to I-287 at Exit 14. The site was chosen due to its central location in the northern part of the Newark Basin, and its accessibility for equipment. Additionally, this site is advantageous because it is directly adjacent to the 13 mile E-W seismic line shot along I-287. The well was permitted through three agencies; the USEPA, New York State Department of Conservation (NYSDEC), and the Rockland County Department of Health (RCDOH). The NYSDEC issued permits to drill, plug, and abandon the well in May, 2011. Surface casing for the well was completed by Ziegenfuss Drilling Inc., and the borehole was completed at a total depth of 6,881 feet by Union Drilling Inc. in October 2011. 150 feet of continuous core was collected during drilling. 50 sidewall cores and a full suite of wireline logs (PEX, ECS, HRLA, DSI, and FMI) were collected prior to plugging. Site restoration was completed in December 2011.

The TriCarb 2-D seismic survey was completed in Rockland County, New York and northern Bergen County, New Jersey. The lines were approximately perpendicular to each other; cross-dip (east-west) and along basin strike (north-south). Source points were spaced at 36.5 m (120-ft) intervals and geophone accelerometers collected data at a 3.05 m (10 ft) intervals. Data acquisition was via vibroseis trucks along the westbound shoulder of New York State Thruway (I-287) and the southbound shoulder of the Garden State Parkway. The east/west line was 13 miles long and the north/south line was 5 miles long. The survey lines intersected near the location of the Tandem Lot Well site.

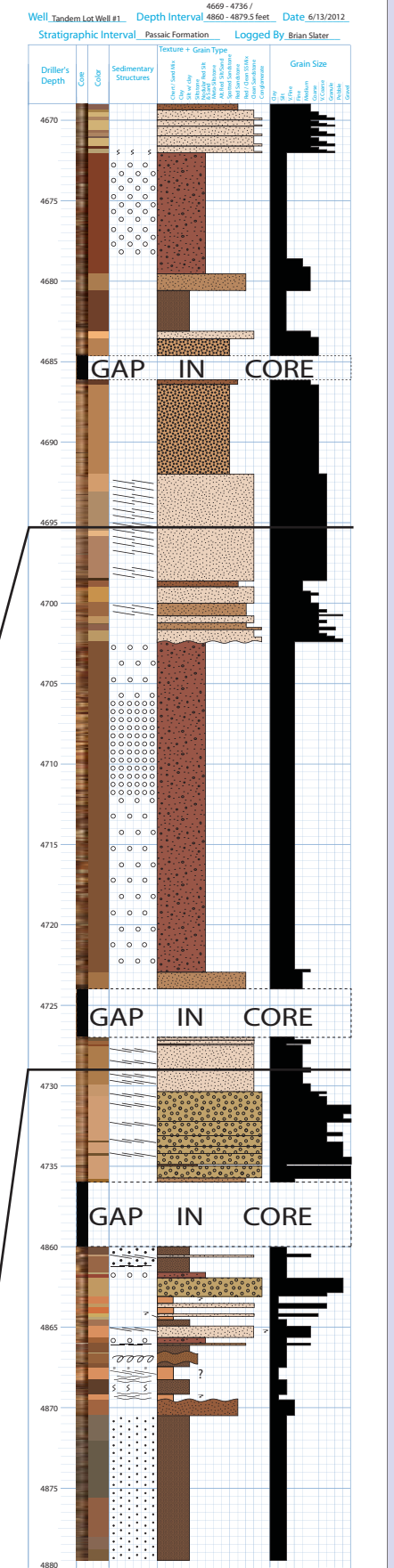
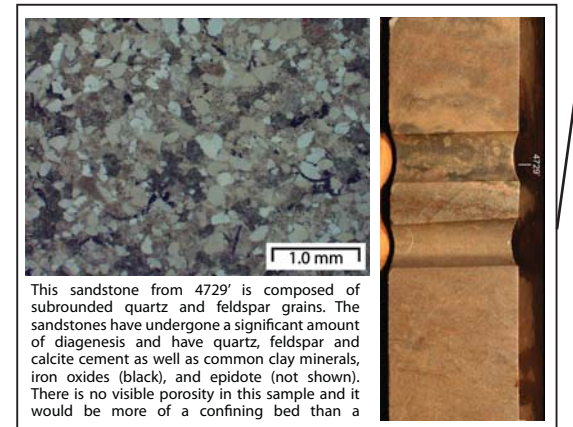
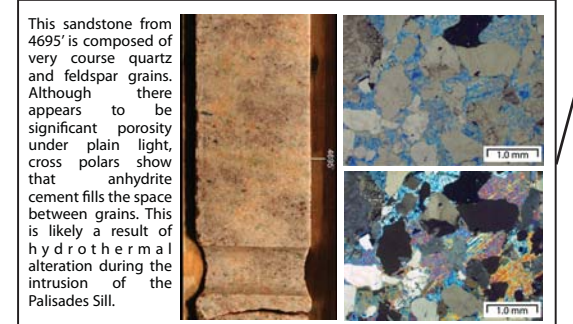


Interpreted data from the east-west seismic line shows the overall geometry of the basin. Although the initial intention of the Tandem Lot Well was to sample the formations below the sill in hopes of finding an equivalent to the Stockton Sandstone, our primary focus has now shifted to the 1,500' of porous sandstone laying above the sill (labelled Reservoir Flow Units Sandstone, highlighted tan).



Core Description:

Approximately 150 feet of continuous core was collected from above the Palisades Sill. The rocks consist primarily of interbedded red and clean sandstones with siltstones and conglomerates. A variety of sedimentary features were observed including cross-bedding, lenticular bedding, bioturbation and nodular concretions. Rock types were highly variable over relatively short vertical intervals and exhibit abrupt changes in grain size.

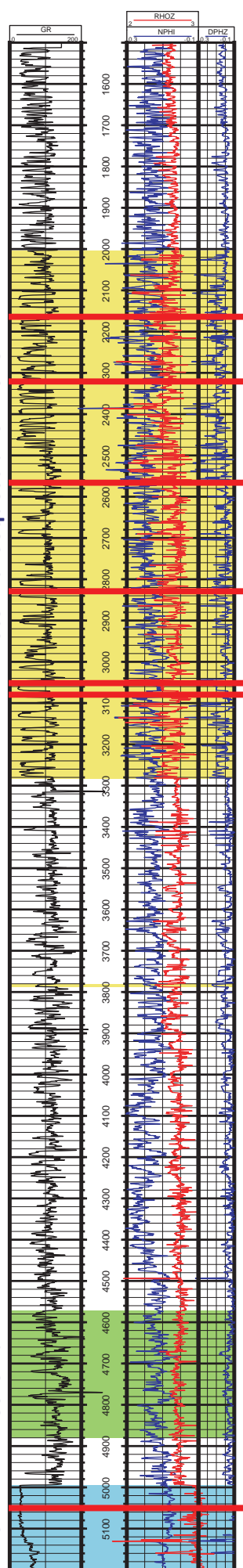


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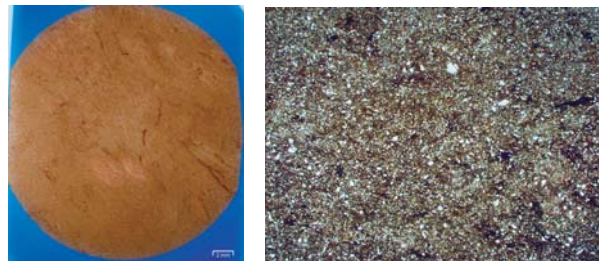
Potential Sequestration Zone

Core Run

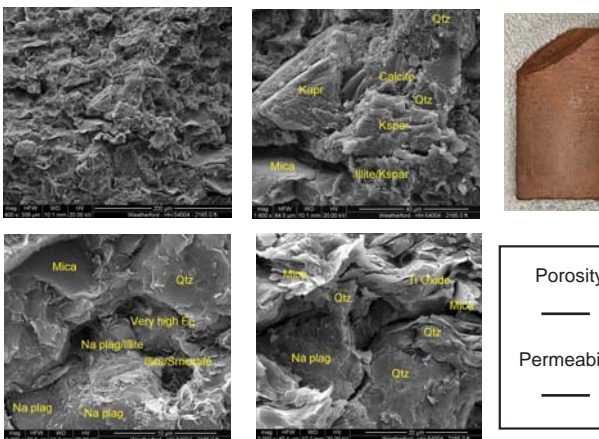
Sill



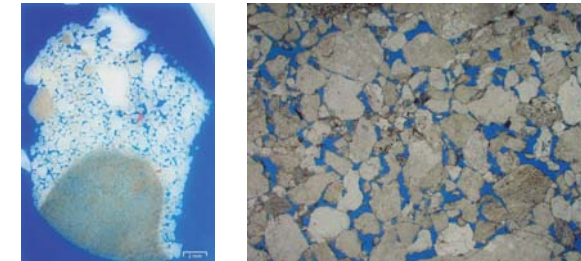
Mudstone Confining Unit - 2,165'



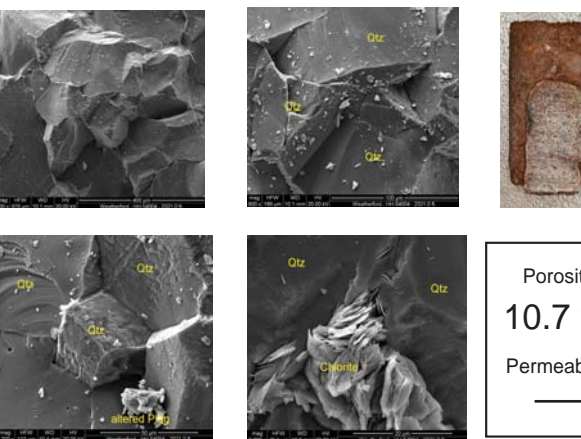
Low porosity, low permeability mudstones, such as the one shown here, have been identified as potential confining units. This rock type is composed of clay with a fine-grained quartz, mica, and feldspar matrix.



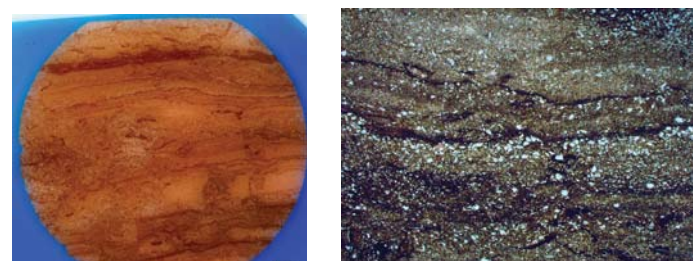
Sandstone Reservoir Unit - 2,321'



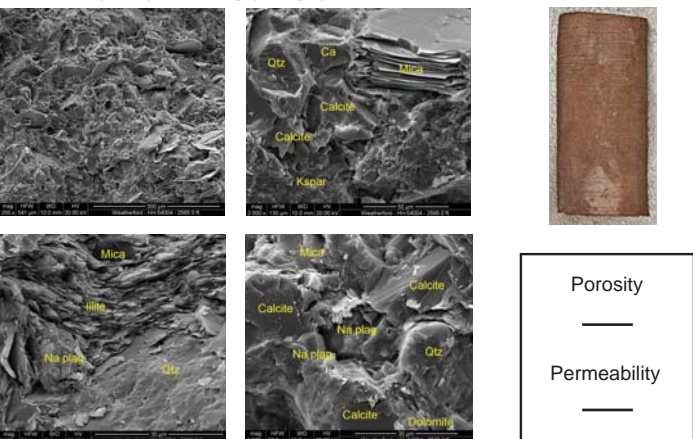
Sandstones, such as the one shown here, have been identified as potential reservoir units. This sample, collected from the "Potential Sequestration Zone," consists of coarse to very coarse sub-angular quartz and feldspar grains. Intergranular porosity (shown in blue) appears to be primary in origin.



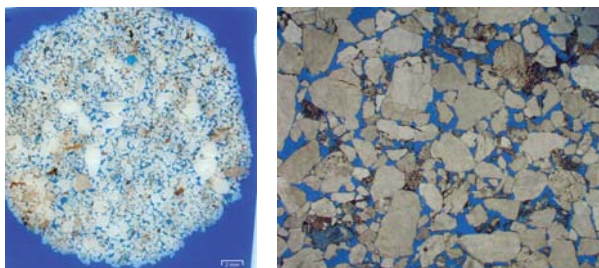
Siltstone Confining Unit - 2,565'



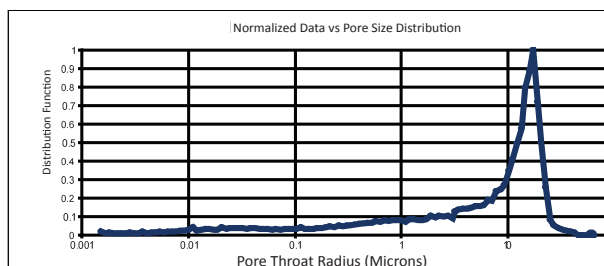
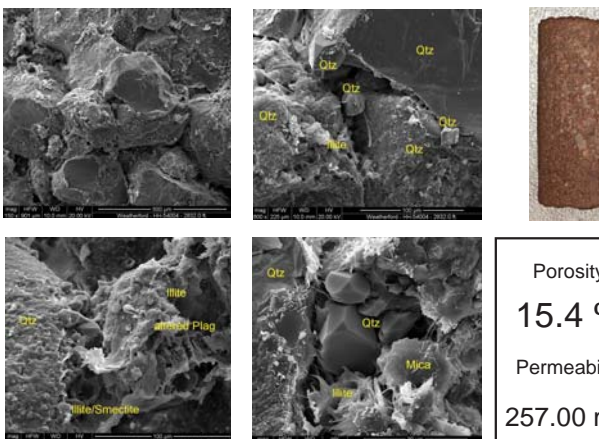
This sample, taken from the middle portion of the "Potential Sequestration Zone," is similar to that from 2,165'. This silty mudstone is composed of clay with a fine-grained quartz and feldspar matrix. There is no visible porosity in this section leading to the interpretation that this unit may act as a potential confining layer during sequestration.



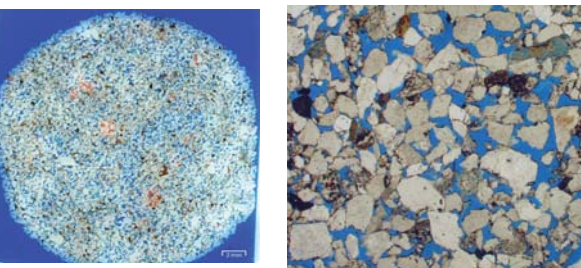
Sandstone Reservoir Unit - 2,832'



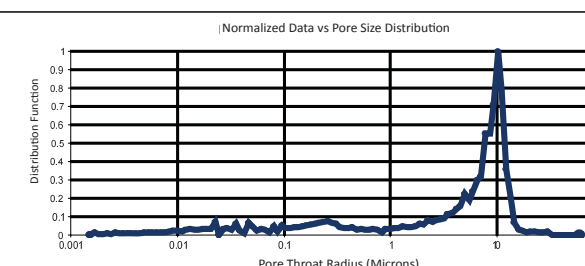
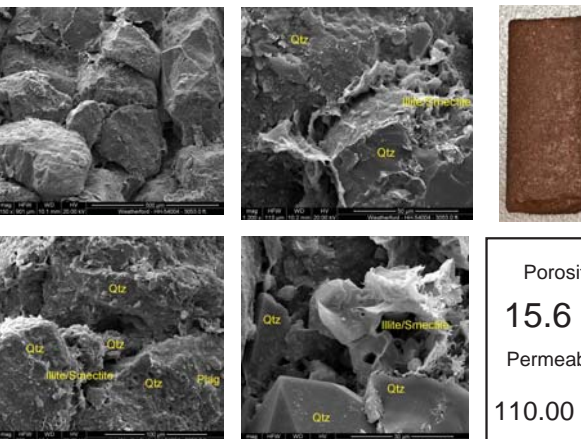
This sample, collected from the middle to lower portion of the "Potential Sequestration Zone," consists of coarse to very coarse sub-angular quartz and feldspar grains. Abundant visible porosity indicates that this unit has the potential to be an excellent carbon sequestration reservoir.



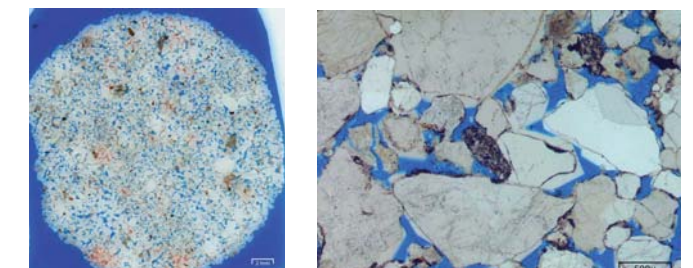
Sandstone Reservoir Unit - 3,053'



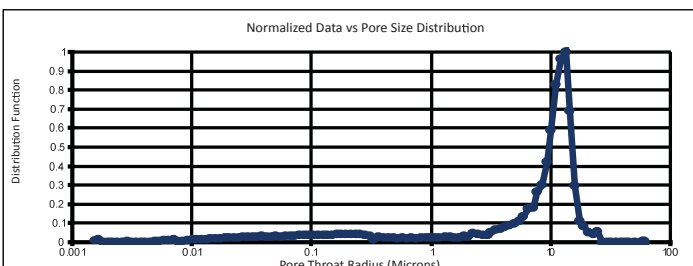
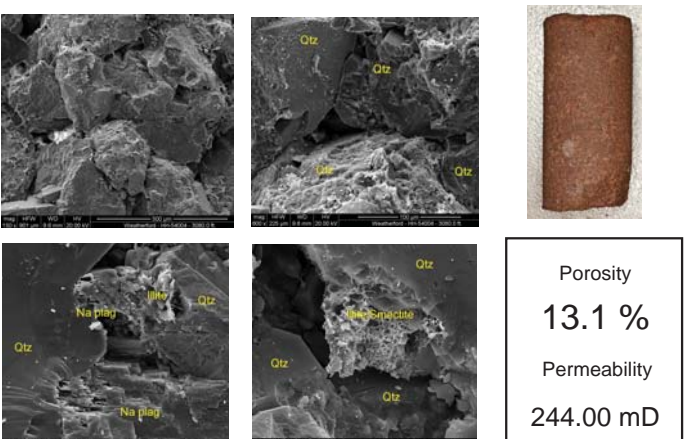
This sample, taken from the lower portion of the "Potential Sequestration Zone," is similar to that from 2,832'. This sandstone is composed of coarse quartz and feldspar grains. Calcite cement (stained red) fills space between some grains, but does not appear to greatly affect the unit's porosity or permeability.



Sandstone Reservoir Unit - 3,080'

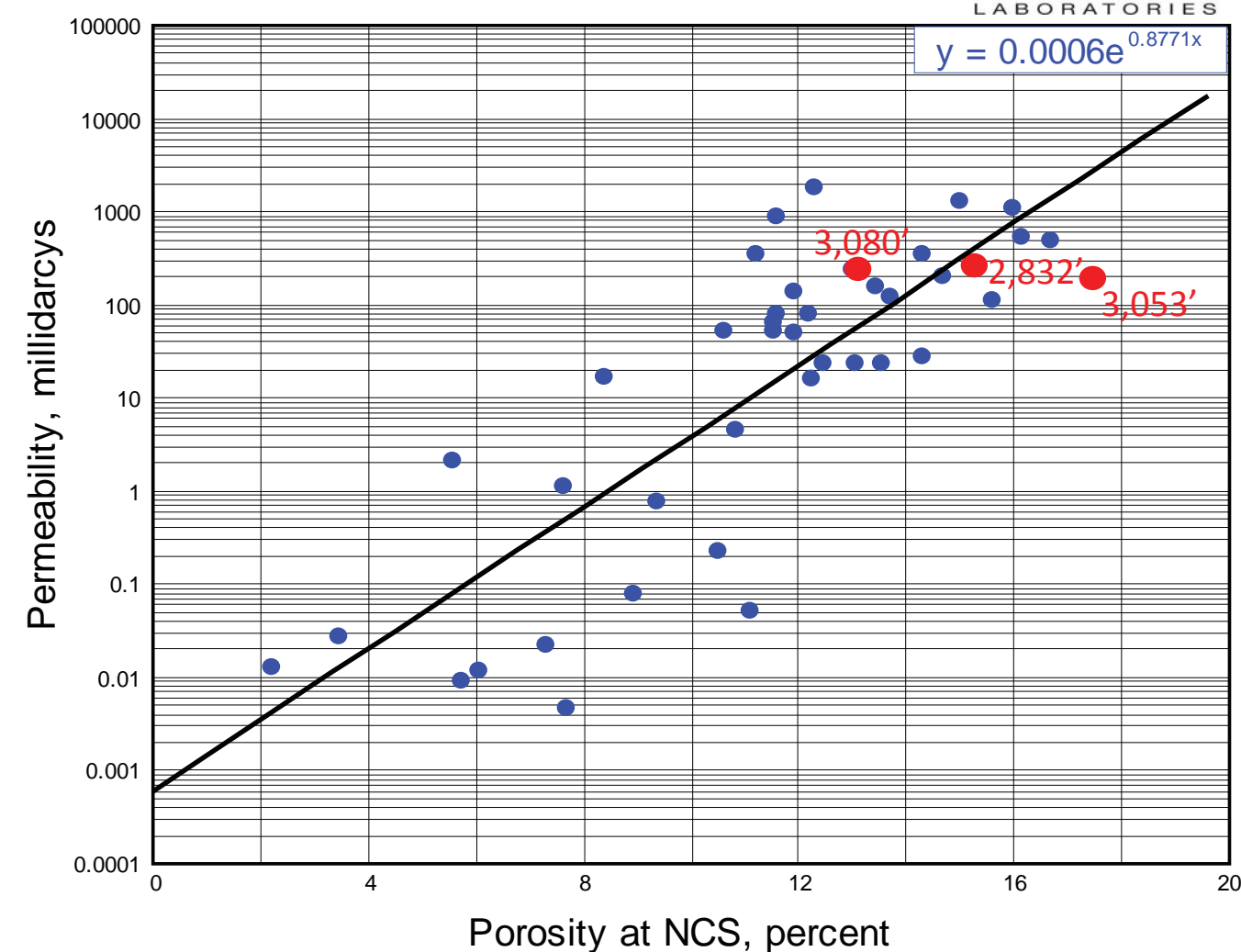


This sample, taken from the lower portion of the "Potential Sequestration Zone," is a sandstone composed of coarse sub-angular quartz and feldspar grains. Just as in sample 3,053', calcite cement (stained red) fills the space between some grains, but does not greatly affect the unit's porosity or permeability.



Porosity & Permeability

(select sidewall cores)



A total of 75 horizontal sidewall cores were collected from the Tandem Lot Well between 622 and 6,800 feet. Thin sections were made from each plug and porosity - permeability tests were conducted on 46 samples. Porosity values range from 3.6 to 15 percent, with an average of 11.4 percent. Permeability values are highly variable, but average 213 millidarcys.

Palisades Diabase: Confining Unit - 5,052'



Although it is stratigraphically lower than the "Potential Sequestration Zone" at the Tandem Lot Site, the Palisades Sill has potential to be a confining unit in other areas of the basin. This sample, collected from the upper portion of the sill is a basalt composed primarily of plagioclase feldspar, pyroxene, and biotite mica.

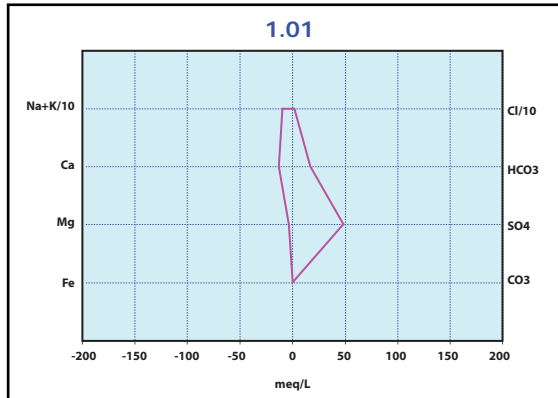
Water Analyses

Schlumberger

Study Samples			Reservoir Conditions		
Sample ID	Cylinder #	Sampling Date	Pressure	Temperature	Depth
1.01	MPSR 0684	10/26/2011	(psia)	(°F)	(ft)
1.02	MPSR 30037	10/26/2011	1,1981	73	3,058
			900	69	2,322

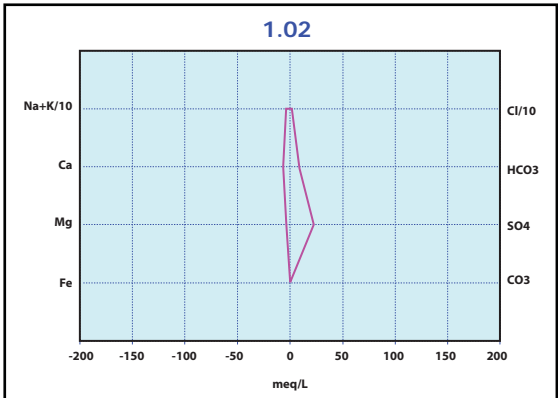
1.01

Parameter	Result	Units
General Analysis		
Specific Gravity	1.004	@ 25°C
Observed pH	7.448	@ 25°C
Resistivity at 77°F	97.675	ohm-cm
Conductivity at 77°F	10.2	mS/cm
Salinity	1099	
Total Dissolved Solids		
Evaporated @ 110°C	9742	mg/L
Measured	7550	mg/L
Calculated	6552	mg/L
Anions		
Fluoride (F)	mg/kg	meq/L
Chloride (Cl)	608.2	17.224
Nitrite (NO2)		
Bromide (Br-)	5.59	0.070
Nitrate (NO3)		
Phosphate (PO4)		
Sulfate (SO4)	2331.72	48.741
Cations		
Lithium (Li)	mg/kg	meq/L
Sodium (Na)	0.4	0.05
Ammonium (NH4)	2108.7	92.09
Potassium (K)	44.0	2.45
Magnesium (Mg)	23.5	0.60
Calcium (Ca)	44.3	3.66
	259.9	13.02
ICP Metals		
Aluminum (Al)	mg/kg	meq/L
Boron (B)	2.0	0.6
Barium (Ba)	0.27	0.0039
Copper (Cu)		
Iron (Fe)	3.27	0.1
Manganese (Mn)	0.65	0.0
Phosphorus (P)	0.32	0.0
Lead (Pb)		
Sulphur (S)	775.8	48.6
Silicon (Si)	11.0	1.6
Strontium (Sr)	3.221	0.074
Zinc (Zn)	0.29	0.0088
ORGANIC ACIDS		
Glycolic	mg/kg	
Formic	27.3	
Acetic	8.5	
Propionic	218.0	
	2.6	

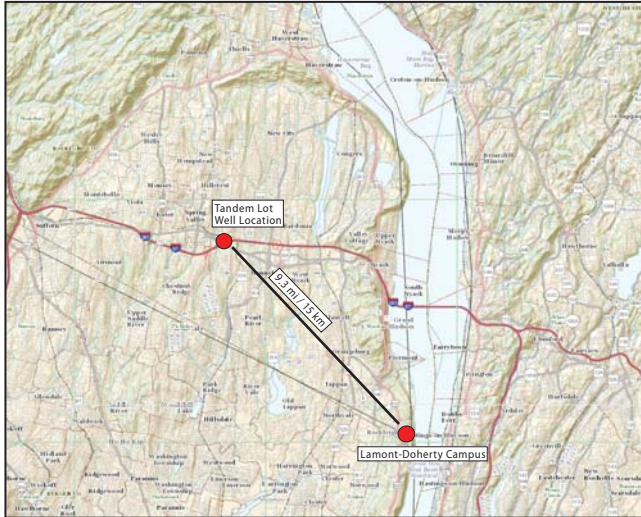


1.02

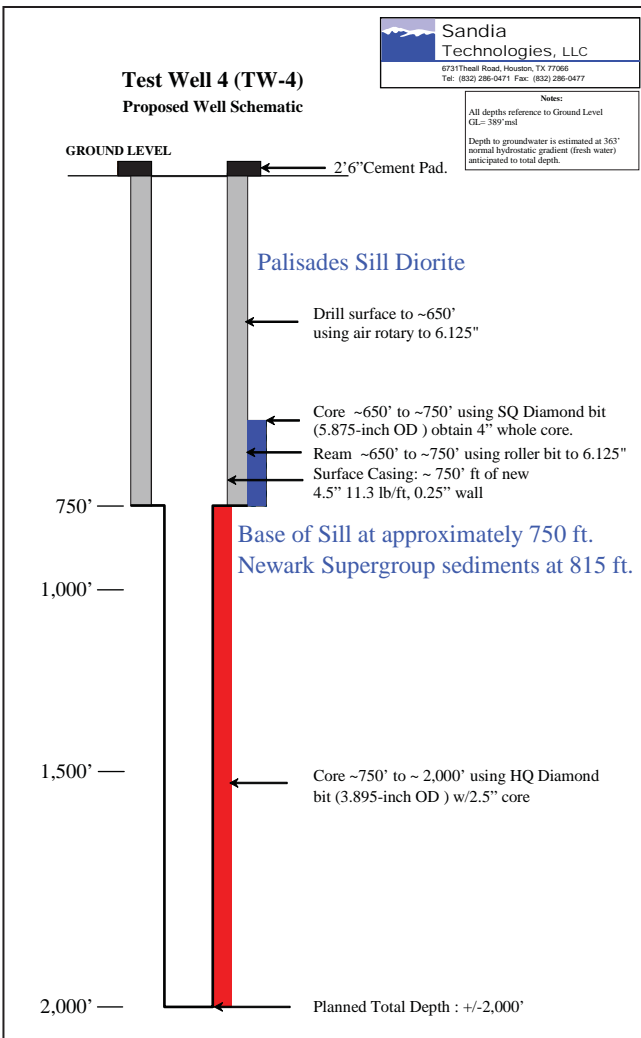
Parameter	Result	Units
General Analysis		
Specific Gravity	1.002	@ 25°C
Observed pH	7.499	@ 25°C
Resistivity at 77°F	202.335	ohm-cm
Conductivity at 77°F	4.9	mS/cm
Salinity	552	
Total Dissolved Solids		
Evaporated @ 110°C	4308	mg/L
Measured	3537	mg/L
Calculated	3163	mg/L
Anions		
Fluoride (F)	mg/kg	meq/L
Chloride (Cl)	287.6	8.1
Nitrite (NO2)		
Bromide (Br-)	4.202	0.053
Nitrate (NO3)		
Phosphate (PO4)		
Sulfate (SO4)	1110.7	23.2
Cations		
Lithium (Li)	mg/kg	meq/L
Sodium (Na)	0.403	0.058
Ammonium (NH4)	898.3	39.2
Potassium (K)	16.0	0.89
Magnesium (Mg)	11.2	0.29
Calcium (Ca)	45.0	3.7
	134.5	6.7
ICP Metals		
Aluminum (Al)	mg/kg	meq/L
Boron (B)	2.0	0.21
Barium (Ba)	0.27	0.0015
Copper (Cu)	0.077	0.0024
Iron (Fe)	0.021	0.0008
Manganese (Mn)	0.17	0.012
Phosphorus (P)	0.24	0.008
Lead (Pb)		
Sulphur (S)	356.0	22.2
Silicon (Si)	10.0	1.4
Strontium (Sr)	1.7	0.039
Zinc (Zn)	4.1	0.13
ORGANIC ACIDS		
Glycolic	mg/kg	
Formic	19.1	
Acetic	3.4	
Propionic	39.8	
	3.0	



Siting the Lamont Well (TW-4)

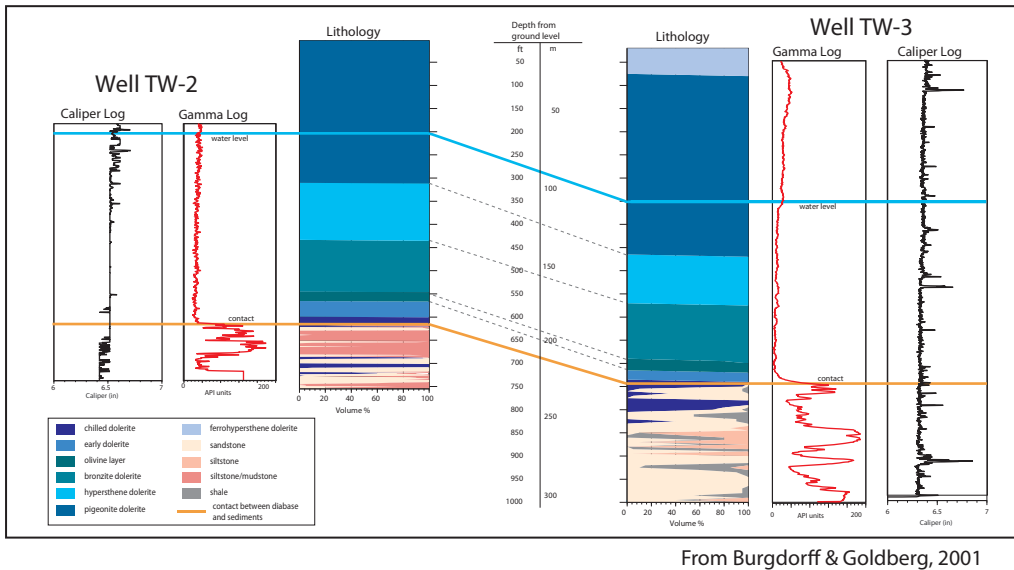


Test Well 4 (TW-4) has been sited on Lamont Doherty Earth Observatory (LDEO) campus in south eastern Rockland County, NY. LDEO is a research unit of Columbia University and has been an active member of the TriCarb Consortium from its inception. The location of the LDEO campus is fortunate in that it lies approximately 9 miles up dip from the Tandem Lot well and rests on a partially eroded portion of the Palisades sill. Drilling through the sill was a costly and time-consuming process at the Tandem Lot site, therefore beginning the TW-4 well in the lower section of the sill should allow a larger portion of the project's resources to be spent collecting data below the sill.

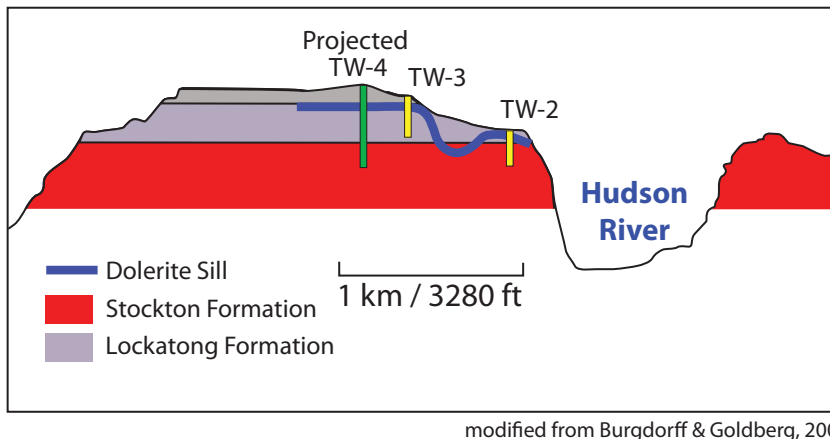


Based on information gathered from the existing Lamont wells, it is anticipated that Test Well 4 will penetrate approximately 750 feet of Palisades Sill before reaching the metamorphosed transition zone into Triassic sediments. We plan to obtain approximately 100 feet of 4-inch core from the base of the sill, before setting surface casing. Coring will then continue into what we believe will first be the interbedded sandstones and mudstones of the Lockatong Formation. We plan to collect roughly 1,250 feet of Newark Supergroup sediments which we hope will include a portion of Stockton Sandstone, the basal unit of the basin and potential sequestration target.

Lamont-Doherty Earth Observatory COLUMBIA UNIVERSITY | EARTH INSTITUTE



From Burgdorff & Goldberg, 2001



modified from Burgdorff & Goldberg, 2001

Conclusions

18 miles of 2-D seismic data shot across the northern Newark Basin gives a clear outline of the basin's overall geometry including the location and thickness of the Palisades Sill.

The completion of the Tandem Lot Well in Rockland County, New York represents the addition of a valuable data point to the very small list of deep wells drilled into the Newark Rift Basin.

Detailed core descriptions have identified a wide variety of rock types including potential sequestration reservoirs and sealing units.

Over 1,000 feet of "Potential Sequestration Zone" have been identified in the wireline log data and verified with core and thin section analyses.

Lab analyses porosity values range from 3.6 to 15%, with an average of 11.4%. Permeability values are highly variable, but average 213 millidarcys.

Formation fluids with salinities as low as those from the Tandem Lot Well are unlikely to be considered for CO₂ sequestration because these waters may be considered a future resource. If sequestration is to take place in the Newark Rift Basin, an area with more saline fluids must be found.

Future Work

A second well (TW-4) is scheduled to be drilled on the Lamont-Doherty Campus later this Summer. This well will be located geographically southeast and stratigraphically up-dip of the Tandem Lot Well Site.

More work must be done to refine and correlate the wireline and core data from the Tandem Lot Well with seismic data in an attempt to project the identified "Potential Sequestration Zone" to areas of the basin where it is present below the 2,500 foot threshold for supercritical carbon sequestration.

Mineralization caused by hydrothermal processes related to the intrusion of the Palisades Sill may have affected the porosity and permeability of potential sequestration reservoirs. Further investigation of this diagenesis is needed.

As an active member of the TriCarb Consortium, a team of scientists at Lawrence Berkeley National Laboratory will be using the data collected from the Tandem Lot Well to model various carbon dioxide injection scenarios in the basin.

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TriCarb Consortium for Carbon Sequestration

Funding Partners
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Development Authority (NYSERDA)
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