Potential Brine Disposal Reservoirs in South-Central New York:

Options for Salt Cavern Storage in Areas Remote to Ocean Disposal

Courtney Lugert, Taury Smith and Richard Nyahay

New York State Museum

Steve Bauer and Brian Ehgartner,

Sandia National Labs

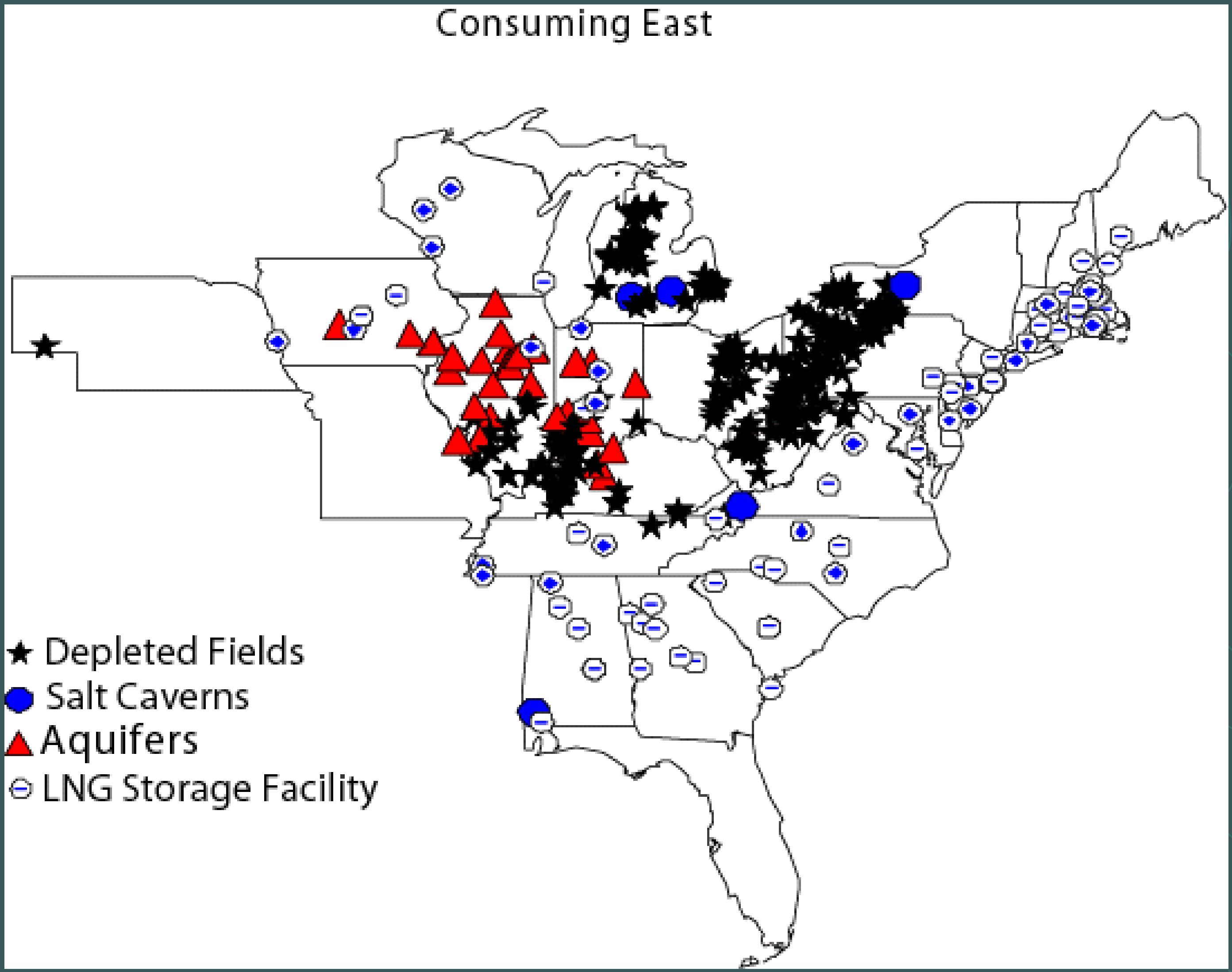
Good market for storage

- New York + New England natural gas consumption = 8% of total US*
- New York storage capacity = 2% of total US*
- New England has no storage capacity*
- All new power plants in NY and NE will probably be natural gas-fired

*Source: EIA Website
1998 Statistics

From Sanford, 2000

Current Storage Fields in Eastern US



Salt Cavern Storage Advantages

- High deliverability and injection rates
- Short cycle times: can fill and extract several times in a year
- Least amount of gas lost to formation during injection and withdraw
- Good usable salt occurs in New York
- Great Market for Storage

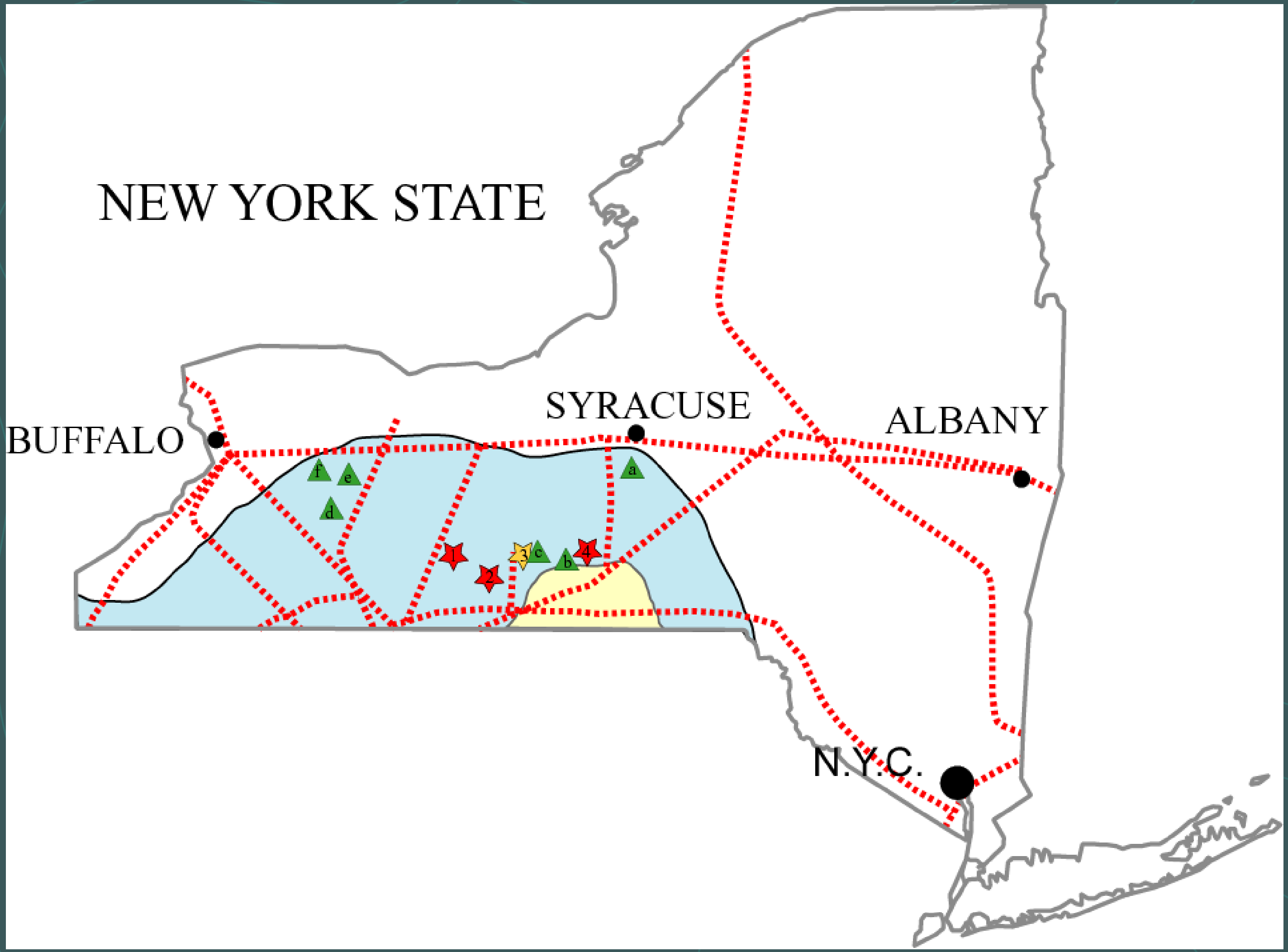
Disadvantages of Salt Cavern Storage

- Money – It takes time and money to make caverns - big up-front cost
- Development of well engineered caverns
- Brine Disposal!

Current Salt Cavern Storage Projects in New York/ Northern PA

- NYSEG - only operational project, converted an existing solution mine to a storage facility
- Tioga – Northern Pa.
- Bath – Attempting to convert an existing LPG storage cavern to natural gas storage
- Avoca – currently looking for brine disposal options

Salt Operations in New York



Avoca Project

- The Original Plan
  - Six caverns to be solution mined for storage
  - 6.72 BCF total capacity, 10 day cycle time at 500 MMCF/D
  - 50 million barrels of brine to be re-injected in six disposal wells
- Everything worked except **brine disposal** – no permeable formations, earthquakes induced during injection, project went bankrupt after $100 million investment

Our Research

- Two Phased Plan
- Phase I - “Usable Salt”
  - Define areas where developing caverns is a possibility
- Phase II – Brine Disposal
  - Within the areas of usable salt, delineate formations with potential as brine disposal reservoirs

Cavern Site Criteria

- Salt thickness and quality (200-300 feet preferred, but need minimum of 100 feet with few non-salt intervals)
- Salt Depth (2000-6000 feet)
- Location (proximity to power, populations, market and pipeline)
- Fresh Water Source (to use for dissolution)
- Brine Disposal Options (ocean, salt plant feed, deep well injection)

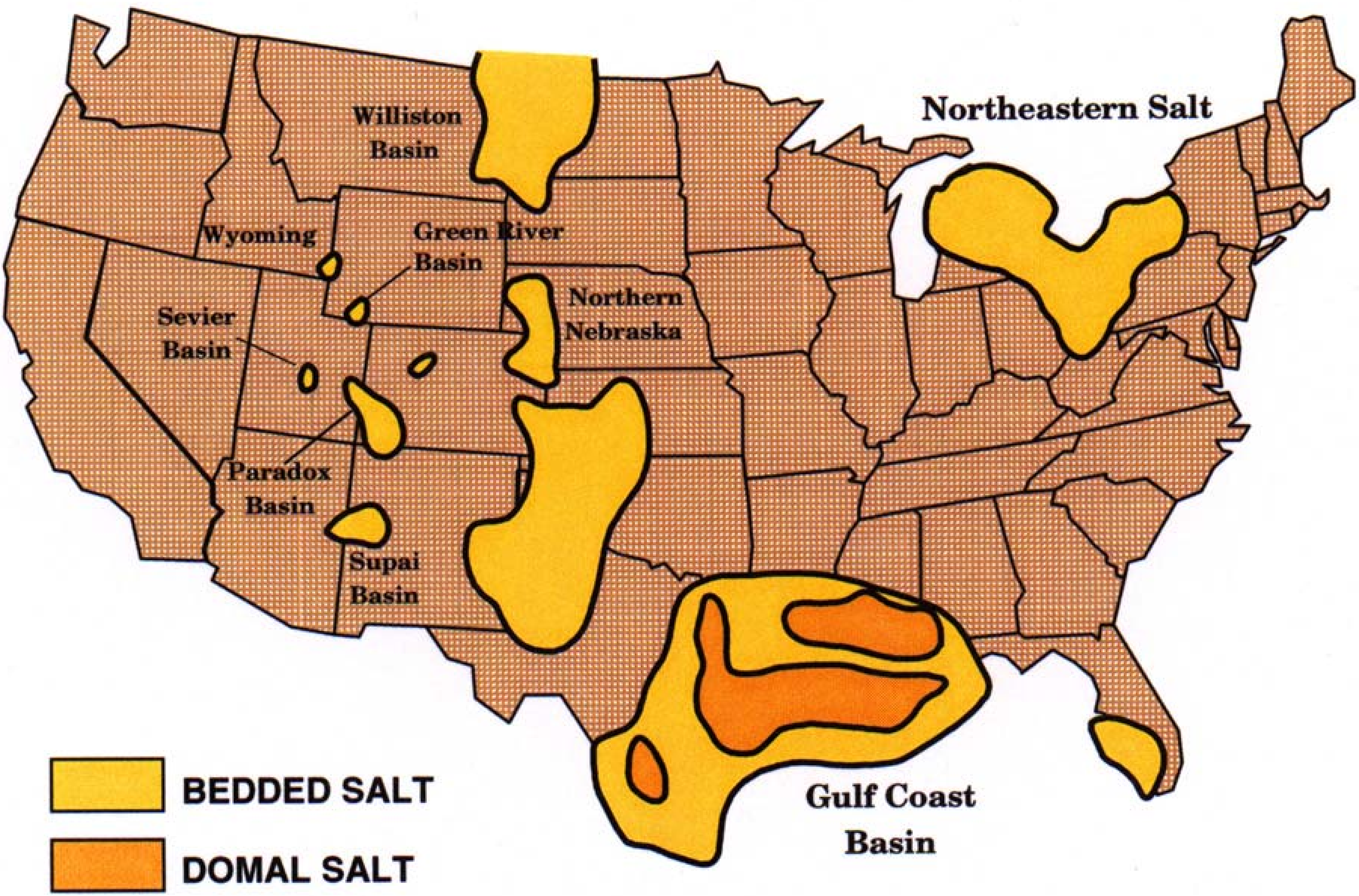
Brine Injection Challenges

- Significant volumes of brine produced during solution mining (6.75 volumes of brine to make 1 volume of cavern)
- Relatively high injection rates are a must (20,000-100,000 barrels of water per day)
- Need good porosity and permeability in disposal reservoirs
- The problem in New York:
  - Porosities and permeabilities in NY and much of the Appalachian Basin are low

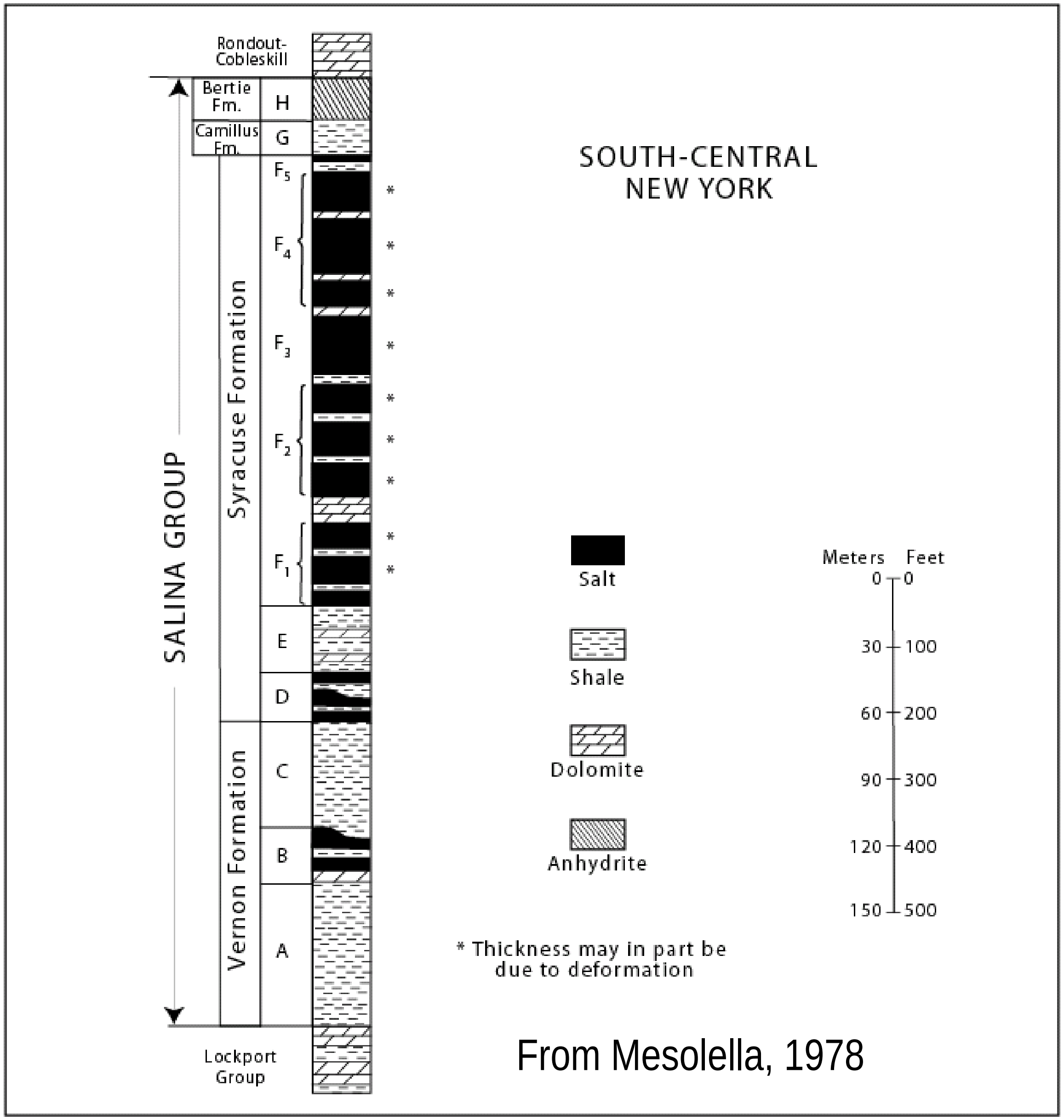
Phase I – Usable Salt Criteria

- We will be looking for salt that is:
  - First - 2000-6000 ft deep
  - Second - intervals of salt that are > 100 ft thick w/ no intervals of non-salt greater than 10ft

- Where both criteria are met = "Usable Salt"

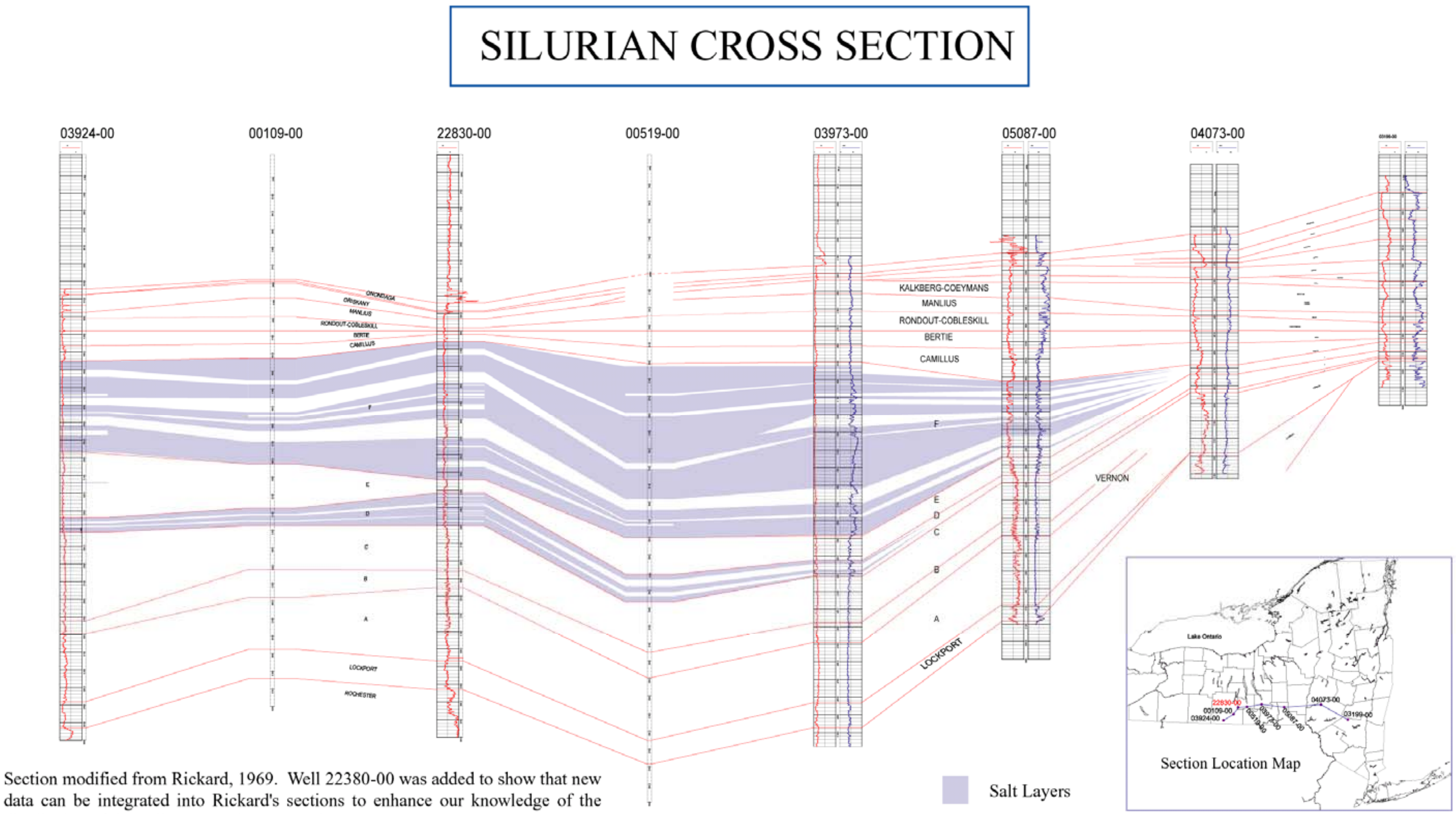

Williston Basin
Northeastern Salt
Wyoming
Green River Basin
Northern Nebraska
Sevier Basin
Paradox Basin
Supai Basin
Gulf Coast Basin
BEDDED SALT
DOMAL SALT

Usable Salt is in Silurian Salina Group



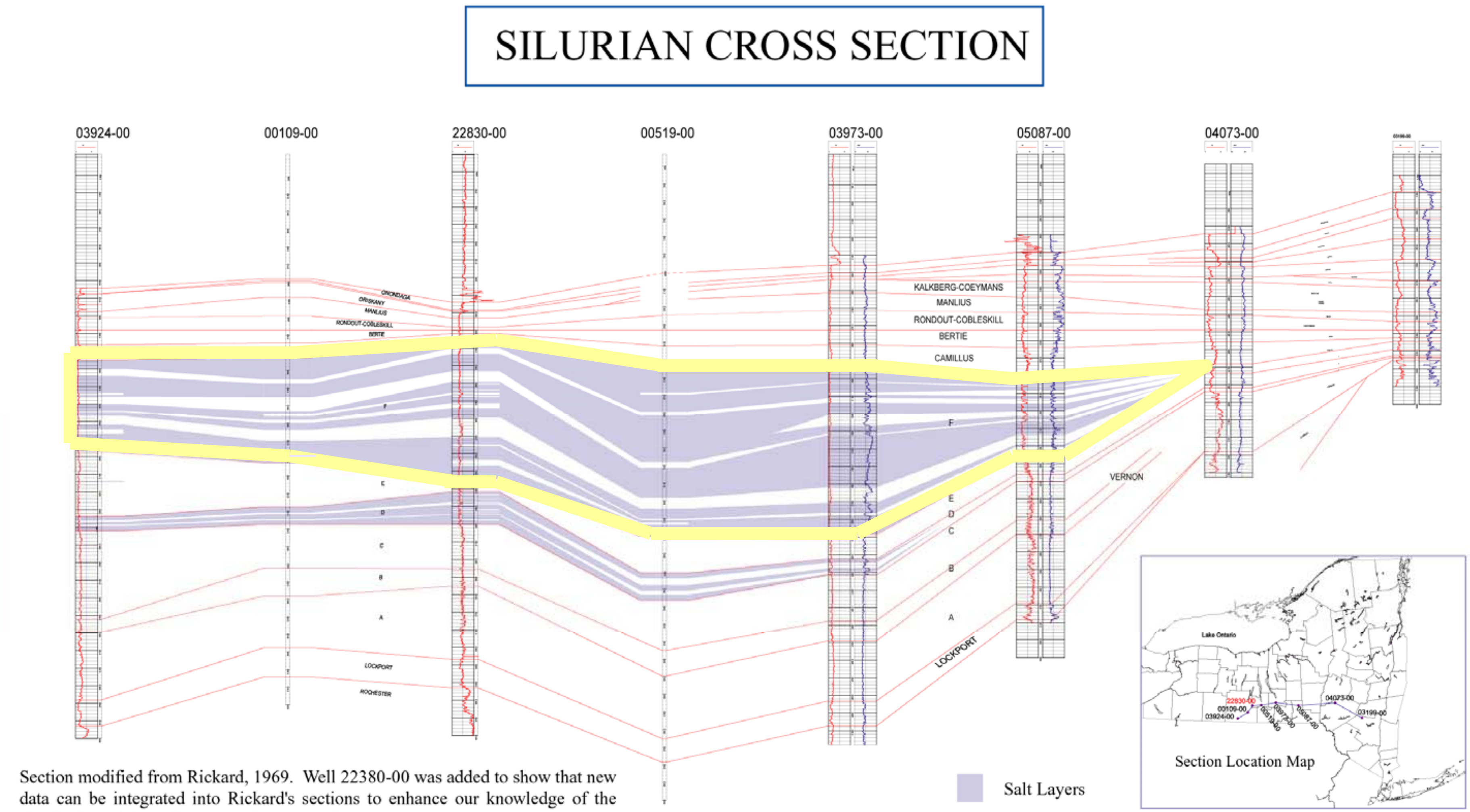
From Mesolella, 1978

Rickard's Cross Section Through South-Central New York



Section modified from Rickard, 1969. Well 22380-00 was added to show that new data can be integrated into Rickard's sections to enhance our knowledge of the distribution of the Salina Group in New York.

Rickard's Cross Section Through South-Central New York



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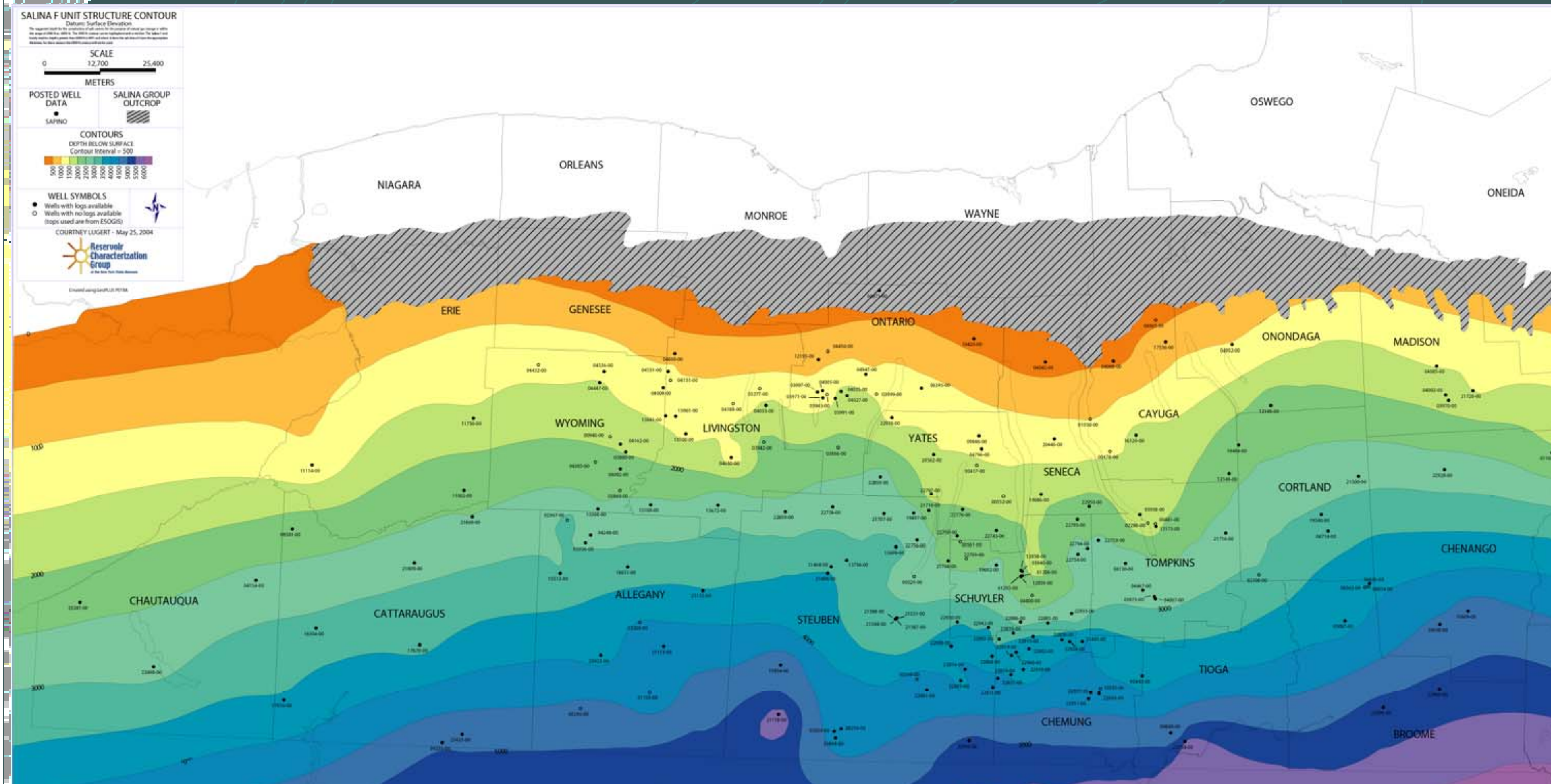
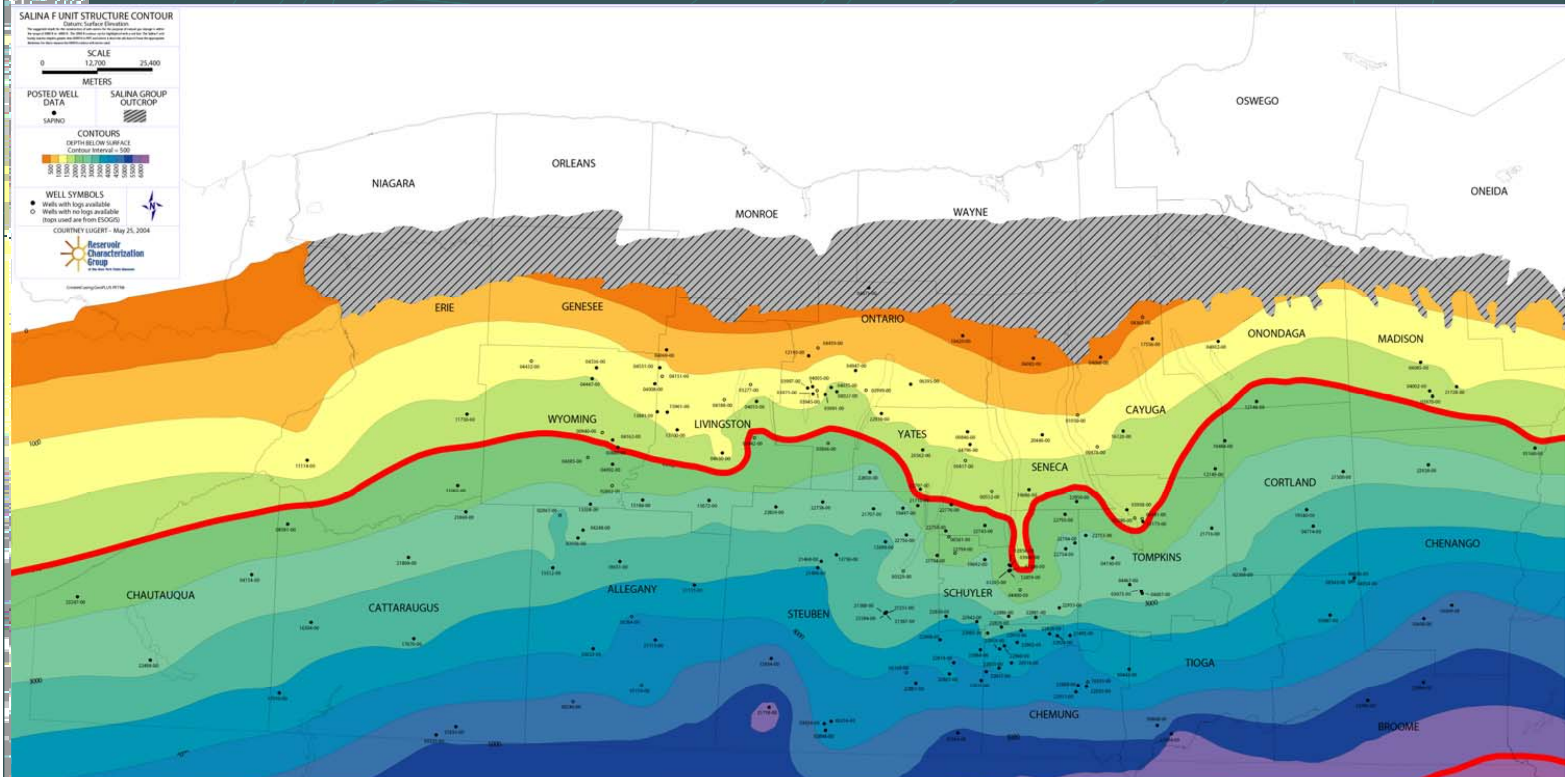
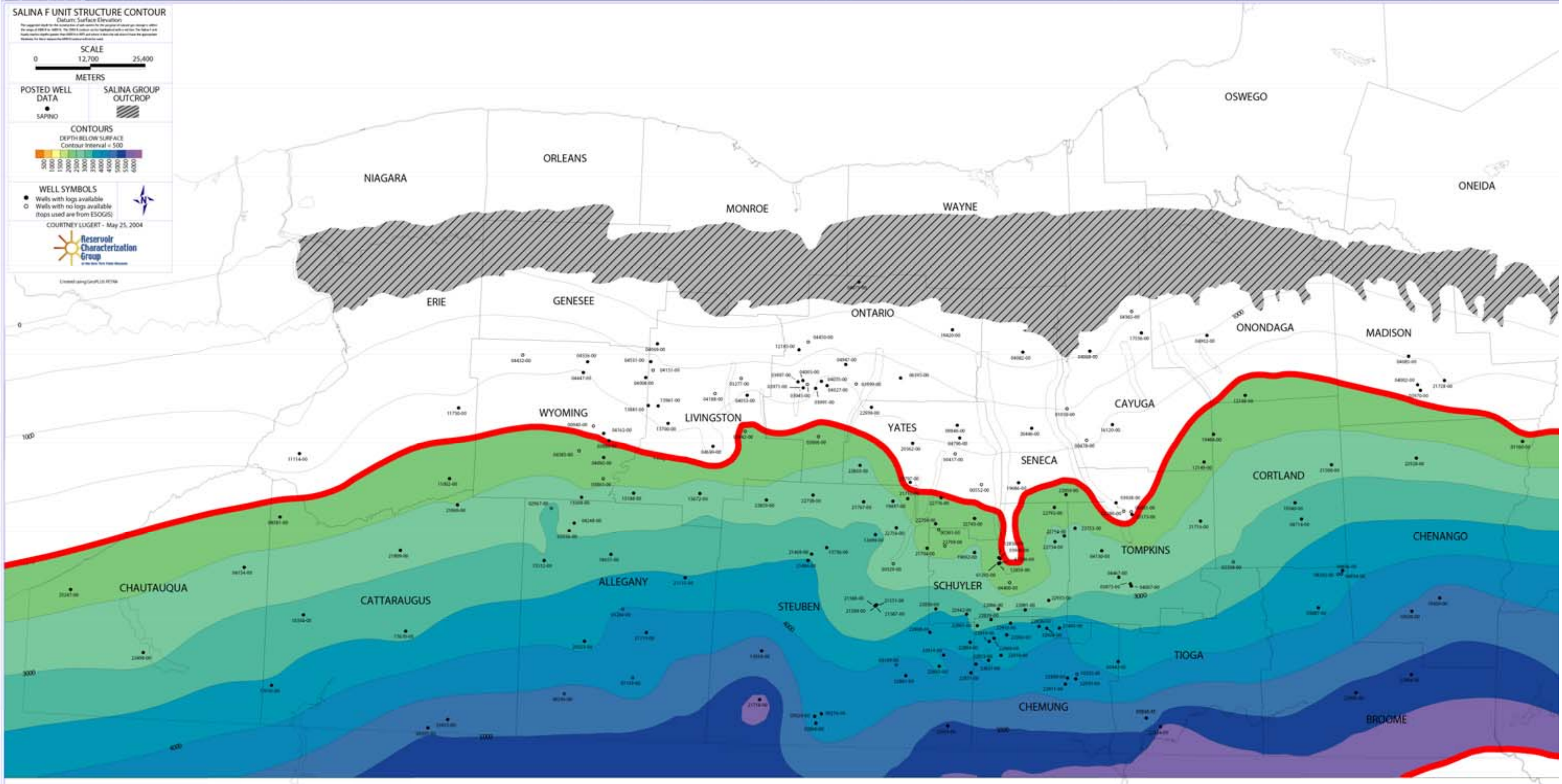
Depth to Salina F unit
Datum: Surface



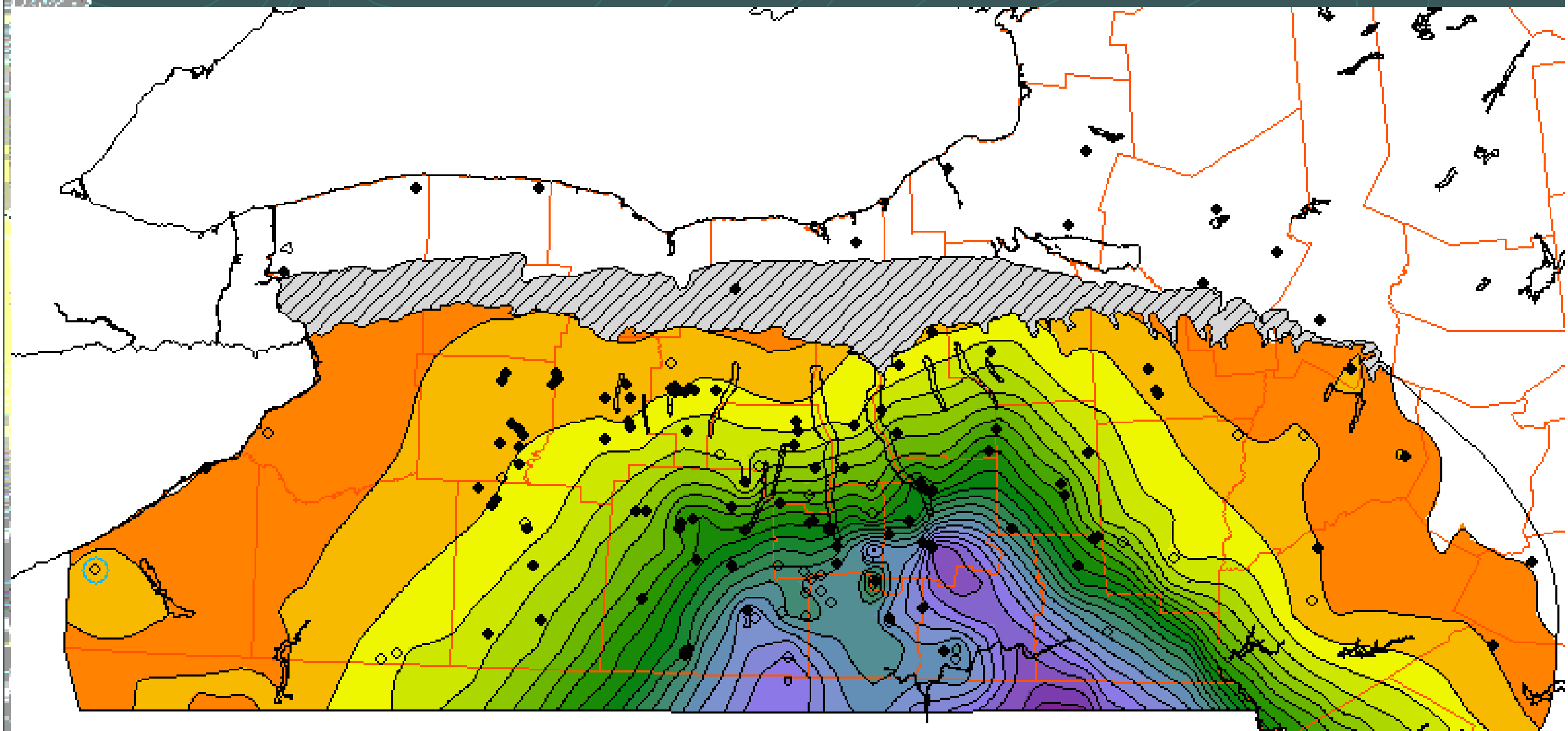
2000 and 6000 ft contours



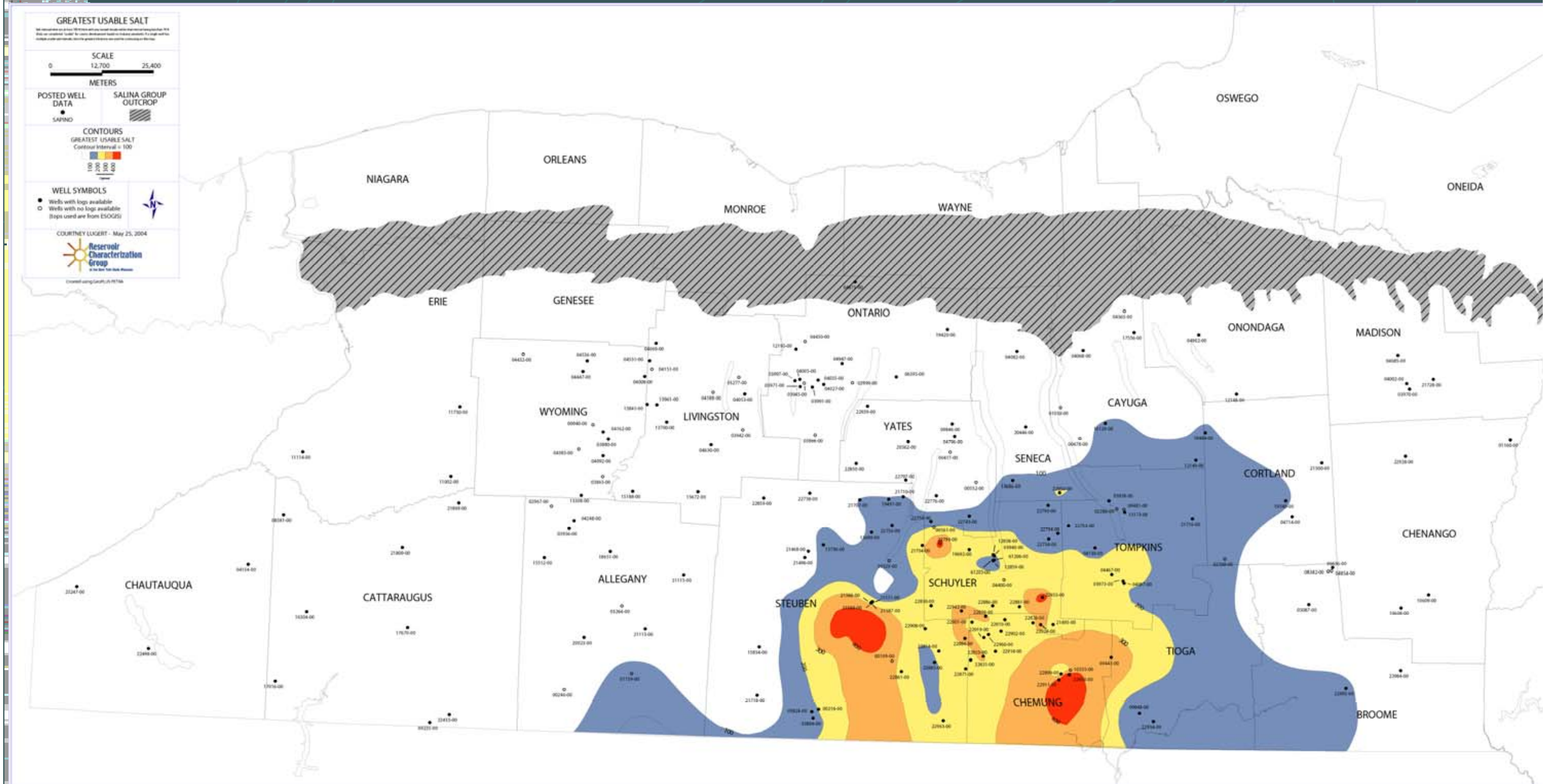
Correct Depth
- 2000-6000 ft below surface



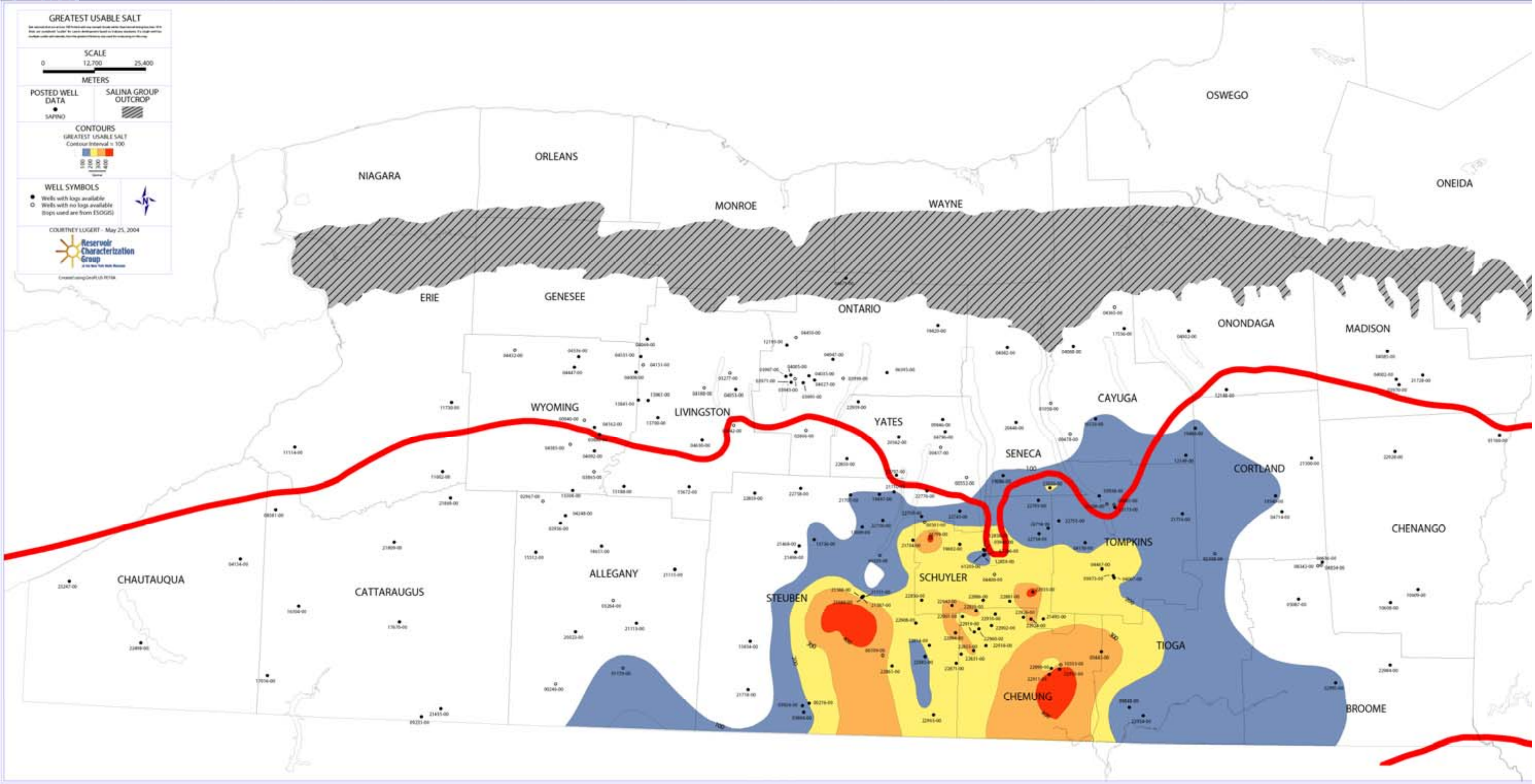
Thickness of Salina F-unit



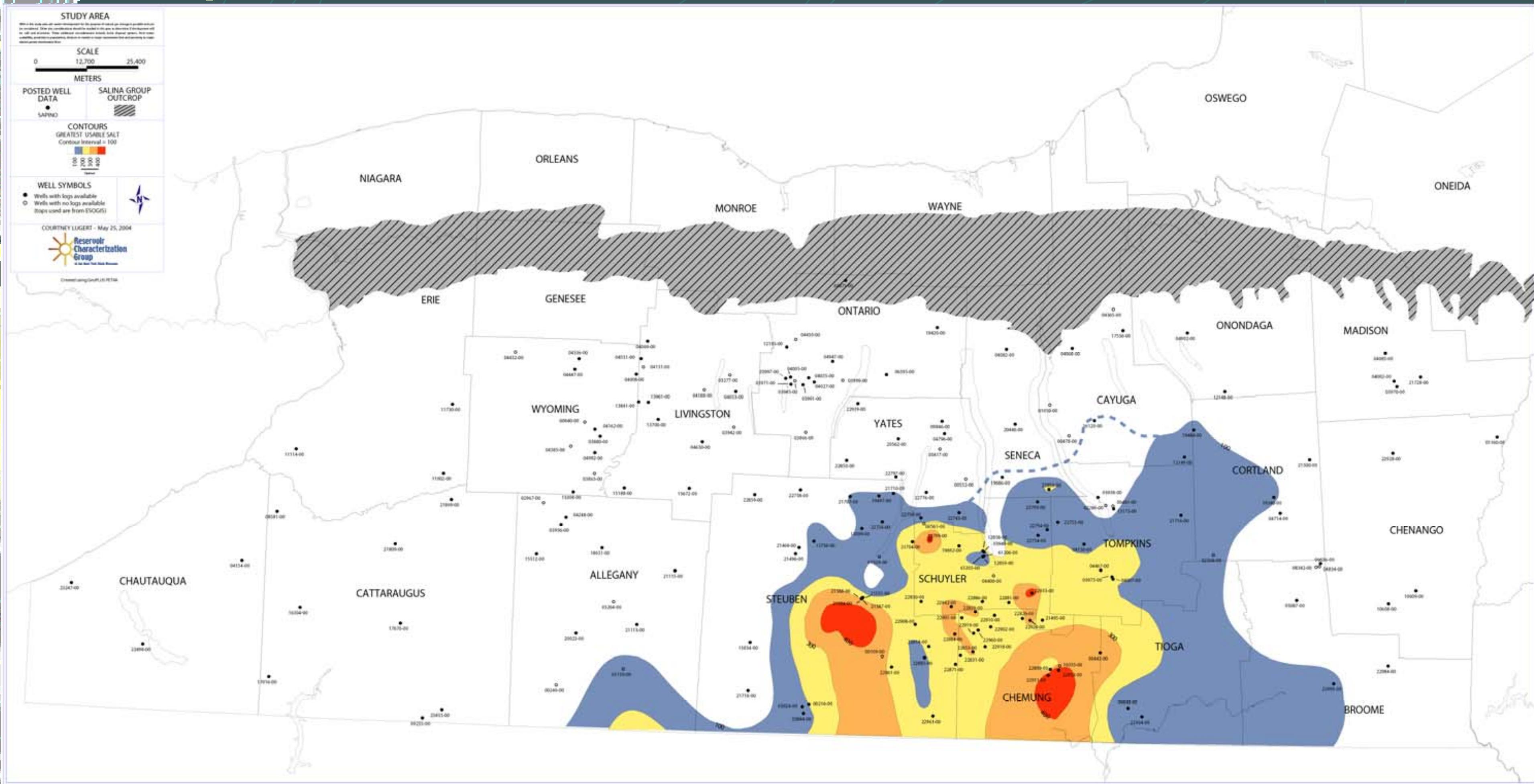
Correct Thickness of Salina F salt - 100 ft thick with less than 10 ft breaks of non-salt



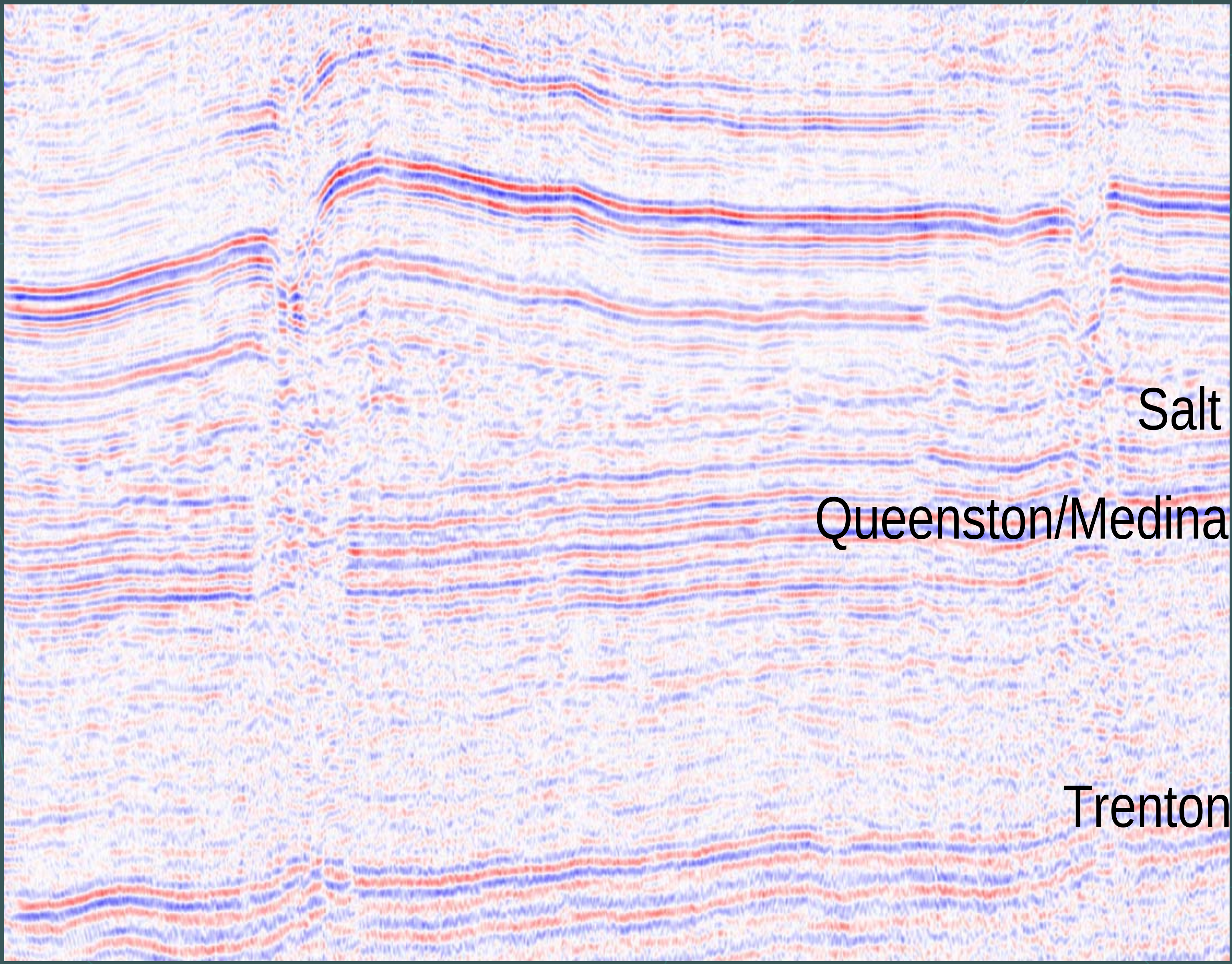
Greatest Usable Salt and 2000’ and 6000’ contours



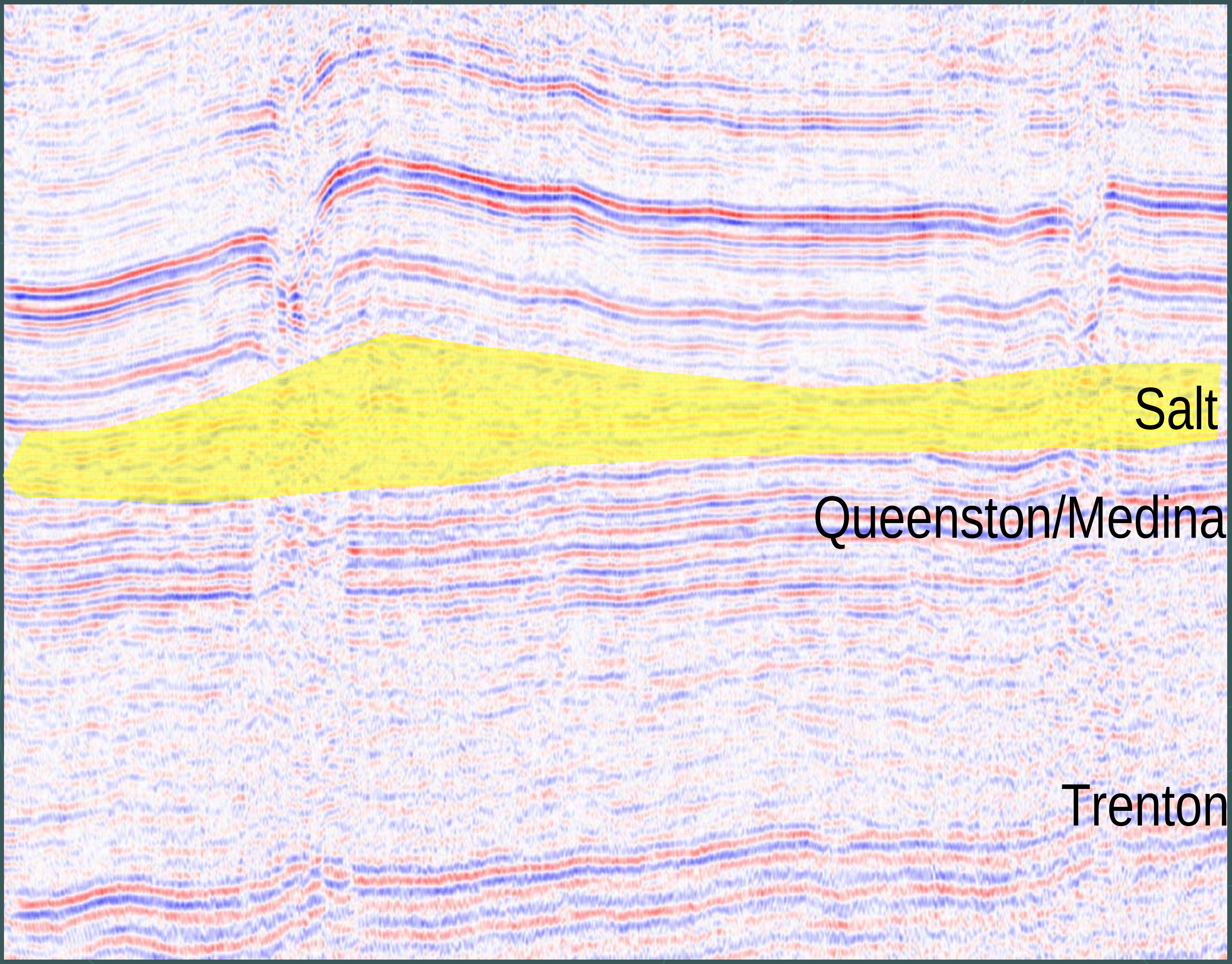
Study Area for Phase II
-area where salt cavern development is possible



Over-thickened salt

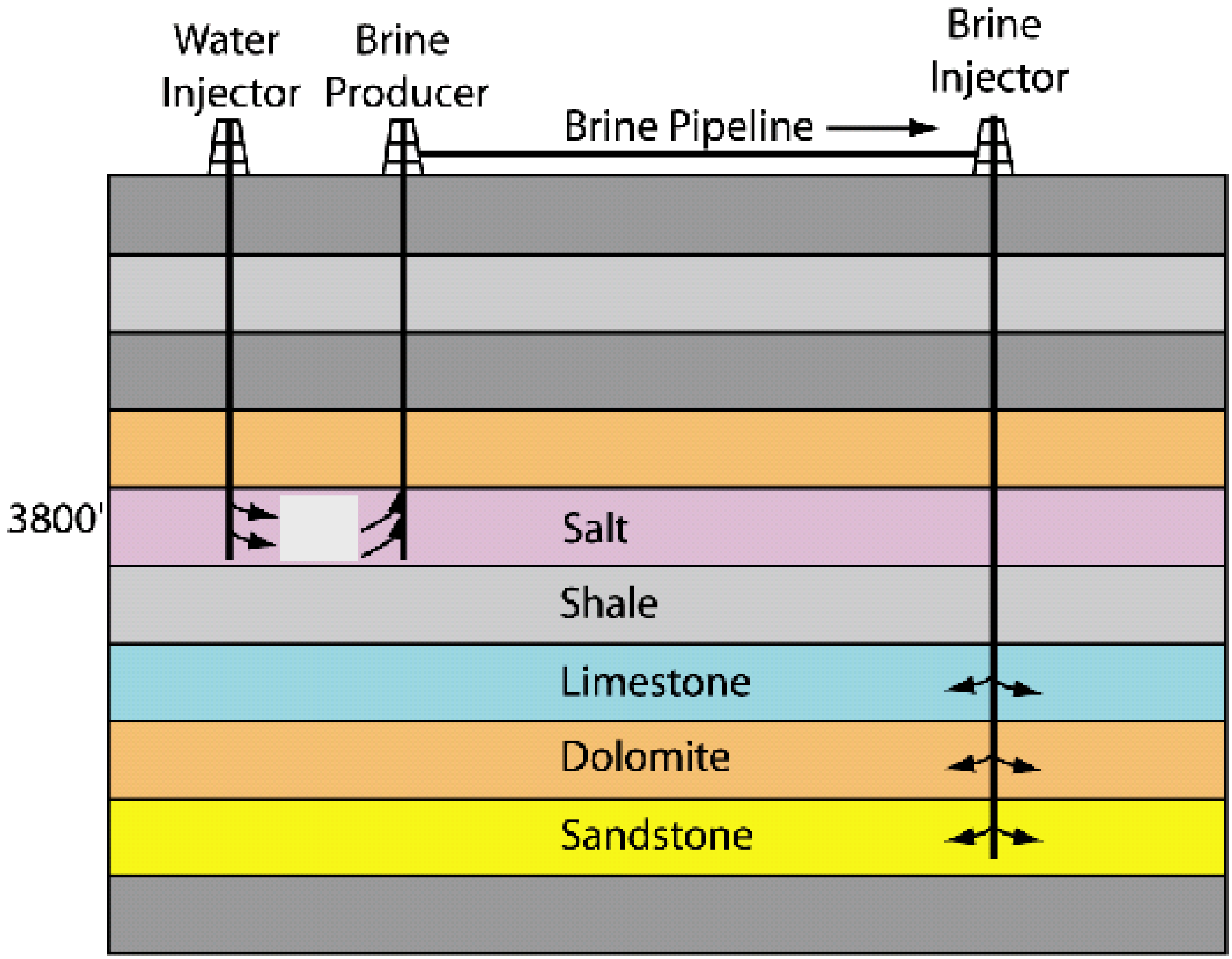


Over-thickened salt



Our Project Design

- Two Phased
- Phase I - “Usable Salt”
  - Define areas where developing caverns is a possibility
- Phase II – Brine Disposal
  - Within the areas of usable salt, delineate formations with potential as brine disposal reservoirs


Water Injector
Brine Producer
Brine Injector
Brine Pipeline
3800'
Salt
Shale
Limestone
Dolomite
Sandstone

What makes a good brine disposal formation ?

- Matrix porosity of at least 10%
- Either good matrix permeability, fracture permeability or a good candidate for induced fracturing
- Connate water salinity similar to the injected brine
- Must be hydraulically separated from sources of potable water

Our Criteria

- Lithology (sandstones and carbonates)
- Porosity and Permeability
- Production History (Here or in nearby states)
- Currently Used for conventional depleted reservoir storage? (If it is a good storage reservoir already, most will not want to use it for brine disposal)

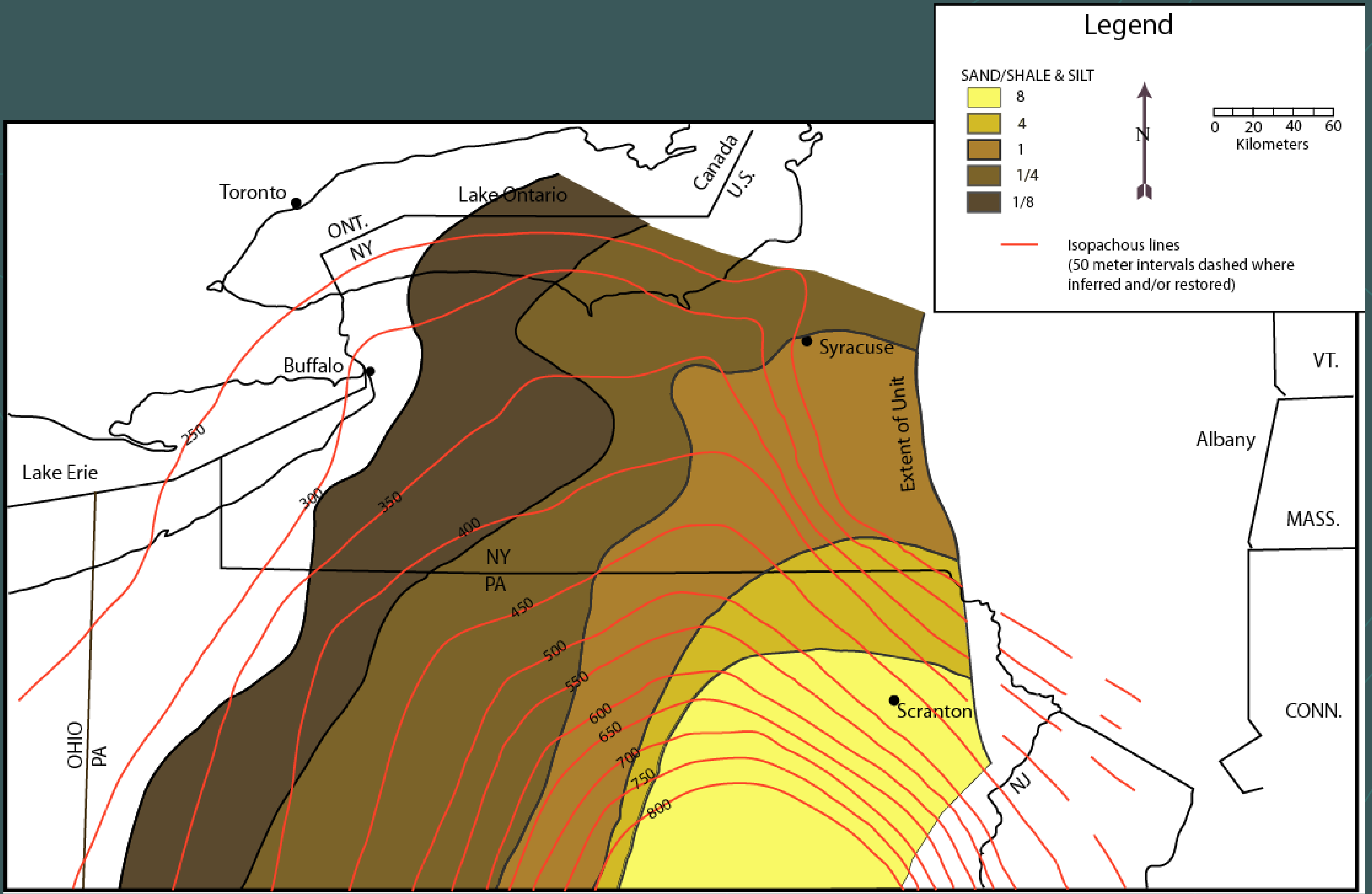
PERIOD		GROUP	UNIT	LITHOLOGY	ENVIRONMENT	POROSITY/ PERM.	OIL OR GAS RESERVOIR TYPE	CURRENTLY USED FOR STORAGE	POTENTIAL AS BRINE DISPOSAL RESERVOIR
DEVONIAN	UPPER	GENESEE	WEST RIVER ITHICA RENWICK SHERBURNE PENNYANN GENESEO	SHALE WITH MINOR SILTSTONE AND LIMESTONE	DEEP MARINE BASIN				NO
			TULLY	LIMESTONE WITH MINOR SILTSTONE AND LIMESTONE	LOW ENERGY			YES, 1, GILBERT [7]	MAYBE
	MIDDLE	HAMILTON	MOSCOW LUDLOWVILLE SKANEATELES MARCELLUS	SHALE WITH MINOR SANDSTONE AND CONGLOMERATE	DEEP BASIN, UNDERWATER DELTA CHANNELS, TIDAL FLATS, OFFSHORE BARS DEEP BASIN, POOR CIRCULATION OF OXYGEN		GAS [6]		MAYBE
			ONONDAGA	FOSSILIFEROUS LIMESTONE & REEFS	SHALLOW MARINE, MEDIUM- LOW ENERGY		GAS, REEF AND FAULT GENERATED FRACTURES [6]	YES, 2, FRACTURED LS AND PINNACLE REEF [1]	MAYBE
	LOWER	TRISTATES	ORISKANY	QUARTZ SANDSTONE	NEAR SHORE, SHALLOW MARINE, HIGH ENERGY	-ave. 9% -open fractures, 200-800 md [4,3]	GAS, FORMATION PINCHES OUT LOCALLY FORMING TRAPS, ANY CLOSED STRUCTURALLY HIGHER POSITION [3,6]	YES, AT LEAST 9 [7,6]	MAYBE
		HELDERBERG	MANLIUS RONDOUT	LIMESTONE AND DOLOSTONE	TIDAL, SHALLOW MARINE SHALLOW MARINE, HIGH SALINITY				NO
SIURIAN	UPPER		AKRON-COBLESKILL	DOLOSTONE AND LIMESTONE	SHALLOW MARINE, NORMAL SALINITY	< 5% < 1md [3]	OIL AND GAS, BASS ISLAND TREND, STRUCTURAL TRAPS, FRACTURES [1]	YES [6]	MAYBE
		SALINA	BERTIE CAMILLUS SYRACUSE VERNON	SHALE, DOLOSTONE, ANHYDRITE AND HALITE	SHALLOW SHELF, HIGH SALINITY RESTRICTED MARINE PLAYA OR LAKE COASTAL PLAIN, SHALLOW SHELF			YES, 1- LPG, 1 OPERATIONAL AND SEVERAL PROPOSED NAT. GAS, CENTRAL NY	NO
		LOCKPORT	LOCKPORT	LIMESTONE AND DOLOSTONE STROMATALITE MOUNDS	SHALLOW SHELF TO CARBONATE FLATS		GAS, PINNICALE REEF, NO MAJOR PRODUCTION		NO
	LOWER	CLINTON	ROCHESTER IRONDEQUOIT	SHALE SANDSTONE LIMESTONE	OPEN MARINE SHELF WARM, CLEAR, SHALLOW SHELF		GAS, STRATIGRAPHIC [6]		NO
			WILLOWVALE SAUQUOIT WOLCOTT SODUS BEAR CREEK FURNACEVILLE KODAK	SHALE SANDSTONE AND SHALE LIMESTONE SHALE HEMATITE & IRON ORE SANDSTONE	NEAR SHORE, SUBTIDAL QUIET WATER TO SHALLOW SHELF SHALLOW MARINE IN DEPRESSIONS BETWEEN NEAR SHORE RIDGES OF SAND				
		MEDINA	GRIMSBY WHIRLPOOL	SANDSTONE AND SHALE	DELTAIC - SHALLOW TURBULENT WATER		GAS, SAND DOMINATED CHANNEL DEPOSITS, PRODUCED FROM FRACTURES [1]	10 GAS STORAGE FIELDS IN WESTERN NEW YORK [1]	MAYBE
ORDOVICIAN	UPPER		QUEENSTON	SANDSTONE AND SHALE	DELTAIC, BRAIDED STREAM	AS HIGH AS 1940 md	GAS, UP DIP FACIES CHANGE [3]	POTENTIAL GAS STORAGE [1]	YES
			OSWEGO LORRAINE UTICA	SHALEY SANDSTONE SHALE WITH SANDSTONE AND SILTSTONE	NEAR SHORE AND BEACH SHALLOW AND MODERATELY DEEP MARINE DEEP BASIN		PORPOSED GAS, GAS SHALE		NO
	MIDDLE	TRENTON-BLACK RIVER	TRENTON BLACK RIVER	FOSSILIFEROUS LIMESTONE DOLOSTONE AND HYDROTHERMAL DOLOMITE	SHALLOW MARINE, TIDAL FLATS AND SLOPE SHALLOW SHELF		GAS, VUGGY HYDROTHERMAL DOLOMITE, FRACTURES-TUG HILL AREA [6]		YES
	LOWER / UPPER	BEEKMAN-TOWN	TRIBES HILL LITTLE FALLS THERESA (GALWAY) POTSDAM	DOLOSTONE, LIMESTONE AND SILSTONE DOLOSTONE SANDSTONE AND SANDY DOLOSTONE QUARTZ SANDSTONE	TROPICAL COASTAL COMPLEX	Numerous porous zones in upper portion of L.F. [4] Basal Potsdam extremely porous and permeable [4]	GAS, vuggy dolomite, STRUCTURAL CLOSURE OF FRACTURE SYSTEM [5,6]	POTENIAL STORAGE RESERVOIR	YES
PRECAMBRIAN			MARBLE QUARTZITE etc>	METAMORPHIC AND IGNEOUS ROCKS					NO

- YES
  - Right Lithology
  - Good Porosity and Permeability
  - History of Production
  - Not used as a storage reservoir
- MAYBE
  - All of the above and currently used for storage

Potential Disposal Reservoirs

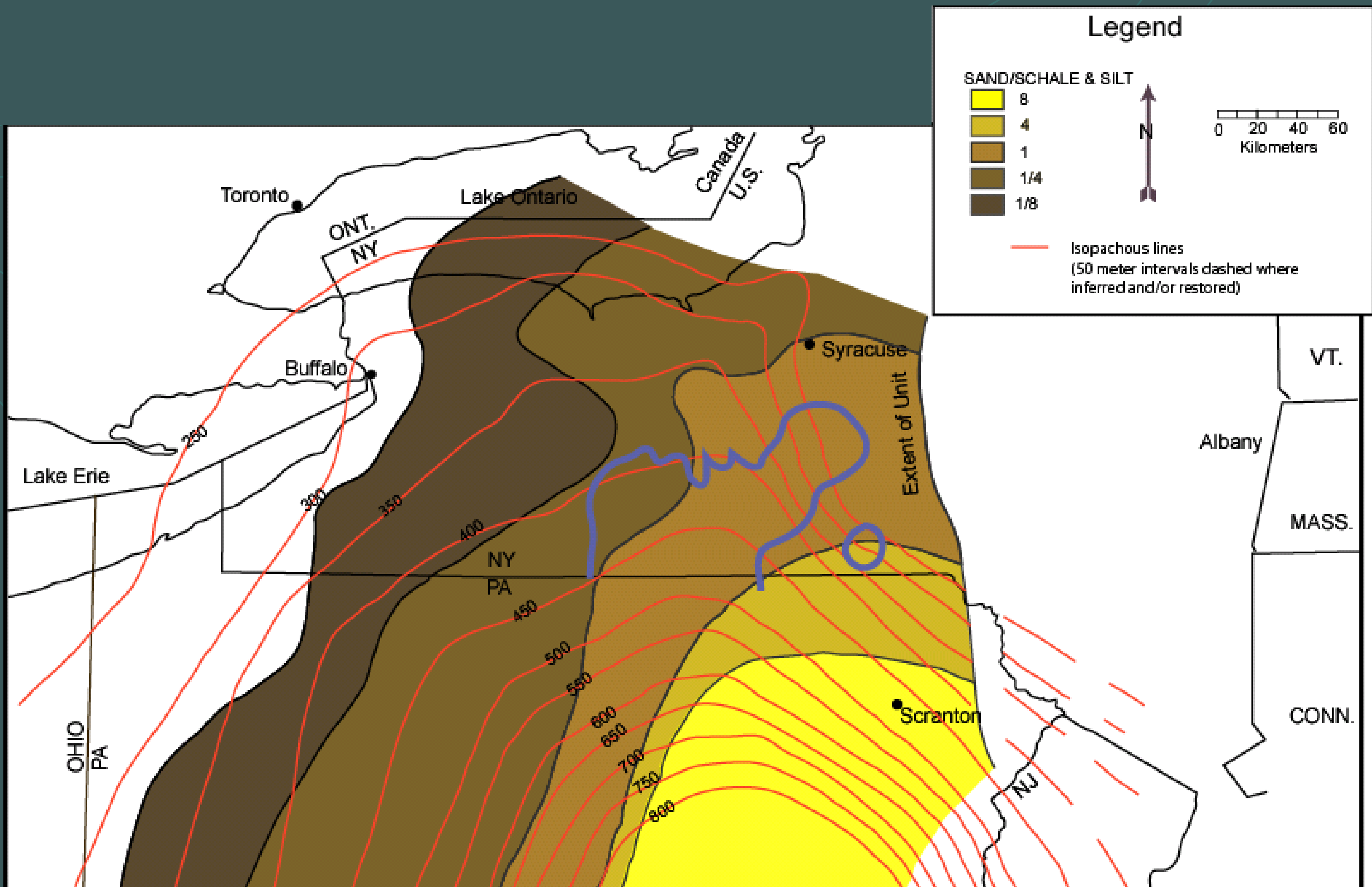
- YES
  - Queenston Formation
  - Trenton-Black River Hydrothermal Dolomite
  - Beekmantown Group
- MAYBE
  - Tully Limestone
  - Hamilton Group
  - Onondaga Limestone
  - Oriskany Sandstone
  - Akron-Cobleskill Limestone
  - Medina

Queenston Sand/Shale Ratio Map



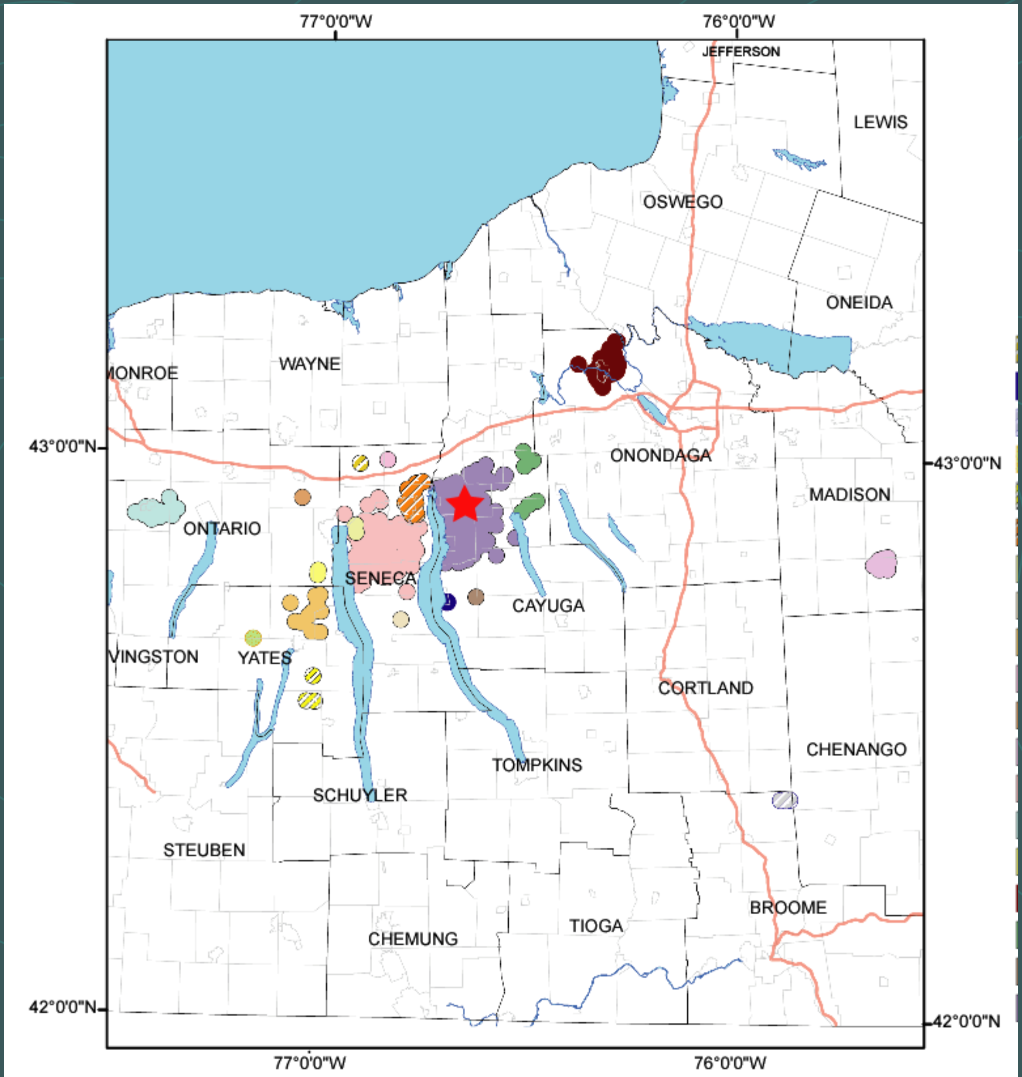
(Modified from Saroff, 1987).

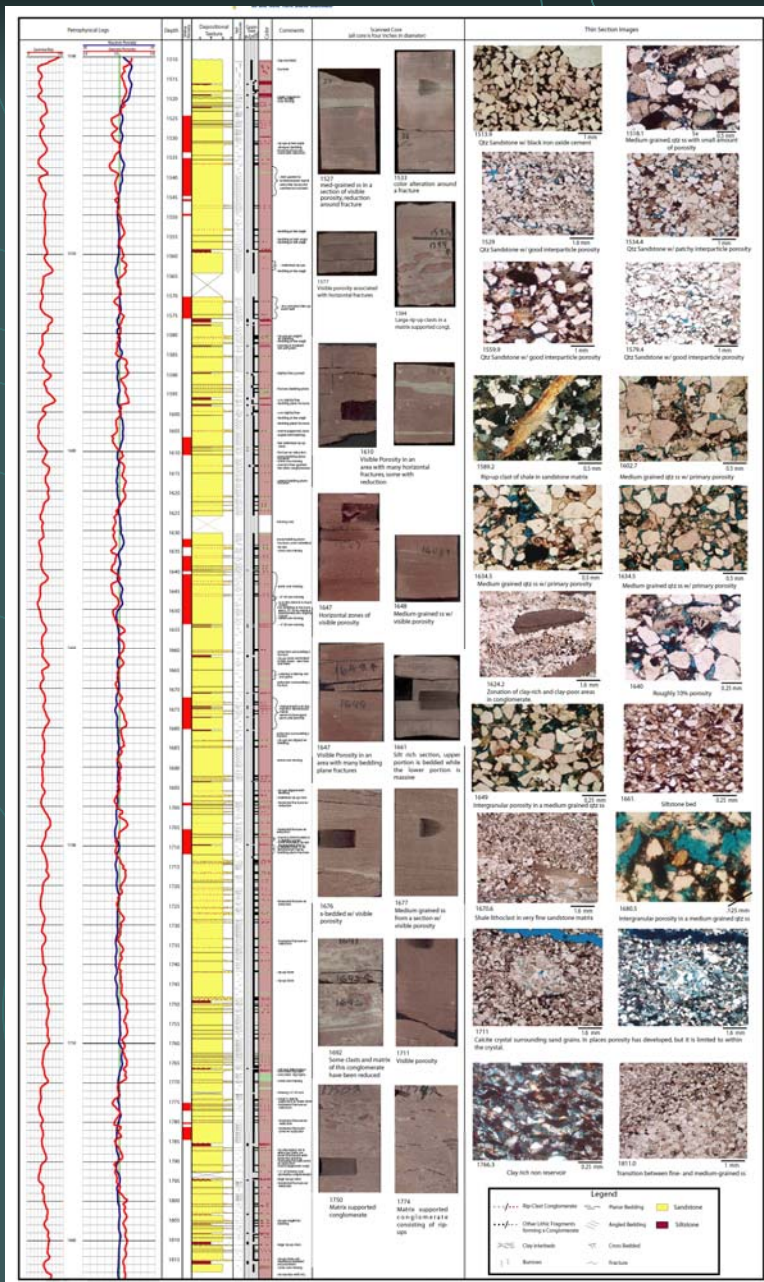
Queenston Sand/Shale Ratio Map



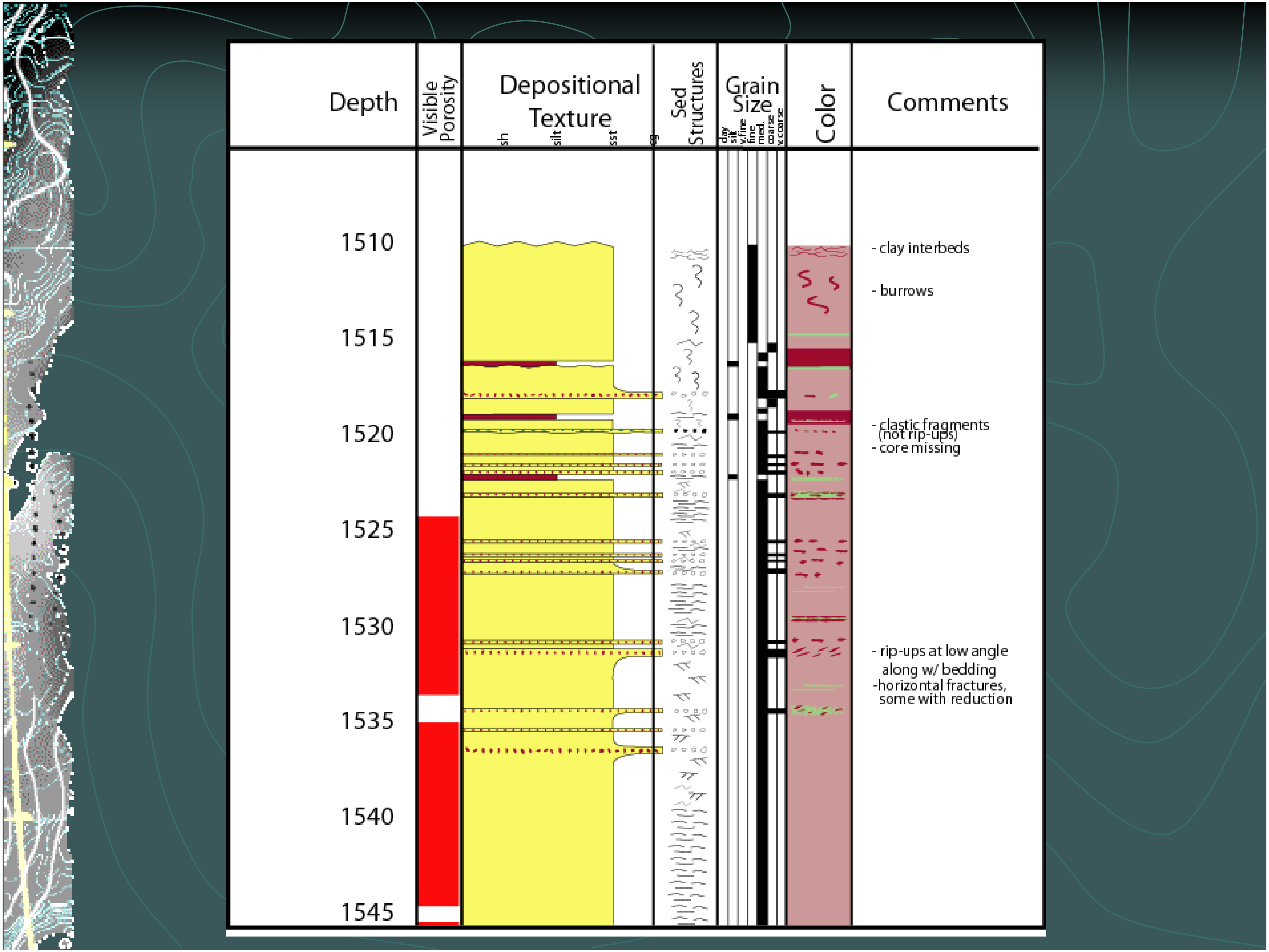
(Modified from Saroff, 1987).

We have a Queenston core in our collection that is from the Auburn Field





We described the core in detail focusing on the depositional texture and defining zones of visible porosity



Depth
Visible Porosity
Depositional Texture
sh
silt
sst
cg
Sed Structures
Grain Size
clay
silt
v.fine
fine
med.
coarse
v.coarse
Color
Comments
1510
1515
1520
1525
1530
1535
1540
1545
- clay interbeds
- burrows
- clastic fragments (not rip-ups)
- core missing
- rip-ups at low angle along w/ bedding
-horizontal fractures, some with reduction

Main Rock Types

Sandstone

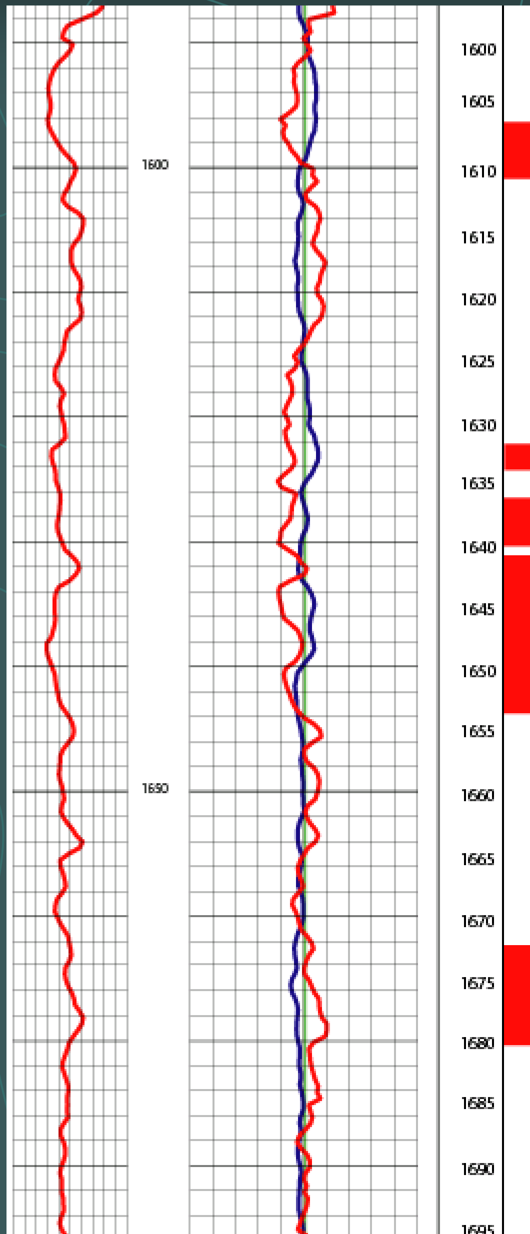
Reservoir Facies

Siltstone

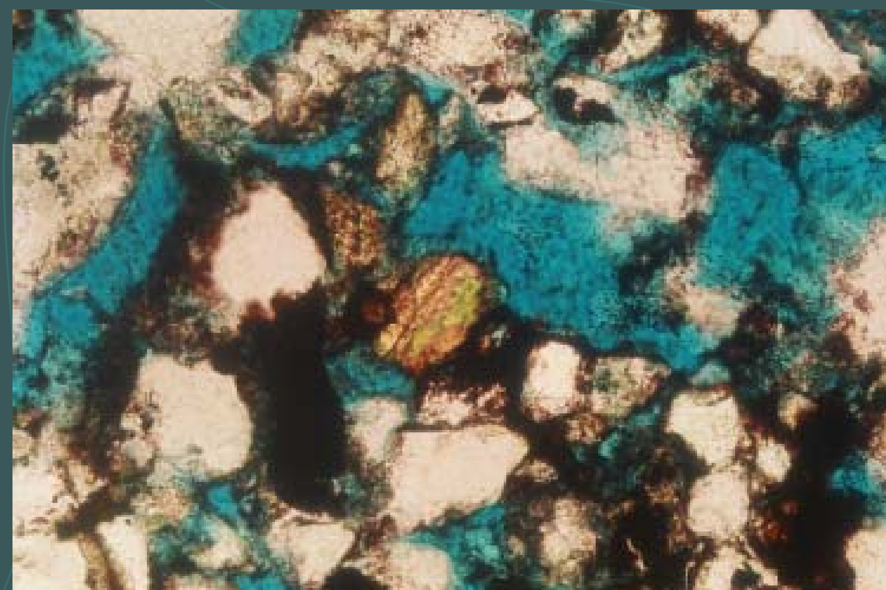
Conglomerate

4 in.

Log Analysis



- Zones of visible porosity correlate reasonably well to areas where the density is less than average (2.5)



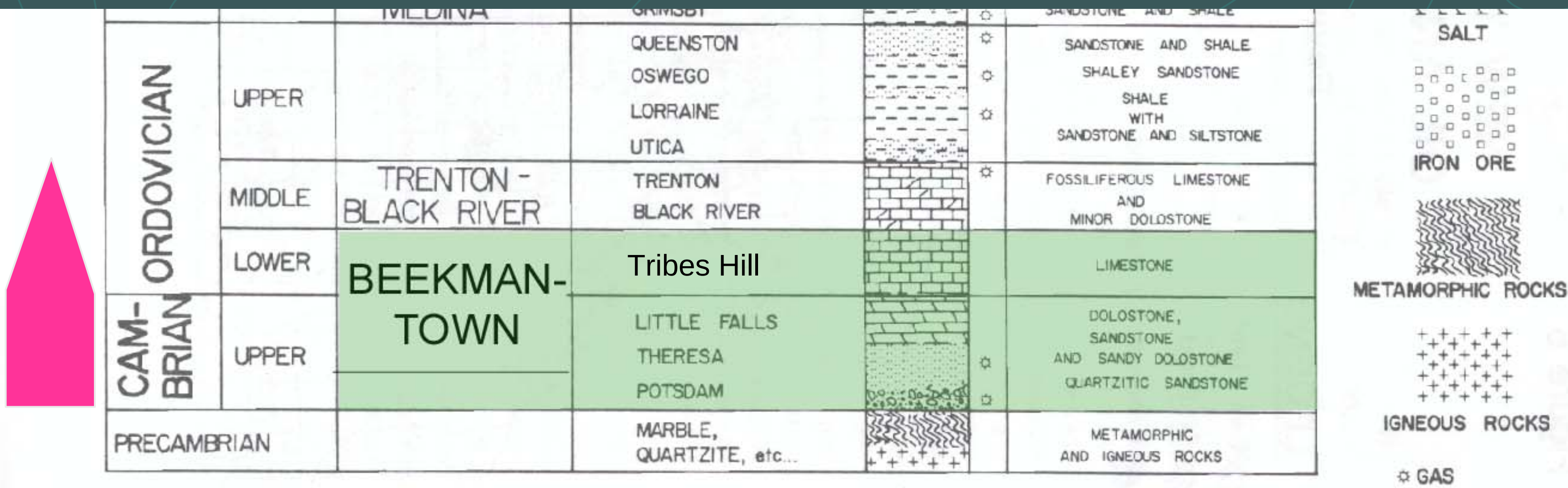
1680.5 .125 mm

Intergranular porosity in a medium grained qtz ss

Queenston Disposal Reservoir Potential

- It is widespread and more sand-rich in in the area of usable salt
- It has shown to have the capacity to accept brine in current disposal operations
- Production from the Queenston has occurred for over 30 years in central New York
- Reservoir in sandstone

Beekmantown Group



Study interval includes Tribes Hill, Little Falls, Theresa and Potsdam Formations and all equivalents in New York

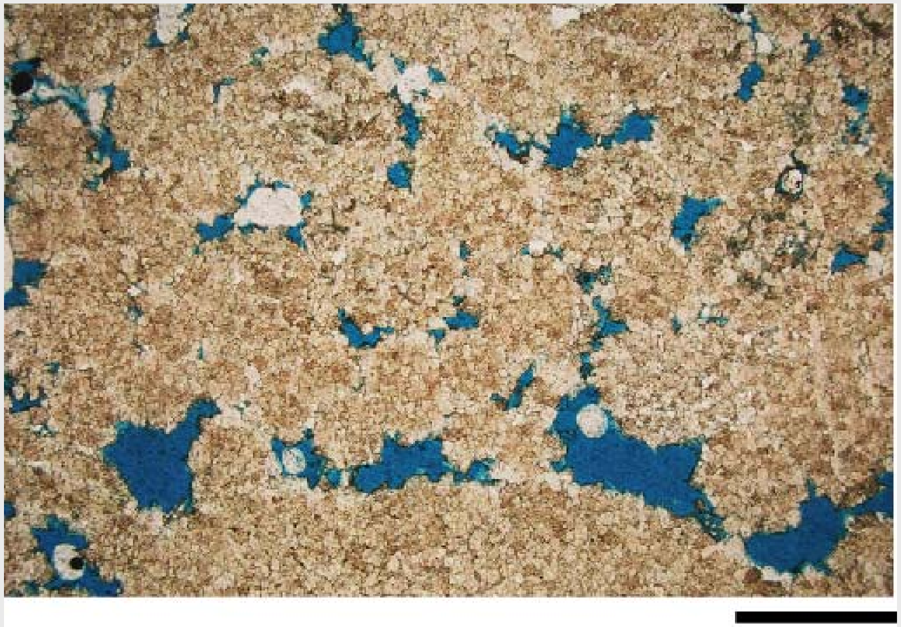
Potential for disposal is in porous dolomite, hydrothermal breccias and possibly in sandstone

The best reservoir potential in the Beekmantown Group is found in the porous dolomites of the Peloidal Grainstone interval in the Little Falls

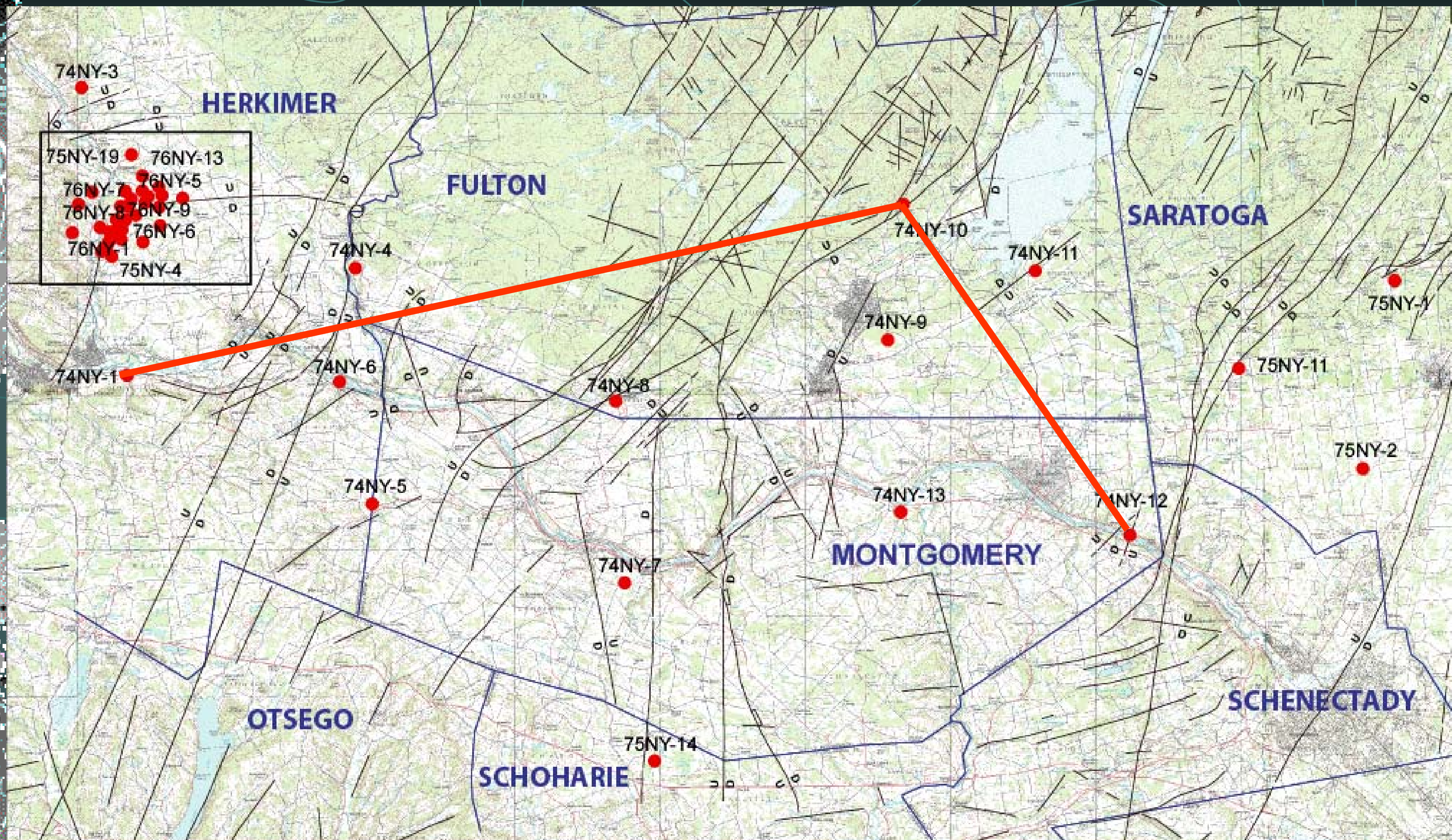
74NY-13: 615 feet

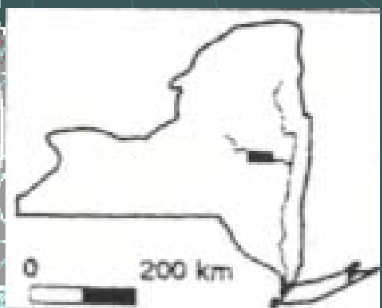
Peloids are either micritized ooids and rounded skeletal grains or fecal in origin.

Environment: Forms in shallow, high-energy conditions.



74NY-10: 701 feet



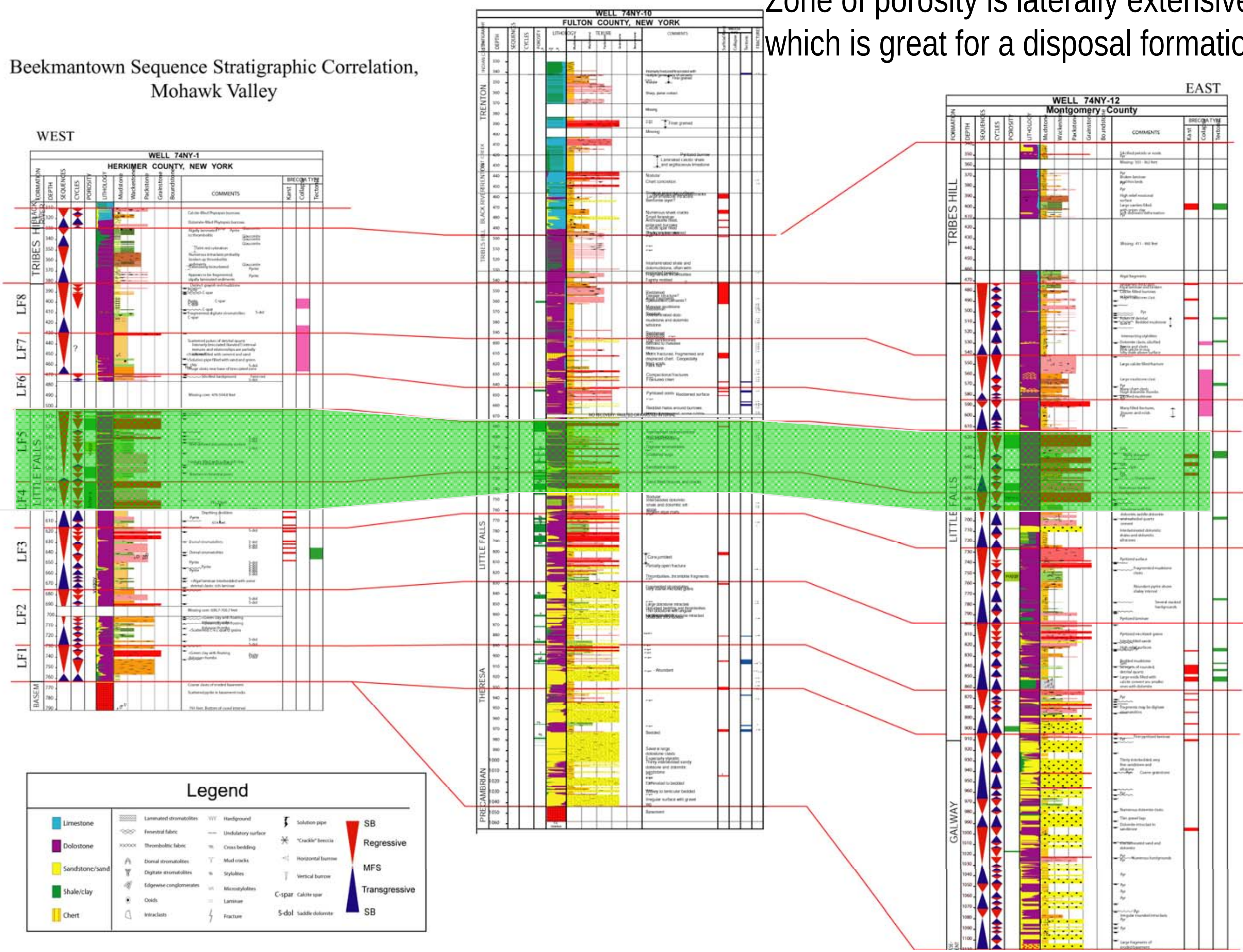


Core locations from Mohawk Valley, New York

All cores go from Utica to basement

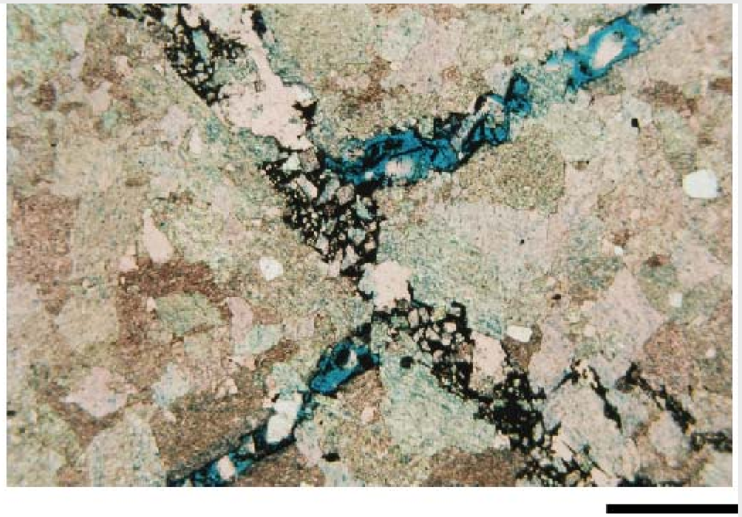
We are currently studying these cores in detail

Zone of porosity is laterally extensive, which is great for a disposal formation



Hydrothermal Breccia

74NY-1: 643 feet



74NY-10: 646 feet 0.5 mm

74NY-10: 658 feet 1.0 mm

These breccias have saddle dolomite and calcite cement, no clay

Environment: Forms due to fault movement and associated thermobaric fluid flow

Reservoir Quality: Could be good if laterally extensive

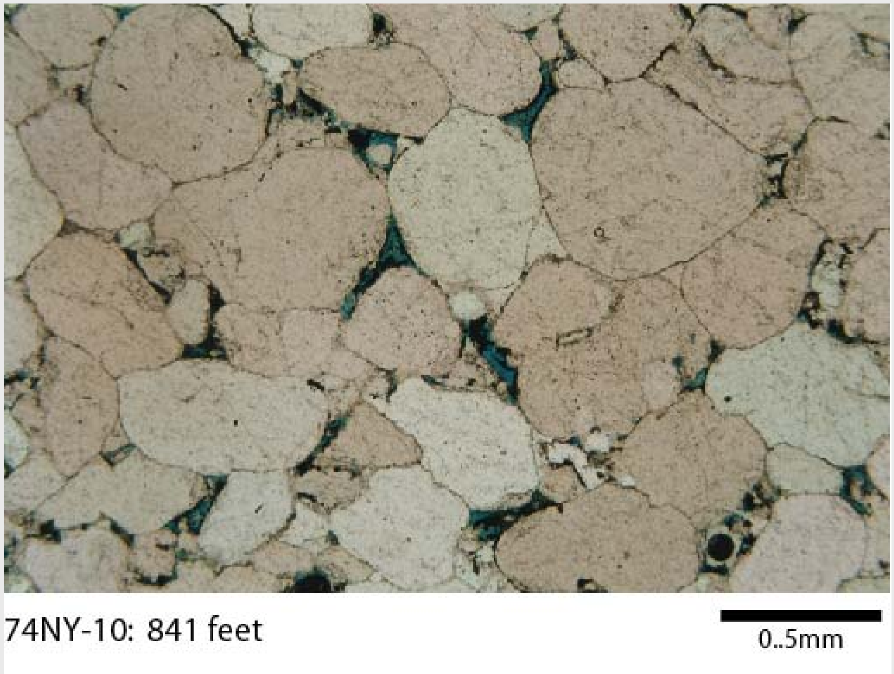
Quartz Sandstone

Sandstone is common, particularly toward base; cross-bedding common; Most is cemented with quartz overgrowths or dolomite

Environment: wave and tide-dominated, shallow marine

Reservoir Quality: Generally poor, some interparticle porosity

74NY-1: 625 feet

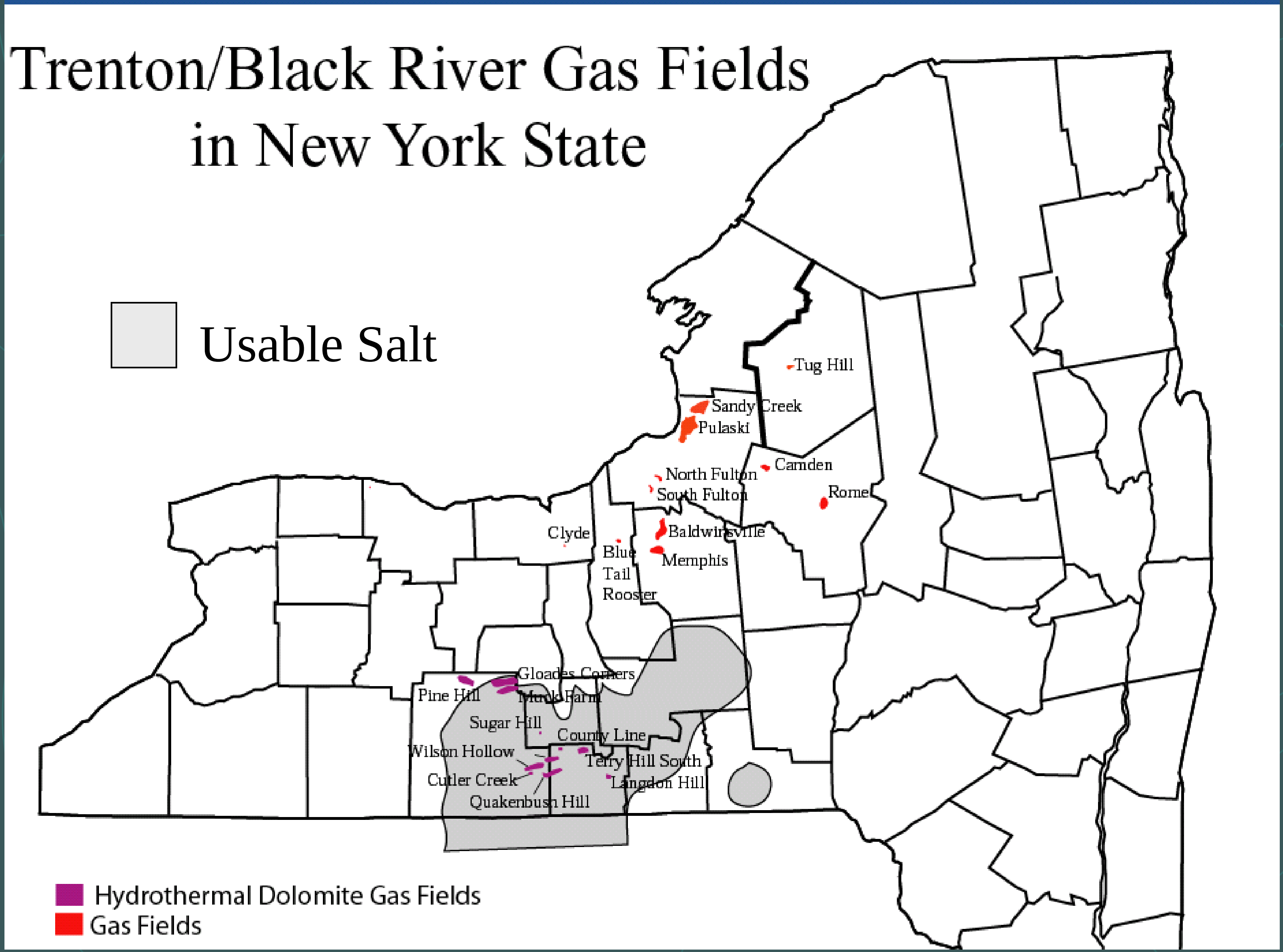


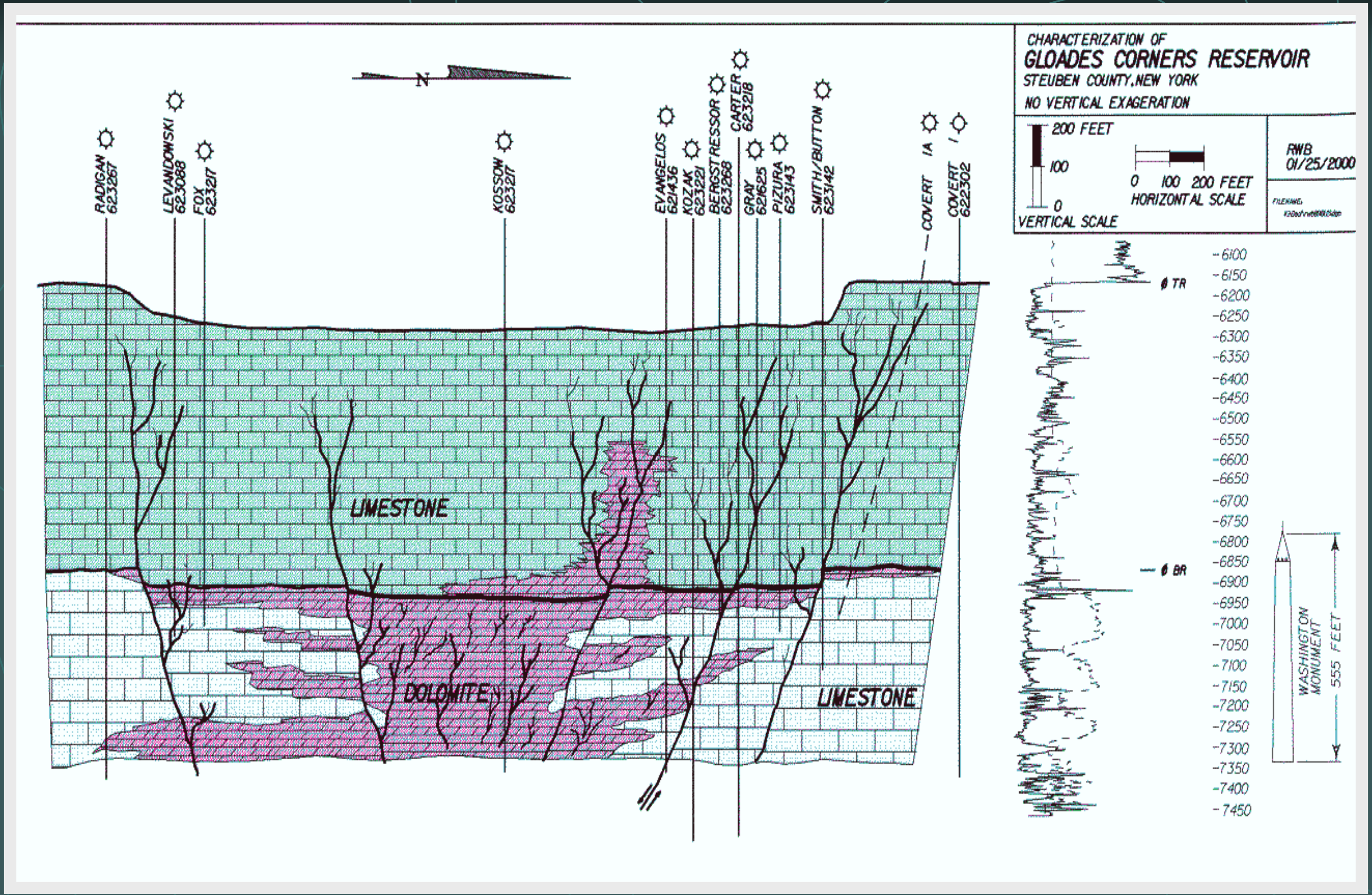
74NY-10: 841 feet

Beekmantown Disposal Reservoir Potential

- Reservoir in porous dolomite and possibly sandstone and hydrothermal breccias
- Porosity is widespread (Beekmantown Study in Ohio showed widespread porosity in “B” Unit; Mohawk Valley study shows laterally-extensive porosity)
- Beekmantown is thick in areas of usable salt

Trenton-Black River

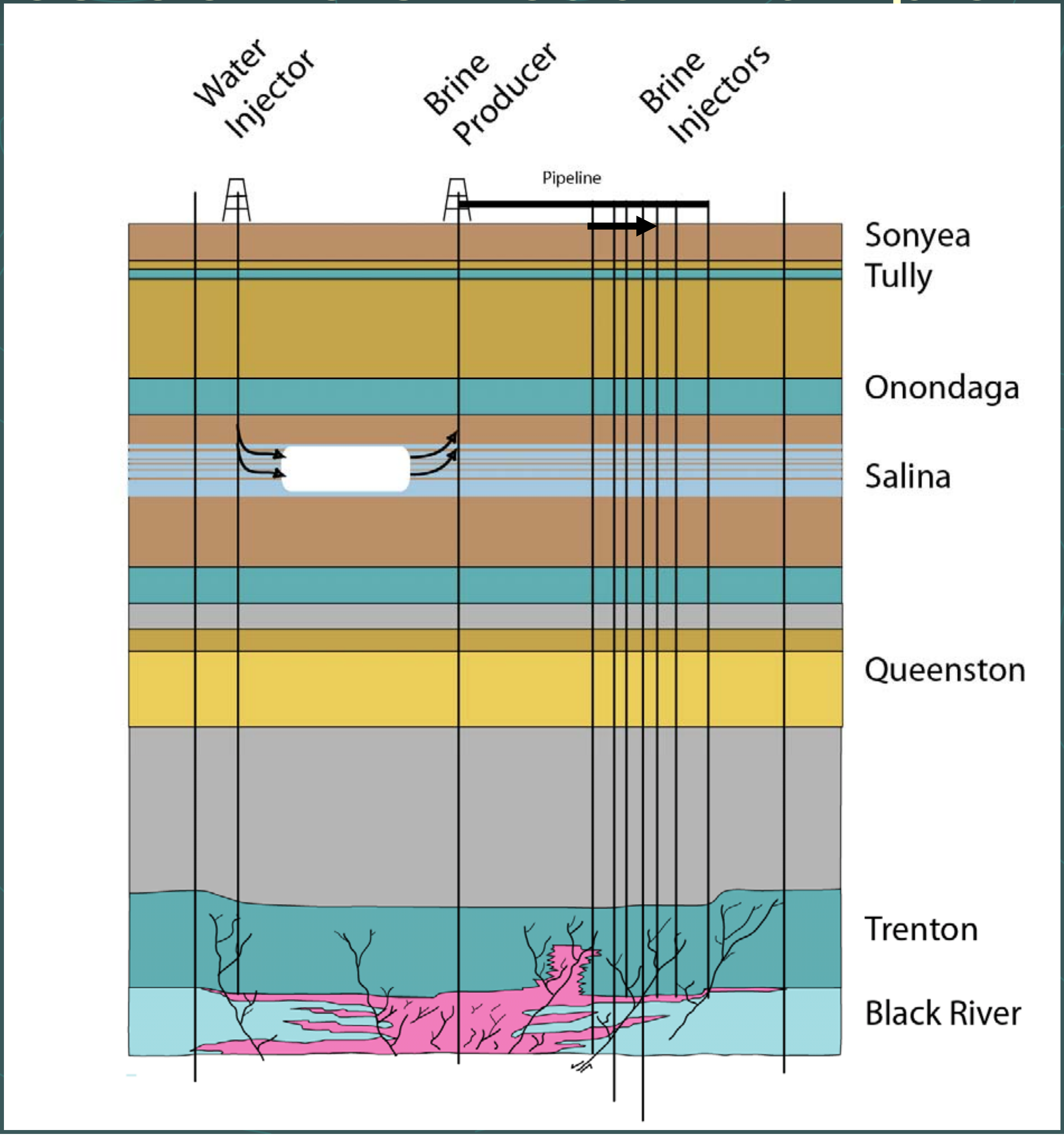




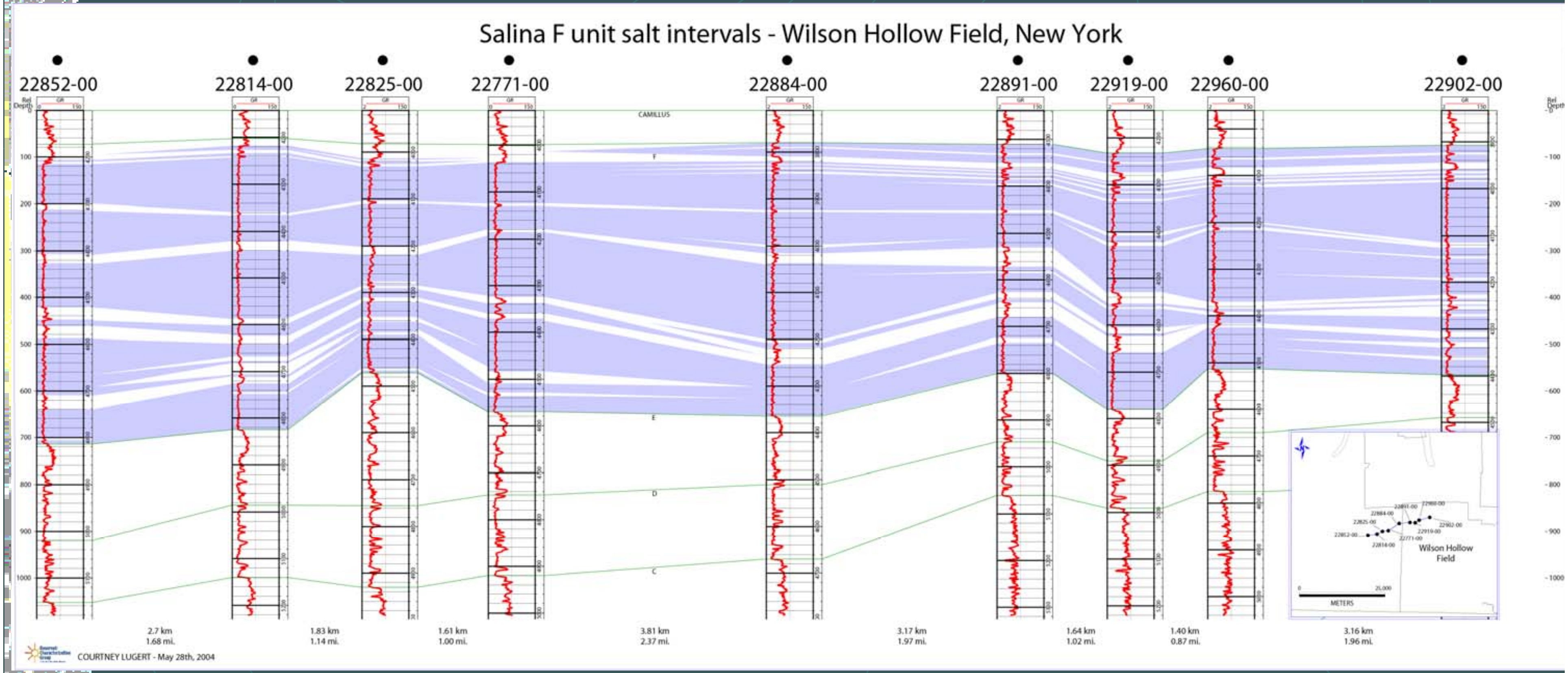
Trenton-Black River Fields typically produce from diagenetic traps in fault-controlled structural lows where patchy matrix dolomite and brecciated zones are common.

Vuggy porosity in hydrothermally altered Black River Group

Glodes Corners Road Example



Cross section through Wilson Hollow Field, NY



Trenton Black River Disposal Reservoir Potential

- Prolific producers in recent time
- Fields are located in area of usable salt
- Most wells are still active and could be converted easily
- The fields may prove to be unattractive for conventional depleted reservoir storage due to the heterogeneity and unknown lateral extent
- Reservoir- vuggy dolomite in Black River

Conclusions

- Brine disposal is the major obstacle to salt cavern storage in the New York
- Our systematic study of potential brine injection reservoirs shows that there are three potential targets in area of usable salt: The Queenston, Trenton Black River and Beekmantown

Future Work

- Continue to make maps of possible brine disposal reservoirs
- Analysis of all logs in area of usable salt for porosity in Queenston and Beekmantown
- Feasibility study of whether Trenton Black River will make good gas storage reservoir. If not, it could be a great brine disposal target

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