Geological Carbon Sequestration Potential in New York State

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New York State Museum

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CARBON DIOXIDE CAPTURE AND STORAGE (CCS)

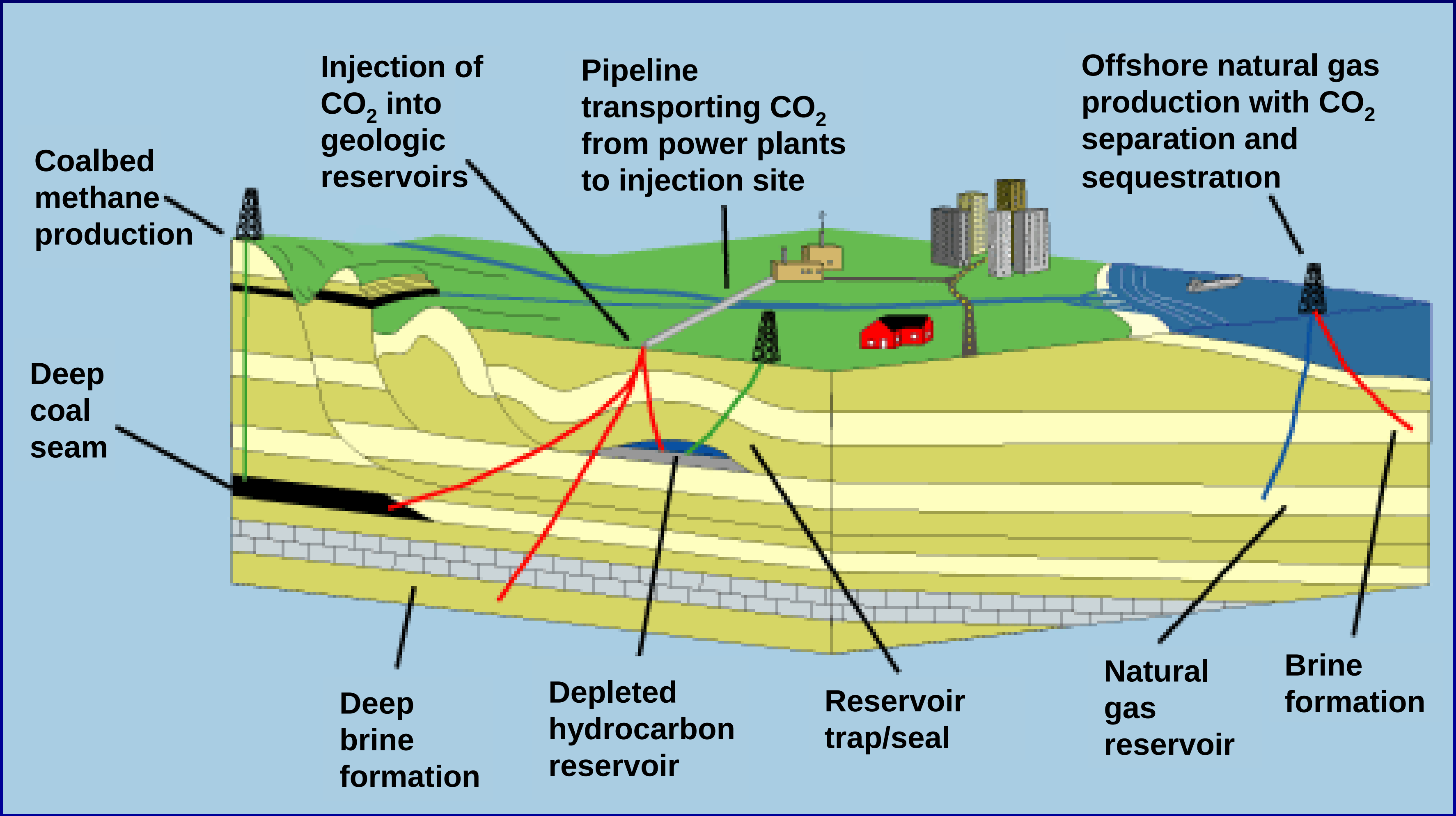
- We conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs.
(The MIT Study- The Future of Coal, 2007)

- For well-selected, designed and managed geological storage sites, IPCC estimates that CO_2 could be trapped for millions of years, and the sites are likely to retain over 99% of the injected CO_2 over 1,000 years. *(IPCC CCS Report 2005)*

Geological Carbon Sequestration

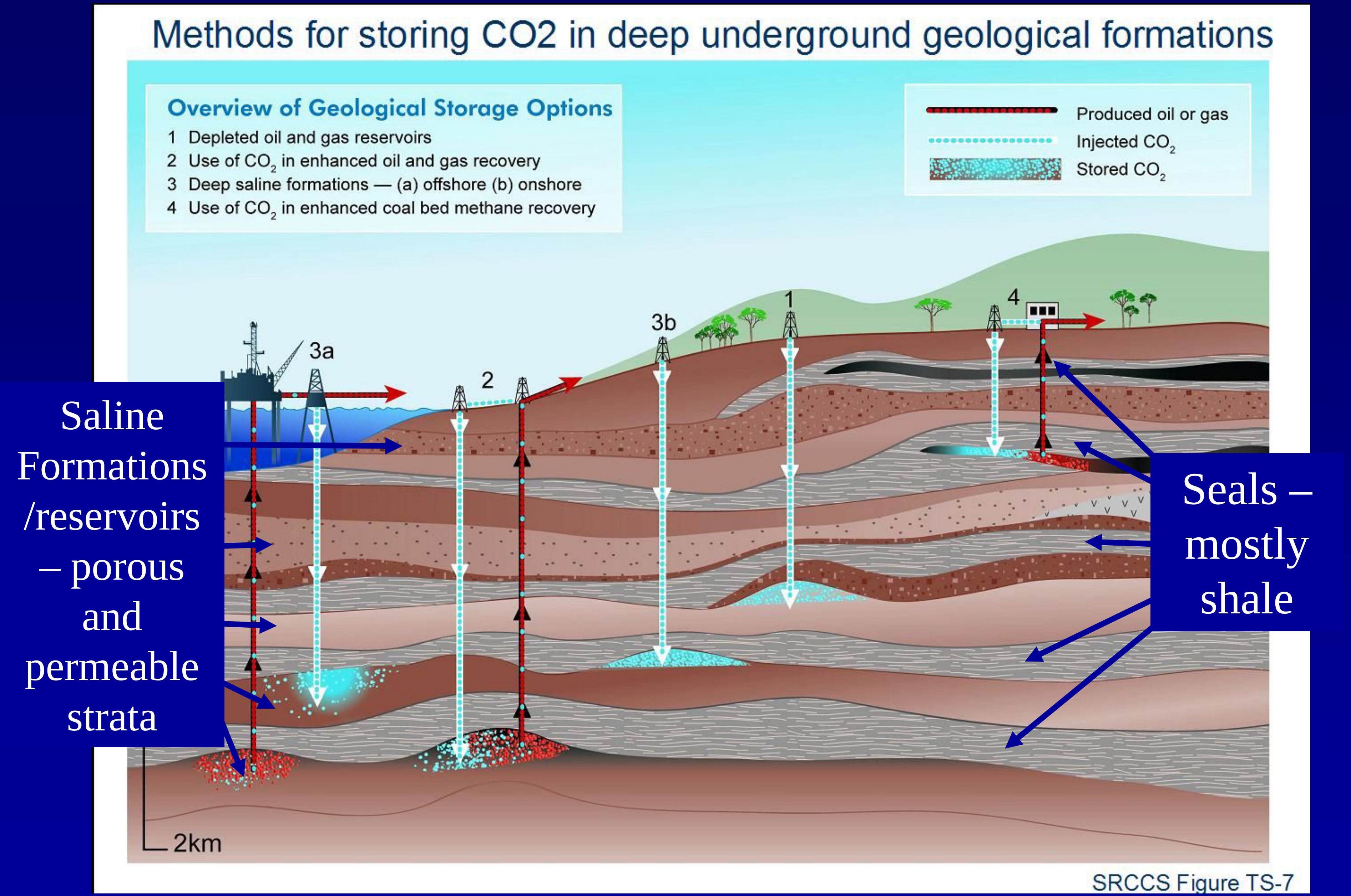
- Geological carbon sequestration consists of CO_2 captured at a point source that is pumped down wells and into formations where it would remain for thousands of years
- The streams of CO_2 would largely come from modified coal-burning power plants
- The capture of the CO2 is another science where much work is currently underway

Carbon Capture and Storage (CCS)



Oil and Gas Geology in Reverse

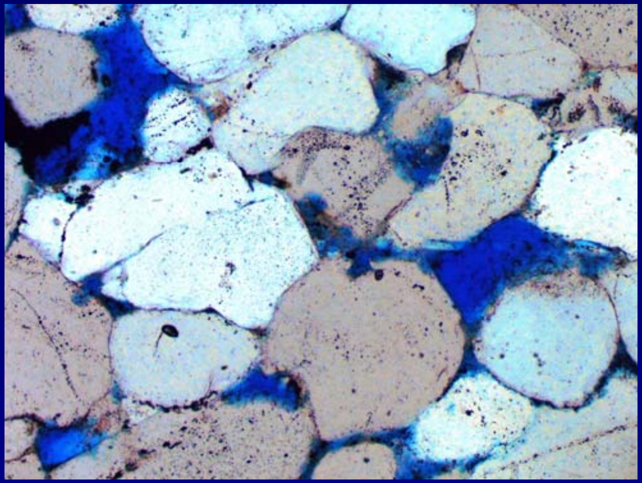
- We are basically looking for formations that either could or do make good oil and gas reservoirs – porous and permeable strata with good overlying seals
- The oil and gas reservoirs in NY have kept the hydrocarbons in place for hundreds of millions of years and the expectation is that any carbon pumped underground would stay there for that kind of time period

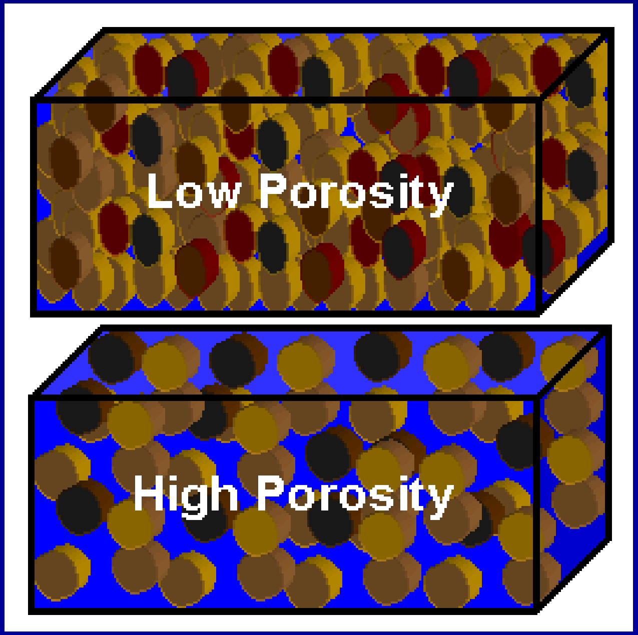


We are looking at options 1-3 (esp. 3) for geological sequestration in NY (from the IPCC 2006 report on CCS after Cook, 1999)

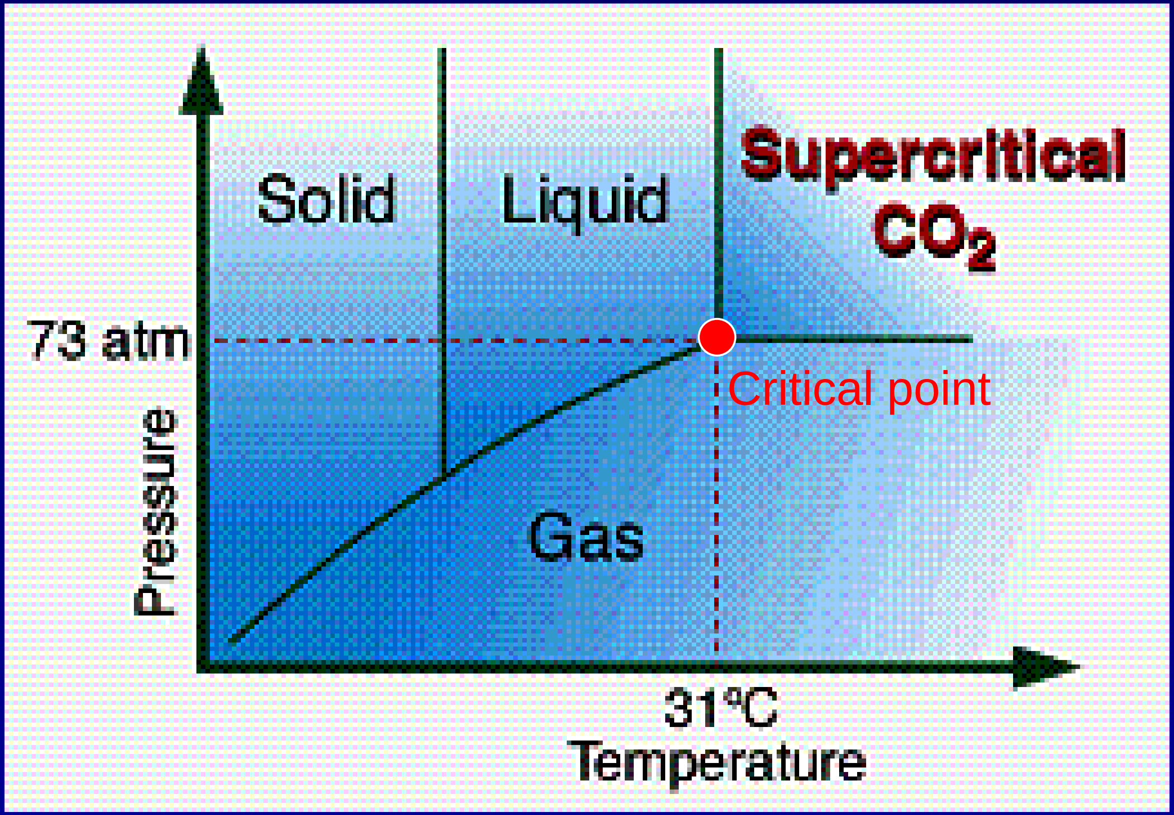
Porosity and Permeability

- Porosity – the measure of void space in a rock or sediments
- Permeability – ability of a rock or sediments to transmit fluids – connectedness of the pores
- Need at least some porosity and permeability to store CO_2
- Also need impermeable seals to trap CO_2





Supercritical State



CO_2 should be sequestered underground in a supercritical state that has the density of a liquid but flows like a gas – In a given space, one can store about 260 times more CO_2 in a supercritical state than in a vapor or liquid state –

In order to keep CO_2 in a supercritical state, it needs to be buried to a depth of at least 2500 feet where the pressure and temperature remain above the critical point

Geological Work with the MRCSP

The Midwest Regional Carbon Sequestration Partnership (MRCSP) began its Phase I work in 2003 and is now well into Phase II of the NETL program. It is considering geological storage, terrestrial sequestration, and legal/regulatory issues.

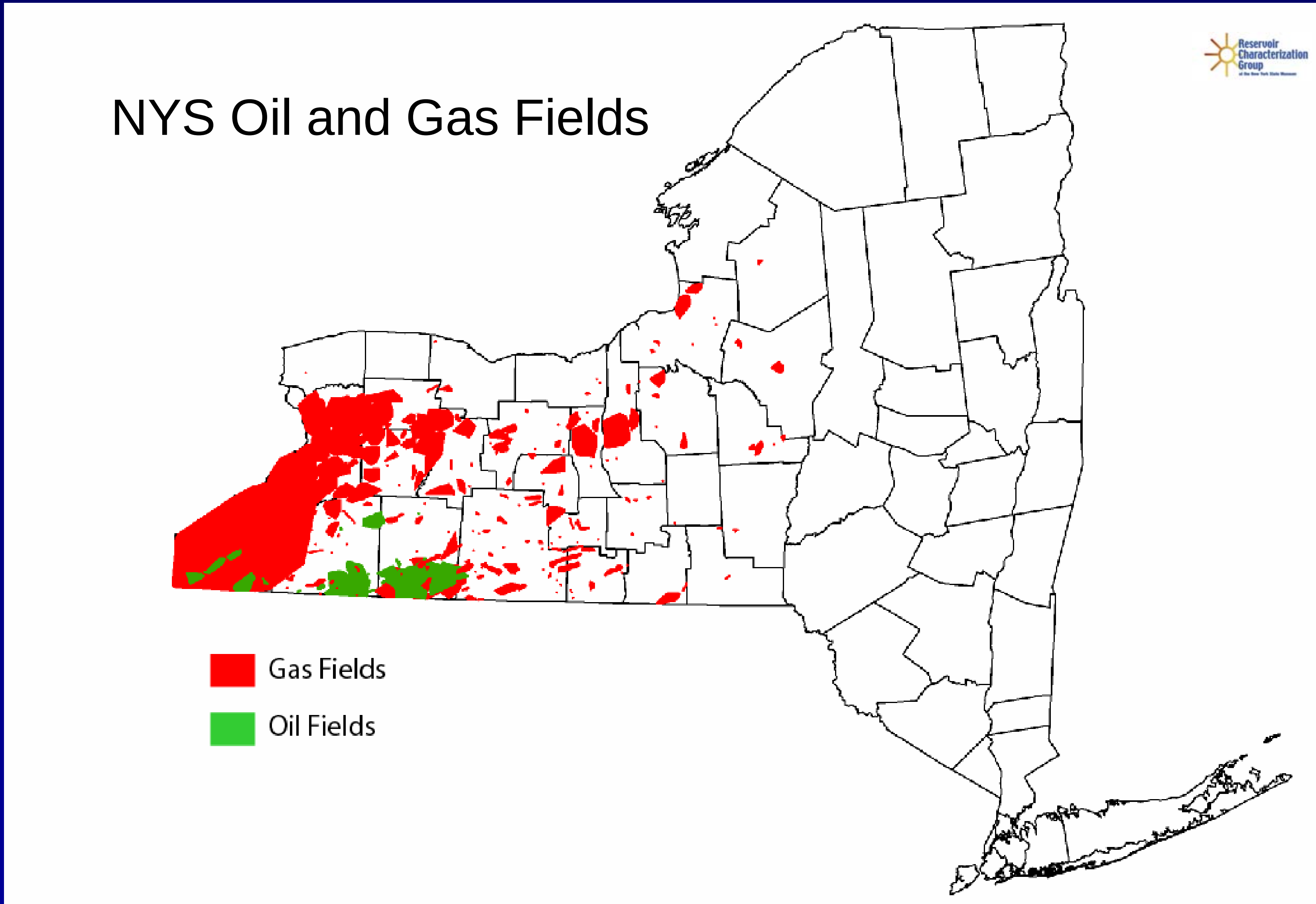
New York State is in the process of joining the MRCSP and is now in the process of getting up to speed and integrating its data with that of the other member states (NYS Museum).

After correlating New York's stratigraphy with that of the other MRCSP states (Phase I), specific target formations have been identified that warrant more detailed investigation (Phase II) and scaled demo (Phase III).

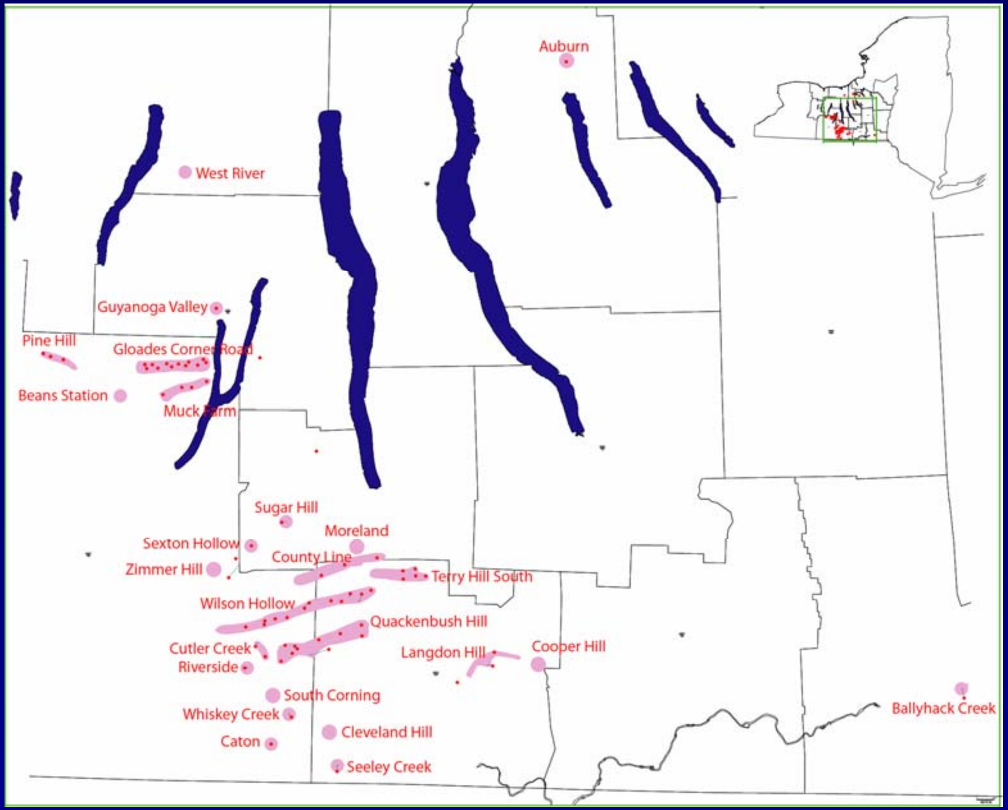
MRCSP
MIDWEST REGIONAL
CARBON SEQUESTRATION
PARTNERSHIP

Geological Sequestration in NY

- Looking for porous and permeable strata at least 2500 feet deep with an overlying impermeable seal. Most likely targets are:
  - Onshore depleted natural gas reservoirs – NY has produced gas for more than 125 years and there are many old fields that could be suitable for carbon sequestration - we know that they have good seals
  - Onshore and Offshore Saline Formations – These are rock formations with porosity and permeability that are currently filled or nearly filled with very salty water (salinity up to 8 times seawater) that are isolated from shallower fresh water



Some of New York's depleted gas reservoirs could make good sequestration targets and CO_2 might actually be used to enhance gas production (oil fields too shallow)



Porous dolomite from Black River Formation – our biggest gas producer today – this formation could probably accept at least one large power plant's CO_2 for plant lifetime

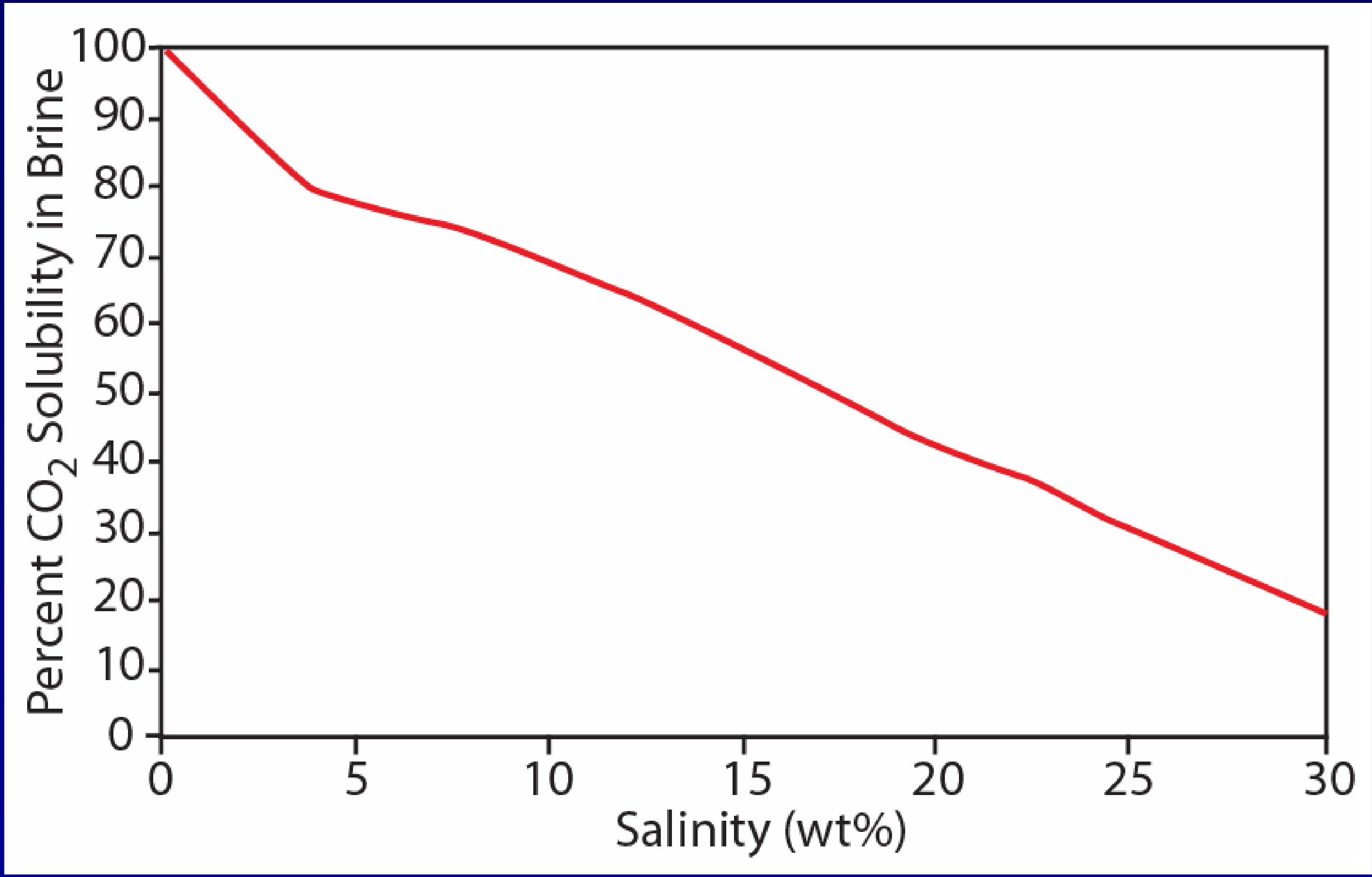
There may be competition for this pore space as most good gas reservoirs are converted to natural gas storage fields, which can make a lot of money for their owners

Reservoir Characterization Group

Saline Aquifers

- A saline aquifer is a rock formation that has saline brine in the pore space – not potable water
- There are two main types of geological sequestration in saline aquifers:
- *Solubility Storage* –CO_2 goes into solution in the in situ water
- *Volumetric Storage:* displacing in situ fluid with CO2 – estimates range from 0.5 to 30% of fluid might be displaced – the question is where does it go? Rock type dependent

Solubility Storage



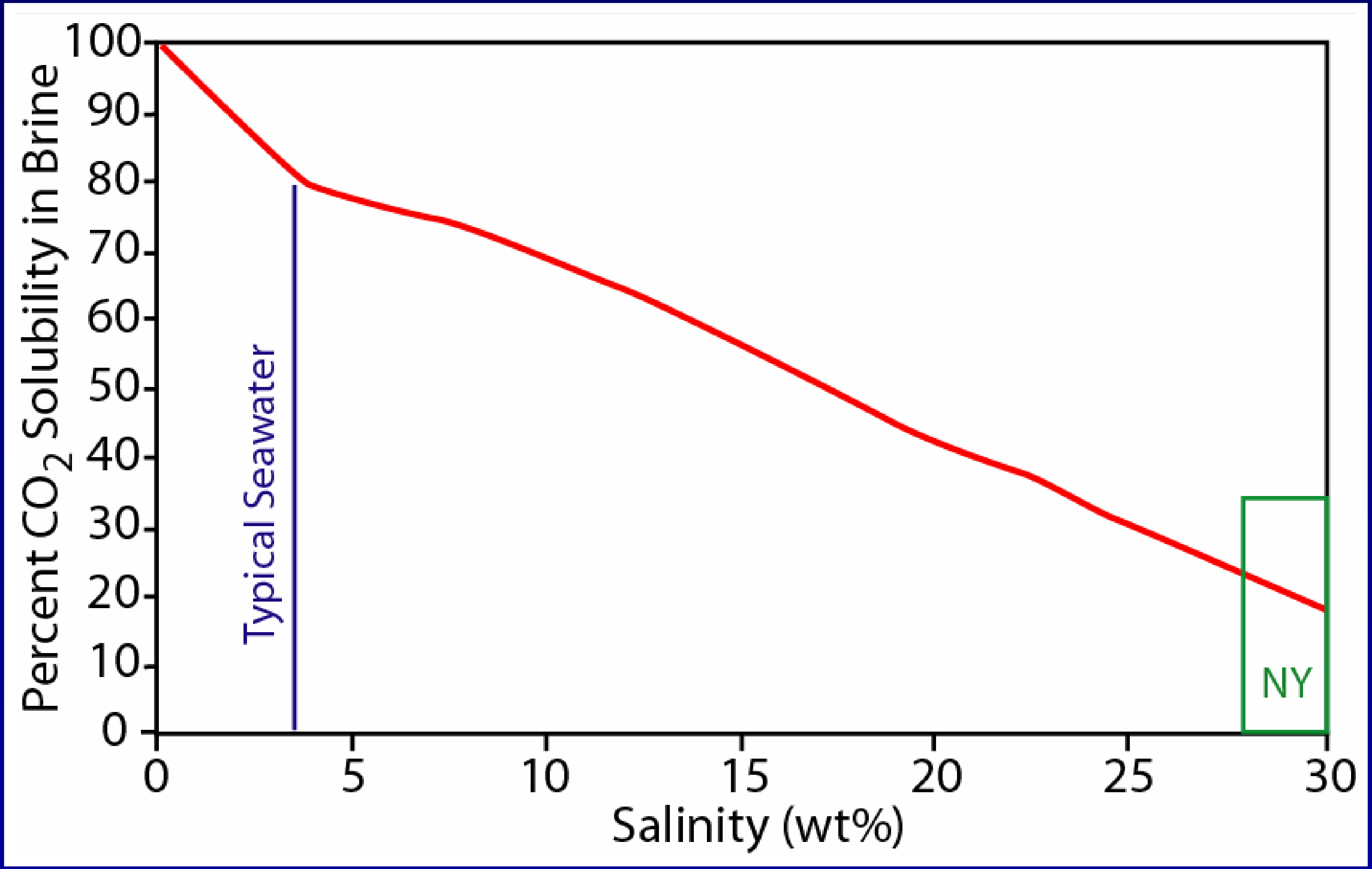
- CO2 dissolves into in situ fluid eventually precipitate minerals that lock CO2 in place permanently

- Solubility of CO2 is strongly dependent on salinity

Measured Salinity of Formation Waters in NY State (DEC, 1988)

- Below Silurian Salt Layer
  - Silurian Bass Island 323,500 ppm (32 wt%)
  - Silurian Medina – 292,121 ppm (29 wt%)
  - Ordovician Queenston – 298,358 ppm (29 wt%)
  - Cambrian Potsdam/Theresa – 300,763 ppm (31 wt%)
- Above Silurian Salt
  - Upper Devonian Oil Zones – 156, 267 ppm (15 wt%)

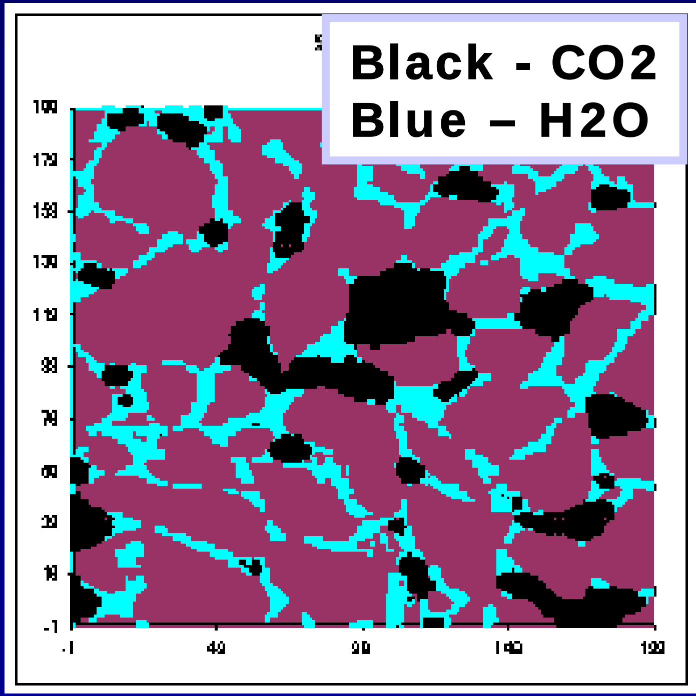
Solubility Storage Potential Very Limited



Because of the high salinity of New York's onshore saline aquifers solution storage will not supply a significant amount of storage capacity

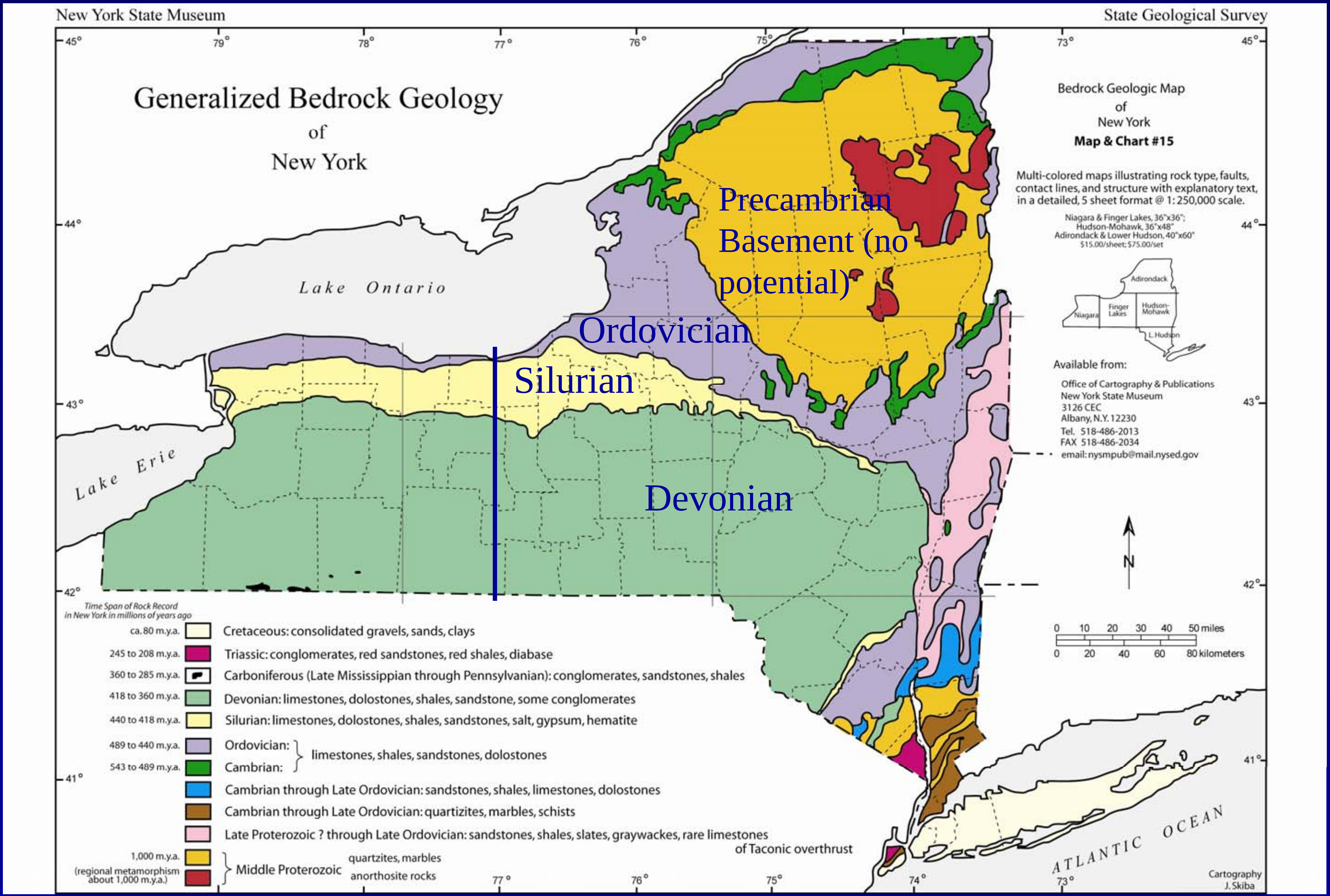
Volumetric Storage

- Volumetric storage means displacing *in situ* fluid with CO_2
- This is controlled by the formation storage efficiency factor - estimates range from 0.5 to 30% of fluid might be displaced
- The question is where does fluid go?
- Rock type dependent – softer, high porosity sediments probably have higher values than harder older rocks (like we have in NY)
- Any sequestration in NY will be primarily of this type

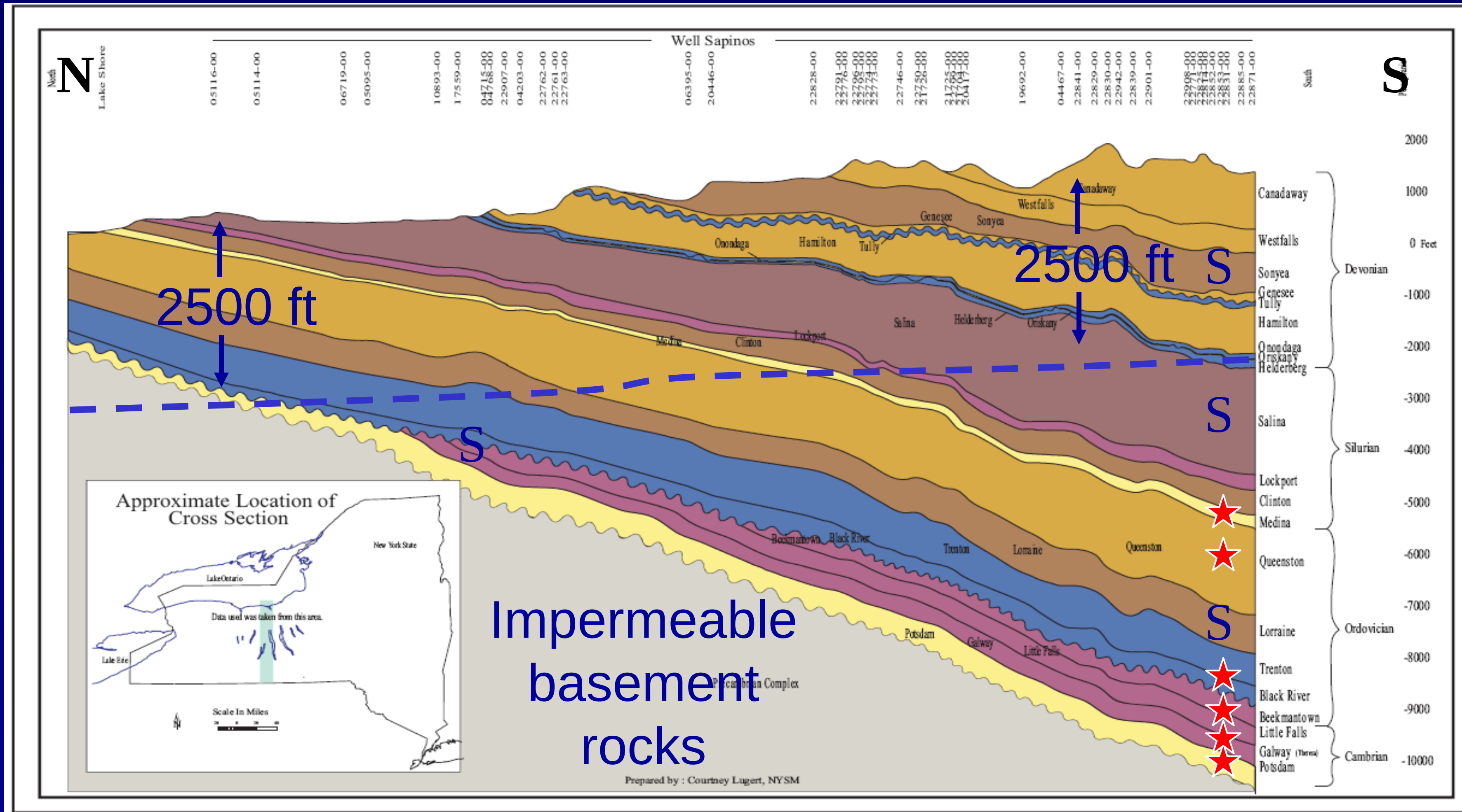


Volumetric storage

Critical question: What % of pore space available for volumetric storage?

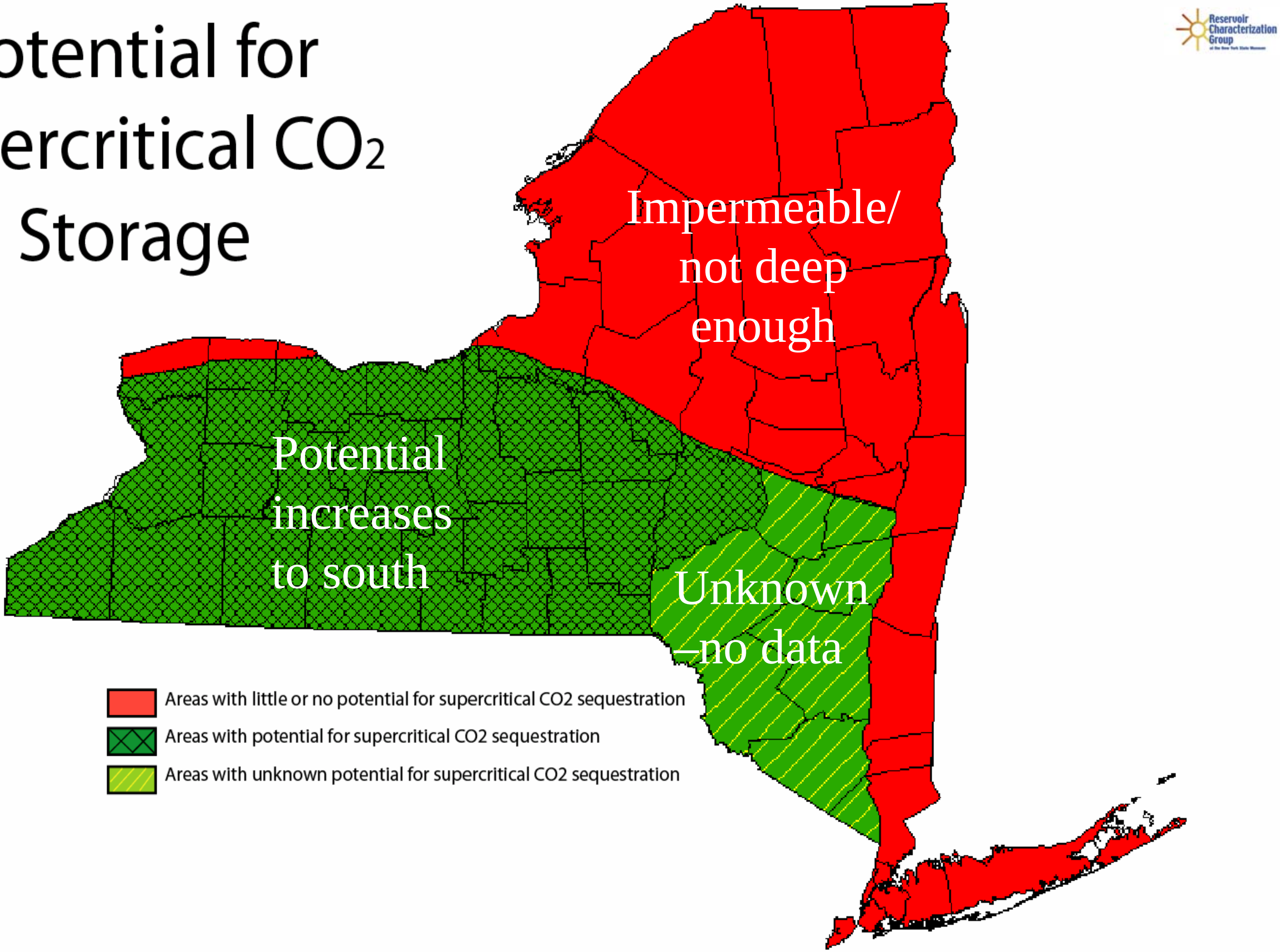


Bedrock geologic map of New York – Layers dip gently to South

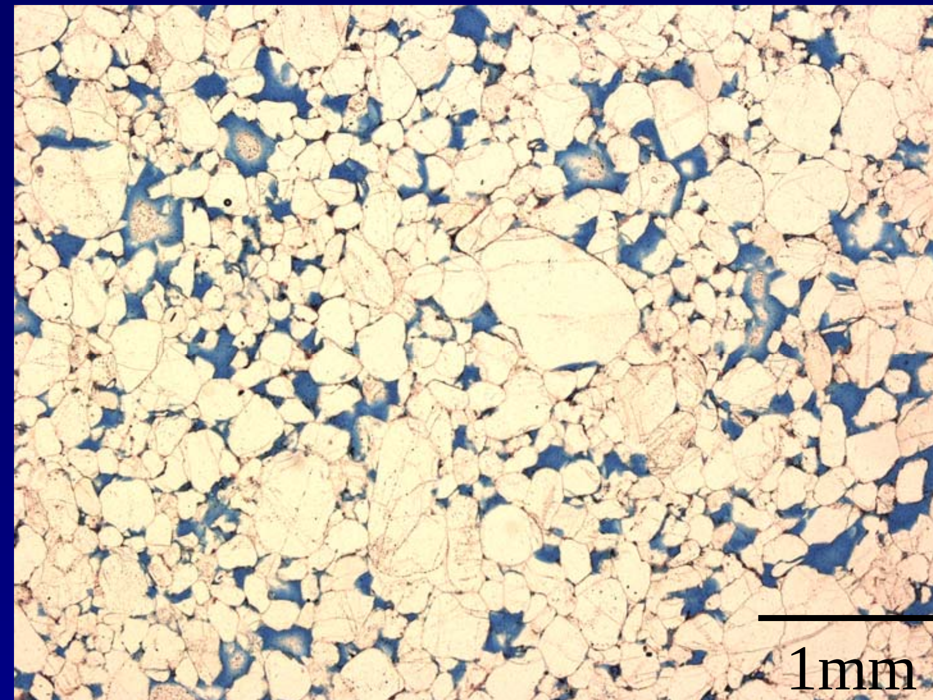


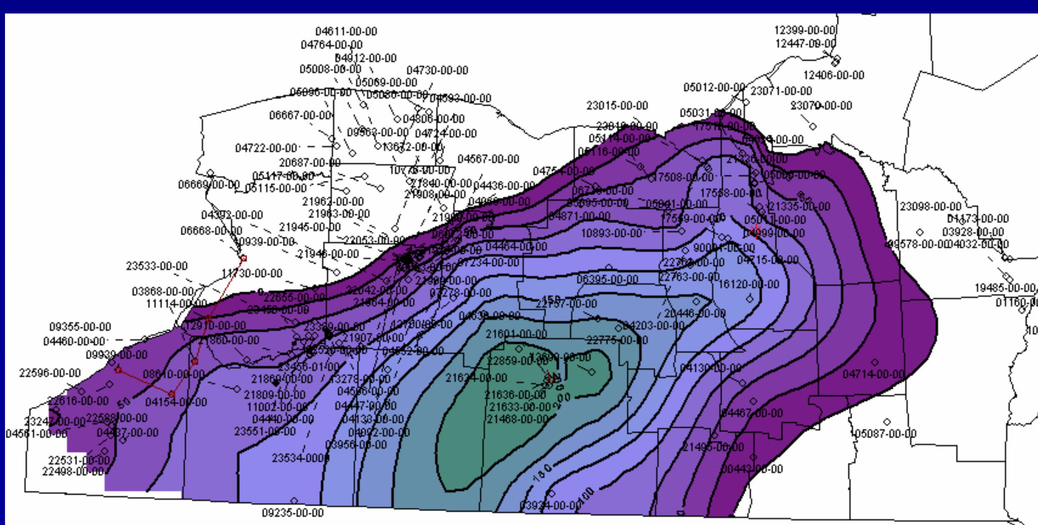
Layers dip or get deeper to the south - Starred layers have potential for sequestration Seals denoted with “S”

Potential for Supercritical CO_2 Storage

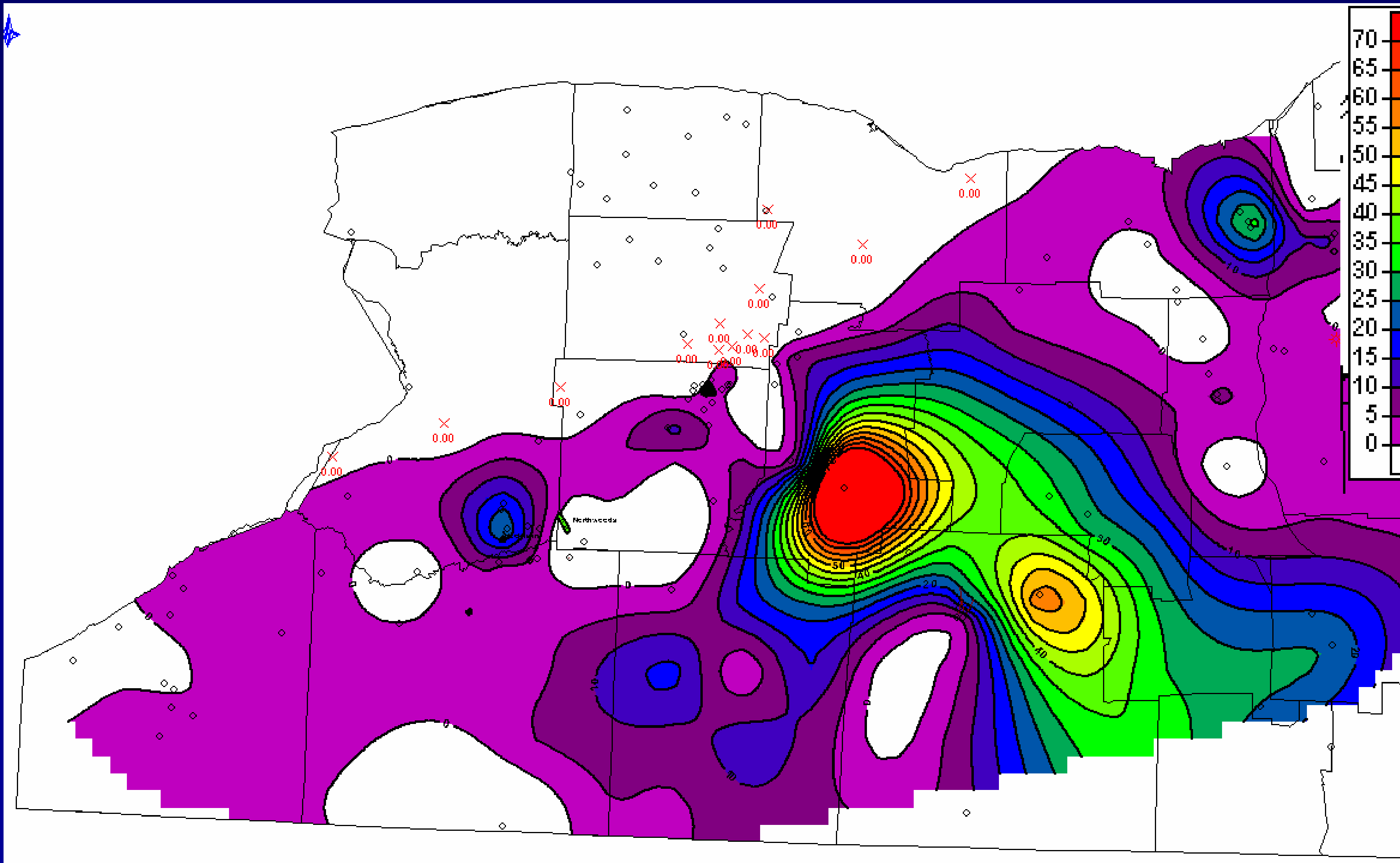


Preliminary assessment based on data collected and analyzed to date



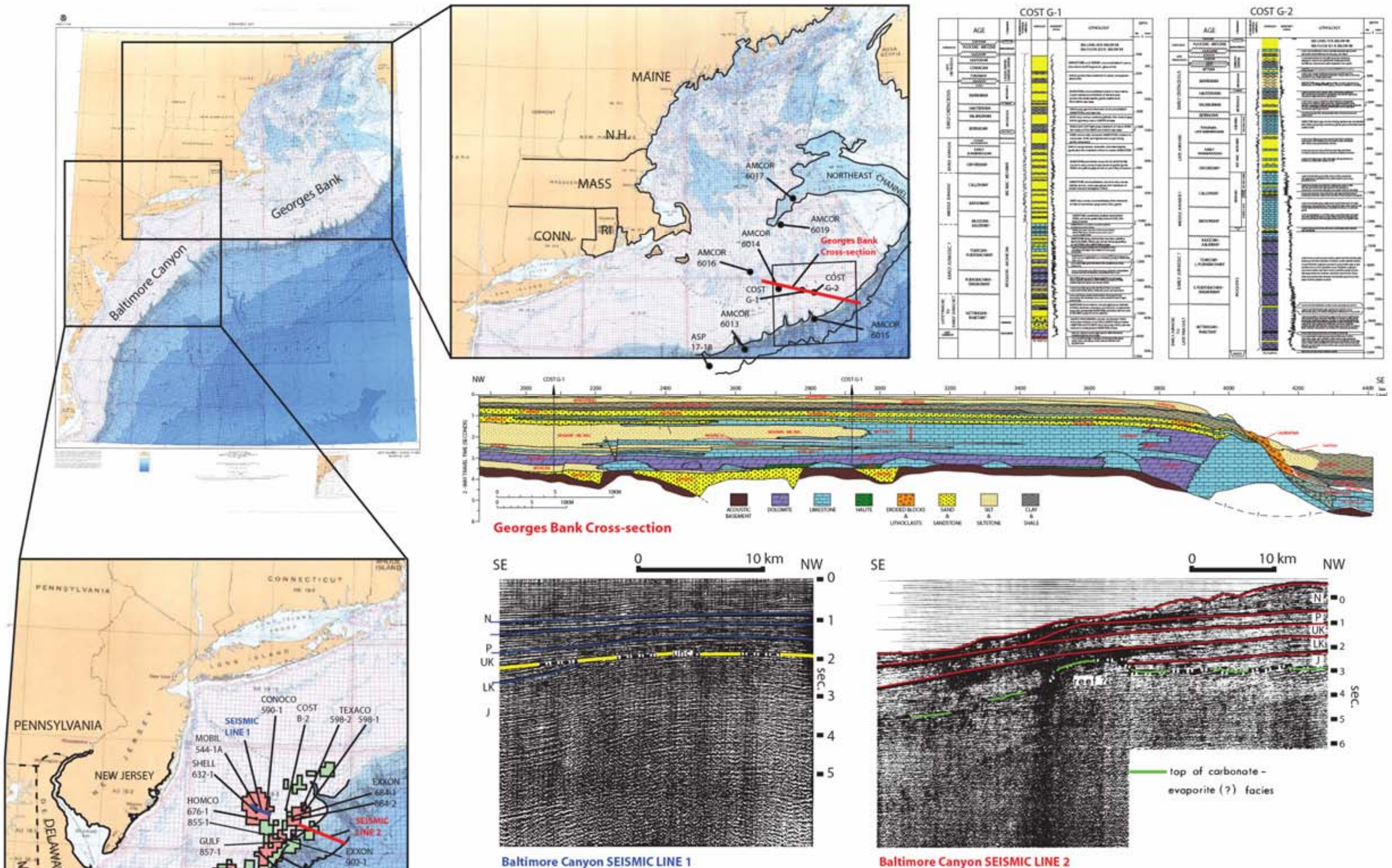


One of our best opportunities is in the Rose Run Sandstone, which has produced some gas but is mainly a saline aquifer - this map shows the thickness of that formation



Total feet of Rose Run Formation with porosity >5% using available density logs (5 foot contours) – thick in central NY

Offshore Carbon Sequestration Targets



	Porosity				Permeability		
Facies / Lithology	n*	Sum (m)	Ave. Φ (%)	Range	n	Ave. K (md)**	Range
Prograded shelf margin limestones	277	1823	2.4	0.0 - 17.0	148	0.34	< 0.01 - 17
Transitional marine sandstones	619	2800	6.1	0.0 - 29.0	351	0.71	< 0.01 - 46
Coastal Plain sandstones	1391	6212	8.7	0.0 - 33.0	650	26.19	< 0.01 - 349
Fine-grained deltaic sandstones	729	2385	9.2	0.0 - 28.0	189	71.11	< 0.01 - 195
Aggraded shelf-margin limestones	189	1015	8.5	0.0 - 26.0	43	5.1	< 0.01 - 156
Limestone buildups	5	65	12.2	0.0 - 13.0	---	---	---
Chalky Tubiphytes packstone	84	26	6.3	0.0 - 31.1	84	0.47	< 0.01 - 12.6
Shoal-water oolite grainstone	53	222	17	0.0 - 36.0	23	2.45	< 0.01 - 12.2
Shelf-margin deltaic sandstones	163	1138	18.2	0.0 - 30.0	---	---	---

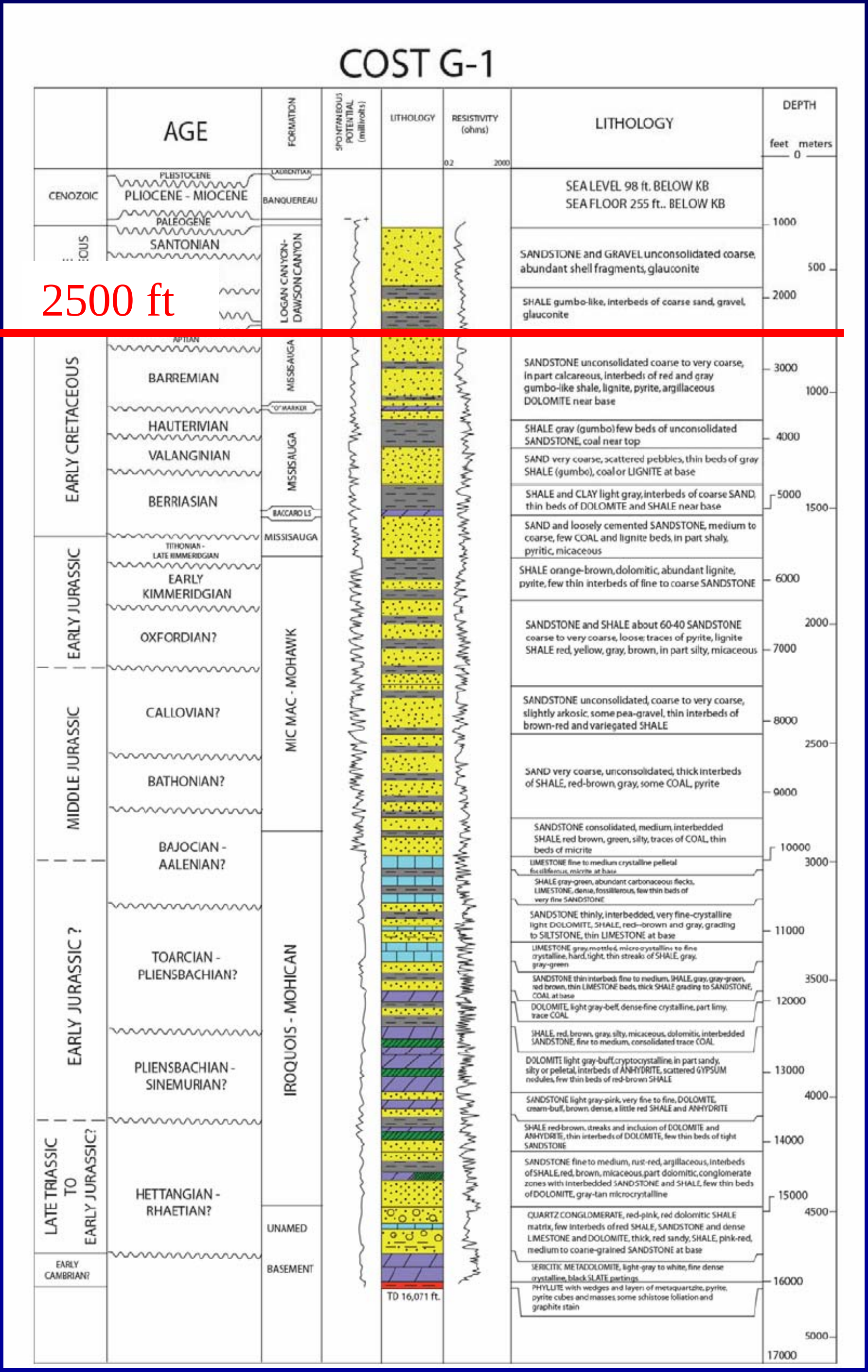
*n = number of beds
** Based on perm plug measurements

Reservoir Characterization Group at the New York State Museum

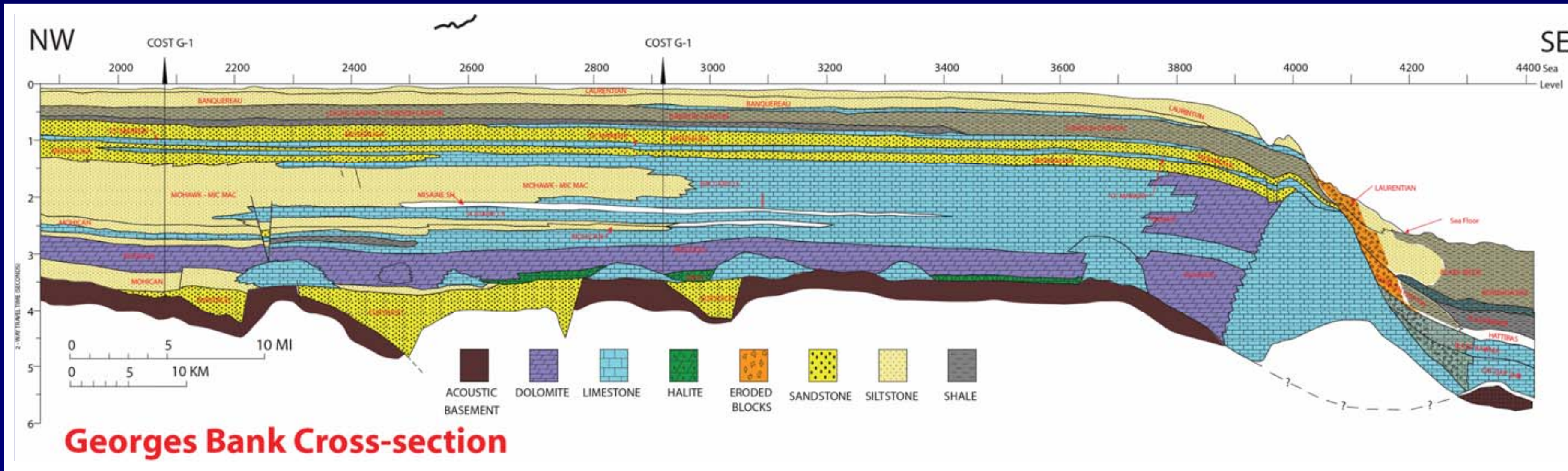
Best potential probably offshore New York

Offshore

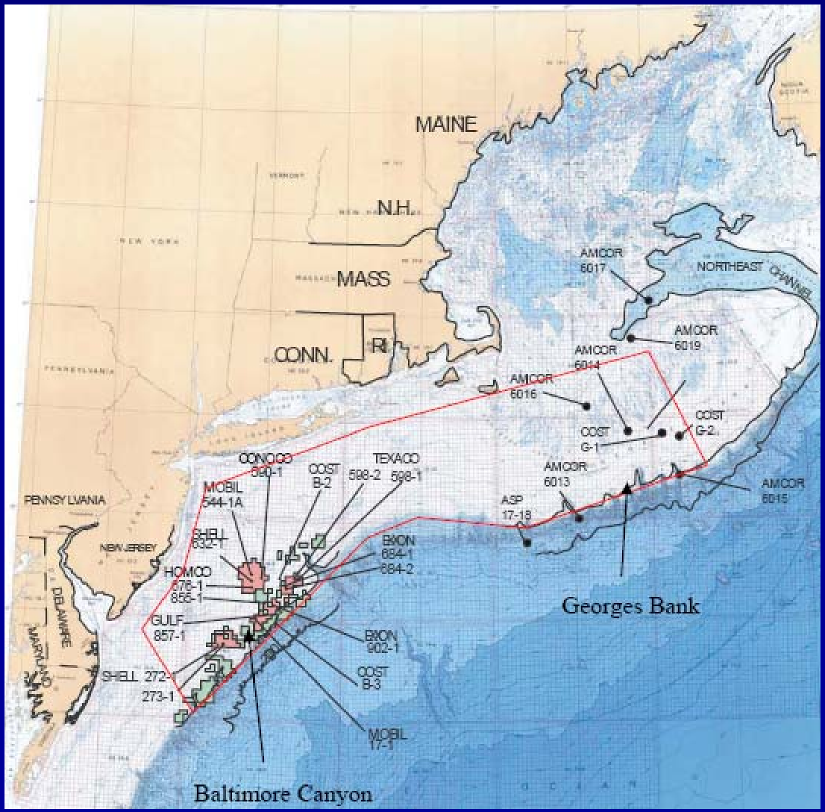
- As many as 25 layers of sandstone below 2500 feet, total thickness of more than 5000 feet, up to 30% porosity and some very high permeability
- Salinity lower than onshore



Yellow beds are sandstones



Georges Bank Cross-section



Generalized cross section shows that the layers are laterally extensive

Could get pretty close to NYC and LI where most power is needed

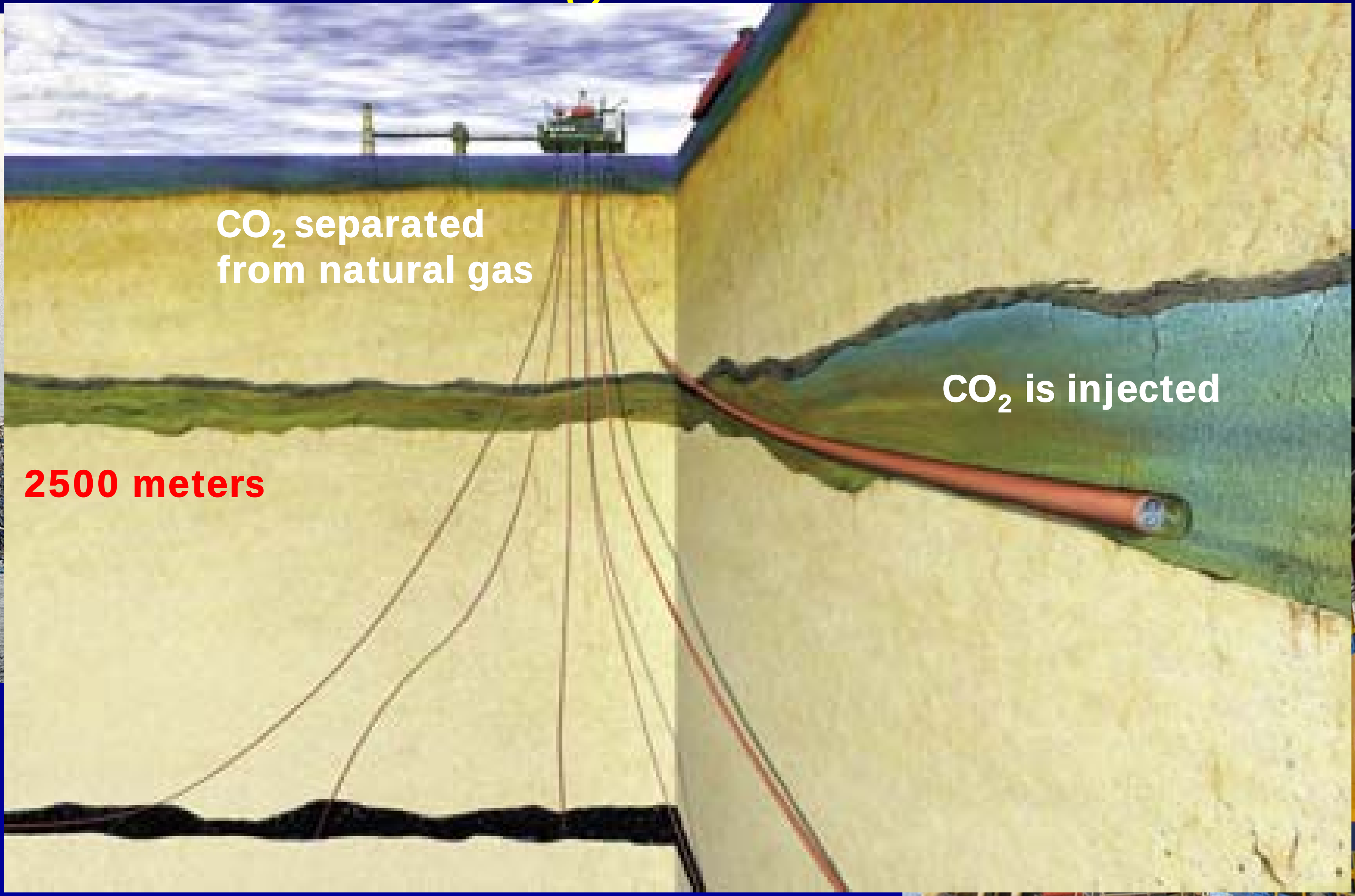
Far less regulatory and safety issues than the onshore saline aquifers

Probably more expensive – offshore wells cost more to drill and operate

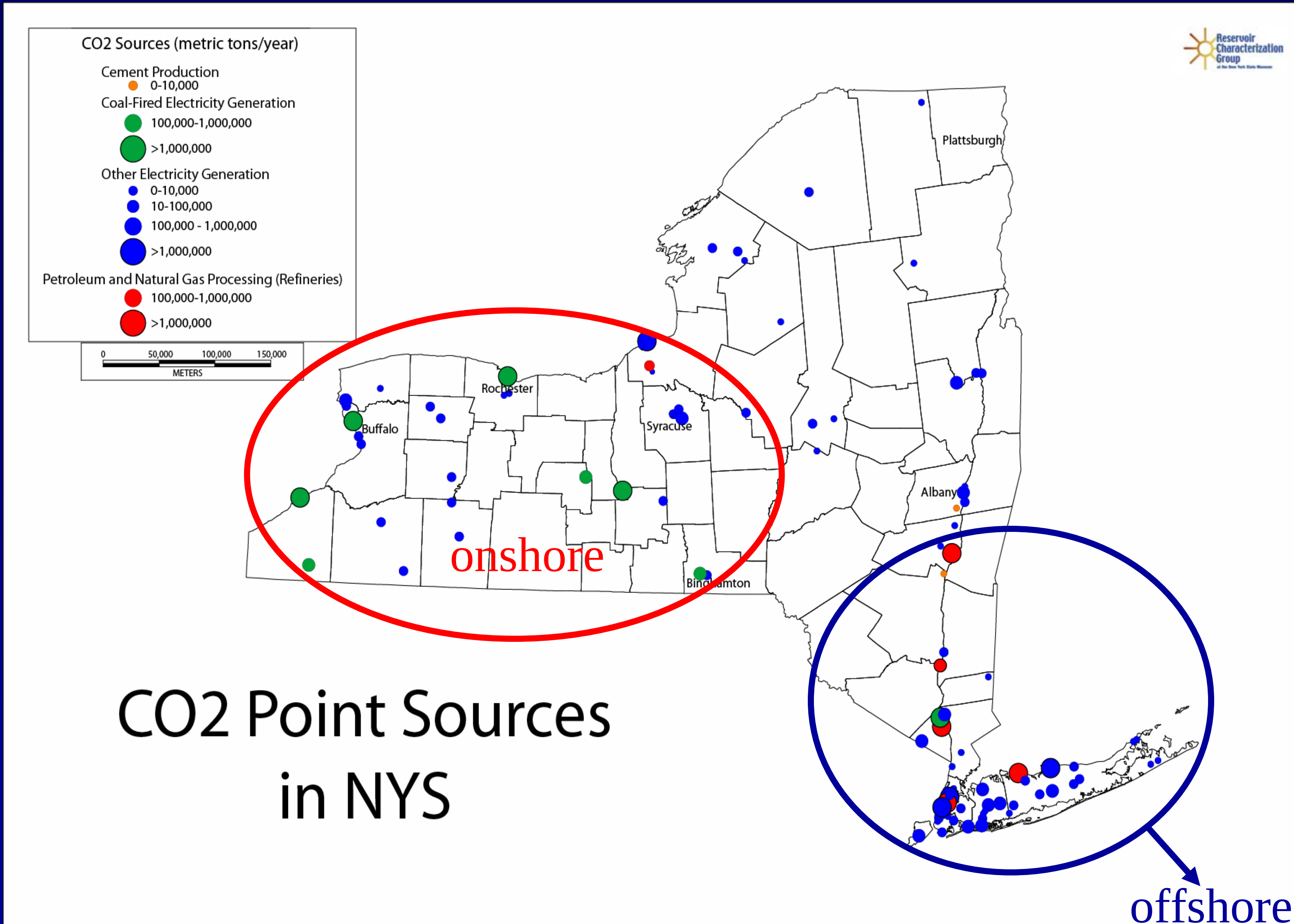
Need to know the offshore NY geology better and proposed study inexplicably rejected by NYSERDA panel

Statoil's Sleipner:
Norwegian North Sea



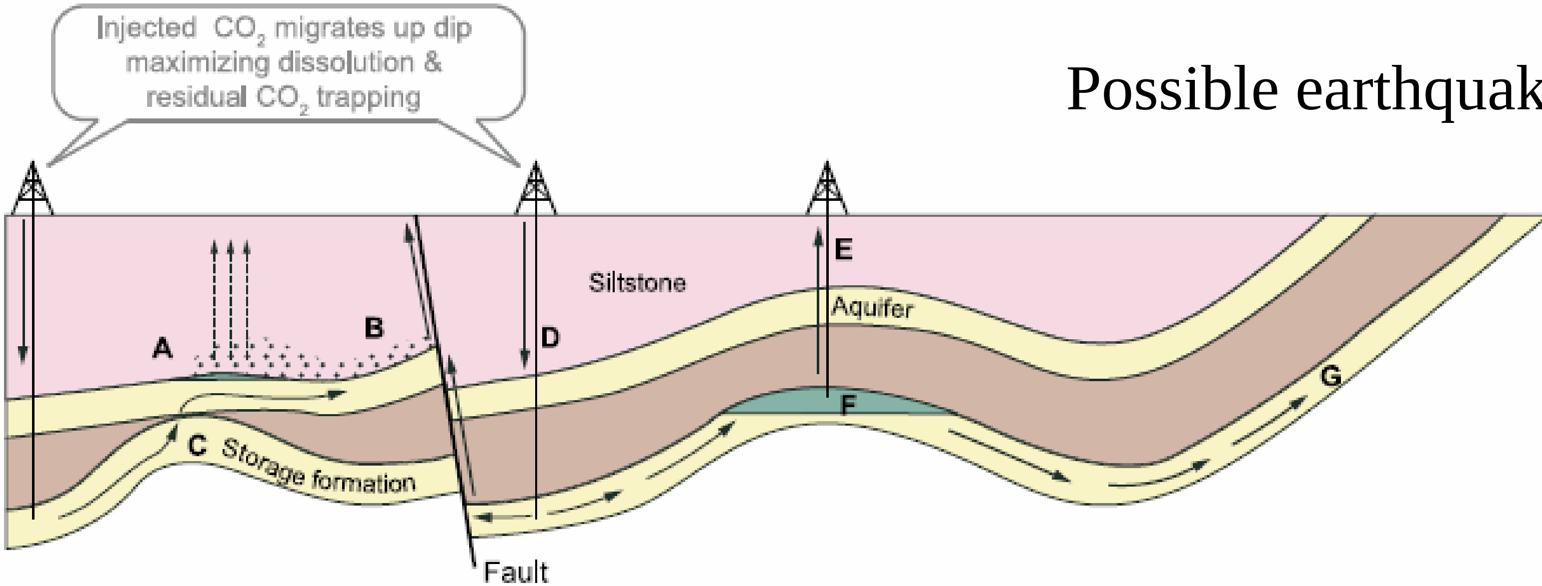


Data source: Statoil



It probably makes sense to look at onshore sequestration for new power plants in Western NY and offshore sequestration for E. NY

Possible earthquakes



Potential Escape Mechanisms

- **A.** CO_2 gas pressure exceeds capillary pressure & passes through siltstone
- **B.** Free CO_2 leaks from A into upper aquifer up fault
- **C.** CO_2 escapes through 'gap' in cap rock into higher aquifer
- **D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault
- **E.** CO_2 escapes via poorly plugged old abandoned well
- **F.** Natural flow dissolves CO_2 at CO_2 / water interface & transports it out of closure
- **G.** Dissolved CO_2 escapes to atmosphere or ocean

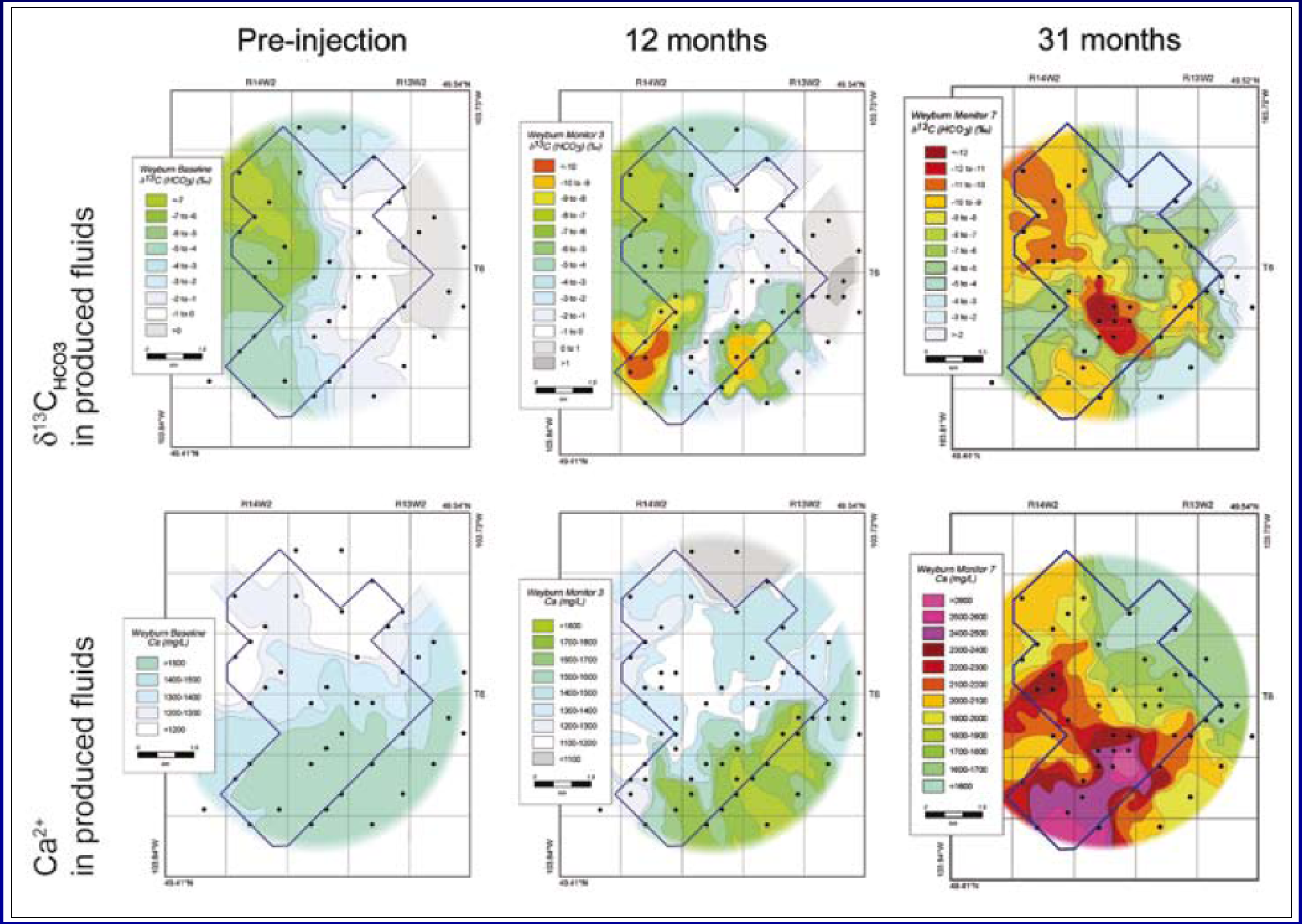
Remedial Measures

- ***A.*** *Extract & purify ground-water*
- ***B.*** *Extract & purify ground-water*
- ***C.*** *Remove CO_2 & reinject elsewhere*
- ***D.*** *Lower injection rates or pressures*
- ***E.*** *Re-plug well with cement*
- ***F.*** *Intercept & reinject CO_2*
- ***G.*** *Intercept & reinject CO_2*

Potential leakage pathways in order of likelihood in NY: well bores, flow updip, faults, fractures and through seal if highly over-pressured

CO_2 as a Health Hazard

- The atmosphere is composed of roughly 0.038% CO_2 (slowly rising)
- Healthy adults can tolerate air with up to 1.5% CO_2 with no adverse effects for at least an hour – that is roughly 40 times atmospheric concentration
- Above that level complications occur
- It is extremely unlikely that these storage projects would ever release concentrated CO_2 at a level that could be harmful to humans - if they leak it is likely to be a slow seep - but all precautions would need to be taken to ensure that this was the case



Monitoring of where the CO2 is going will be a critical part of any project – this map shows how CO2 is moving through a field in W Canada

What We Know

- There are potential formations both onshore and offshore of New York that could possibly hold significant amounts of CO_2
- Onshore these formations occur in the southern half of the western part of the State but porosity and permeability are generally low – there is a chance it will not work in many of these formations
- Offshore there is potential in up to 25 formations with high porosity and permeability - higher cost (?) but also a much higher probability of success

What We Need To Know

- Prior to approving any large-scale sequestration projects, the State needs to know:
  - What onshore and offshore formations, if any, can accept the volumes of CO_2 needed in a safe and cost-effective manner? This will require further mapping as well as seismic interpretation, drilling, coring, injection tests and monitoring of potential onshore and offshore sites
  - What sort of reactions will take place between the injected CO_2 and the *in situ* rocks and fluids? It may be that mineralization occurs around the wells that greatly decreases permeability and storage potential. This will require testing using cores and reactive transport modeling.