Offshore CCS Development for the Northeastern U.S. Atlantic Shelf

EXPLORE ATLANTIC CARBON STORAGE

Exploring Potential Long-Term Offshore Regional Atlantic Carbon Storage

Neeraj Gupta (gupta@battelle.org), Joel Sminchak (Sminchak@battelle.org)
Battelle, Columbus, Ohio, USA

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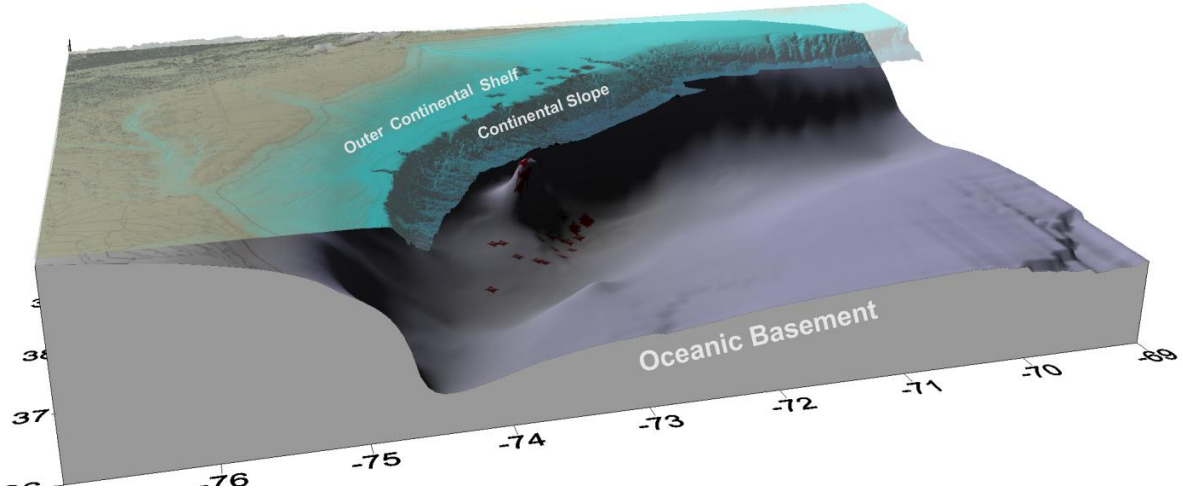
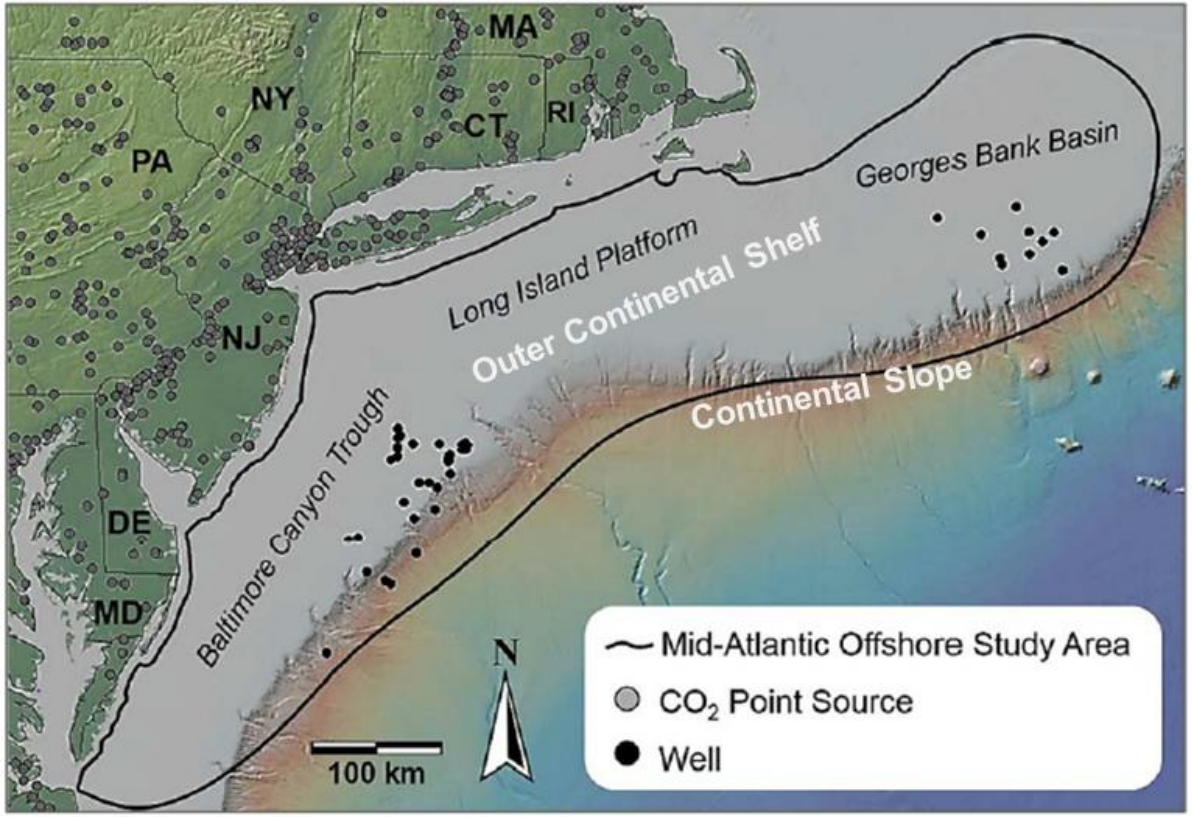
U.S. Northeast Atlantic Outer Continental Shelf

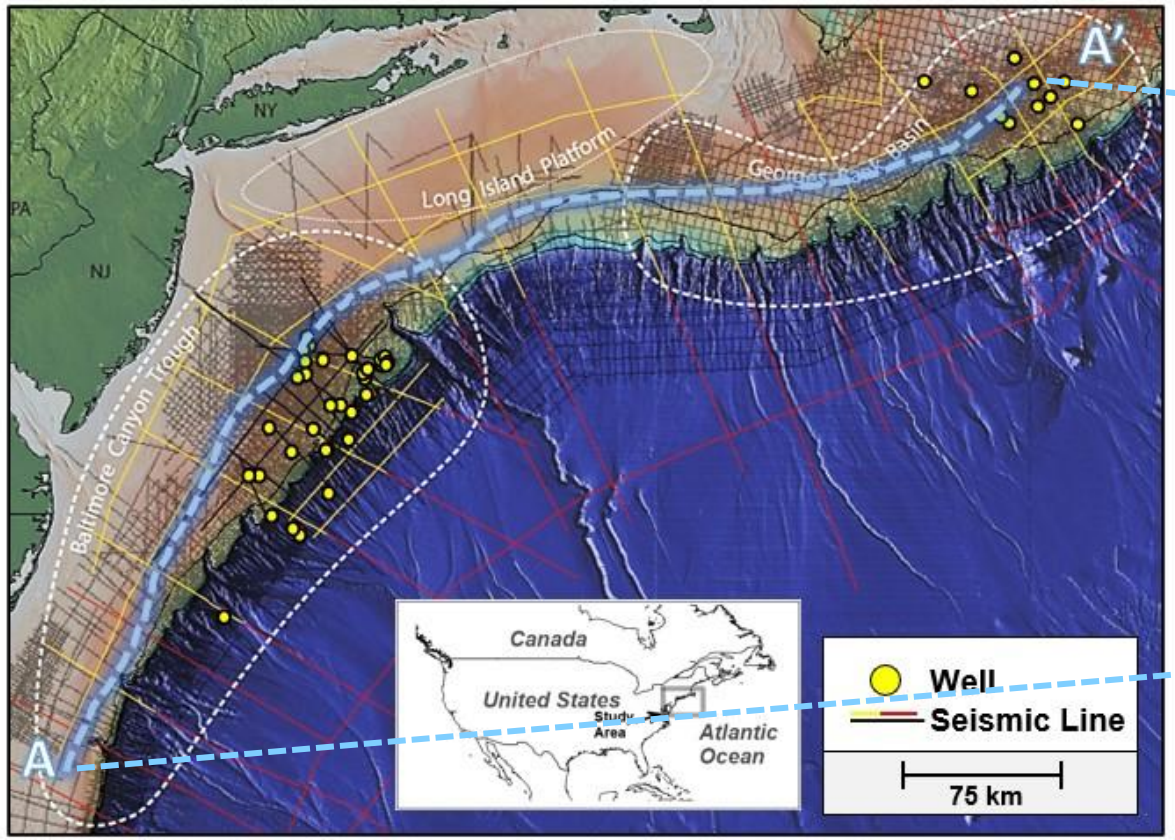
- Atlantic Outer Continental Shelf extends 80-160 km off east coast, 15-100 m water depth.
- Only 44 deep wells drilled in 1970s-1980s, no oil & gas activity.

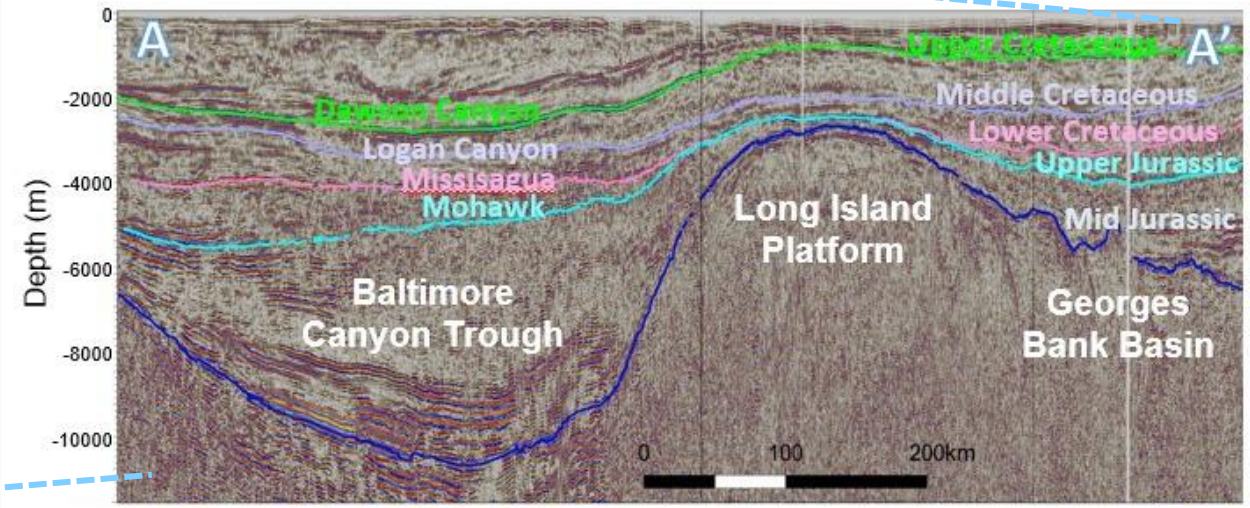




U.S. Northeast Atlantic Outer Continental Shelf

- 2,000-10,000+ meters thick rock layers in large geological structures.
- Focus area = Baltimore Canyon Trough.

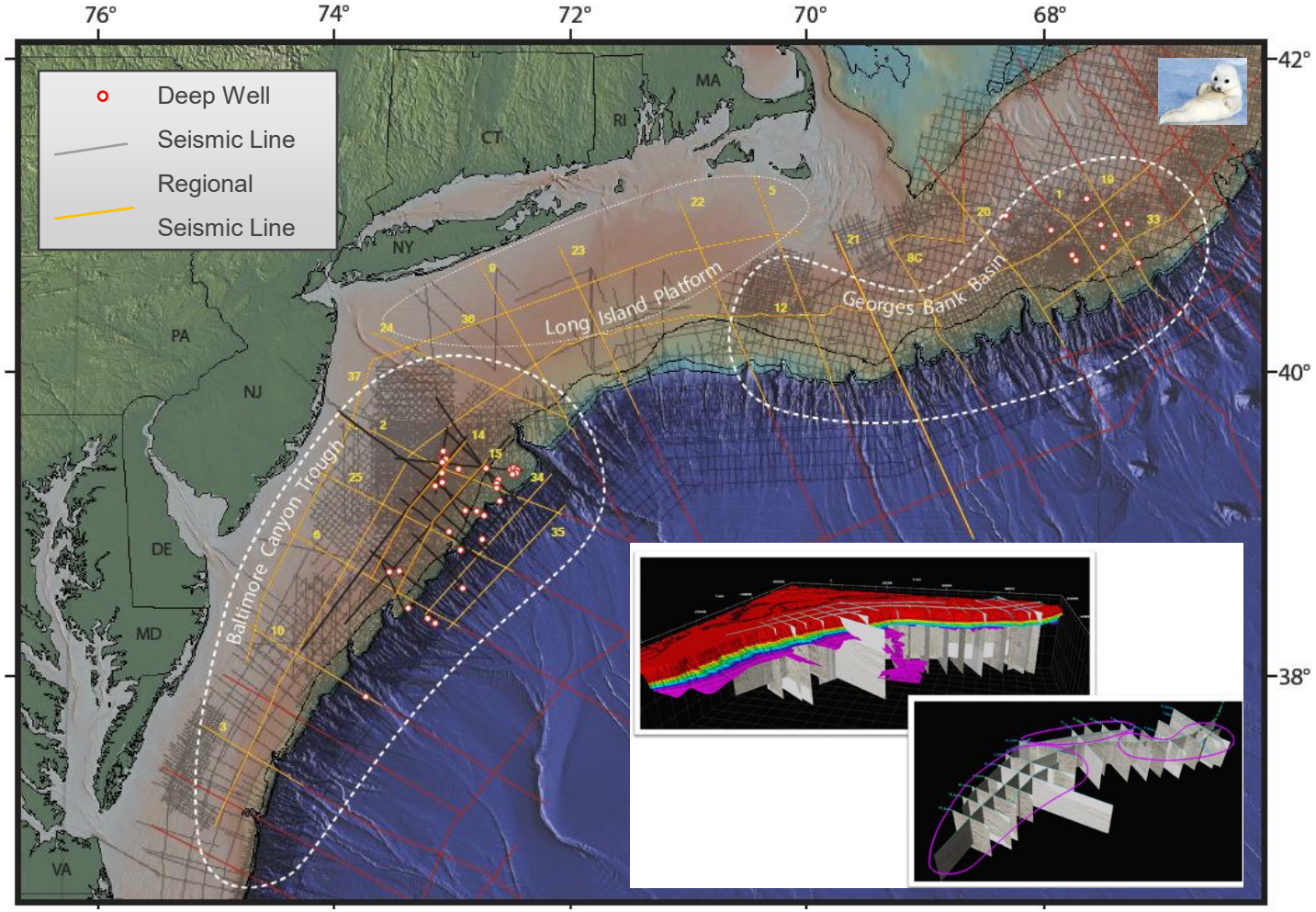




U.S. Northeast Atlantic Outer Continental Shelf

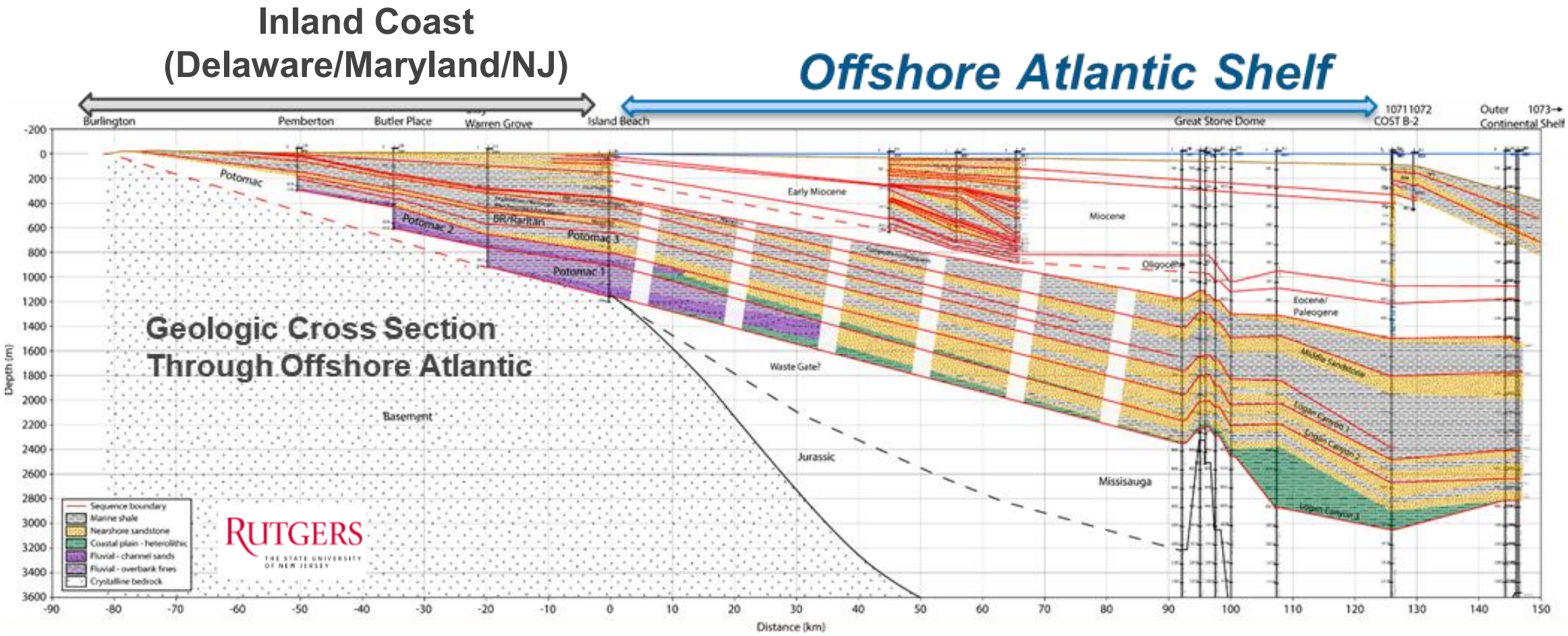
- 20,000 km of seismic survey, geophysical well logs, rock core tests available in study area.

1: sandstone **2: mudstone**



U.S. Northeast Atlantic Outer Continental Shelf

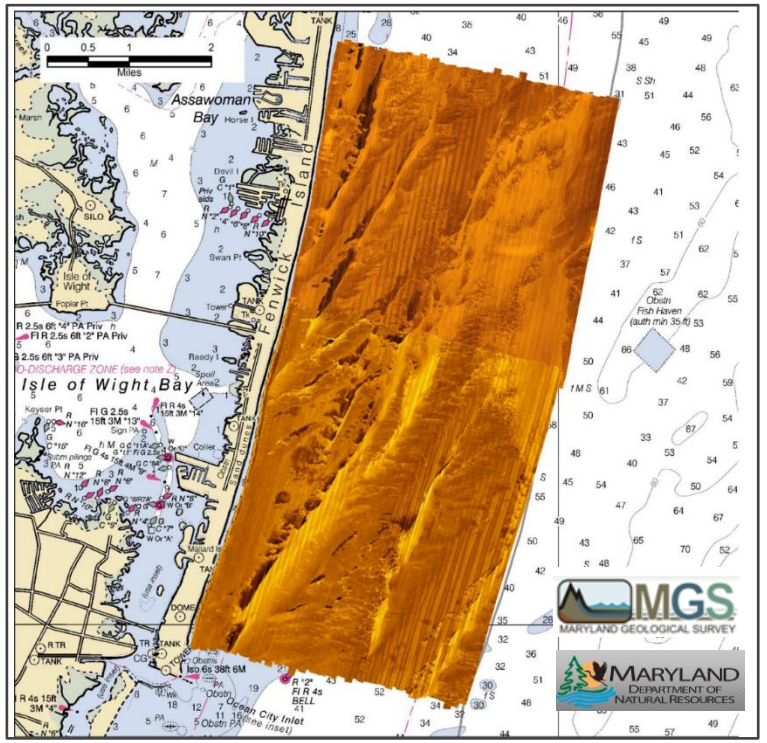
- Coastal plain extends from onshore areas to offshore outer continental shelf.
- Layers reflect paleo sea level fluctuations over last 200 million years to Jurassic period.



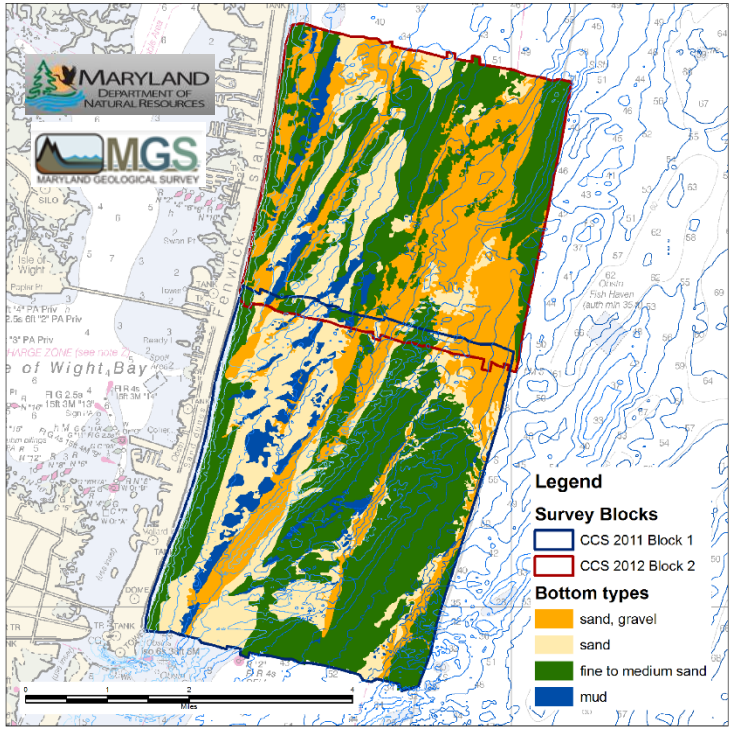
U.S. Northeast Atlantic Outer Continental Shelf

- Bordered by barrier islands, relatively shallow waters ~15-100 m deep, sandy muddy seabed.
- State waters extend 3 nautical miles offshore, federal waters.

Seabed Bathymetry



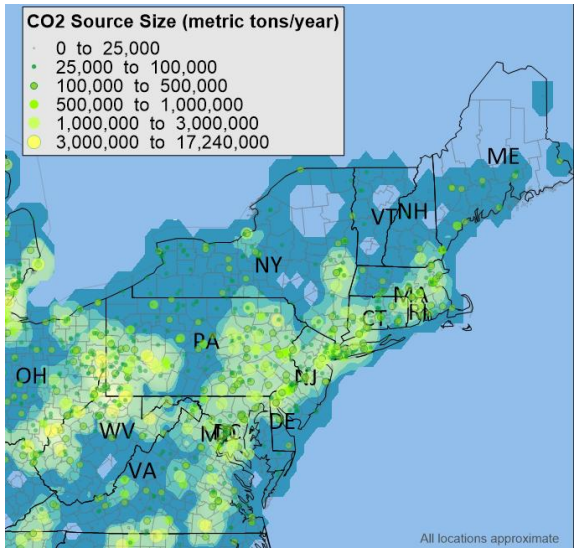
Bottom Sediment Type

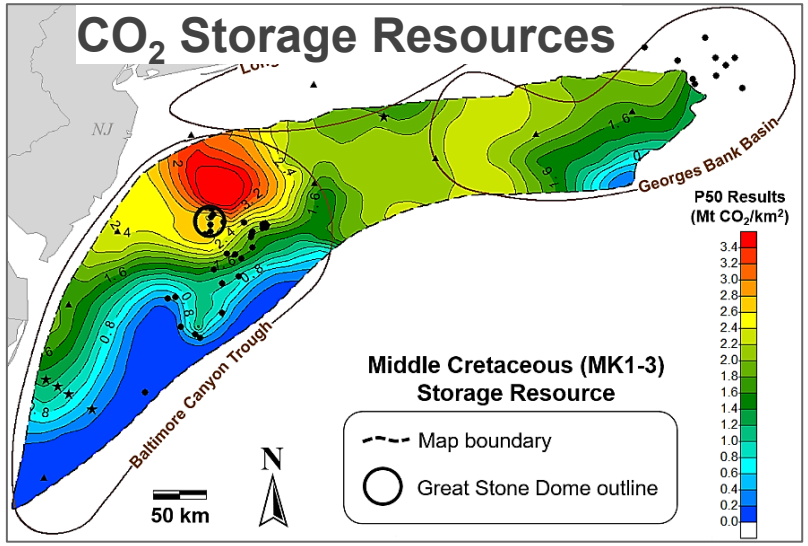


Background: Carbon Sequestration Potential Along the U.S. Northeast Atlantic Outer Continental Shelf

- Very large storage resource in Mid-Atlantic Outer Continental Shelf: **150-1136 gigatons.**
- **Opportunities**: large carbon storage resources, shallow water along outer continental shelf, large area, favorable geological setting & rock properties, **provides decarbonization options for eastern US industry**.
- **Challenges**: limited exploration, lack of infrastructure, environmental/stakeholder issues, source-sink routing.
- **Development Plan**: obtain community feedback, establish economic development pathways, minimize environmental impacts, define CO_2 pipeline transport feasibility, offshore drilling, well field, monitoring, logistics, cost-benefit risks.

Industrial CO_2 sources





EXPLORE-ACS Project Team and Technical Advisory Committee

- EXPLORE-ACS was a 2-year research project led by Battelle under U.S. DOE NETL Grant DE-FE0032407.
- The project built upon previous research by Battelle, Rutgers, and others.

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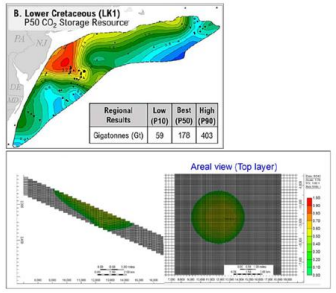
MGS MARYLAND GEOLOGICAL SURVEY

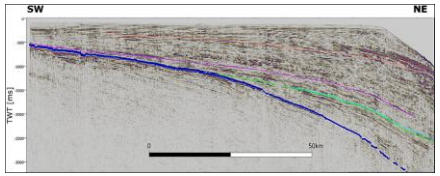
TAC: EQT ENBRIDGE

EXPLORE-ACS Project Approach

- The project defined components necessary to develop CO_2 storage along northeast U.S. Atlantic offshore region in a CO_2 storage development plan.
- ***Many options may be necessary for this area***: various CO_2 storage options, subsea well completions, onshore-offshore wells, low-impact exploration.

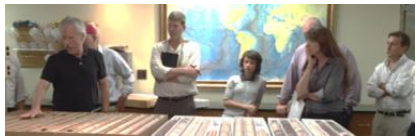


CO_2 Storage Resources
- Geologic Setting
- Caprock Integrity
- Wellfield Design
- Risk Assessment

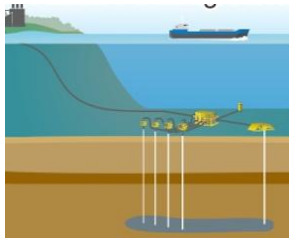


Stakeholder
- Public Feedback
- Industry Needs
- Economic Development
- Environmental Protection

Infrastructure
- Source Assessment
- Pipeline/Shipping Plan
- Injection Field Design
- Exploration Plans
- Safety Plans



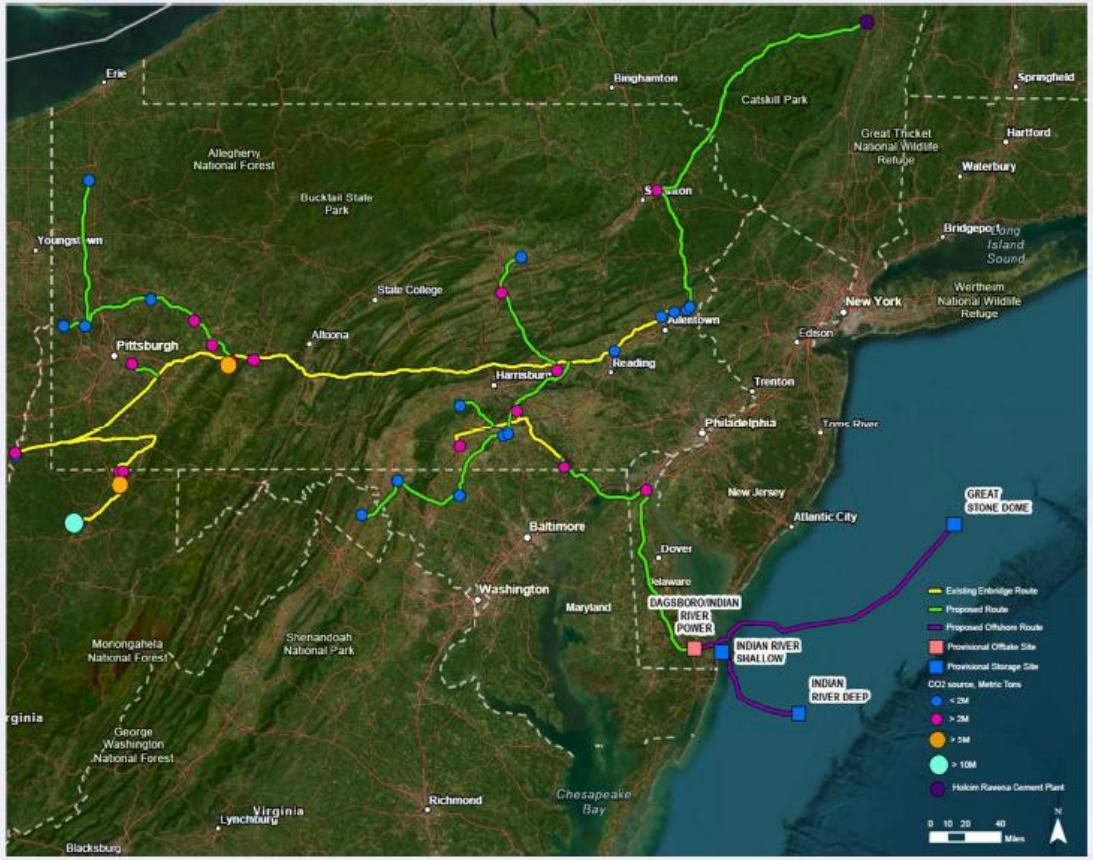
CO_2 storage Development Plan



What would a CO_2 storage system along the NE offshore Atlantic look like?

- ~78 million metric tons CO_2/year emissions in NE U.S., few options for CS.
- Existing onshore pipeline routes may be repurposed for CO_2 pipeline transport for onshore industrial sources of CO_2.
- Coastal offtake points may use common areas for fiber optic cables, wind energy and horizontal drilling to minimize impacts.

On-Shore Routing Analysis



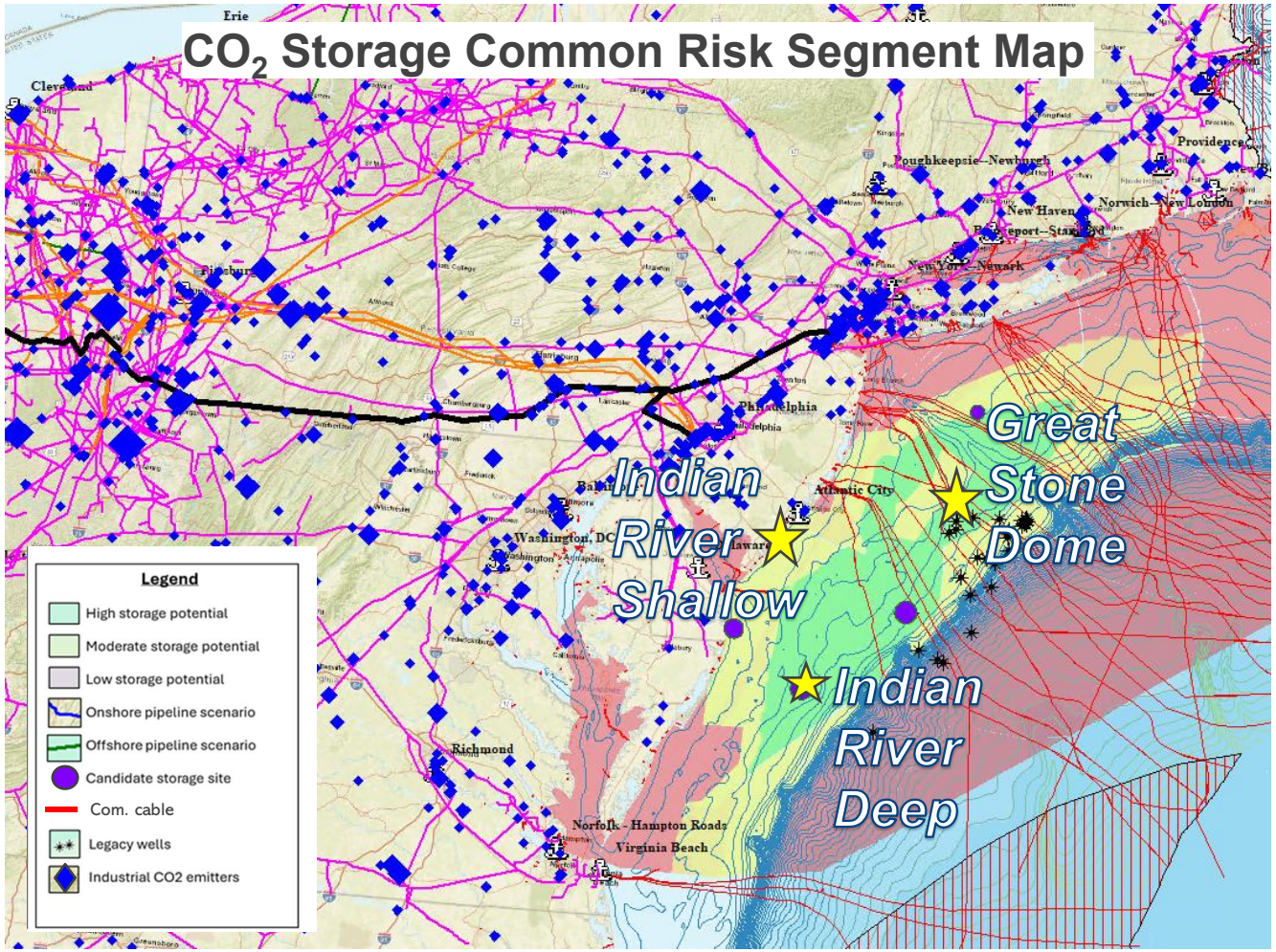
- Total Length 1990 km
  - New Easement - 1165 km
  - Enbridge Easement - 824 km
  - Offshore Routes – 463 km
- Total Potential Collection – 78,107,280 MT
  - Preferred Partners – 7,548,280 MT
  - Non-Preferred Partners – 70,559,244 MT
  - Note: Holcim Albany, NY Facility Output not incl.

Facility Name	CO2 Emissions MT	Preferred
ARGOS USA	934,718	Y
Certainteed Gypsum	70,668	Y
Heidelberg Materials US Cement LLC/Nazareth	677,774	Y
Heidelberg Materials/Evansville Cement Plt & Quarry	435,388	Y
Lehigh Cement Company LLC	1,913,921	Y
Keystone Cement Company	633,023	Y
Hercules Cement Stockertown PLT Quarry	549,208	Y
Lafarge NA Whitehall Plant	433,997	Y
Holcim (US), Inc	561,134	Y
Magnesita Refractories/York	310,973	Y
Armstrong Cement & Supply	213,999	Y
Vitro Flat Glas LLC	212,883	Y
US Gypsum - Washingtonville Plant	80,984	Y
US Gypsum - Aliquippa Plant	72,291	Y
Gold Bond SHI Plant	78,980	Y
Lehigh White Cement Co LLC	78,778	Y
Vitro Meadville Flat Glass LLC	72,600	Y
Helix Ironwood, LLC	2,045,586	N
Hunterstown Combined Cycle	2,257,370	N
CPV Fairview Energy Center LLC	2,617,107	N
Brunner Island, LLC	2,734,667	N
Seward Generation LLC	2,866,873	N
Hummel Station LLC	2,913,626	N
York Energy Center	2,927,419	N
US Steel (Edgar Thomson)	2,995,635	N
Homer City	3,490,341	N
Delaware City Refinery	3,667,360	N
Mitchell (WV)	3,697,469	N
Longview Power	3,921,168	N
Fort Martin Power Station	4,798,556	N
Keystone	4,919,965	N
Conemaugh	5,417,511	N
Harrison Power Station	11,600,466	N
TRC	7,000,000	N
Lackawanna Energy Center	3,308,603	N
Holcim Ravina	0	Y
TOTAL PREFERRED PARTNERS	7,331,319	
TOTAL NON-PREFERRED PARTNERS	73,179,722	
TOTAL ALL CO2 SOURCES:	80,511,041	

Where are the best areas for carbon sequestration along the NE offshore Atlantic?

- The project team developed "common risk segment" maps to outline the best areas for CO_2 storage based on geology, operational restrictions, cost, and environmental features along the NE Atlantic offshore.

- Large area (7500 km^2) off the coast of DE, MD, NY, NJ, VA with high CO_2 storage potential.



What rocks are best for carbon sequestration along the NE offshore Atlantic?

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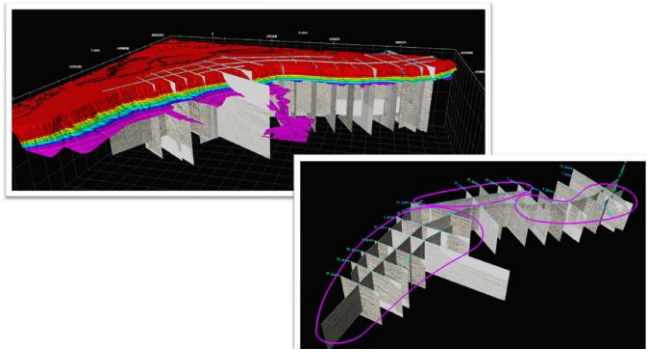
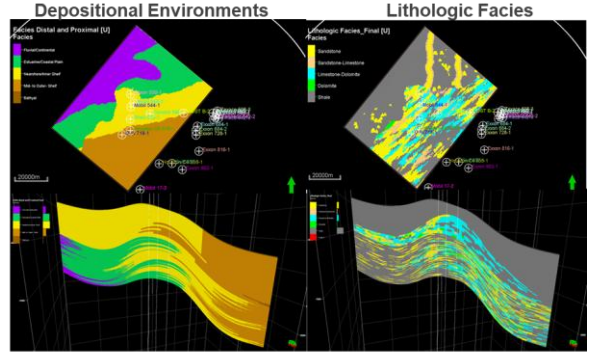
- Data from seismic surveys, offshore test wells, rock core tests, & geophysical well logs were evaluated for 3 potential sites.
- Results showed that there are deep Cretaceous age rocks (66-145 million years old) 1,500-2,800 m deep along the Atlantic offshore suitable for CO_2 storage. On a local scale, these rocks have variable properties related to depositional cycles when the ocean levels were rising and falling, which affects their potential for CO_2 storage.

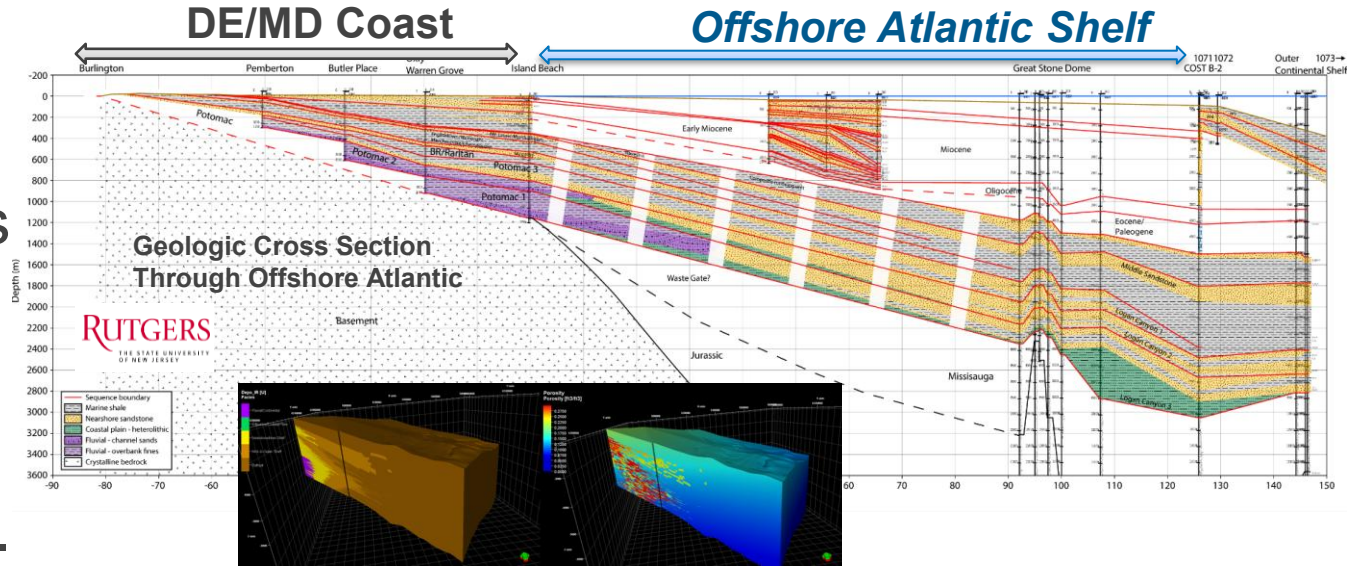
Seismic Data for Offshore Atlantic



Great Stone Dome GeoModel



Depositional environment and lithologic facies modeling for Great Stone Dome in map view (top) and cross-section view (bottom)



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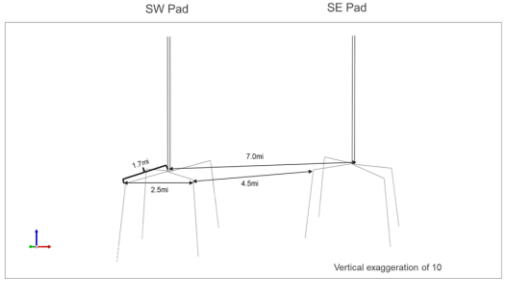
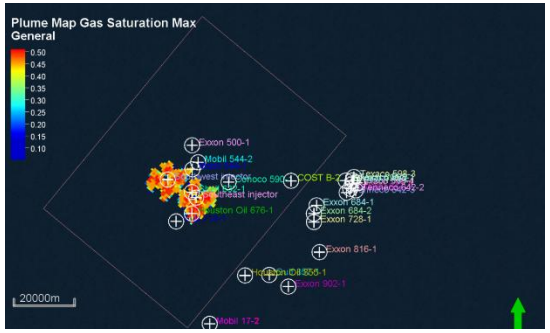
How Much CO_2 Can be Injected in the Rock Layers?

Great Stone Dome- 8 Wells, 17 MMT/yr, 500 MMT total over 30 years!

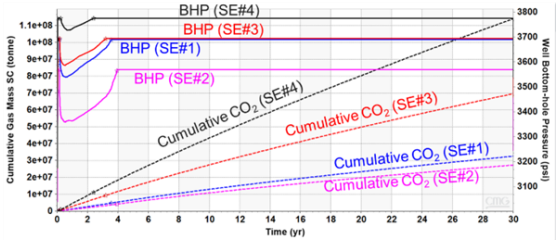
- **Injection rate:** 17 MMT/yr through 8 wells in 2 well pads, **500 MMT cumulative**
- **Reference Depth:** 1900 m
- **Fluid System:** 50,000 ppm salinity, 2720 psi





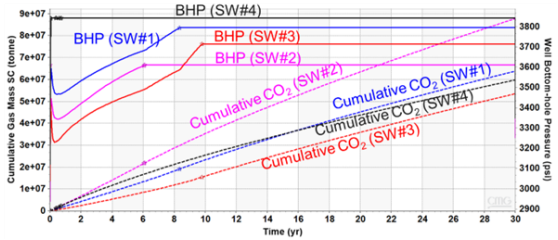
Max allowable BHP and cumulative injected CO_2 by well, respectively:
- #1 – 3690psi, 33MMT
- #2 – 3570psi, 27MMT
- #3 – 3694psi, 70MMT
- #4 – 3775psi, 114MMT

Cumulative of 244MMT of injected CO_2 at SE pad



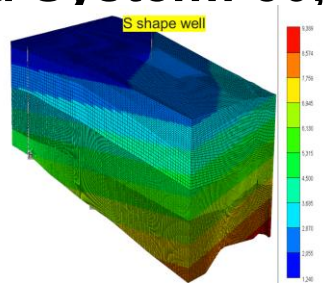
Max allowable BHP and cumulative injected CO_2 by well, respectively:
- #1 – 3843psi, 64MMT
- #2 – 3610psi, 88MMT
- #3 – 3715psi, 54MMT
- #4 – 3797psi, 60MMT

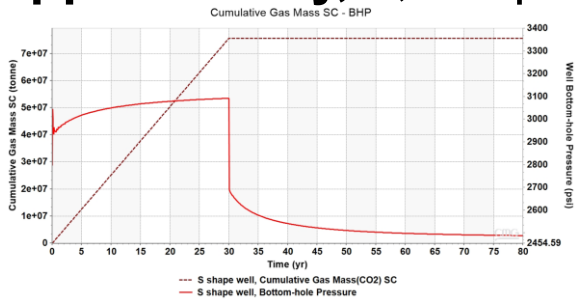
Cumulative of 266MMT of injected CO_2 at SW pad



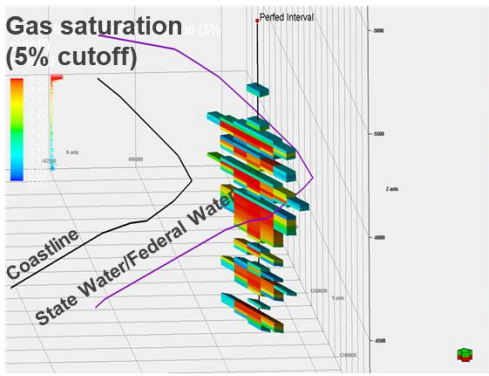
Indian River Shallow- Single Well, 2.5 MMT/yr

- **Injection rate:** 2.5 MMT/yr through a single injection well, **75 MMT cumulative**
- **Reference Depth:** 1700 m
- **Fluid System: 50,000 ppm salinity,** 2,469 psi





End of 30-year injection period



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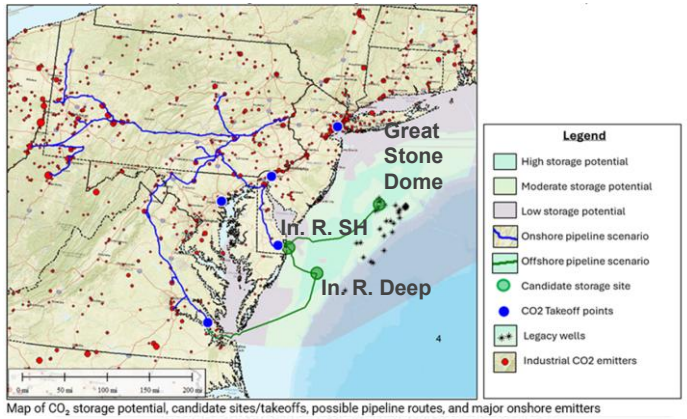
What Are Key Factors for the Geological Setting for Carbon Storage?

- Reservoirs are significantly more variable than previously modeled
- Despite reservoir heterogeneity, geological analysis showed thick (>35 m), laterally continuous units containing reservoir-quality porosity and permeability
- Hub-scale storage (~17MMT/yr) is viable based on reservoir simulations
- Wide-range of data availability (well data, 2D seismic)
- Additional data collection efforts (stratigraphic test well, seismic) and further analysis of existing data would help verify promising project findings

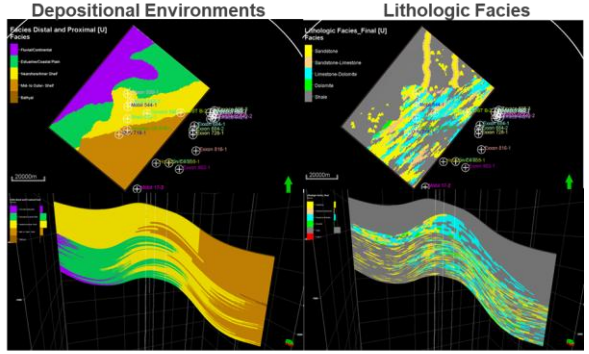


Map of CO_2 storage potential, candidate sites/takeoffs, possible pipeline routes, and major onshore emitters

Composite CRS map for Mid-Atl Offshore storage

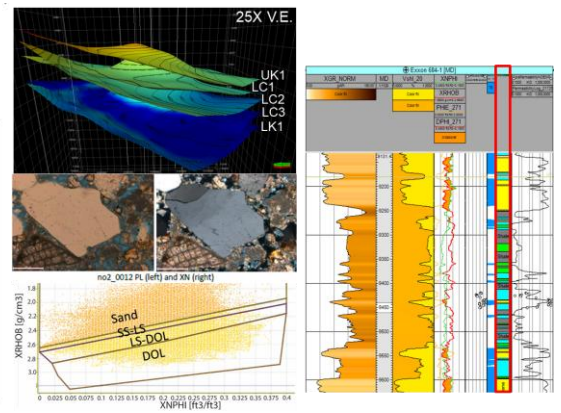
~8,000 mi^2 of low-risk area within composite CRS map

Great Stone Dome GeoModel

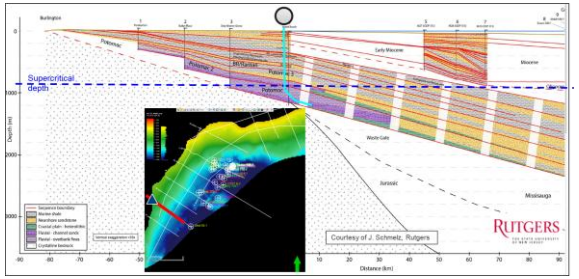


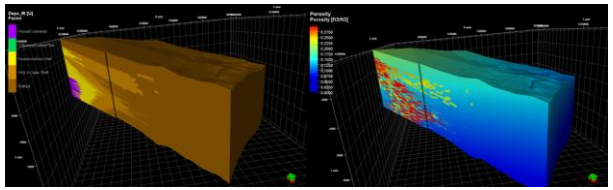
Depositional environment and lithologic facies modeling for Great Stone Dome in map view (top) and cross-section view (bottom)

Great Stone Dome GeoModel



Indian River Shallow GeoModel

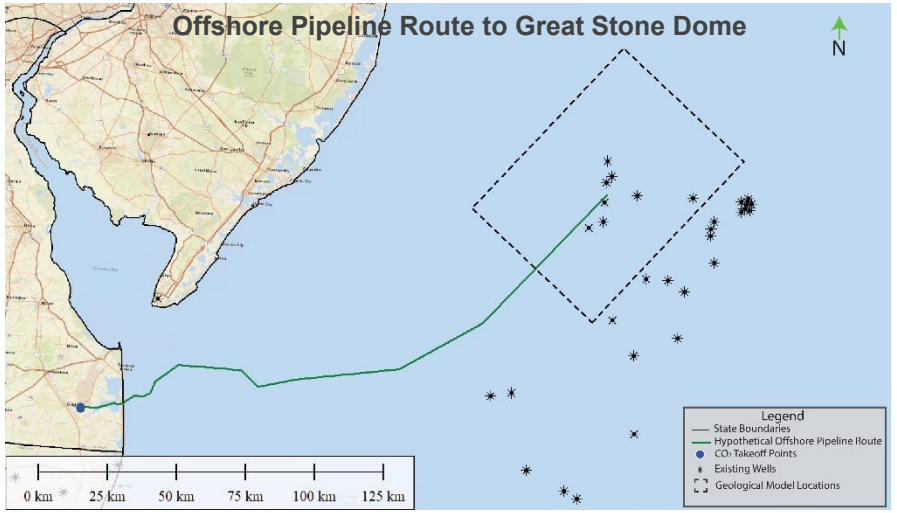


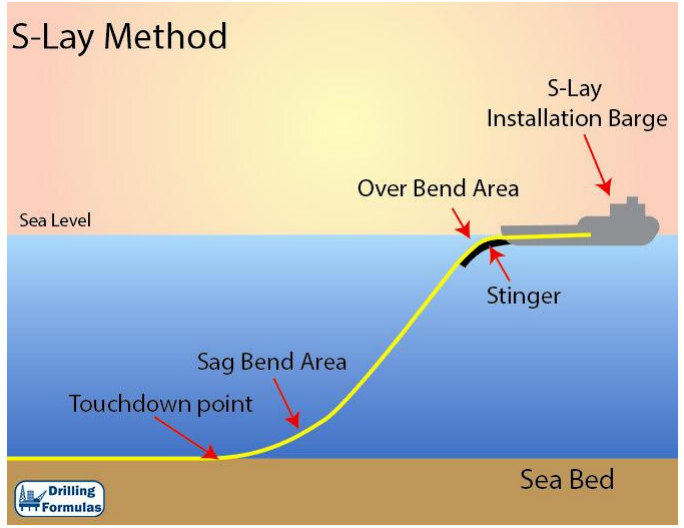


What would a CO_2 storage system along the NE offshore Atlantic look like?

- There are feasible routes for an offshore CO_2 pipeline that would avoid sensitive environmental areas and other seabed features.
- The pipeline would be 16-inch diameter with 2-inch concrete coating, similar to other offshore pipelines around the world.
- Installation from a barge via S-lay method.

Offshore Pipeline Installation

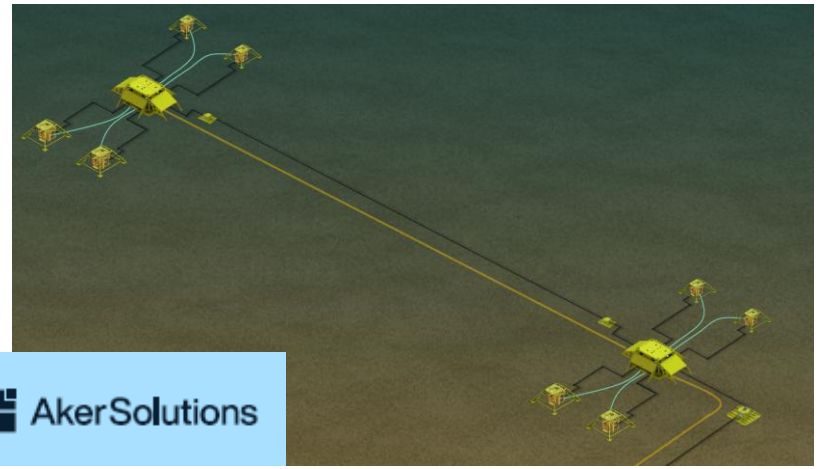




What would a CO_2 storage system along the NE offshore Atlantic look like?

- Temporary “jack-up” rigs would be used to drill injection wells.
- The CO_2 injection system would include subsea well completions, manifolds, and connecting pipelines.
- Multiple injection wells would be necessary for higher injection rates.
- A clustered wells with central manifold configuration would reduce costs but would require horizontal wells.
- The system would be on the seabed with no visibility at the surface.

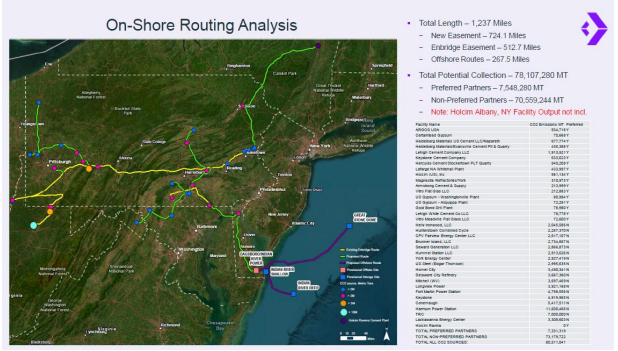
Seabed CO_2 Storage System
Clustered Wells with Central Manifold

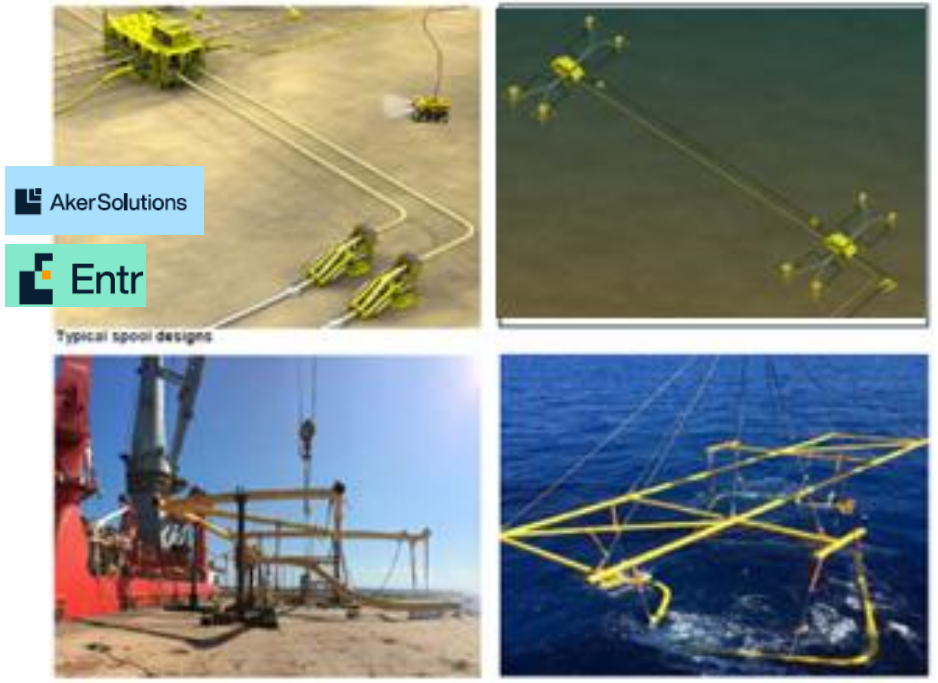


Seabed Injection Wellhead

What are Key Factors for Offshore CO_2 Storage Infrastructure?

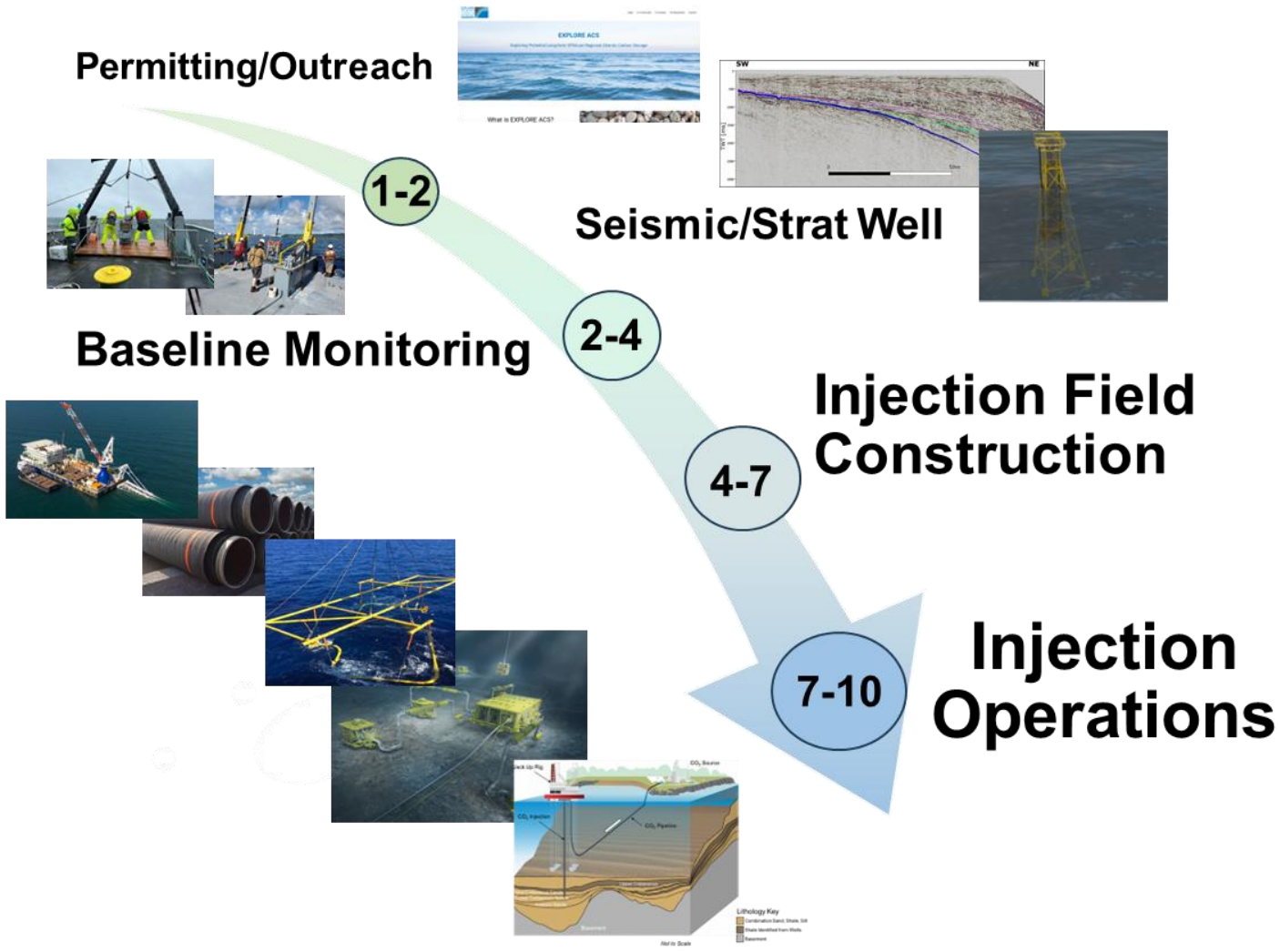
- CO_2 infrastructure design for the northeast U.S. Atlantic offshore provides options for industry in the region.
- Development of these systems would likely take 5-10 years for permitting, exploration, construction, and baseline monitoring.
- Offshore CO_2 pipeline routing showed feasible routes and shoreline offtake points near communication cables or offshore wind energy. Horizontal pipeline drilling under barrier islands can reduce environmental impacts and community concerns.
- The injection field was specified as a subsea system with 1-8 injection wells, central manifolds, and clustered wellpads to minimize visual disturbance and costs.





EXPLORE-ACS Roadmap

- **CS Timeline**- estimate for CS development on Atlantic offshore = 7-10 yrs.
- Similar to offshore energy projects.
- Contingent on BOEM policy, permits, outreach.
- Most equipment requires 18-24 month lead times.
- ***Advantages to early movers for leasing, shaping policy, obtaining right of ways.***



Thank You!

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Contact: gupta@battelle.org or

frank-collins@battelle.org for information.

EXPLORE ATLANTIC CARBON STORAGE

Exploring Potential Long-Term Offshore Regional Atlantic Carbon Storage