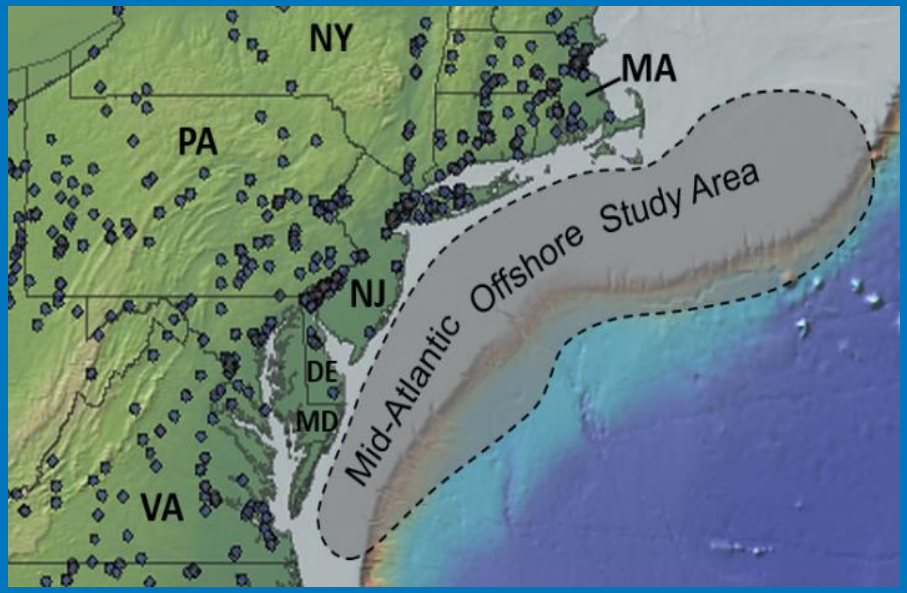
Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment

Project Number: DE-FE0026087



PRESENTED BY

Neeraj Gupta, PI

Battelle

U.S. Department of Energy

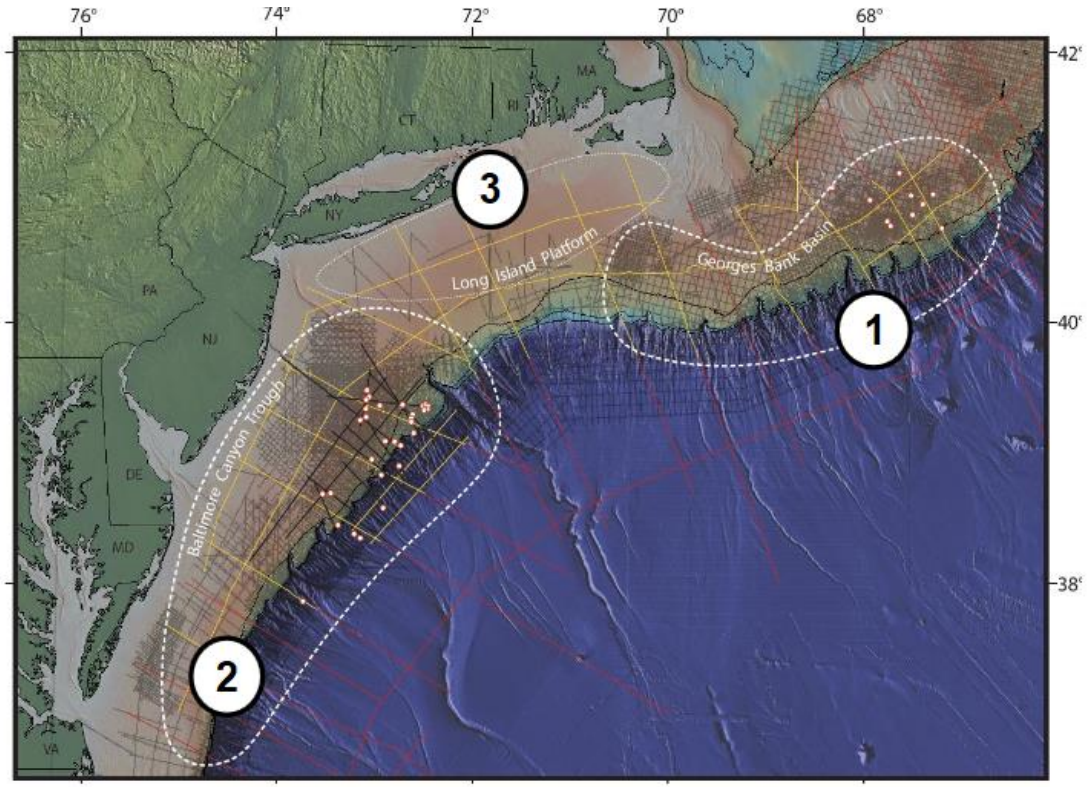
National Energy Technology Laboratory

Mastering the Subsurface Through Technology, Innovation and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 16-18, 2016

Presentation Outline

- Program Benefits
- Goals and Objectives
- Technical status
- Accomplishments
- Synergy Opportunities
- Project Summary



Mid-Atlantic U.S. offshore study area is comprised of three major sub regions: (1) Georges Bank Basin, (2) Baltimore Canyon Trough, and (3) Long Island Platform

Team Members

- Battelle
- Harvard University
- Rutgers University
- Lamont-Doherty Earth Observatory
- Delaware Geological Survey
- Pennsylvania Geological Survey
- Maryland Geological Survey
- United States Geological Survey
- Virginia Dept. of Mines, Minerals, and Energy
- Texas Bureau of Economic Geology

Benefit to the Program:
Benefit Statement

This project will develop a prospective resource assessment offshore of the mid-Atlantic U.S., including the mid-Atlantic and north-Atlantic offshore planning areas. The key project outcomes include:

- A systematic carbon storage resource assessment of the offshore mid-Atlantic coastal region
- Development of key input parameters to reduce uncertainty for offshore resource assessment and efficiency estimates
- Evaluation of risk factors that affect storage resource assessment
- Industry and regulatory stakeholder outreach through development of a road map to assist future CCS projects

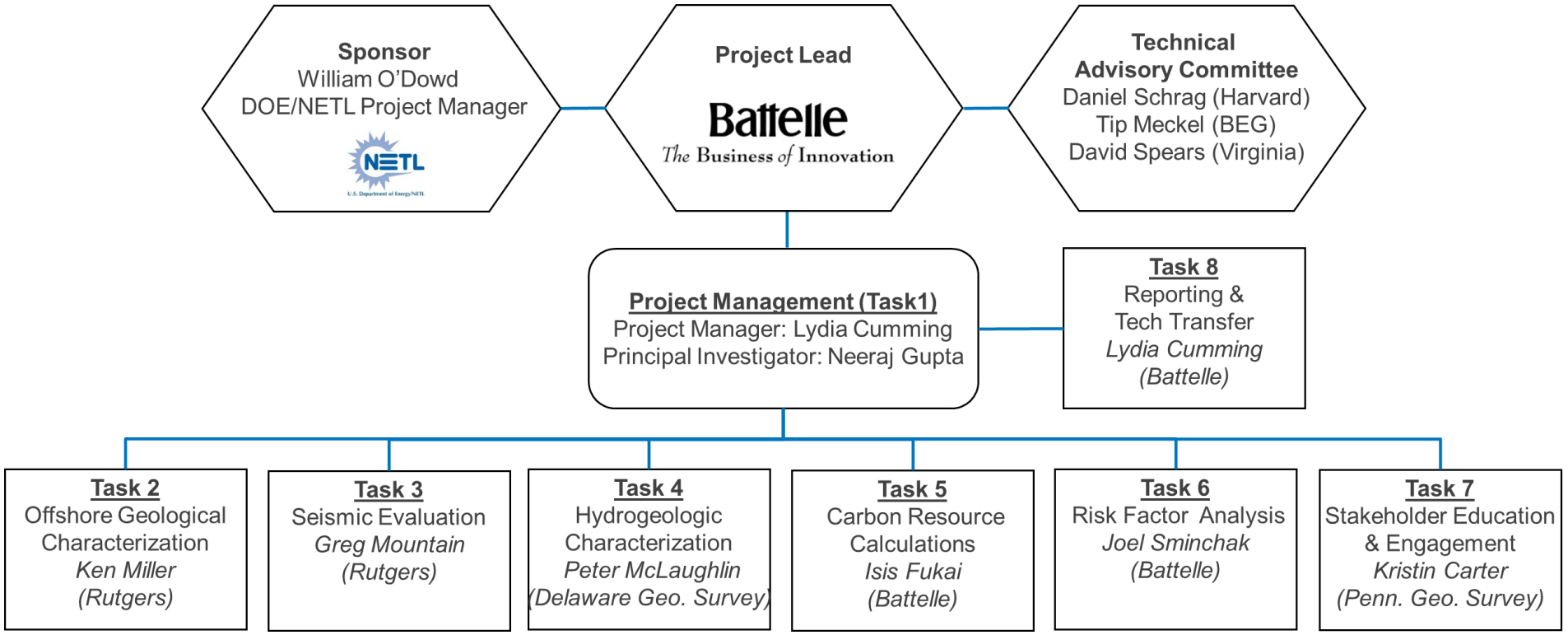
Benefit to the Program:
Program Goals

- *Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 percent* by assessing US offshore storage potential
- *Develop Best Practice Manuals for MVA; site screening, selection, and initial characterization; outreach; well management activities; and risk analysis and simulation* by producing information that will be useful for inclusion in DOE Best Practices Manuals.

Project Overview:
Goals and Objectives

Carbon Storage Program Goal	Mid-Atlantic U.S. Project Objectives	Decision Point/ Success Criteria
Support industry's ability to predict CO_2 storage capacity	Define the geologic characteristics of candidate storage zones Use seismic data to better define continuity of reservoirs and seals Catalog hydro geologic properties of mid-Atlantic offshore area Integrate data for prospective CO_2 storage resource calculations	Constrained study to areas with realistic storage potential Evaluated and selected seismic for additional processing Determined suitable C-storage resource calculation method
Develop Best Practice Manuals	Estimate storage potential Examine risk factors Engage stakeholders to guide future projects	Input to related BPMs

Project Overview:
Organization Chart



LAMONT-DOHERTY EARTH OBSERVATORY

USGS science for a changing world

Harvard University Center for the Environment

Virginia Department of Mines Minerals and Energy

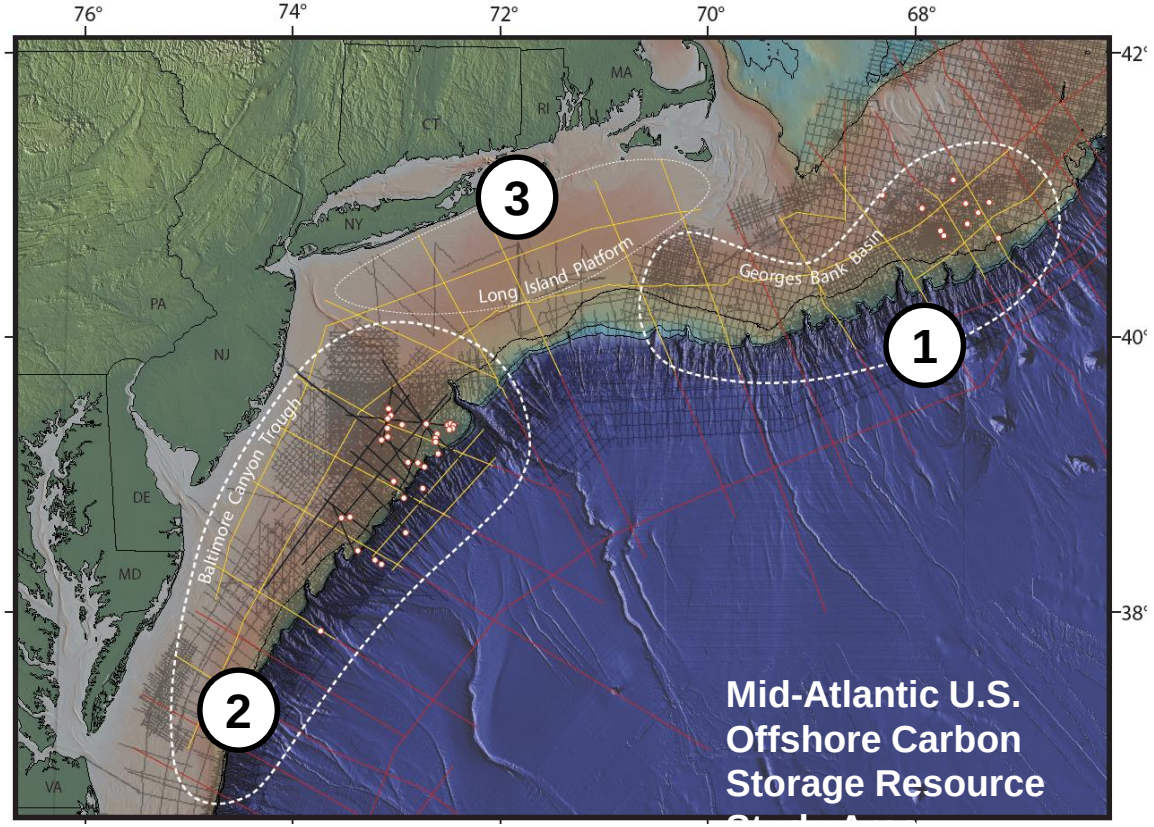
Bureau of Economic Geology

All team members support and contribute towards each task as applicable

Technical Status: Task 2

Defining the geologic characteristics of candidate storage sites

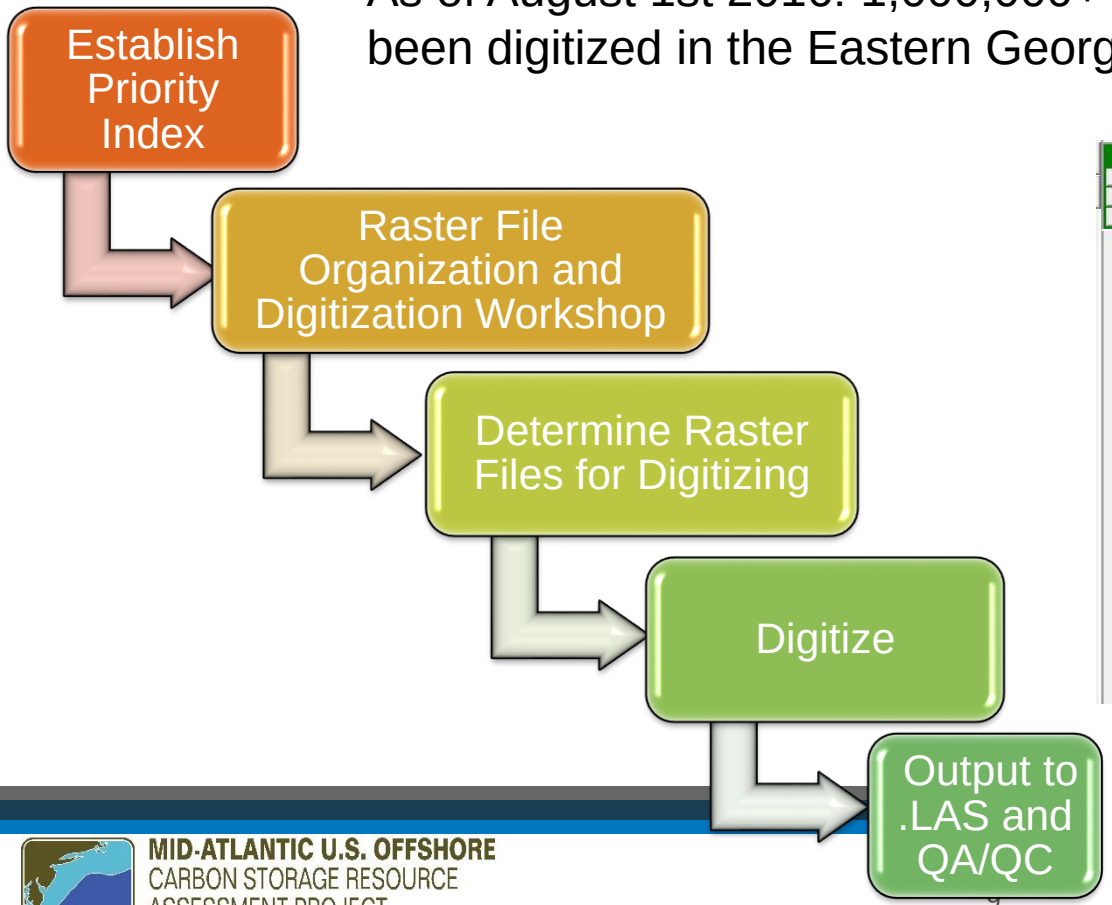
- Compile and review existing geologic and geophysical data
- Interpret porosity and mineralogy via well log and core analyses
- Correlate with seismic data
- Develop formation maps and cross sections

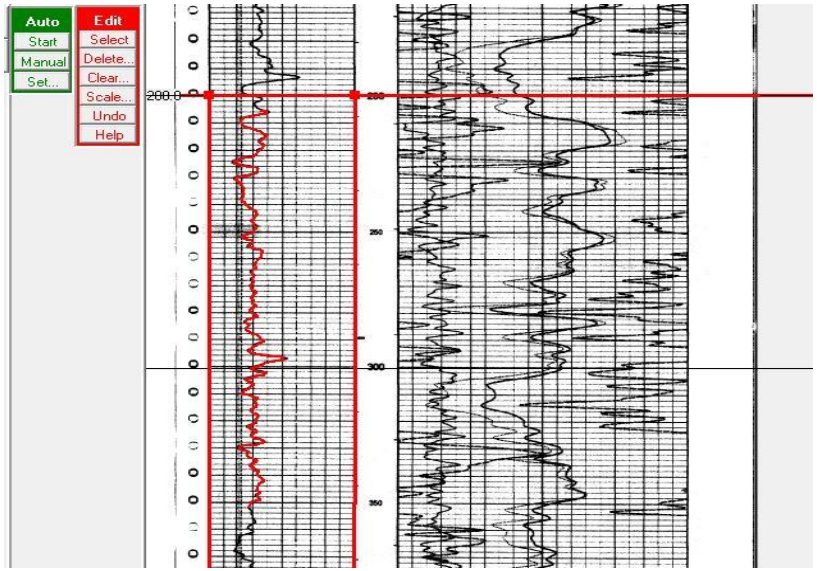


(1) Georges Bank Basin
(2) Baltimore Canyon Trough
(3) Long Island Platform

Technical Status: Task 2
Log Digitization Efforts

- 682 unique image files from 10 wells were acquired from the BOEM database.
- As of August 1st 2016: 1,000,000+ feet of geophysical log data have been digitized in the Eastern Georges Bank Basin (EGBB).





An image file mid-digitization showing the process of transforming paper image files into digital database curves. Image taken from Petra™ software package

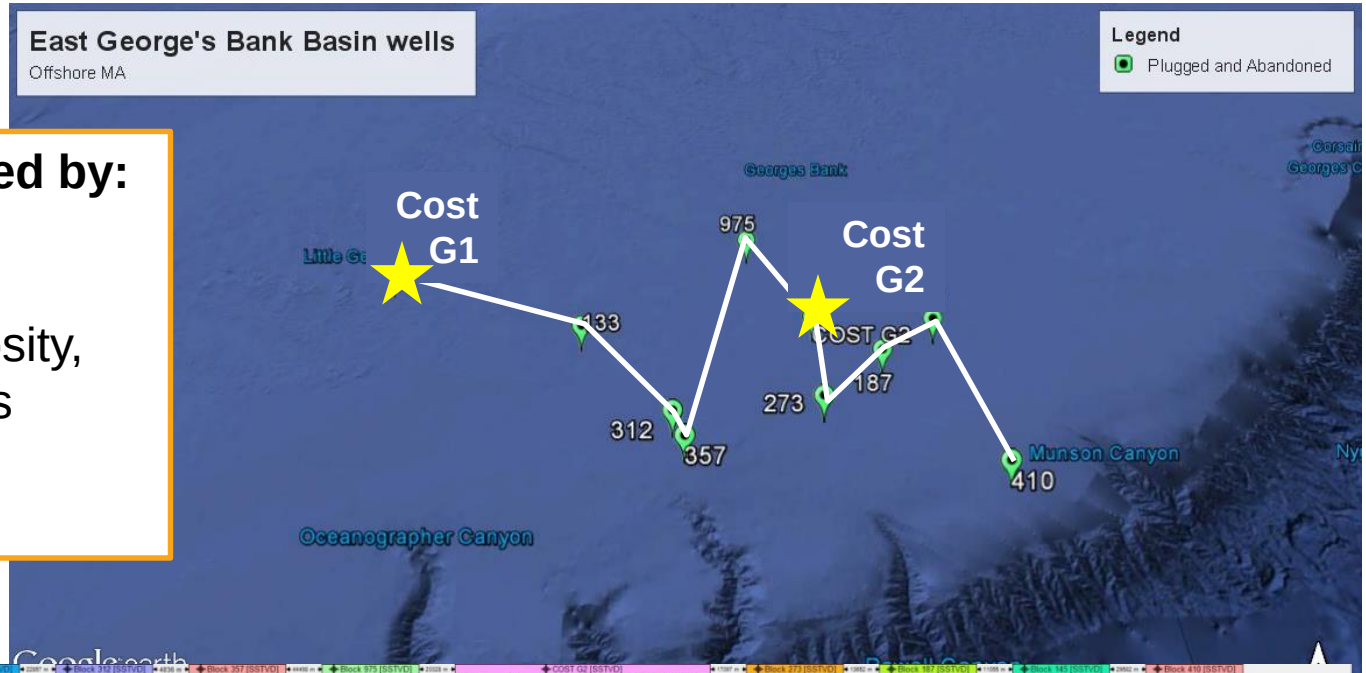
Technical Status: Task 2

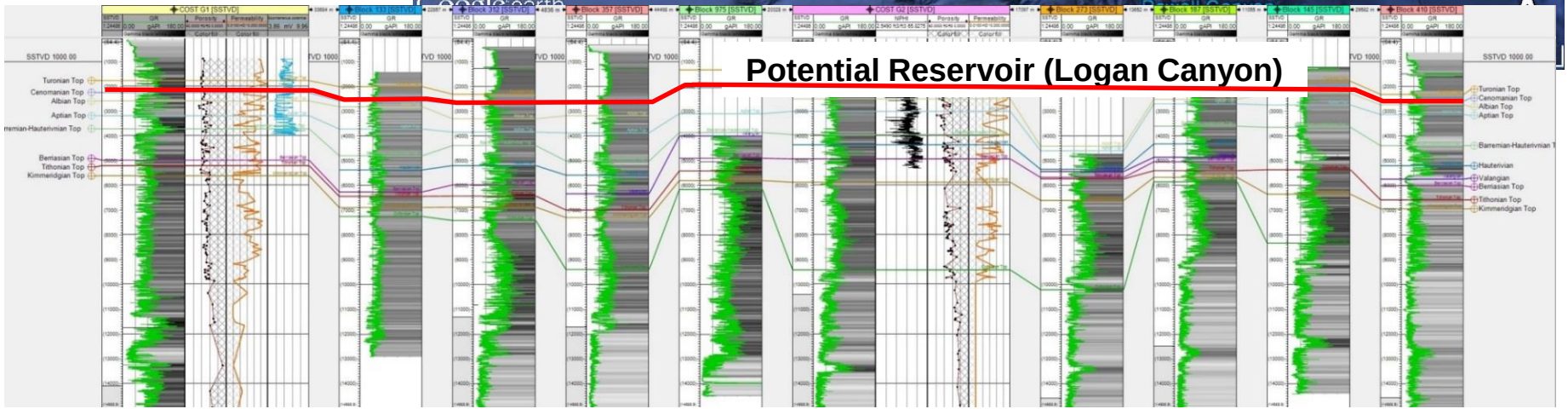
Preliminary lithologic interpretations completed for EGBB

Public data published by:
- USGS, BOEM

Types of data:
- Gamma Ray, Porosity, Density, Sonic logs
- Biostratigraphic

★ Type Wells





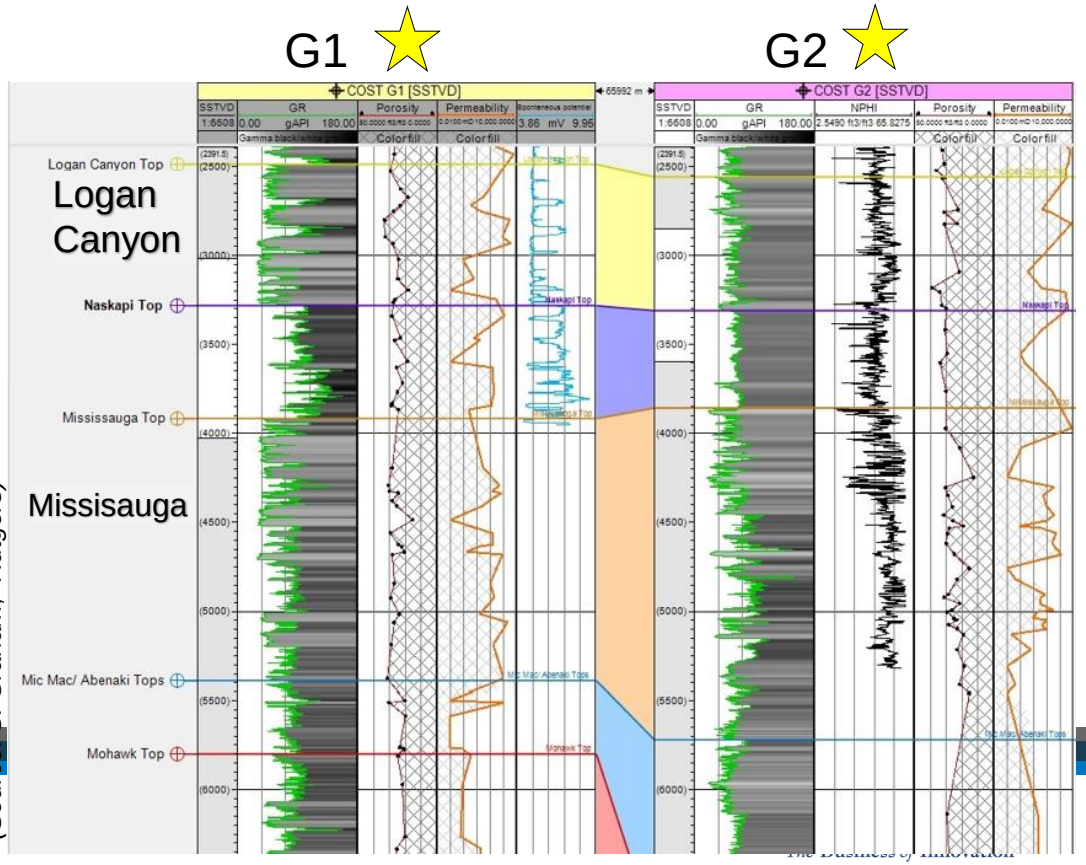
(Source: S. Graham, Rutgers)

Technical Status: Task 2

Potential saline sand reservoirs in EGBB identified

- Saline sand reservoirs located 2,500-10,000 ft in depth
  - Logan Canyon, Missisauga, Mohawk Formations
  - Sands hundreds of feet thick, separated by shales and coals

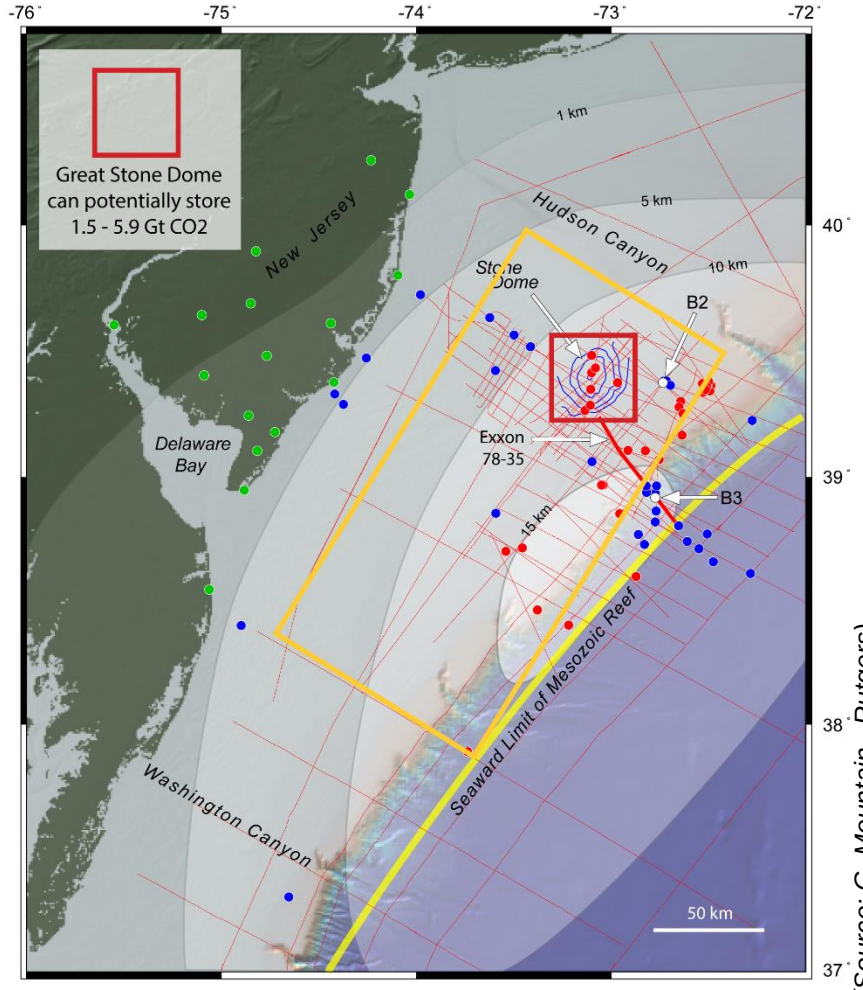
- Porosity ranges from 22-35%
- Permeability ranges from 300 mD - 3000 mD



(Source: S. Graham, Rutgers)

Technical Status: Task 2
Characterization of the BCT is being expanded

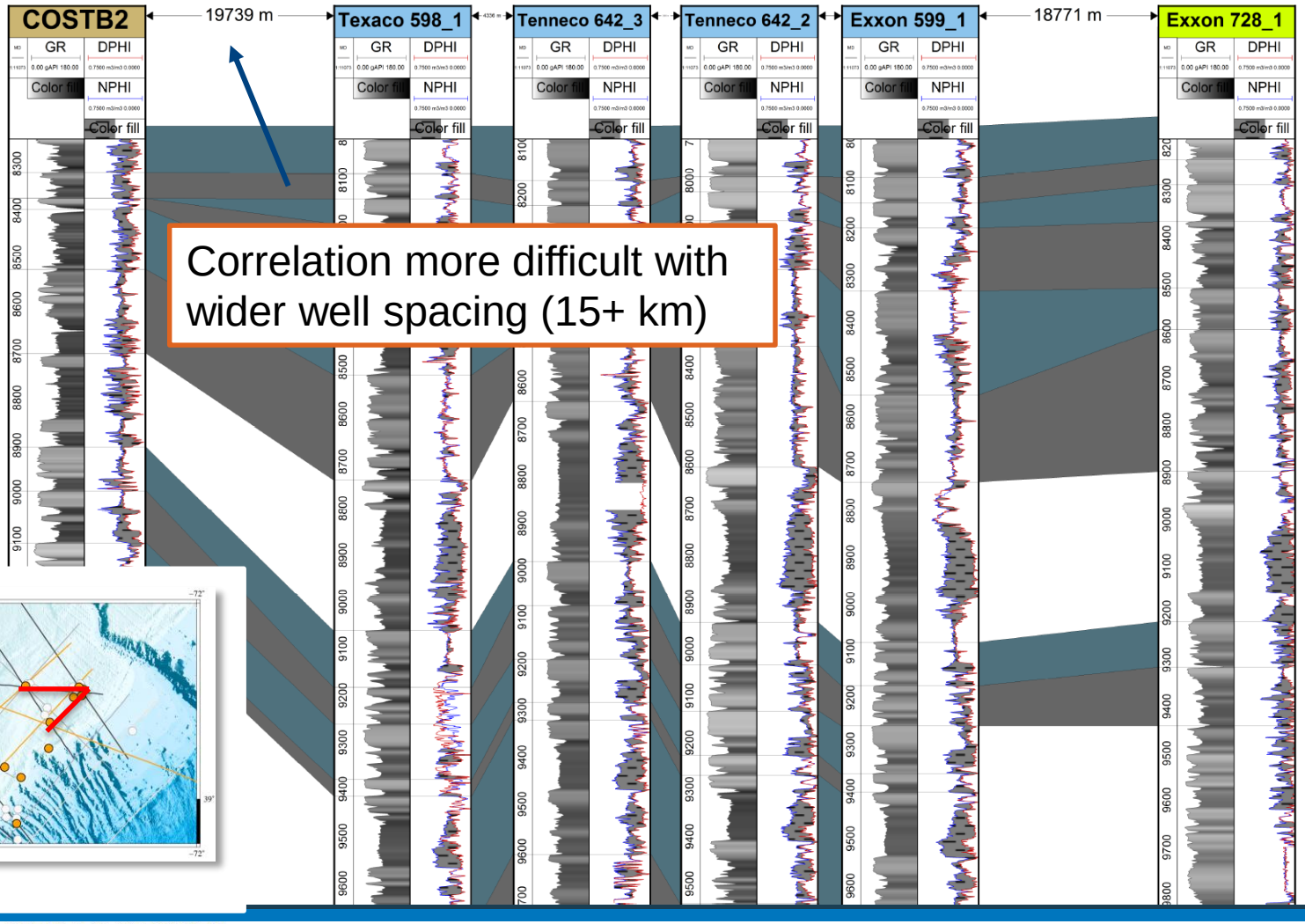
- Characterization of Baltimore Canyon Trough (BCT) began under another DOE funded project (MRCSP Program)
- Expanding study of potential reservoir sands
  - Compiling well data
  - Performing well-top correlations
  - Cenozoic- & Mesozoic- age carbonates, sandstones, shales
  - Logan Canyon Sands, Mississauga Fm, Mohawk Fm



(Source: G. Mountain, Rutgers)

Technical Status: Task 2

Tracing Logan Canyon Sands/Sandstone Reservoir across the BCT



(Source: C. Lombardi, Rutgers)

Technical Status: Task 2

Biostratigraphy/Chronology of the Great Stone Dome has been updated

	Exxon 500	Mobil 544-1 228 ft (m) 83 ft kb 5090 ft	Conoco 590 5580 ft	Shell 632 201 ft (62 m) 84 ft kb	HOM 676 220 ft (67 m) 96 ft kb 5630 ft	Gulf 718 6020 ft
Turonian	HO G. helvetica 5400′ HO *R. planus 5400′ HO *C. achylosum 5460′ HO P. stephani 5460′ 5670 ft	HO P. stephani 5090′ HO P. gibba 5090′ HO *C. achylosum 5093′ 5270 ft	HO G. helvetica 5580′ HO *C. achylosum 5580′ HO *R. planus 5580′ P. stephani 6005′ P. turbinata 6005′ 6030 ft	In Turonian 5030′ 5530 ft	HO G. helvetica 5630′ HO P. stephani 5630′ HO P. turbinata 5630′ HO *C. achylosum 5915′ 6020 ft	HO *R. planus 6020′ HO *C. achylosum 6260′ HO G. helvetica 6320′ HO P. stephani 6320′ 6470 ft
Cenomanian U ? M	HO R. cushmani 5670′ HO *C. kennedyi 5760′ HO *P. albianus 5790′	HO R. cushmani 5270′ HO *L. alatus 5368′ HO *P. albianus 5435′	HO R. cushmani 6030′ HO *L. alatus 6060′ HO *C. kennedyi 6090′	Top Cenomanian 5530′ 6074 ft	HO R. cushmani 6020′	HO *R. greenhorn-ensis 6470′ 6500 ft HO *C. kennedyi 6620′ HO *P. albianus 6710′
Cenomanian L	5840 ft HO **A. cristatus 5910′ HO *B. africana 6060′ 6328-6388 ft	HO **S. vestitum 5450′ 5465 ft HO **T. apiverru -catus 5510′ 5955 ft	6104 ft 6604-6725 ft 6780 ft	5600 ft 6215-6255 ft	HO *B. africana 6074′ HO *N. truitti 6074′ 6087 ft 6700-6775 ft 6750 ft	7180-7278 ft ??? ft
Albian		HO **P. [?]trichopap -illosus 6410′ 6690 ft	HO **A. potomac -ensis 6780′ HO **P. trichopap -illosus 6780′ HO **T. appiverru -catus 6780′ 7043-7267 ft 7320 ft	In Albian 5610′ 6820-6900 ft	HO **T. variverru -catus 6755′ HO **P. trichopap -illosus 6755′ HO **T. apiverru -catus 6755′ 7200-7460 ft 7640 ft	HO **T. apiverru -ucatus 7550′ HO *B. africana 7670′ 8120-8305 ft
Aptian	7035-7168 ft 7440 ft	HO **C. tabulatum 6690′ 6760-6790 ft 7150 ft	HO **C. tabulatum 7320′ 8100 ft	In Aptian 7050′ 7500 ft	HO **C. tabulatum 7640′ 8450 ft	
Barremian	HO **C. austral -ensis 7440′ 7600 ft HO **C. tabulatum 7740′ Berriasian @ 9960′	HO **M. simplex 7150′ 7340 ft Berriasian @ 7400′	HO **M. simplex 8100′ 8200 ft Hauter. or older @ 9300′	In Barremian 7710′	HO **M. [?] simplex 8450′ 8600 ft Hauter. or older @ 9740′	8726 ft HO **C. attadalica 10340′ Hauter. or older @ 11780′

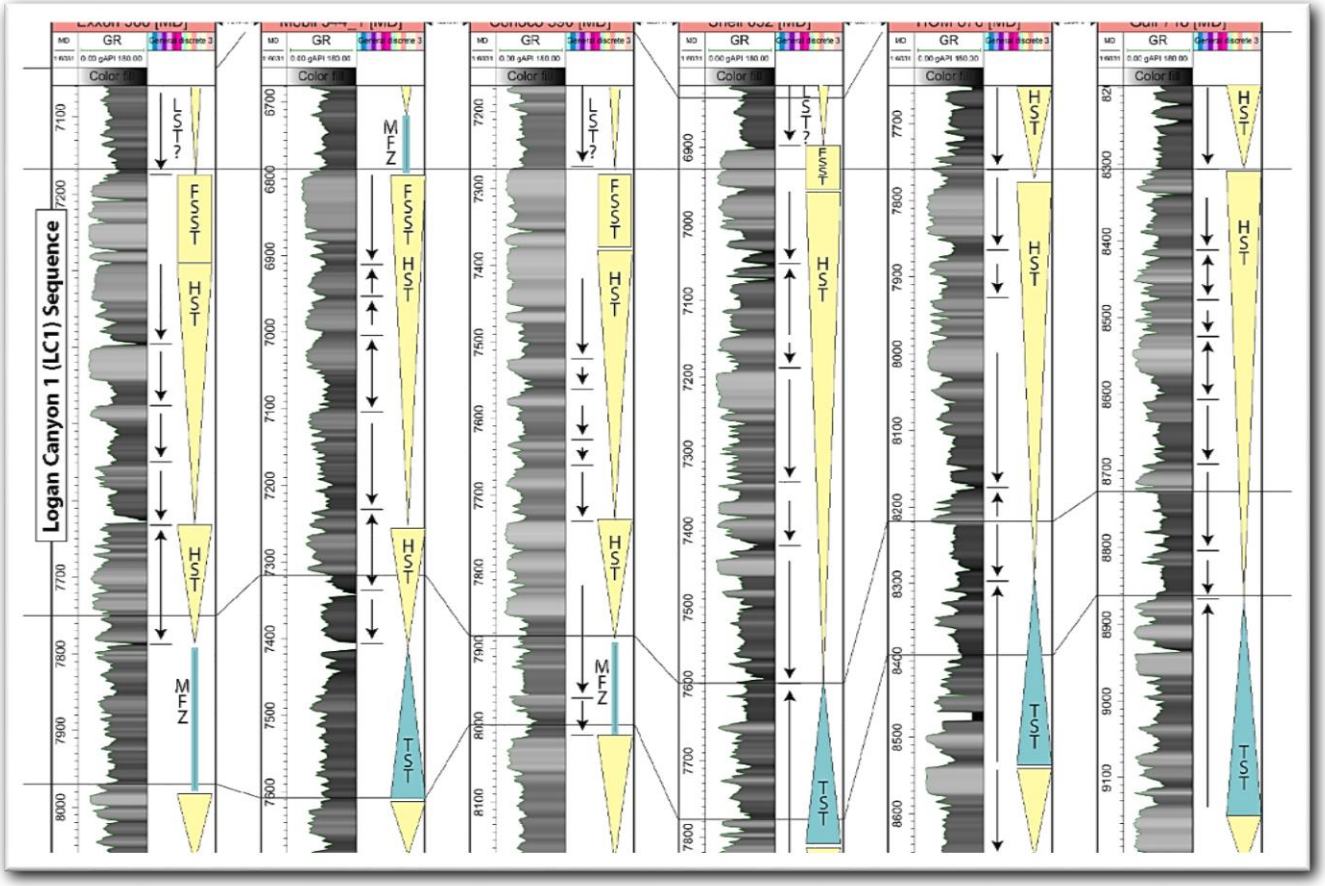
(Source: C. Lombardi, Rutgers)

HO = Highest Occurrence

Technical Status: Task 2

Sequence stratigraphy used to improve prediction of reservoir and caps

New sequence stratigraphic interpretation of Great Stone Dome



(sources: Libby-French,1984; C. Lombardi, Rutgers)

Systems tracts of the Logan Canyon 1 Sequence = Logan Canyon Lower Sandstone

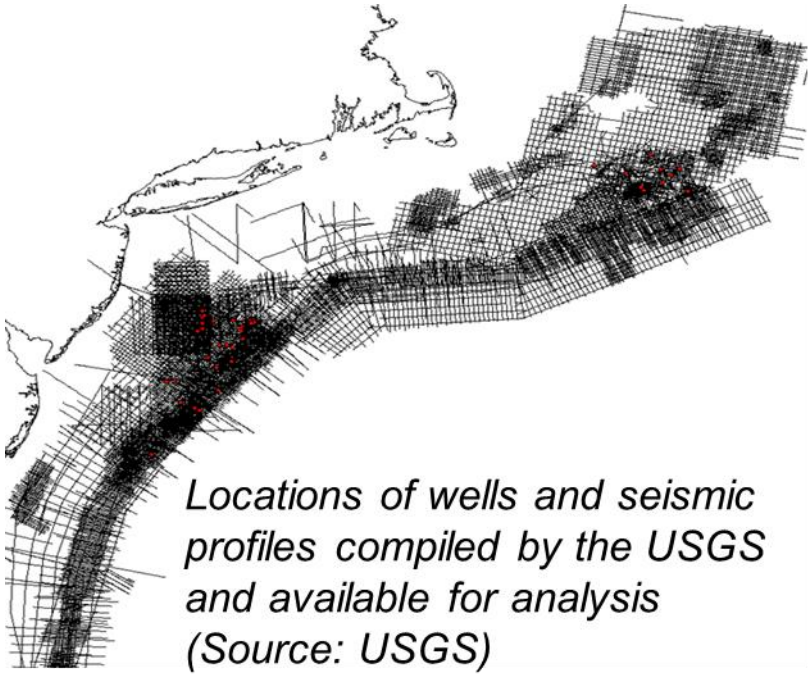
LST: Low Stand System Tract; **HST**: High Stand System Tract;
MFZ: Maximum Flooding Zone; **TST**: Transgressive System Tract

Technical Status: Task 3

Using seismic data to better define continuity of reservoirs

- Bureau of Ocean Energy Management (BOEM) newly released multichannel seismic data from 1970s-1980s

- Augmented with lines from USGS, academic, and other seismic surveys
  - Strategic selection of seismic lines for reprocessing
  - Modern workflow processing will be applied to enhance resolution

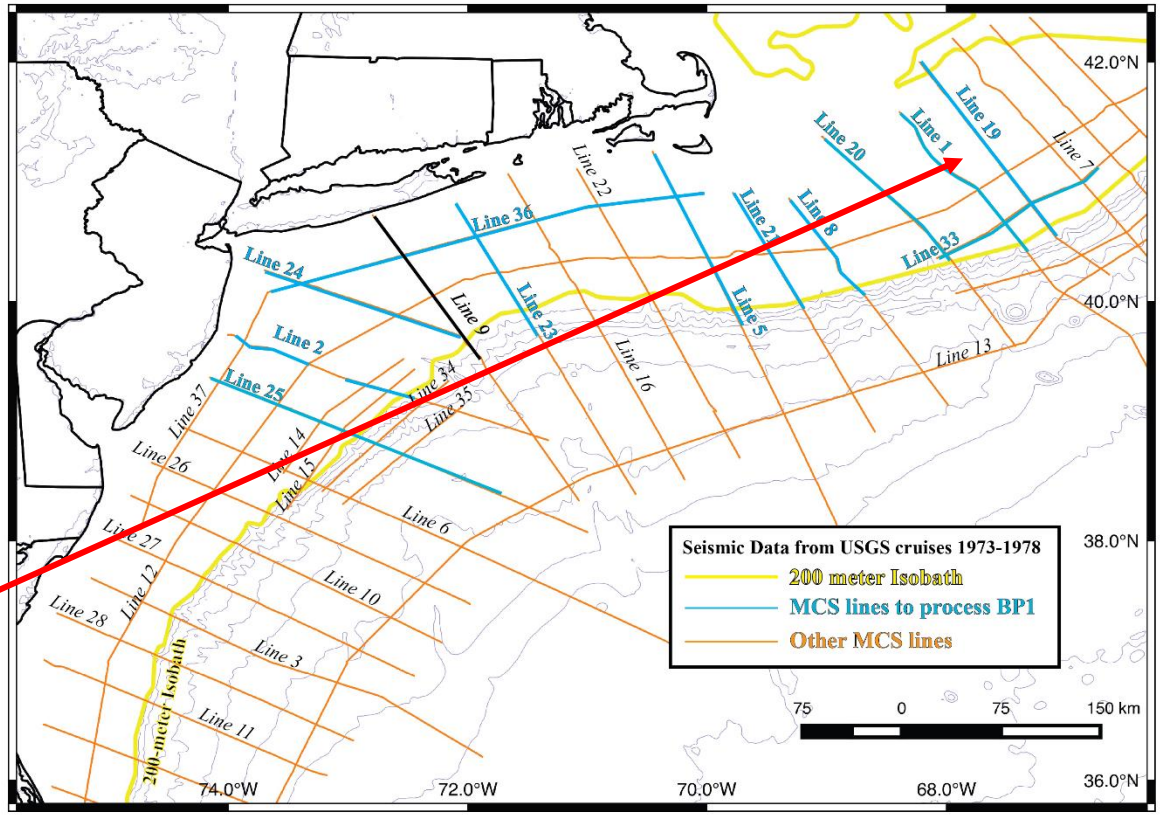


Locations of wells and seismic profiles compiled by the USGS and available for analysis (Source: USGS)

Technical Status: Task 3

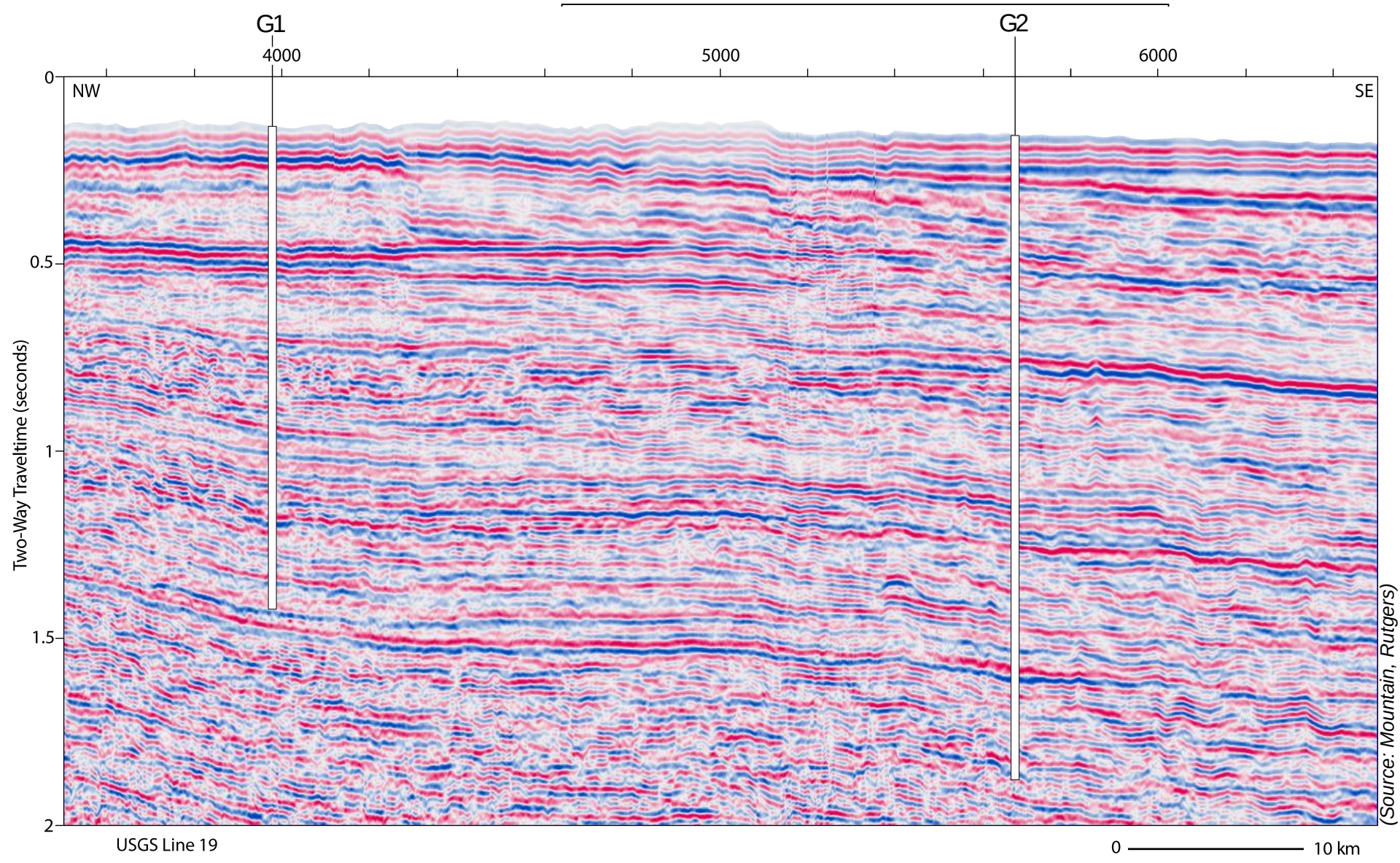
The initial seismic reprocessing plan has been developed

- 4000 line km total, to be completed in 3 batches
- Lines selected based on:
  - Key targets and best-quality seismic lines
  - Location and quality of available metadata
  - Team input
- Example result (line 19) shown on next slide



(Source: W. Fortin, LDEO)

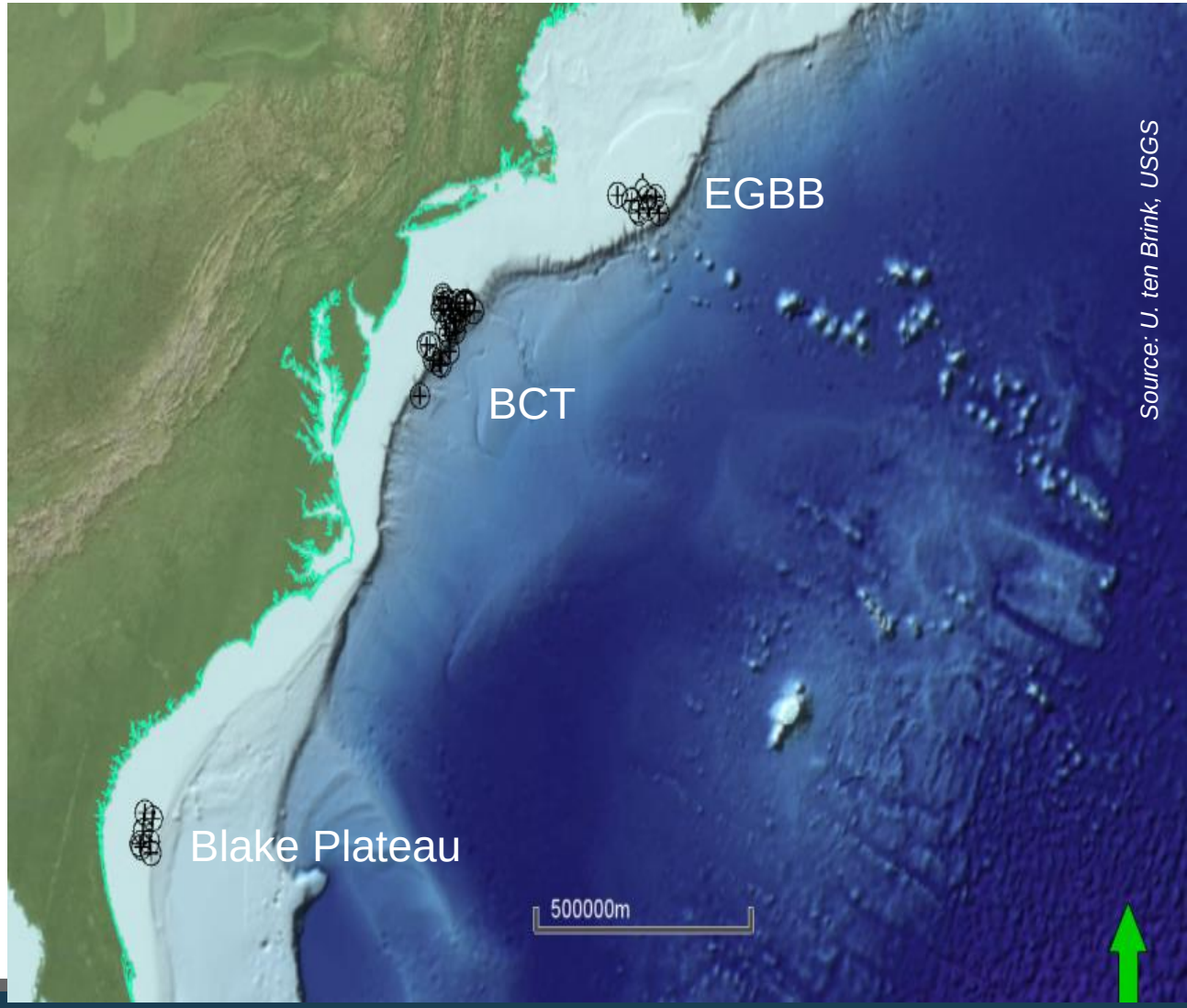
Example Result of Initial Reprocessing, Line 19



Technical Status: Task 3

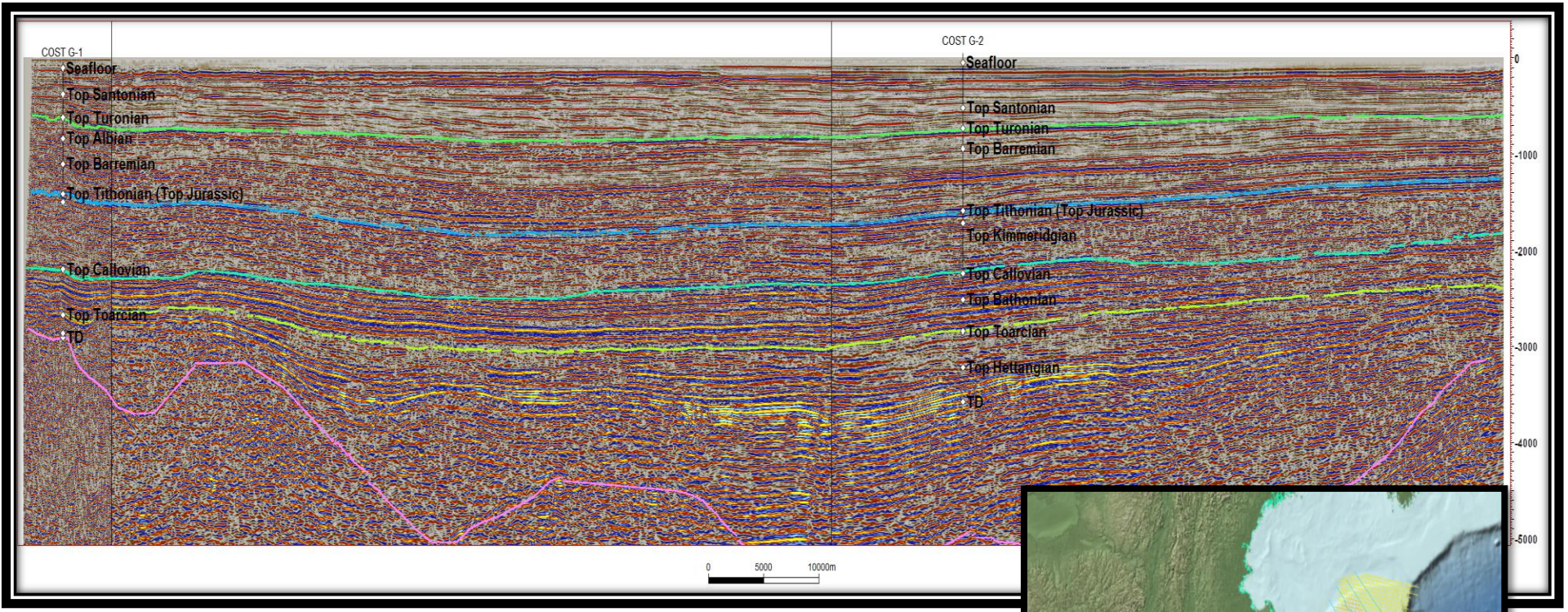
Begun loading tops into database for Depth-TWT conversion

- USGS has 46 emplaced wells in 3 main clusters: EGBB, BCT, and Blake Plateau
- 16 wells populated and assigned with well tops thus far

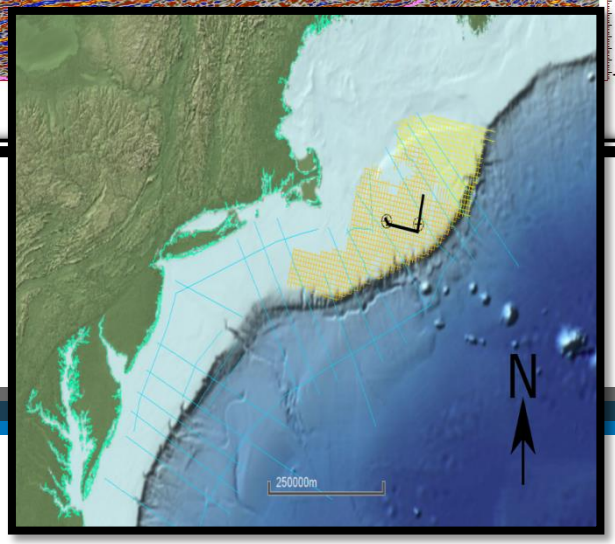


Technical Status: Task 3

Example COST G-1 COST G-2 reference composite section



- 13 digitized velocity surveys imported to Petrel
- 5 interpreted and well correlated horizons so far

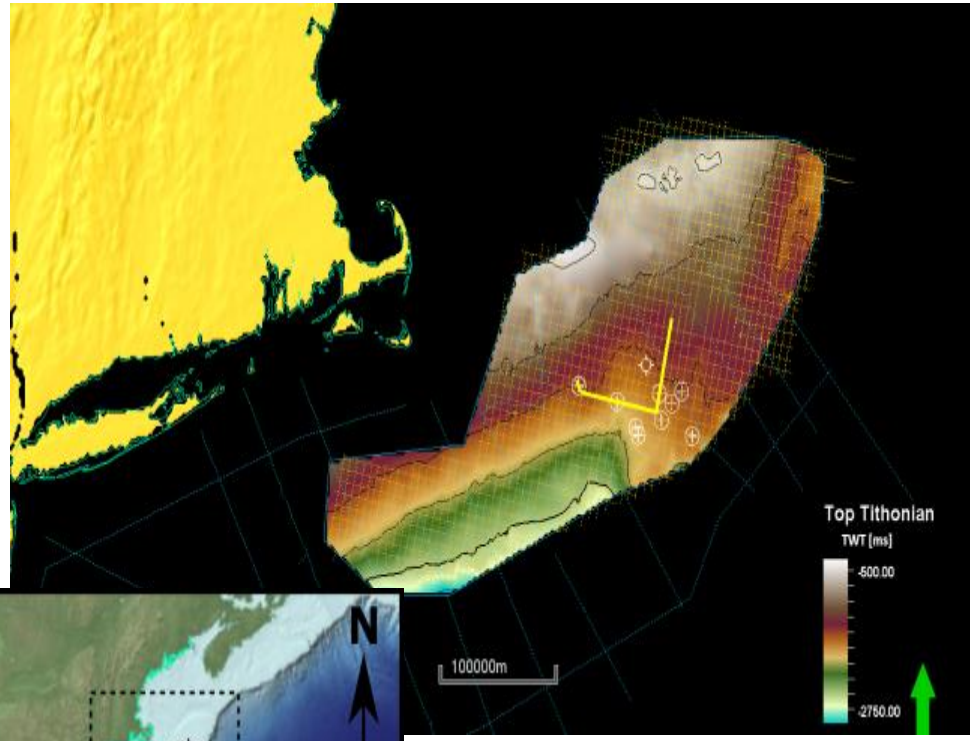


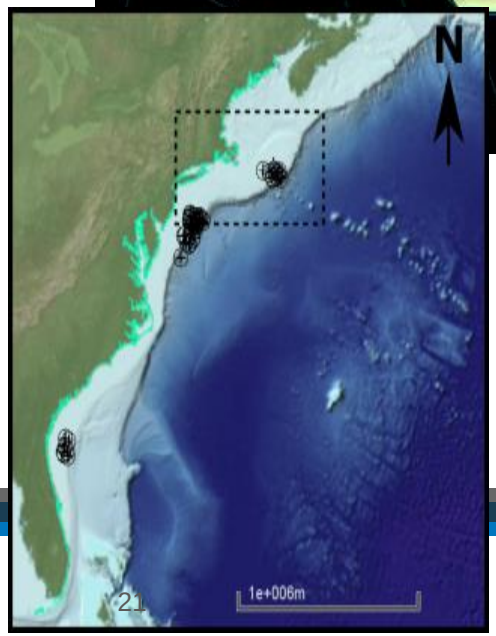
Source: Uchten Brink, USGS

Technical Status: Task 3

Example TWT structural map

- Georges Bank Top Jurassic and Top Turonian structural maps being built
- Tops are interpreted on a dense grid and interpolated into structural maps
- Challenges to overcome:
  - Multiple paleontological works sometimes contradictry
  - Not all well tops conform
  - Small geometry problems





(Source: U. ten Brink, USGS)

Technical Status: Task 4 Cataloging hydrogeologic properties

Technical Approach

- Detailed inventory of existing samples and data from the OCS
  - Conventional core and sidewall cores
  - Washed and unwashed drill cuttings
  - Prepared materials (thin sections, palynology slides, nanofossil slides, microfossil slides, kerogen slides, core peels, geochemical samples)
- Compilation of existing hydrogeologic data from available reports, databases and published literature
  - Assessment of data quality and determination of data gaps
  - Additional sampling and analysis as required
  - Synthesis of hydrogeologic properties data to characterize zones of interest for storage

Technical Status: Task 4

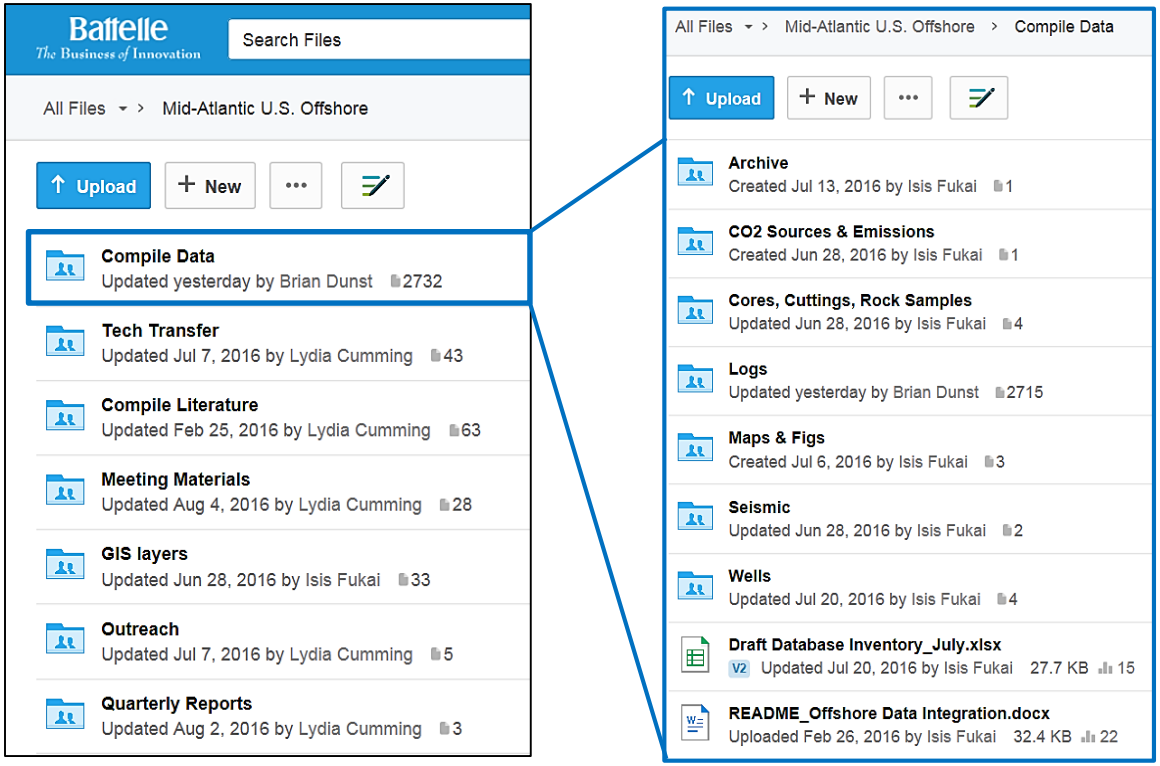
Efforts focused on detailed inventorying the DGS OCS Repository

- Inventory of conventional and sidewall core holdings, geophysical logs, prepared materials (EGBB wells), and washed cuttings (EGBB wells) (complete)
- Inventory of prepared materials and washed cuttings ongoing for BCT wells (>50% complete)
- Sample review and selection underway
- Hydrogeologic properties data compilation and assessment to commence after inventory

Technical Status: Task 5

Integrating data for prospective CO_2 storage resource calculations

- Technical Approach
  - Follows substantial completion of data collection (Tasks 2-4)
  - Data compilation into a central repository (Box)
  - Data being digitized, summarized in spreadsheets
    - Petra/Petrel
    - ArcGIS



Technical Status: Task 5
Data Inventory/compilation Status

MID-ATLANTIC OFFSHORE STORAGE RESOURCE ASSESSMENT
Master Database Inventory

Updated 8/8/2016

***Study Area Well Count:* 44**

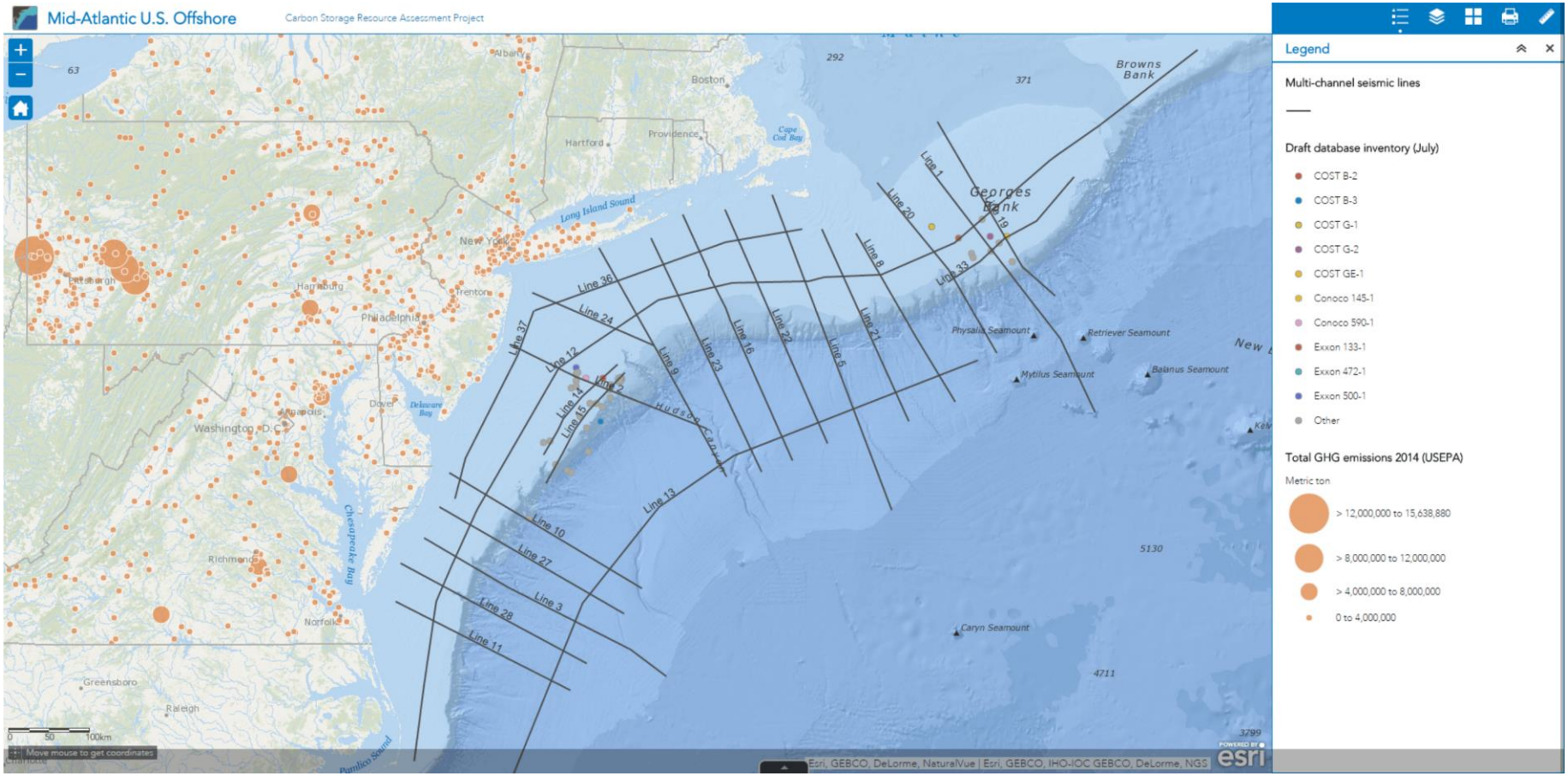
Well / Hole Name	Block #	Well API	Operator	Study Area Sub Region	OPD Section #	OPD Section Name	Latitude	Longitude	Well Total Depth (ft)	Reference Datum	Datum Depth (ft)	Water Depth (ft)	Spud Date	Completion Date
Conoco 145-1	145	6104000007	Conoco	Georges Bank	NK19-12	Lydonia Canyon	40.8330	-67.2853	14,398	KB	85	300	5/13/1982	8/25/1982
Conoco 590-1	590	6110500007	Conoco	Baltimore Canyon	NJ18-3	Hudson Canyon	39.3761	-72.9672	11,908	KB	73	242	4/17/1978	6/7/1978
COST B-2	594	6110500001	Ocean Prod	Baltimore Canyon	NJ18-3	Hudson Canyon	39.3756	-72.7344	16,039	KB	90	298	12/14/1975	2/28/1976
COST B-3	66	6110400002	Chevron	Baltimore Canyon	NJ18-6	Wilmington Canyon	38.9169	-72.7728	15,820	KB	42	2686	10/9/1978	1/24/1979
COST G-1	79	6106200001	Ocean Prod	Georges Bank	NK19-11	Hydrographer Cny	40.9311	-68.3053	16,071	KB	98	157	4/6/1976	7/27/1976
COST G-2	141	6104000001	Ocean Prod	Georges Bank	NK19-12	Lydonia Canyon	40.8364	-67.5083	21,874	KB	79	272	1/6/1977	8/6/1977
Exxon 133-1	133	6104000002	Exxon	Georges Bank	NK19-12	Lydonia Canyon	40.8181	-67.9343	14,100	KB	85	225	7/24/1981	11/24/1981
Exxon 500-1	500	6110500016	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon	39.4847	-73.1006	12,253	KB	79	204	7/18/1979	9/28/1979
Exxon 599-1	599	6110500019	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon	39.3642	-72.4872	17,121	KB	82	442	4/25/1980	11/2/1980
Exxon 684-1	684	6110500002	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon	39.3028	-72.6417	17,615	KB	38	399	3/29/1978	12/23/1978
Exxon 684-2	684	6110500010	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon							9	7/15/1979
Exxon 728-1	728	6110500022	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon							1	7/5/1981
Exxon 816-1	816	6110500020	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon							30	5/7/1981
Exxon 902-1	902	6110500013	Exxon	Baltimore Canyon	NJ18-3	Hudson Canyon							78	4/15/1979
Exxon 975-1	975	6104100001	Exxon	Georges Bank	NK19-9	Corsair Canyon							981	3/10/1982
Gulf 718-1	718	6110500005	Gulf	Baltimore Canyon	NJ18-3	Hudson Canyon							79	3/31/1979
Gulf 857-1	857	6110500008	Gulf	Baltimore Canyon	NJ18-3	Hudson Canyon							78	1/29/1979
Homco 676-1	676	6110500006	Houston O&M	Baltimore Canyon	NJ18-3	Hudson Canyon							78	9/22/1978
Homco 855-1	855	6110500012	Houston O&M	Baltimore Canyon	NJ18-3	Hudson Canyon							78	2/8/1979

44 wells:
38 with raster logs
21 with digital Logs
20 with core samples
14 with log and core samples

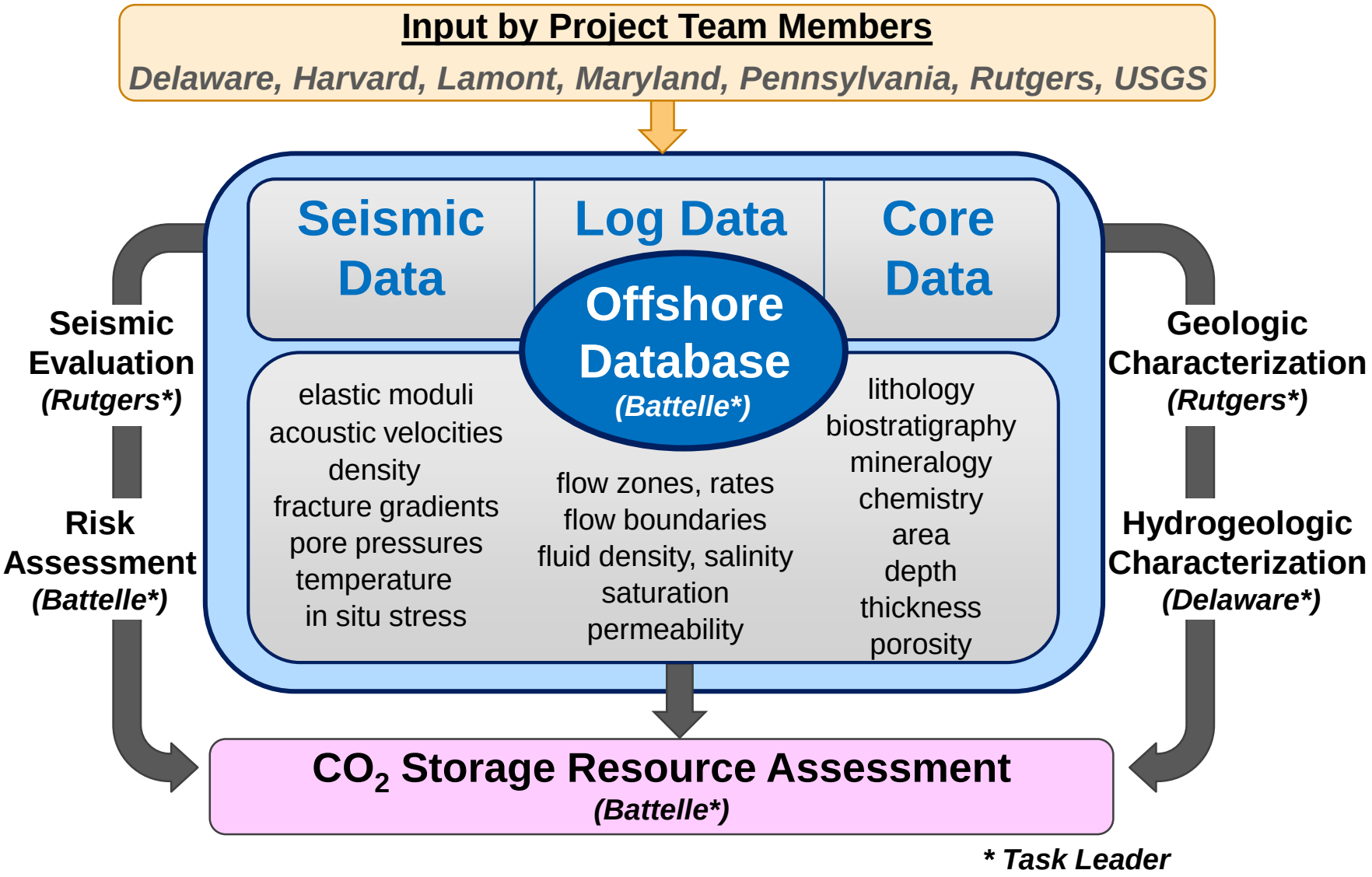
Technical Status: Task 5

Data Inventory/compilation Status

ArcGIS Online map showing datasets assembled for study



Technical Status: Task 5



Technical Status: Tasks 6-8
Other Supporting Tasks

- Risk Assessment
  - Looking at geological risk factors (e.g., faults) and near surface features (e.g., pipelines, telecommunication cables)
  - Describing confining layers and evaluating potential for long-term CO_2 migration
- Stakeholder Outreach
  - Developed a Project Overview Factsheet, Logo
  - Preparing a stakeholder list
- Technology Transfer
  - SECARB Annual Stakeholder Briefing
  - CSLF International Workshop on Offshore Geologic CO2 Storage
  - 2016 CCUS Conference

Accomplishments to Date

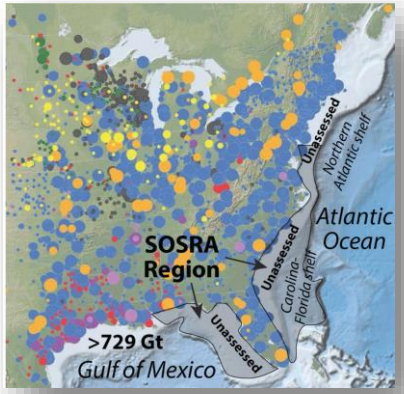
- 1,000,000+ feet of geophysical log data digitized in the EGBB
- Potential saline reservoirs in EGBB and NBCT identified and stratigraphically characterized
- 13 digitized velocity surveys to Database
- Data populated in 16 wells for Depth-TWT
- Detailed Core Inventory completed

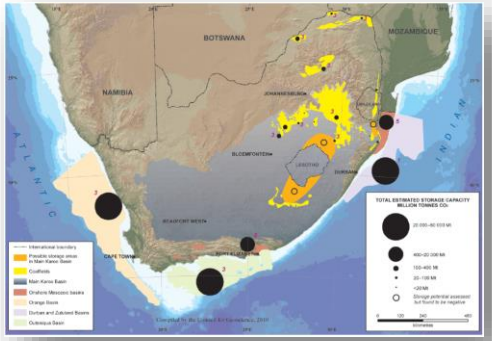
- Developed ArcGIS Online map of study area to facilitate data inventory and information transfer/display
- Integrated data in online platform and Petra database to facilitate petrophysical analysis and calculation of prospective CO_2 storage resource

Synergy Opportunities

- Building on the offshore characterization performed for the MRCSP Program
- Collaborating with other DOE Offshore Projects
  - Share boundaries with SOSRA
  - Project technical advisors involved in SOSRA, Gulf Coast Projects
- Adding to the international pool of information
  - CSLF International Offshore Geologic Storage workshop, April 2016
  - World Bank - South Africa

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



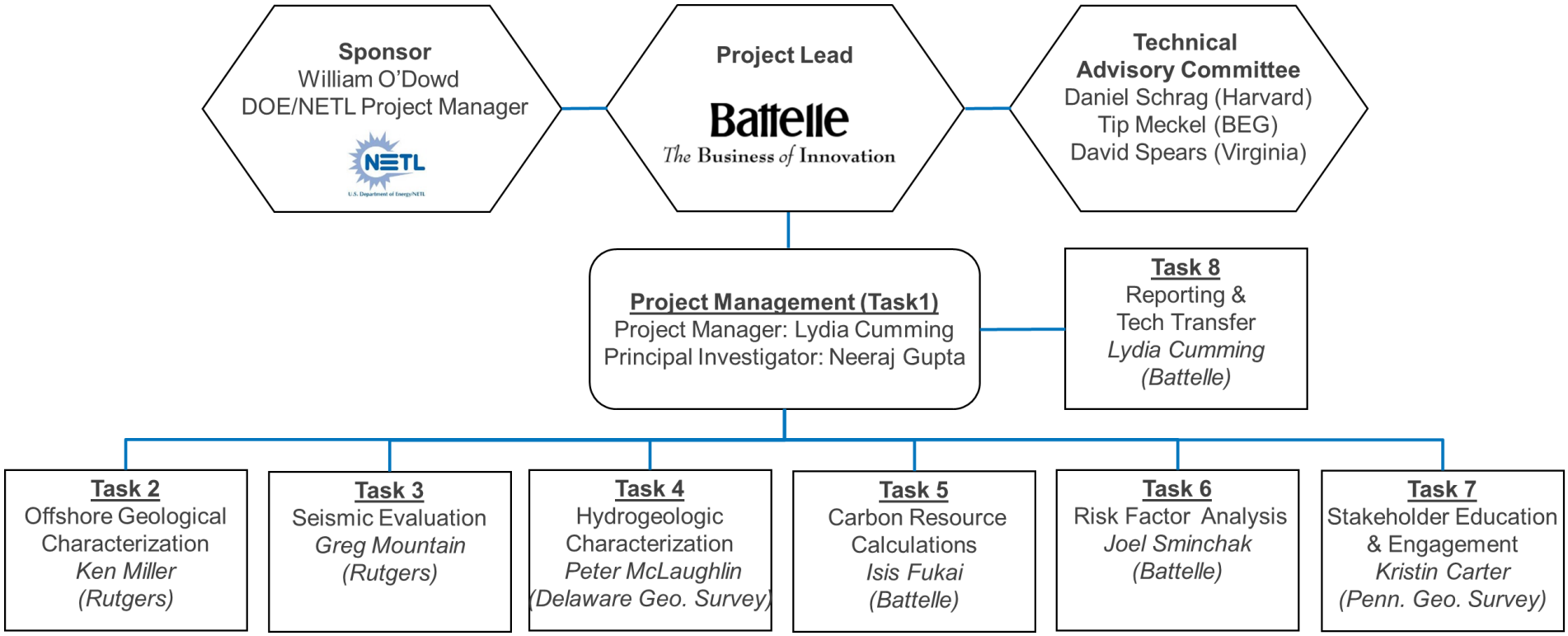


Summary

- Developing a prospective resource assessment offshore of the mid-Atlantic U.S.
- A diverse, collaborative, expert team is collaborating very well
- The existing geological, geophysical, and petrophysical data to be used for this project have been identified and obtained
  - Data and samples from a relatively small number of clustered wells
  - Challenges disparate data sets, missing metadata for some seismic lines, and no ongoing E&P in area
- Detailed analysis and reprocessing are helping to improve understanding of the geologic framework
- Initial evaluation indicates potential zones (e.g. Logan Canyon) for CO_2 storage
- Project is synergistic with MRCSP and other offshore projects

Appendix

Organization Chart



LAMONT-DOHERTY EARTH OBSERVATORY

USGS science for a changing world

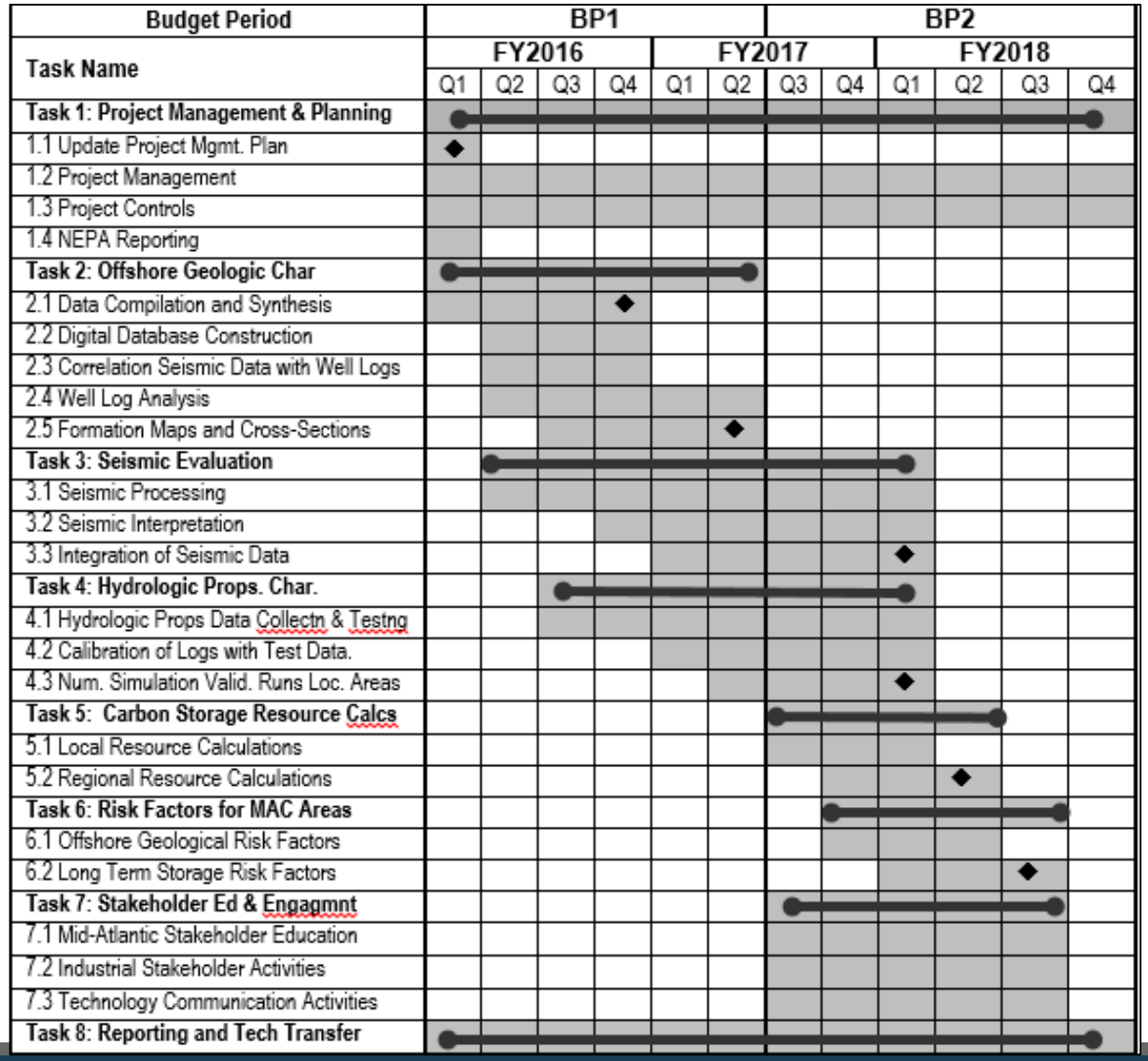
Harvard University Center for the Environment

Virginia Department of Mines Minerals and Energy

Bureau of Economic Geology

All team members support and contribute towards each task as applicable

Gantt Chart



Budget Period	BP1						BP2					
Task Name	FY2016				FY2017				FY2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Project Management & Planning												
1.1 Update Project Mgmt. Plan												
1.2 Project Management												
1.3 Project Controls												
1.4 NEPA Reporting												
Task 2: Offshore Geologic Char												
2.1 Data Compilation and Synthesis												
2.2 Digital Database Construction												
2.3 Correlation Seismic Data with Well Logs												
2.4 Well Log Analysis												
2.5 Formation Maps and Cross-Sections												
Task 3: Seismic Evaluation												
3.1 Seismic Processing												
3.2 Seismic Interpretation												
3.3 Integration of Seismic Data												
Task 4: Hydrologic Props. Char.												
4.1 Hydrologic Props Data Collectn & Testng												
4.2 Calibration of Logs with Test Data.												
4.3 Num. Simulation Valid. Runs Loc. Areas												
Task 5: Carbon Storage Resource Calcs												
5.1 Local Resource Calculations												
5.2 Regional Resource Calculations												
Task 6: Risk Factors for MAC Areas												
6.1 Offshore Geological Risk Factors												
6.2 Long Term Storage Risk Factors												
Task 7: Stakeholder Ed & Engagmnt												
7.1 Mid-Atlantic Stakeholder Education												
7.2 Industrial Stakeholder Activities												
7.3 Technology Communication Activities												
Task 8: Reporting and Tech Transfer												

Bibliography

No peer reviewed papers as of August, 2016