CCUS Opportunities in Southwestern Pennsylvania Oil Fields: Case Studies from the Midwest Regional Carbon Sequestration Partnership*

Kristin M. Carter[1], Brian J. Dunst[1], Robin V. Anthony[1], and Katherine W. Schmid[1]

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[1]Pennsylvania Geological Survey, Pittsburgh, PA (krcarter@pa.gov)

Abstract

The Midwest Regional Carbon Sequestration Partnership (MRCSP) has prepared a focused assessment of carbon capture utilization and storage (CCUS) opportunities in the tri-state area of Ohio, Pennsylvania, and West Virginia. This area is home to both shallow and deep depleting oil and gas fields that are still actively produced; fields considered to be depleted; fields that have been converted to natural gas storage; and unconventional shale gas and oil/condensate fields. This mix of activity offers an array of potential options for miscible (approximated by reservoir depths of 2500 ft or more) and immiscible (<2500 ft) enhanced recovery and carbon storage in the Ohio River Valley.

As part of this assessment, geologic case studies prepared for the Washington-Taylorstown, Linden, and New Freeport fields have identified specific CCUS prospects (including stacked potential) for Washington and Greene counties in southwestern Pennsylvania. These include both miscible and immiscible CO_2-enhanced oil recovery (CO_2-EOR) and CO_2-enhanced gas recovery (CO_2-EGR) for Upper Devonian Venango Group reservoirs; carbon storage in the Lower Devonian Oriskany Sandstone; and possible future opportunities for CO_2-EGR and carbon storage in the Middle Devonian Marcellus and Upper Ordovician Utica shales. These case study fields are proximal to CO_2 point-sources derived from the power and industry sectors, which are located along the Ohio River to the west and Monongahela River to the east.

The western flank of the Washington-Taylorstown Field offers miscible CO_2-EOR opportunities in the Gordon Sandstone (porosities of ~20 percent and permeabilities of 106-145 mD). The field's eastern flank and adjoining Linden Field offer immiscible CO_2-EOR opportunities in the Gantz and Gordon sandstones, and CO_2-EGR in the Fifty-Foot Sandstone. Like Washington-Taylorstown Field, the New Freeport Field offers miscible CO_2-EOR in the Gordon Sandstone, but what's more, the overlying Nineveh and underlying Fourth sandstones also serve as miscible CO_2-EOR targets, since the Venango Group is deeper in Greene County.

Eastern Washington and Greene counties may offer multiple carbon storage opportunities. The depth to top of the Venango Group is greater here, and given the documented productivity of multiple Venango sandstones, stacked carbon storage may be possible. In addition, the underlying Oriskany Sandstone offers a deeper storage target when some Venango Group sandstones may be in the immiscible depth range.

The prospect of applying CO_2-EGR methods to shales, although yet untested in the Appalachian Basin, could bring an important nuance to future CCUS applications. Based on certain reservoir engineering and economic considerations, it is recommended that CO_2-EOR applications focus on areas of wet gas production and do so at the latter stages of shale gas development, rather than waiting for reservoir depletion.

Selected References

Carter, K.M., and D.G. Patchen, 2017, A Geologic Study to Determine the Potential to Create an Appalachian Storage Hub for Natural Gas Liquids - Final Report: Appalachian Oil & Natural Gas Research Consortium, West Virginia University, Morgantown, WV, 162 p.

Harper, J.A., and C.D. Laughrey, 1987, Geology of the Oil and Gas Fields of Southwestern Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 87, 166 p.

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  - Kentucky - Stephen Greb, David Harris, Brandon Nuttall, Thomas Sparks
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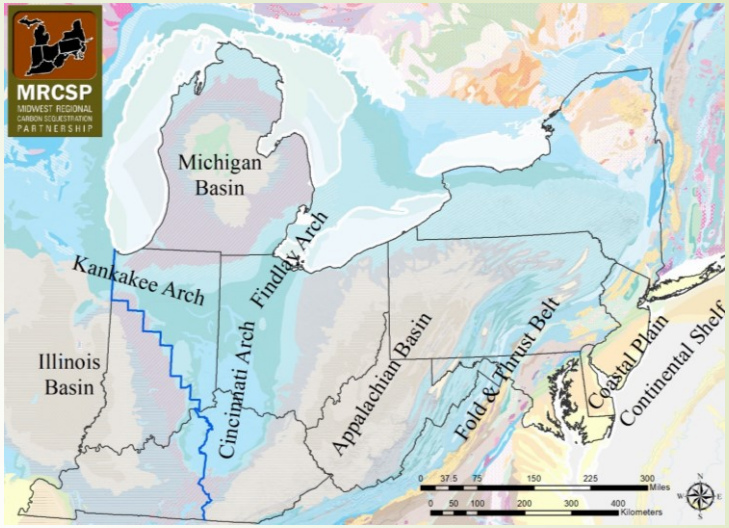
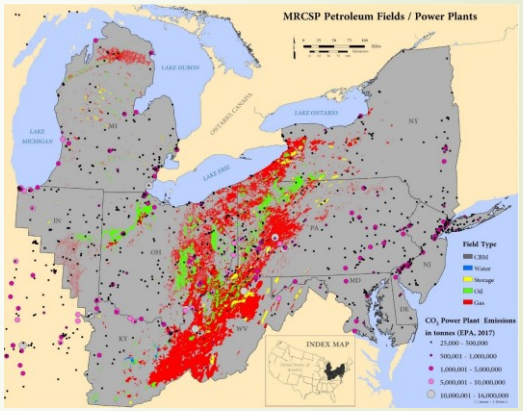
  - West Virginia - Gary Daft, Philip Dinterman, J. Eric Lewis, Jessica Moore
- **Battelle project direction** - Neeraj Gupta, Lydia Cumming, Joel R. Sminchak, Autumn Haagsma
- **U.S. DOE NETL program management** - Andrea McNemar

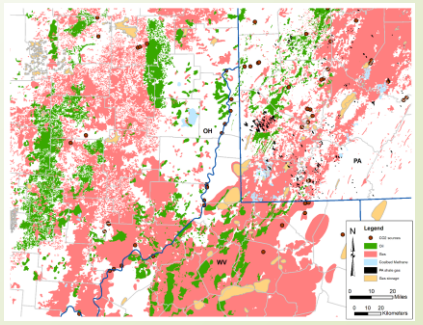
DOE-NETL Cooperative Agreement DE-FC26-05NT42589

Today's Focus

- MRCSP and our scope of work
- Methods
- Results
- Applications for stacked storage







Scope of Work

- *MRCSP Phase III – Regional Geologic Characterization: Collaboration of Geoteam members from the 10-state region*

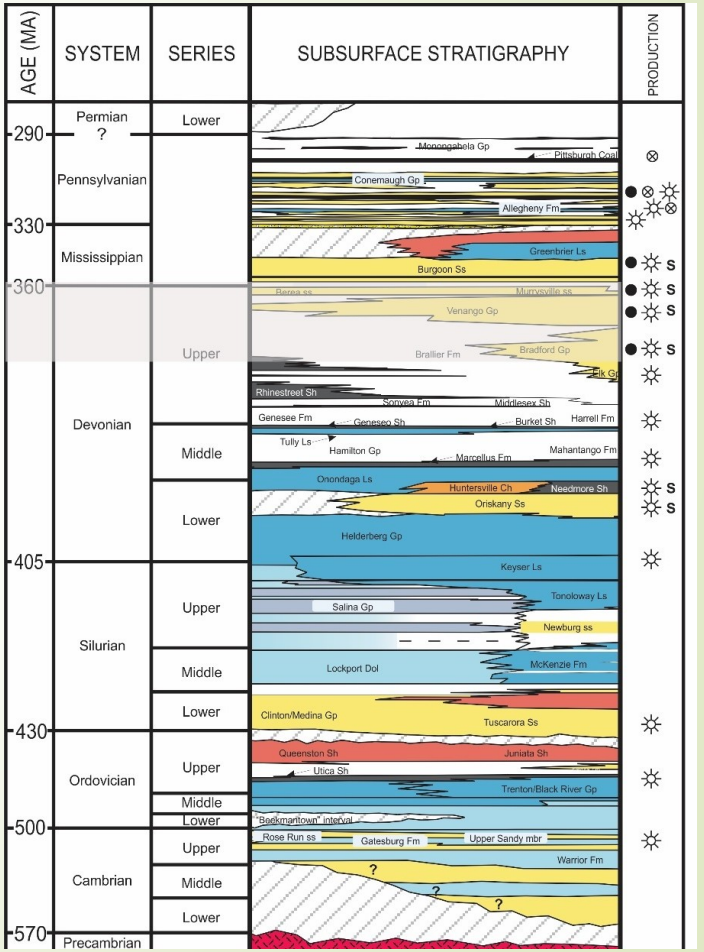
- *Enhanced recovery opportunities in the Appalachian basin: Kentucky, Maryland, New York, Ohio, Pennsylvania and West Virginia*

- *Evaluation of CCUS opportunities: Pennsylvania (lead)*
  - *"…identify new potential CO_2 enhanced oil recovery (EOR) and enhanced gas recovery (EGR) opportunities in the Appalachian basin portion of the partnership, with particular focus on the tri-state area of Ohio, Pennsylvania and West Virginia."*

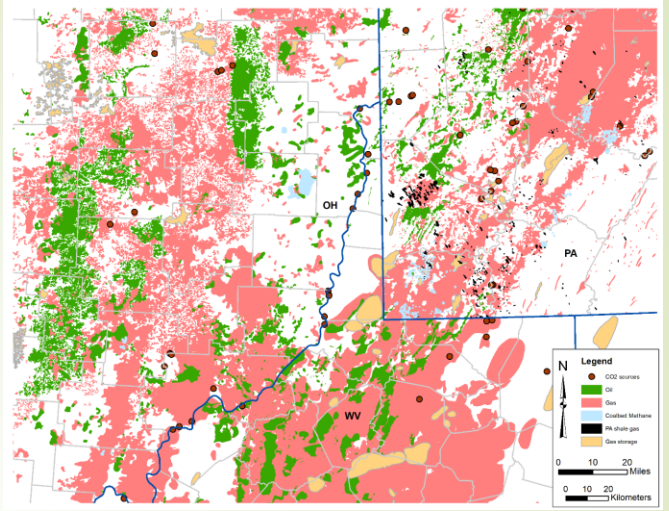
CCUS Opportunities in the Appalachian Basin

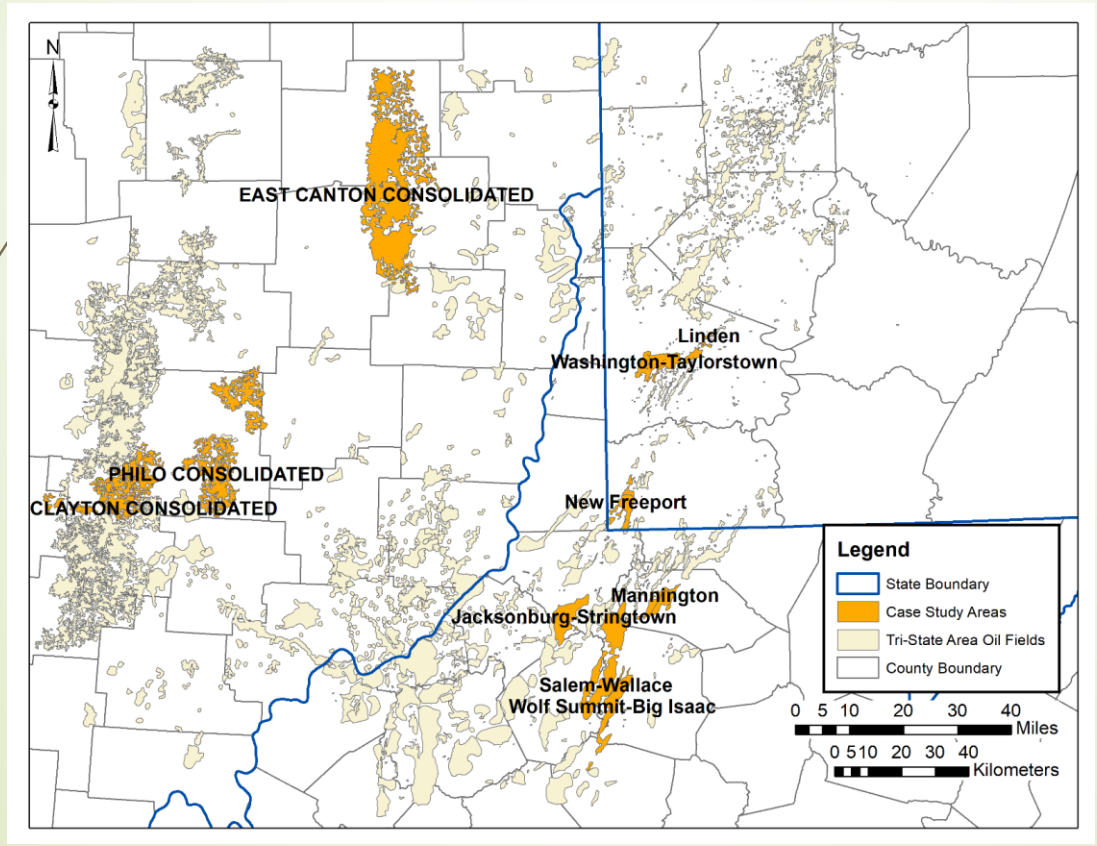
- ***Immiscible opportunities*** include shallow oil and gas reservoirs, as well as abandoned natural gas storage fields
- A majority of ***miscible opportunities*** are comprised of natural gas reservoirs, with a limited number of gas storage fields
- ***Stacked opportunities*** refer to two or more reservoirs layered on top of one another (at least in part) within the same geographic area

Immiscible/ miscible depth range



Our Case Studies

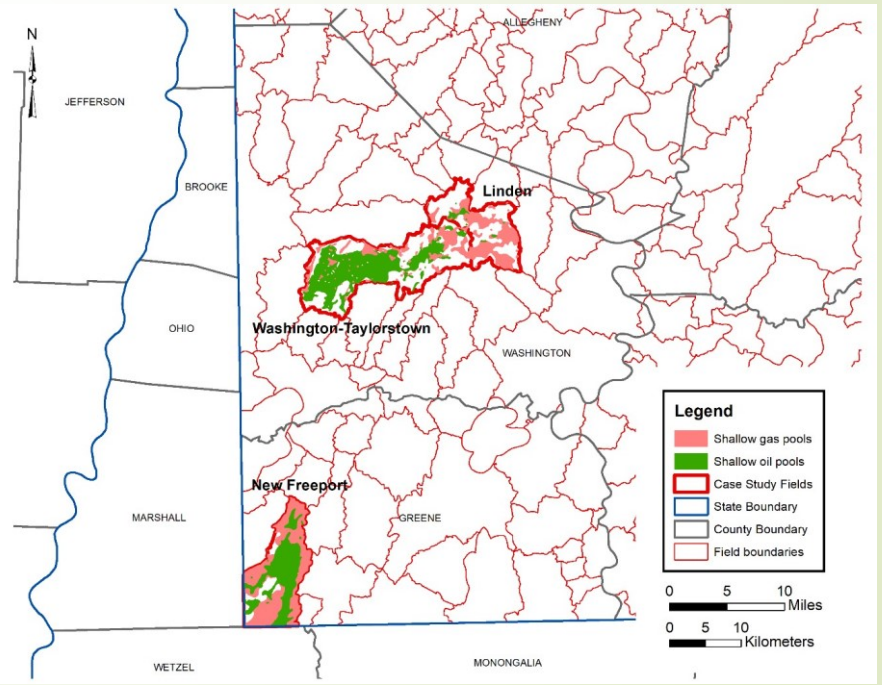


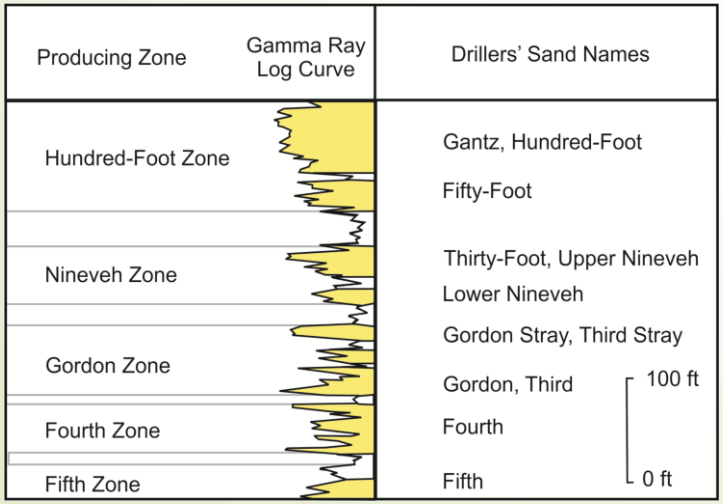


- 10 case studies
- 3 in PA,
  3 in OH and
  4 in WV

Pennsylvania's Case Studies

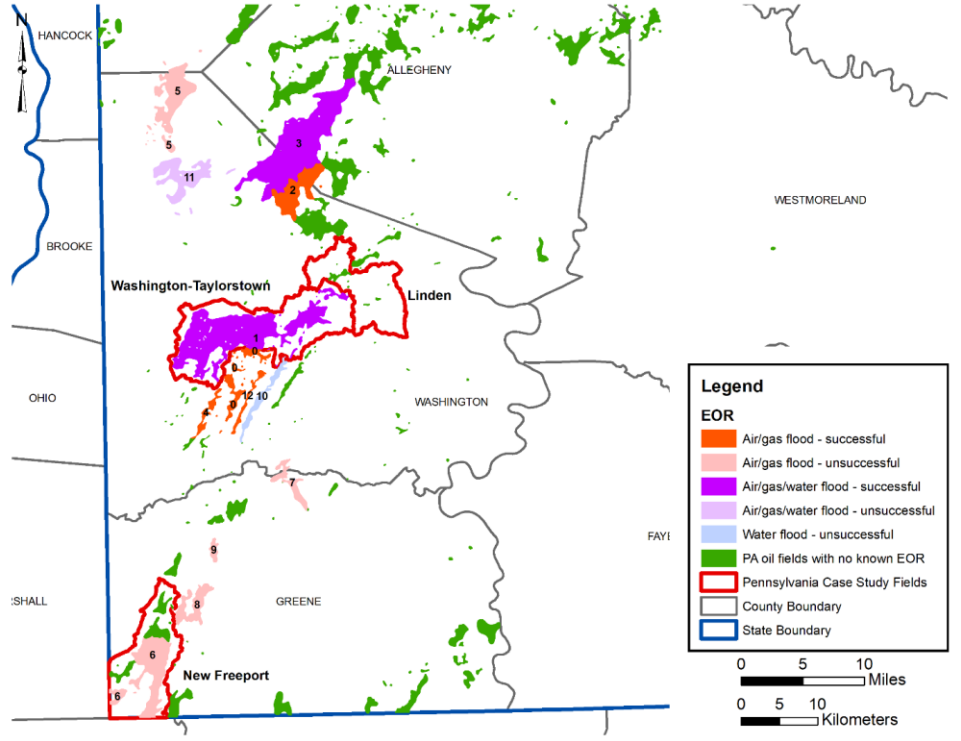
- Washington-Taylorstown Field
- Linden Field
- New Freeport Field





Methods

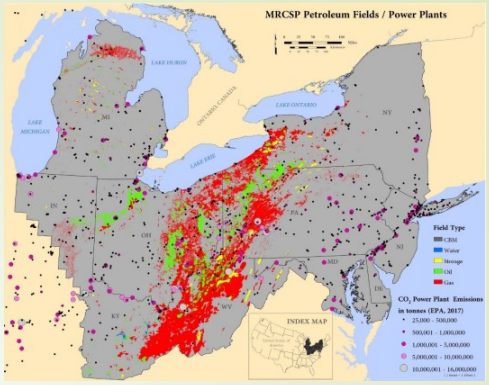
- **Inventory** – Compile information on both historical and modern-day oil and gas resource development in the tri-state area of OH, PA and WV using existing MRCSP data and GIS
- **Analyze** – Interpret subsurface lithostratigraphy and characterize potential storage reservoir attributes
- **Identify** – Determine prospective locations for miscible and/or immiscible EOR/EGR proximal to CO_2 sources by applying rating criteria



from Riley et al. (2010)

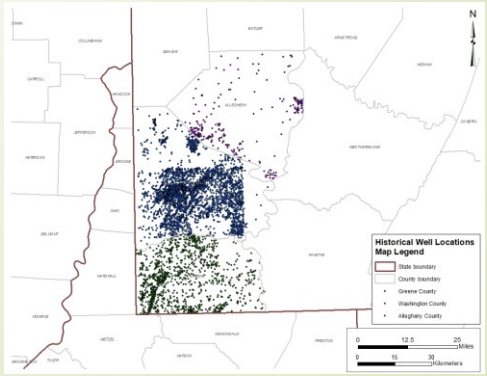
Digital Datasets

- **WVGES – petroleum fields geodatabase**
  - PA's 2015 oil and gas fields and pools geodatabase
  - PA's 2016 TORIS field-level data evaluation
- **Appalachian Storage Hub Study**
  - Complementary digital data and subsurface mapping products
  - Model for assessing hundreds of opportunities with publicly available data in a geospatial context and presenting results in case study format
- **Historical wells** – 7000+ in three PA counties
- **Geophysical logs** – 15,000+ geophysical logs for conventional oil & gas wells in western PA (including those counties in the tri-state study area) have been consumed into EDWIN during the past few years



WVGES, 2019

Carter and Patchen, 2017



PAGS, 2017

Venango Group Reservoir Characteristics, Washington and Greene Counties

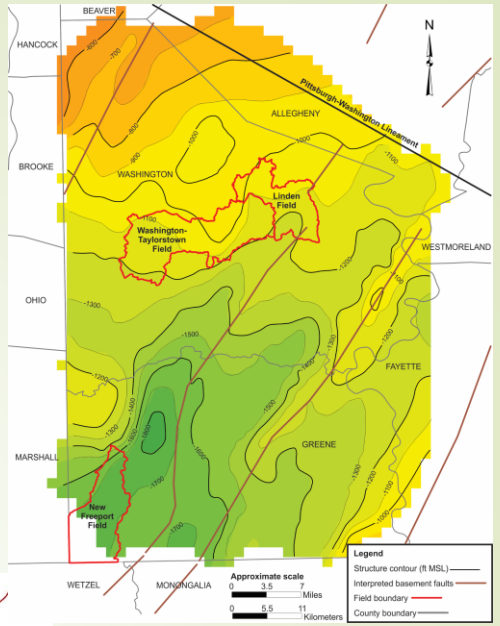
Drillers' Sand Name	Top Formation (ft)			Thickness (ft)		Porosity (%)		
	Min	Max	Avg	Gross	Net	Density	Neutron	Average
Hundred-Foot	1813	3306	2563	81	55	11	6	9
Gantz	1813	3306	2633	18	11	14	6	10
Fifty-Foot	1839	3342	2591	60	48	7	6	7
Nineveh	1968	3395	2708	39	23	12	7	10
Gordon Stray	2018	3451	2745	13	7	9	9	9
Gordon	2050	3482	2792	43	30	11	7	9
Fourth	2116	3555	2896	26	16	8	6	7
Fifth	2175	3611	2979	40	29	11	6	9

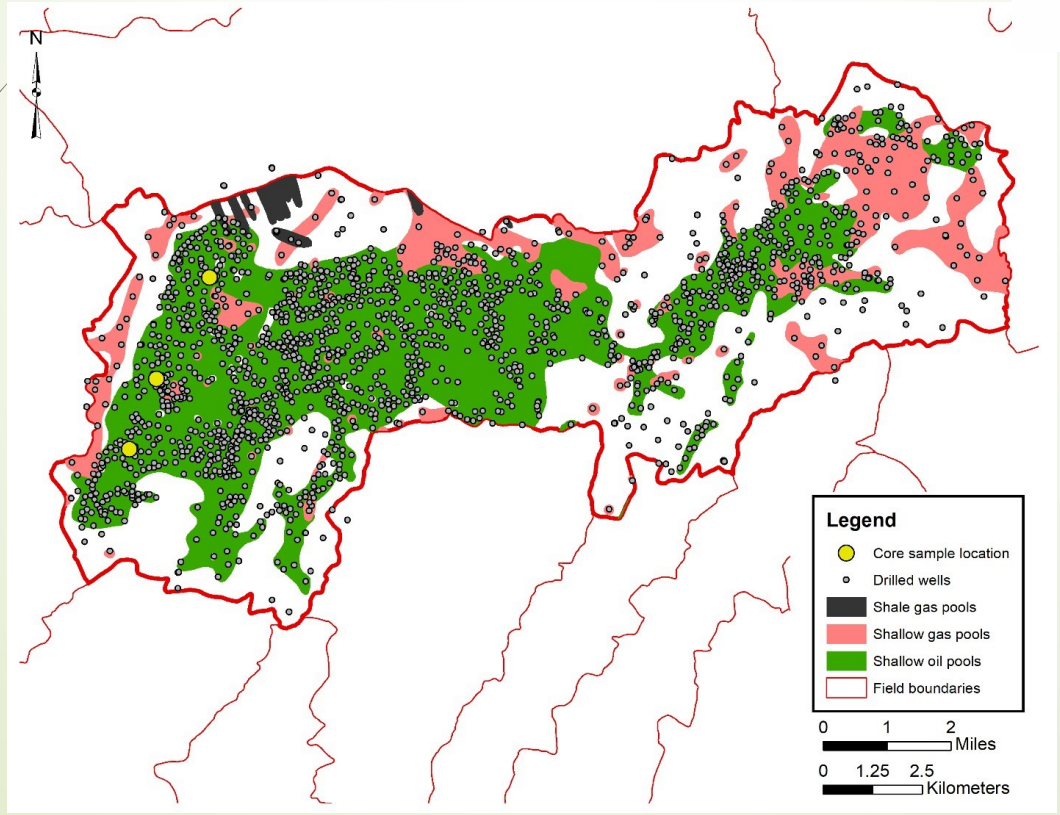
Oil Field Rating Criteria

- Average depth
- Acreage
- Net thickness
- Average porosity
- Permeability
- Trap integrity
- Reported oil saturation
- Reported gas saturation
- Salinity
- Water saturation
- Pressure minus estimated miscibility pressure
- Cumulative oil production
- Remaining oil
- Potential oil recovery
- Number of producing wells (reservoir-specific) per acre
- Mode CO_2 storage (computed)
- Legacy well penetrations
- Stacked opportunity?

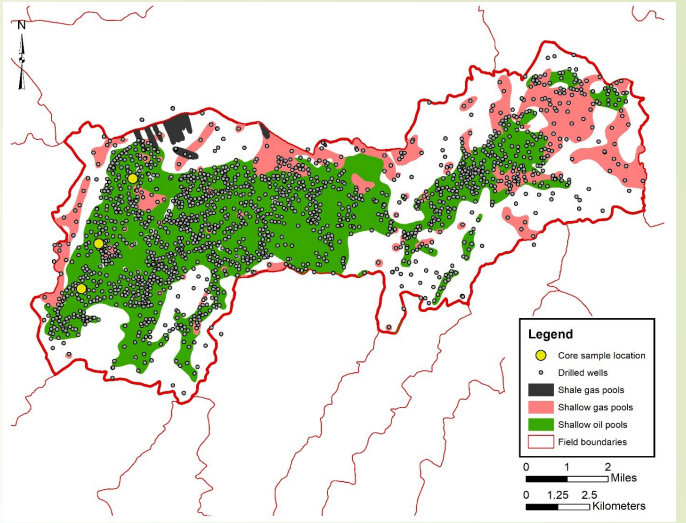
Reservoir-specific data
Production-related data
Logistical information

Washington-Taylorstown Field

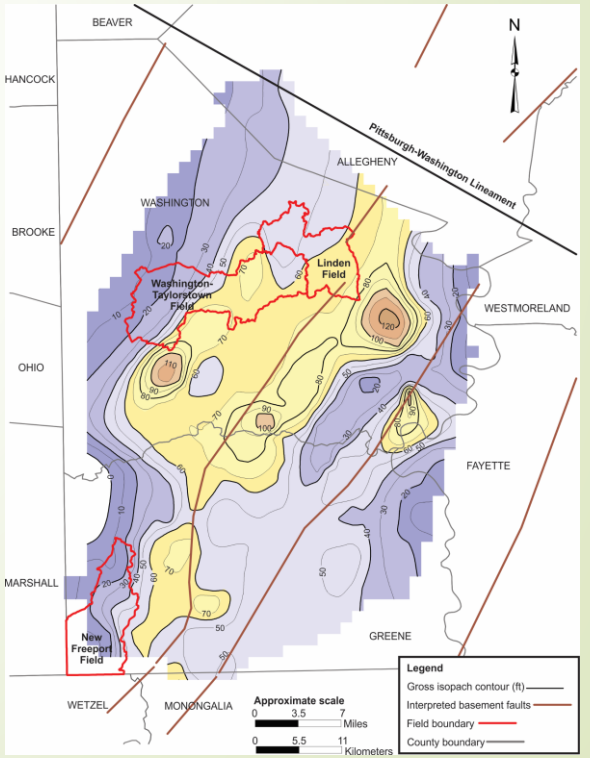




Washington-Taylorstown Field

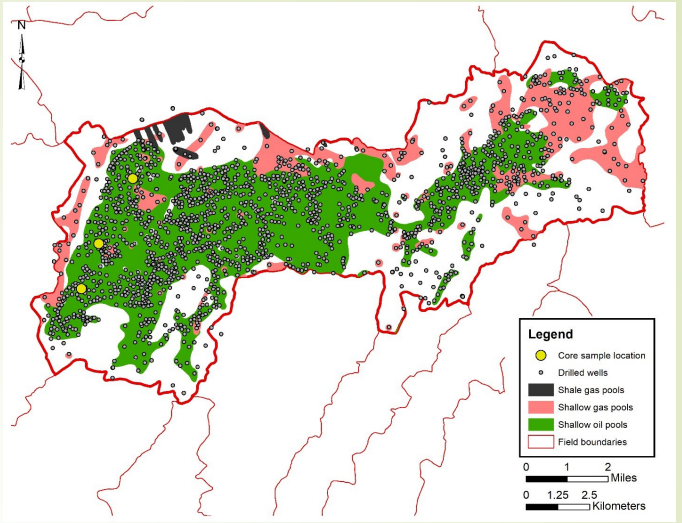


- Straddles the City of Washington, with western and eastern limbs in more suburban to rural areas
- Production from multiple sandstone units, but mainly the 50-ft and Gordon (west) and Gantz, 50-ft and Gordon (east)
- Oil production on western limb, oil and gas production on eastern limb
- Core data and EOR activities (western limb)



Gordon sandstone isopach

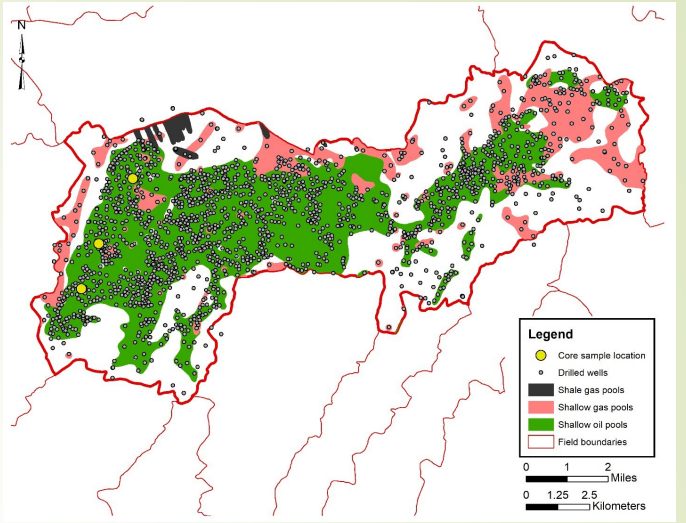
Washington-Taylorstown Field

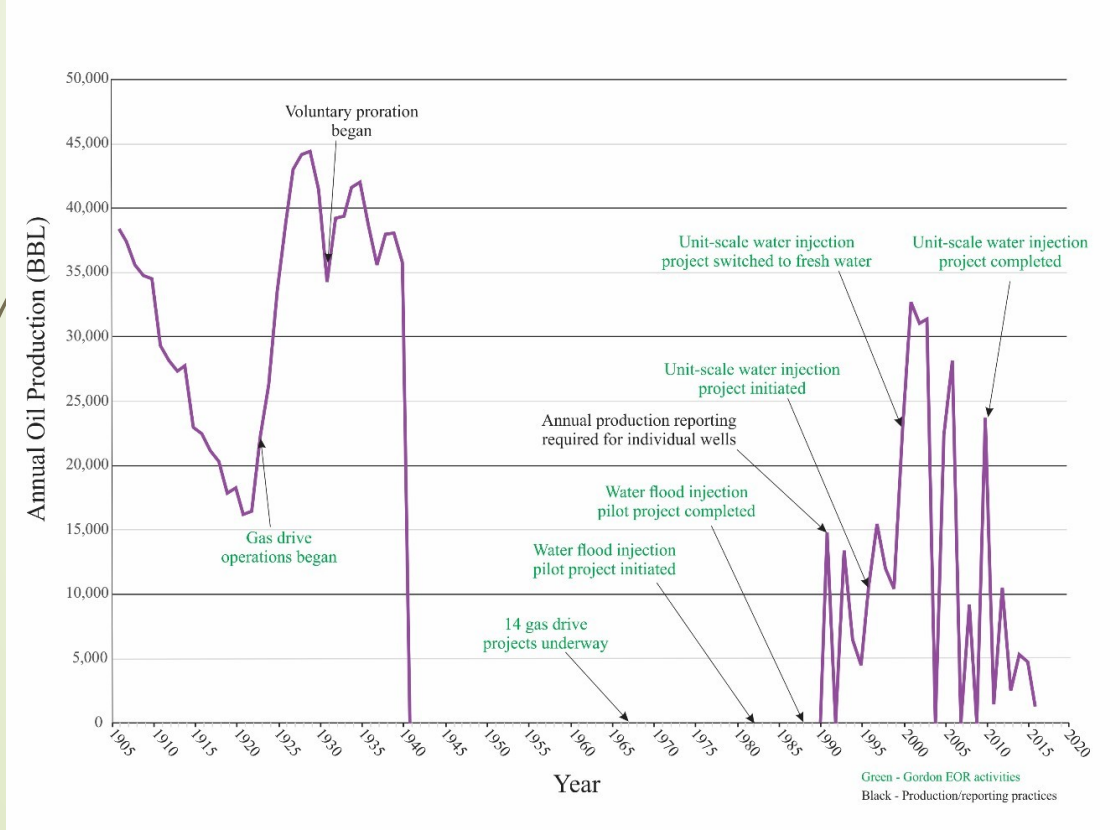


- Core-derived porosity and permeability from western limb of the field
- James McMannis No. 9 (API#3712501189)

Sample		Permeability (mD)	Porosity (%)
Gordon Stray	Minimum	0.23	1.21
	Maximum	0.68	12.63
	Average	0.45	7.97
Gordon	Minimum	0.16	13.19
	Maximum	284.54	28.29
	Average	106.37	20.47

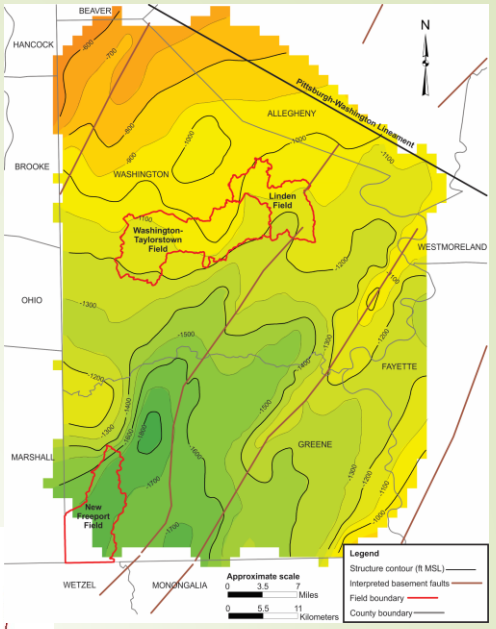
Washington-Taylorstown Field

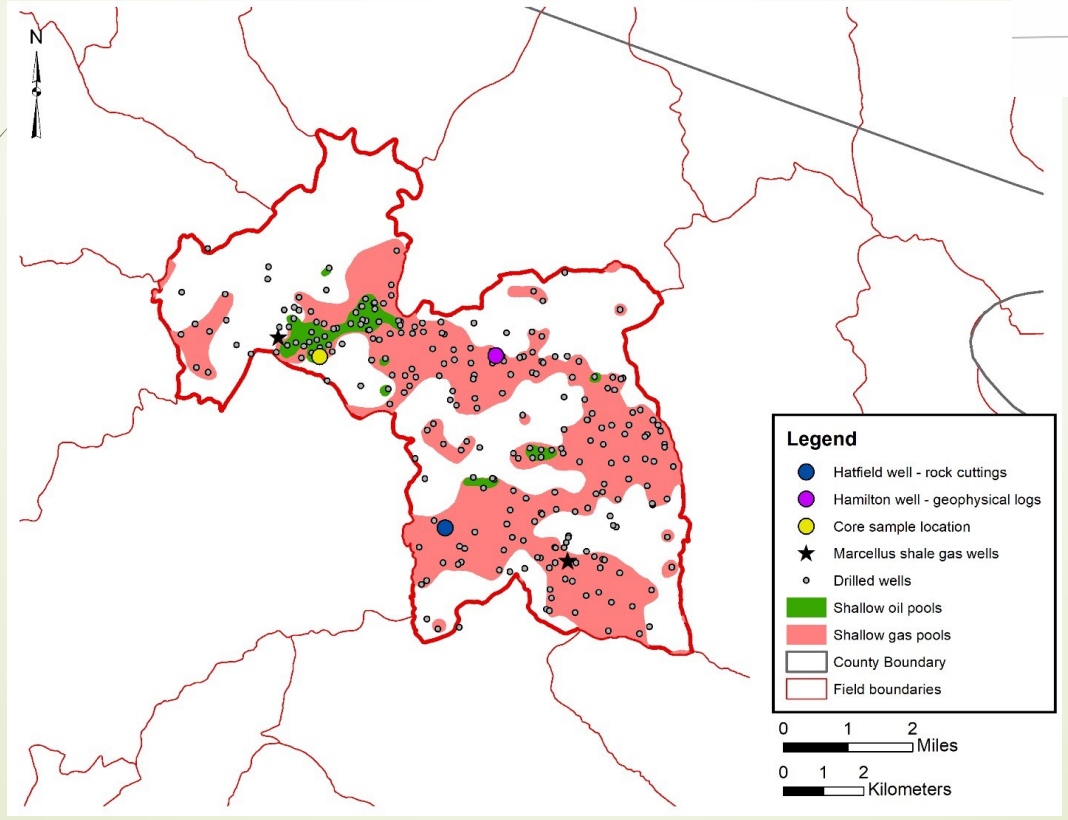




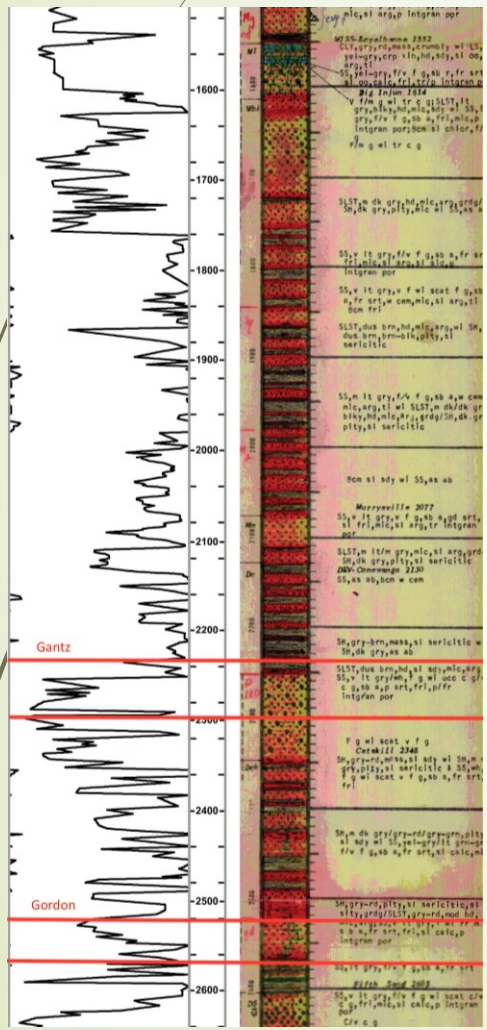
- Primary production: 1885-1923
- Secondary (gas drive) effort: 1923~1970
- Water injection pilot project: 1982-1989
- Water injection (full scale): 1996~2010

Linden Field

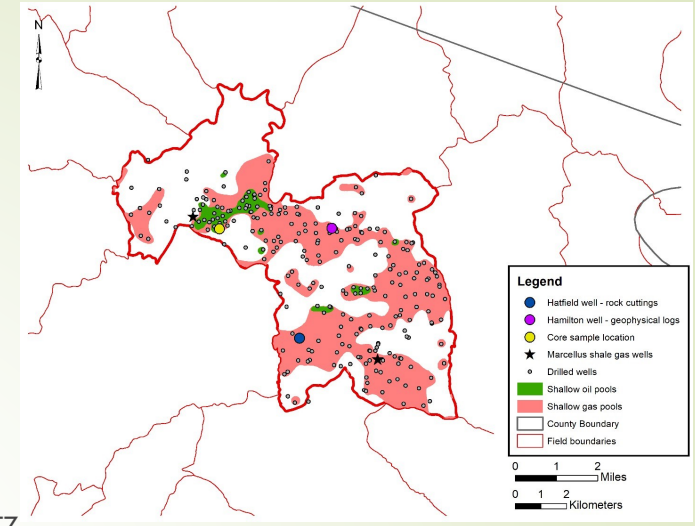


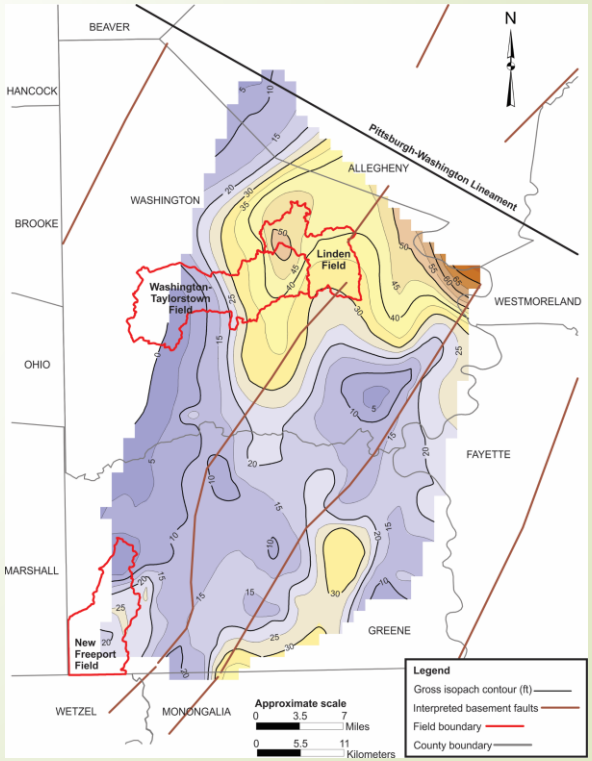


Linden Field



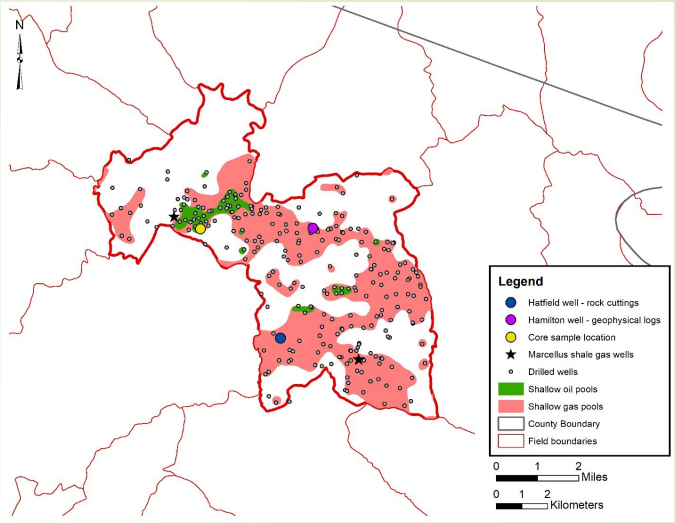
- Just east of Washington-Taylorstown Field, with limited oil development in the first half of the 20th century
- Produced from the Gantz and Gordon sandstones (Venango Group)
- Log donation yielded bulk density log, sample description to accompany existing EDWIN data (Hamilton logs – API#3712520107)
- Core data available (Kenamond No. 1 – API#3712592783)
- Rock cutting samples analyzed for bulk mineralogy (XRD) and pore space characterization (SEM) (Hatfield cuttings – API#3712590083)

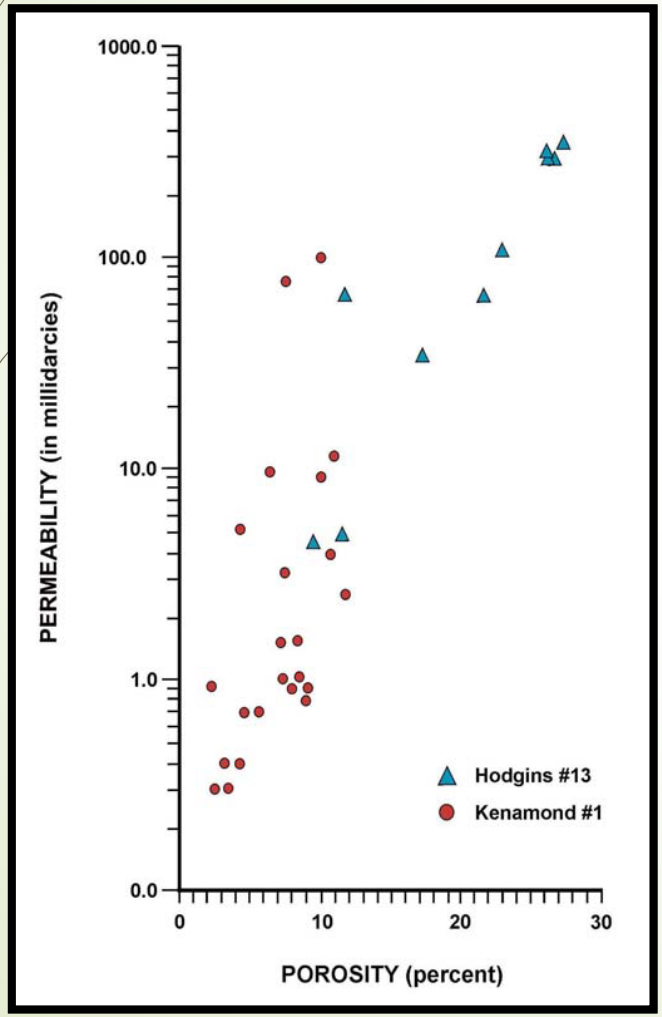




Gantz sandstone isopach

Linden Field

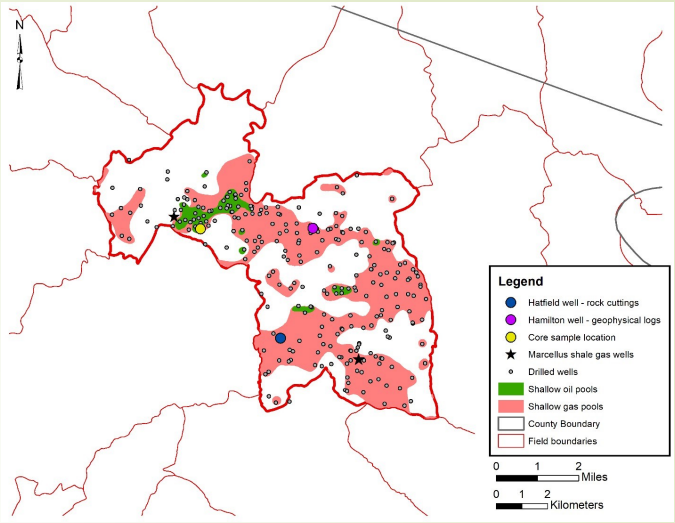


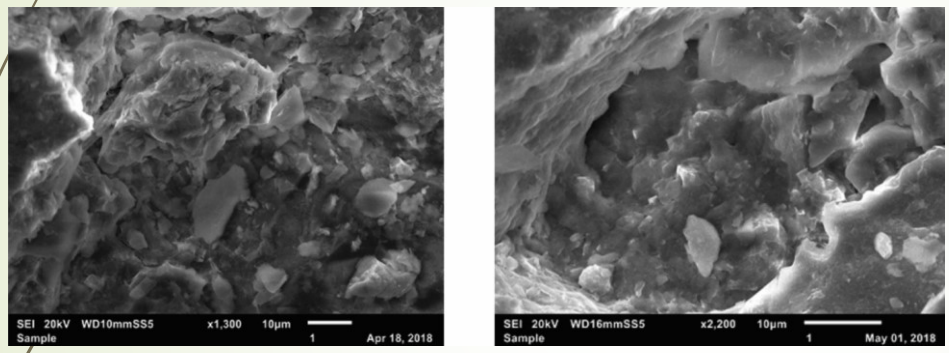


from Harper and Laughrey (1987)

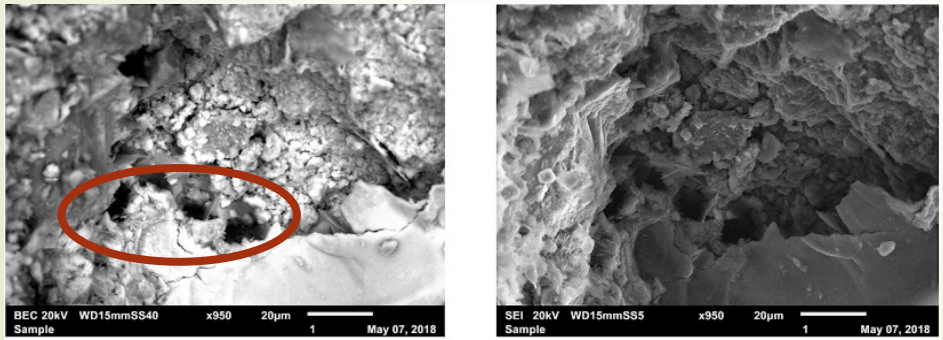
- Kenamond No.1 (API#3712592783) core: ϕ increases with K; neither correlate with grain size
- Dissolution of carbonate (and to lesser extent, feldspar and chert) is responsible for the rock's secondary porosity
- Effective porosity is result of reduced primary pore space and secondary porosity due to mineral dissolution

Linden Field





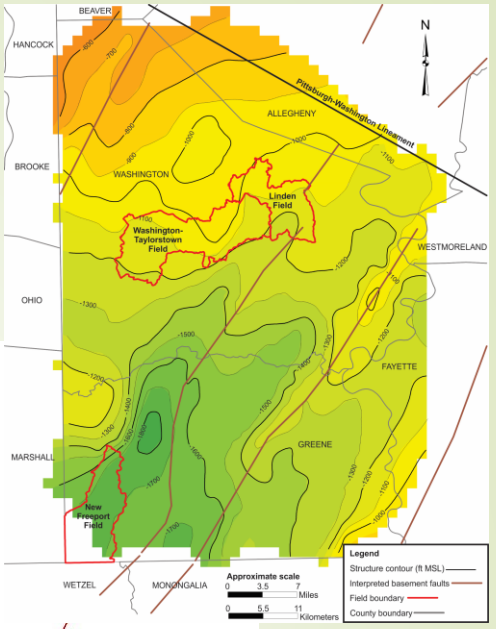
Platy clay minerals in the Gantz (left) and Gordon (right) sandstones

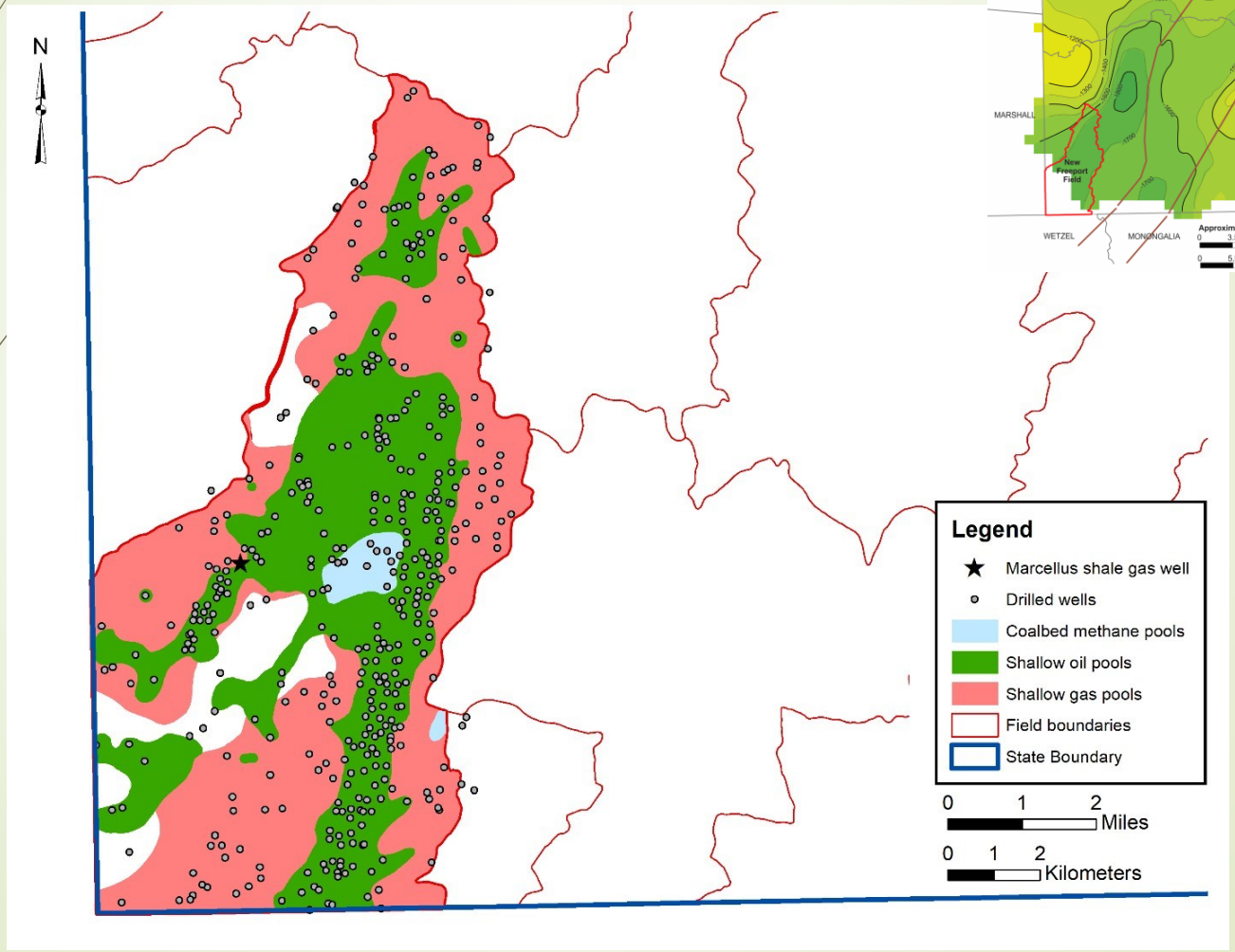


Gordon sandstone porosity (backscatter electron composition, left; secondary electron imaging, right)

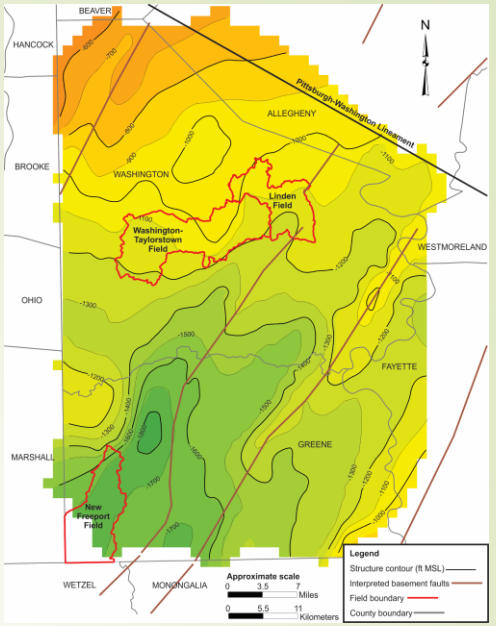
- Harry Hatfield No. 1 (API#3712590083) rock cuttings
- Platy clay minerals and quartz cementation reduce primary porosity

New Freeport Field





New Freeport Field

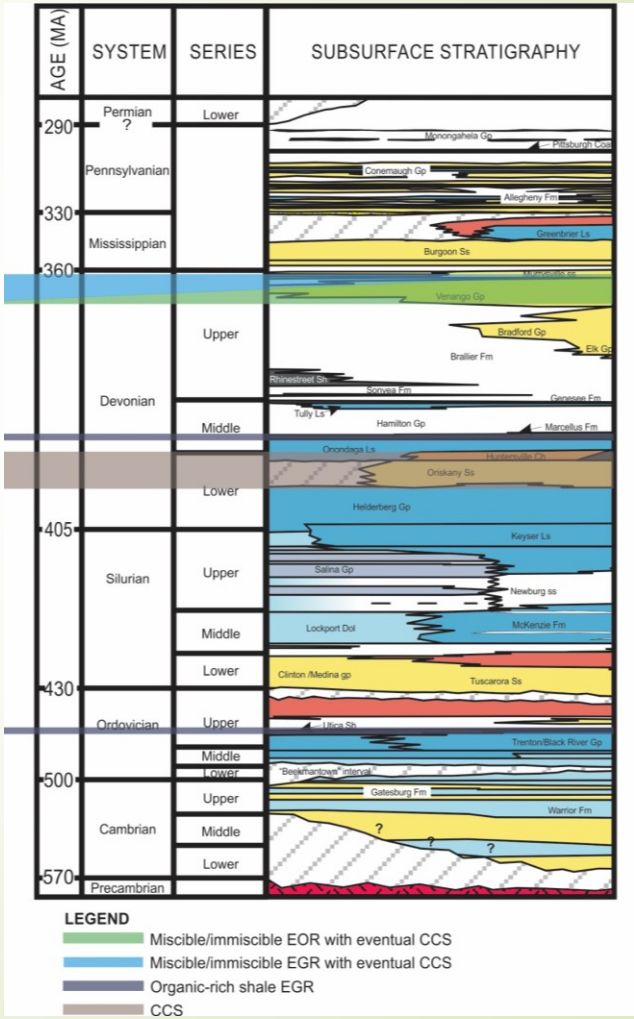


- Not as much data (relied solely on geophysical logs)
- Situated in the Gordon fairway, but Nineveh sandstone is also a great local reservoir here
- Miscible depths anticipated for CCUS applications

Drillers' Sand Name	Top Formation (ft)			Thickness (ft)		Porosity (%)		
	Min	Max	Avg	Gross	Net	Density	Neutron	Average
Nineveh	2833	3395	3153	57	**43**	18	6	**12**
Gordon	2892	3476	3209	44	**51**	10	3	**7**
Fourth	2950	3553	3278	15	11	8	5	7

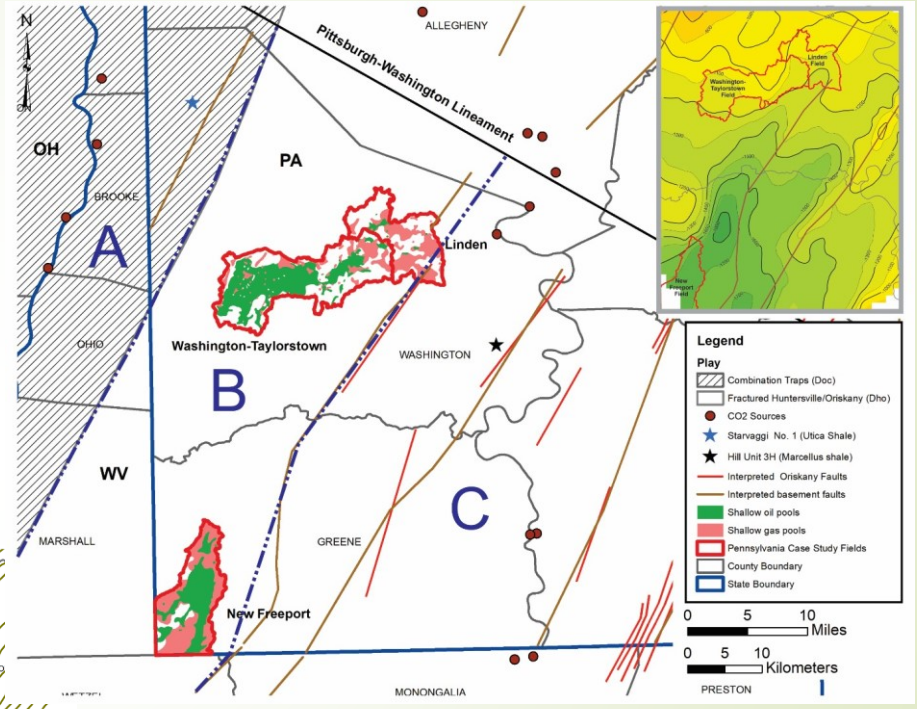
Stacked Storage Potential in Southwestern PA

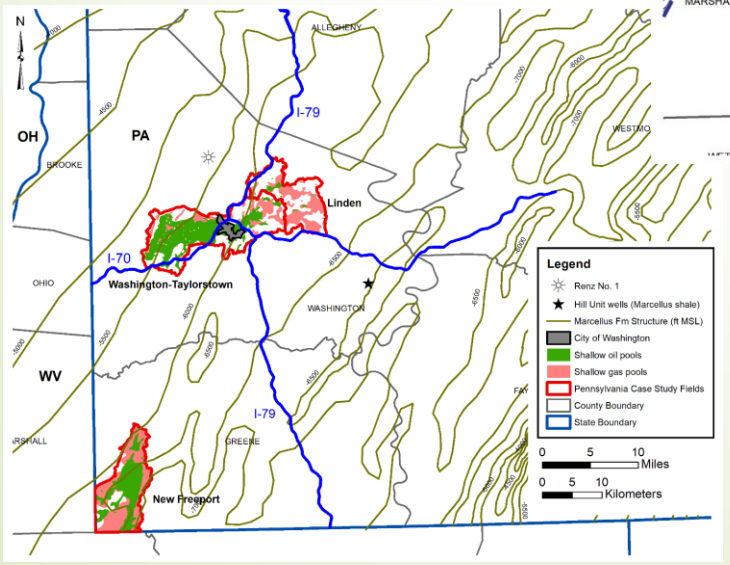
- Miscible and immiscible **CO_2-EOR/CO_2-EGR** for Upper Devonian Venango Group reservoirs
- Permanent **carbon storage** in Lower Devonian Oriskany Sandstone (combination traps and fractured Huntersville Chert/ Oriskany Sandstone plays)
- Possible **future CO_2-EGR** opportunities in the Middle Devonian Marcellus and Upper Ordovician Utica shales



A Birdseye View…

- Upper Devonian enhanced recovery with eventual CCS
- Lower Devonian CCS
- Organic-rich shale EGR with eventual CCS





Marcellus structure contour map

Summary

- **Pennsylvania case studies** highlight the type, amount and utility of the digital data inventories prepared by MRCSP Geoteam members during our Phase III project period.
- **Data transforms** have been developed to make the most of publicly available data by evaluating relationships among data that we have to inform and close data gaps.
- Combining field-level data with **carbon storage resource estimation methods** developed/refined by MRCSP Geoteam members will provide end users with a sense of scale for various injection targets.
- We intend to carry this work forward by **collaborating** with industry to find mutually beneficial ways to utilize and store CO_2, thereby fostering responsible management of subsurface geologic formations.

Thank you!

Kristin Carter, P.G., C.P.G.

Primary Investigator
Pennsylvania Geological Survey
krcarter@pa.gov
412-442-4234