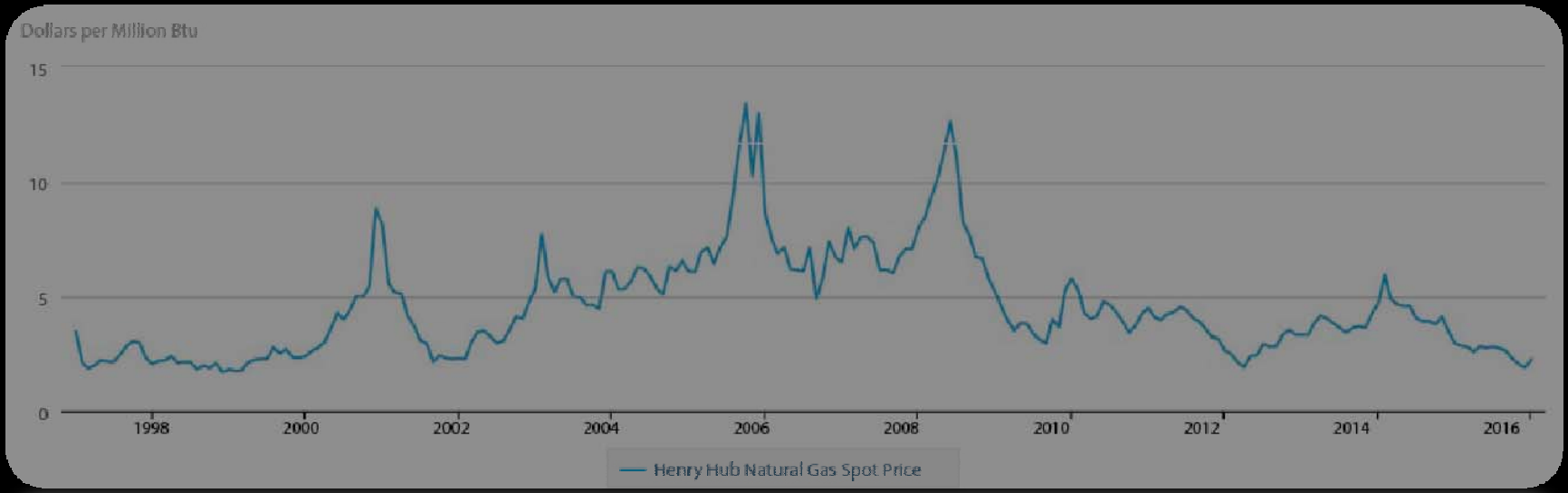
What's Trending in Oil and Gas @ WVGES

GEOLOGY UNDERLIES IT ALL

Jessica Moore

Appalachian Geological Society March 2016 Meeting



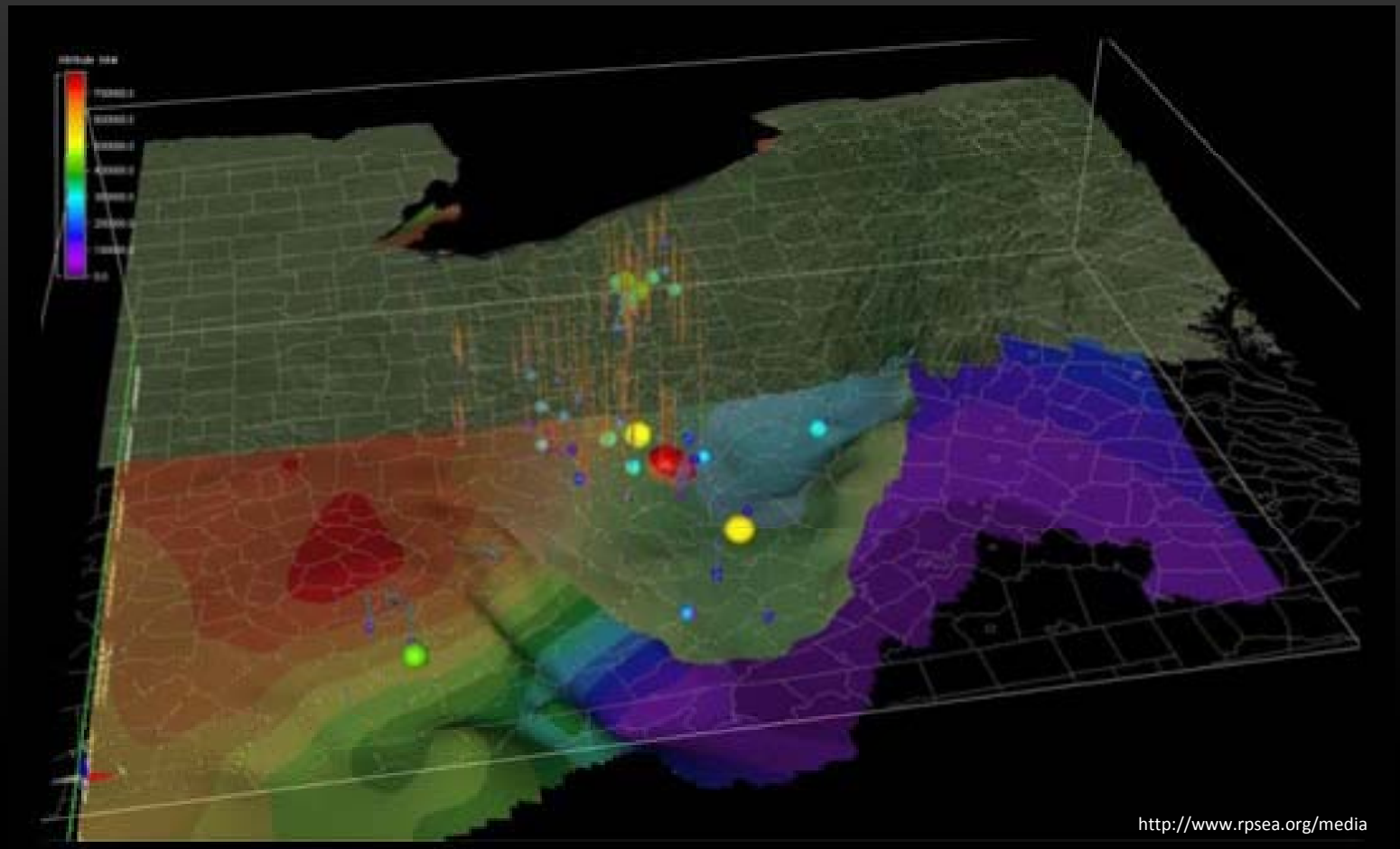
Current or Recently-Concluded Projects

- Subsurface Brine Disposal Framework
- Midwest Regional Carbon Sequestration
- Wellbore Integrity

US Dept. of Energy / Battelle Memorial Laboratory

- Ethane Storage Hub *(Benedum Foundation)*
- Low-Temp Geothermal
- Data Preservation *(USGS)*

RPSEA Brine Disposal



Develops a geologic and operational framework for brine disposal in the Northern Appalachian basin

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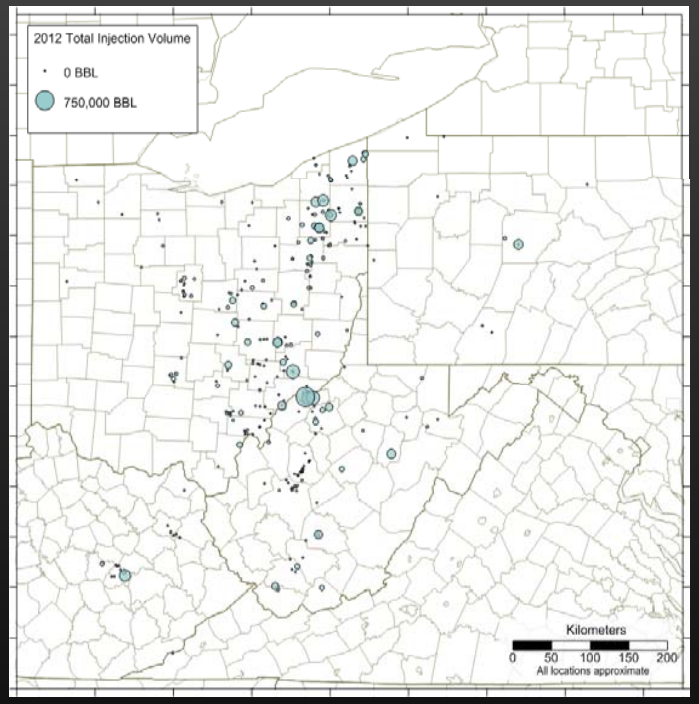

RPSEA Brine Disposal

Class II UIC brine disposal wells with active permits (as of August 2013) classified by deepest injection formation.

Deepest Injection Formation	KY	OH	PA	WV	Total
Pennsylvanian-Mississippian (Big Injun, Weir, Maxton, etc.)	12	2		46	60
Upper Devonian (Berea, Dev. Shale, Bradford)	1	26	2	18	47
Middle Devonian (Onondaga, Huntersville)		4		5	9
Lower Devonian (Oriskany-Helderberg-Huntersville, Bass Is.)		9	3	4	16
Upper Silurian (Lockport, Newburg, Corniferous)	9	60		2	71
Lower Silurian Clinton-Medina		48	2	1	51
Undifferentiated Knox	5	6			11
Rose Run	1	7			8
Copper Ridge, Trempealeau		21			21
Mount Simon, Basal sandstone		28			28
N/A	2				2
Total	30	211	7	76	324

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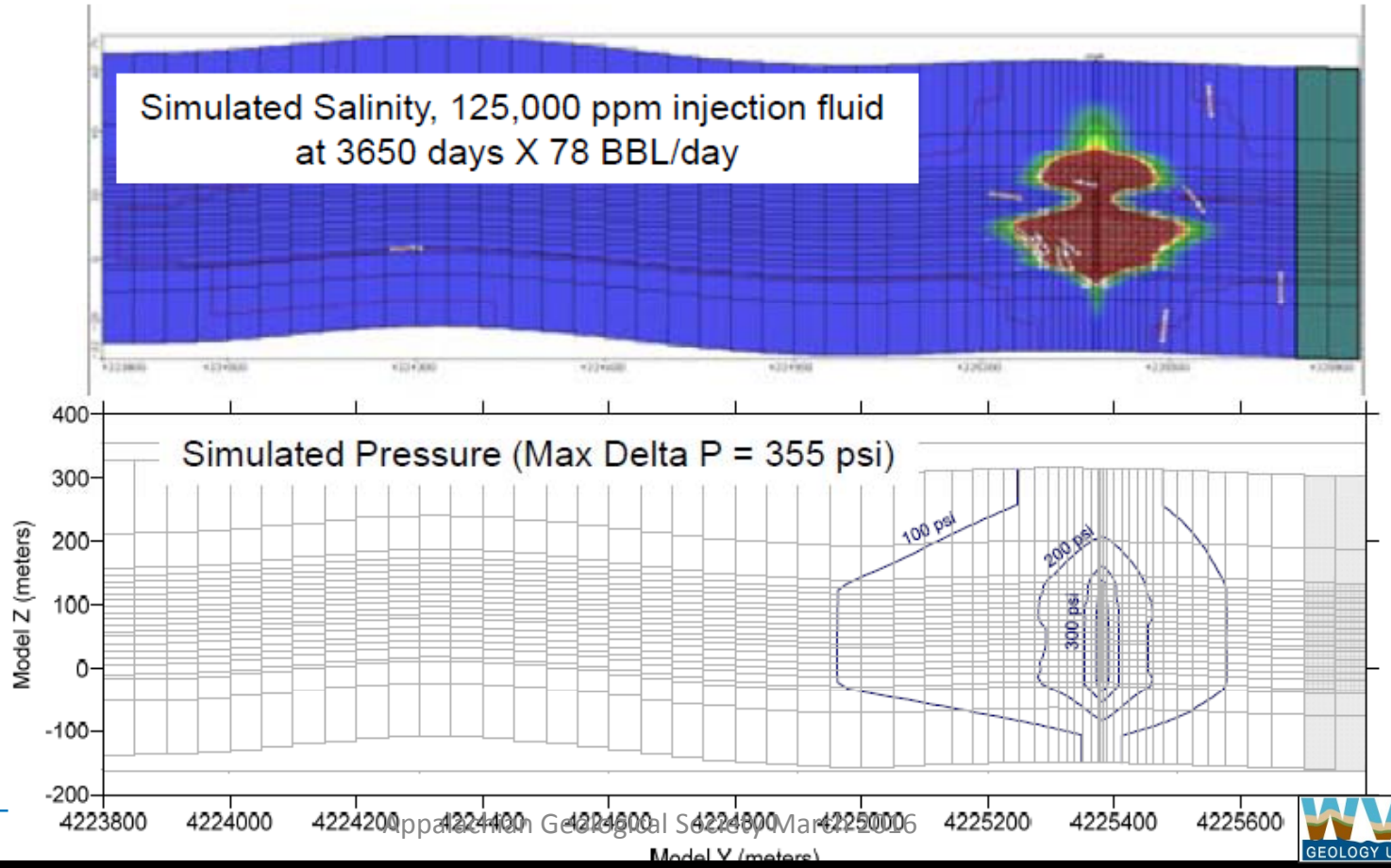
Weir Sandstone

-Model based on Weir injection well in W. Appalachian basin

-78 BBL/day injection rate 10 yrs

-Anticline structure with sealing fault



VE = 10x

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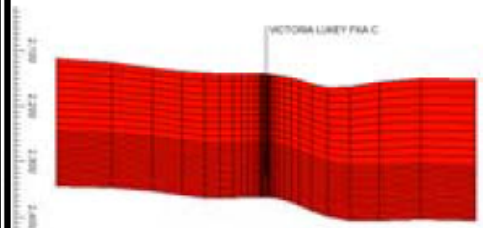
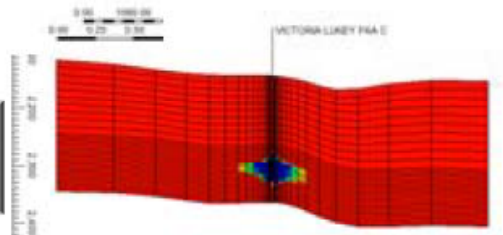
Lockport Dolomite "Newburg"

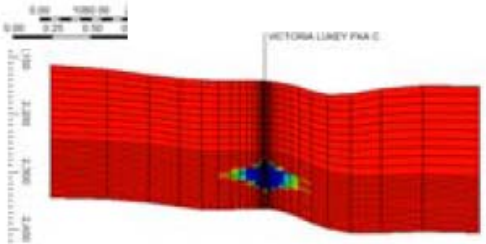


At time = 0 yrs



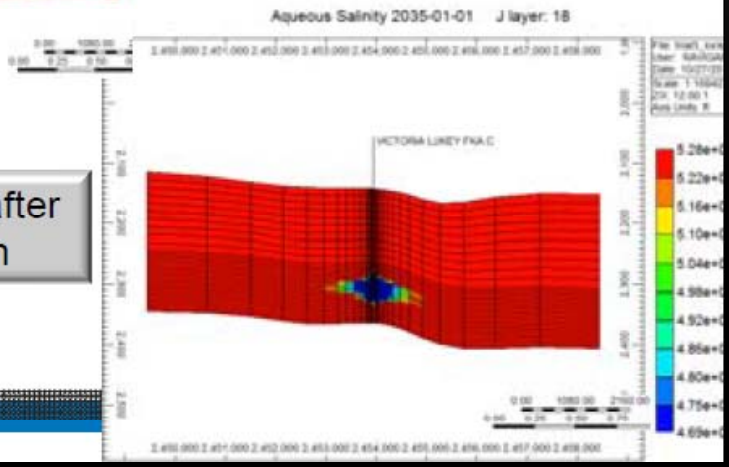
At time = 5 yrs of injection

- 10 years injection @ 300 bbl/day.
- Formation salinity 278,000 ppm, injection 200,000 ppm.



At time = 10 yrs of injection

- Simulated salinity profile through time.
- 10 years injection, 15 yrs post-injection.



At time = 25 yrs after end of injection

http://www.pioga.org/wp-content/uploads/2015/08/Gupta-Analysis-of-Brine-in-Appalachian-Basin.pdf

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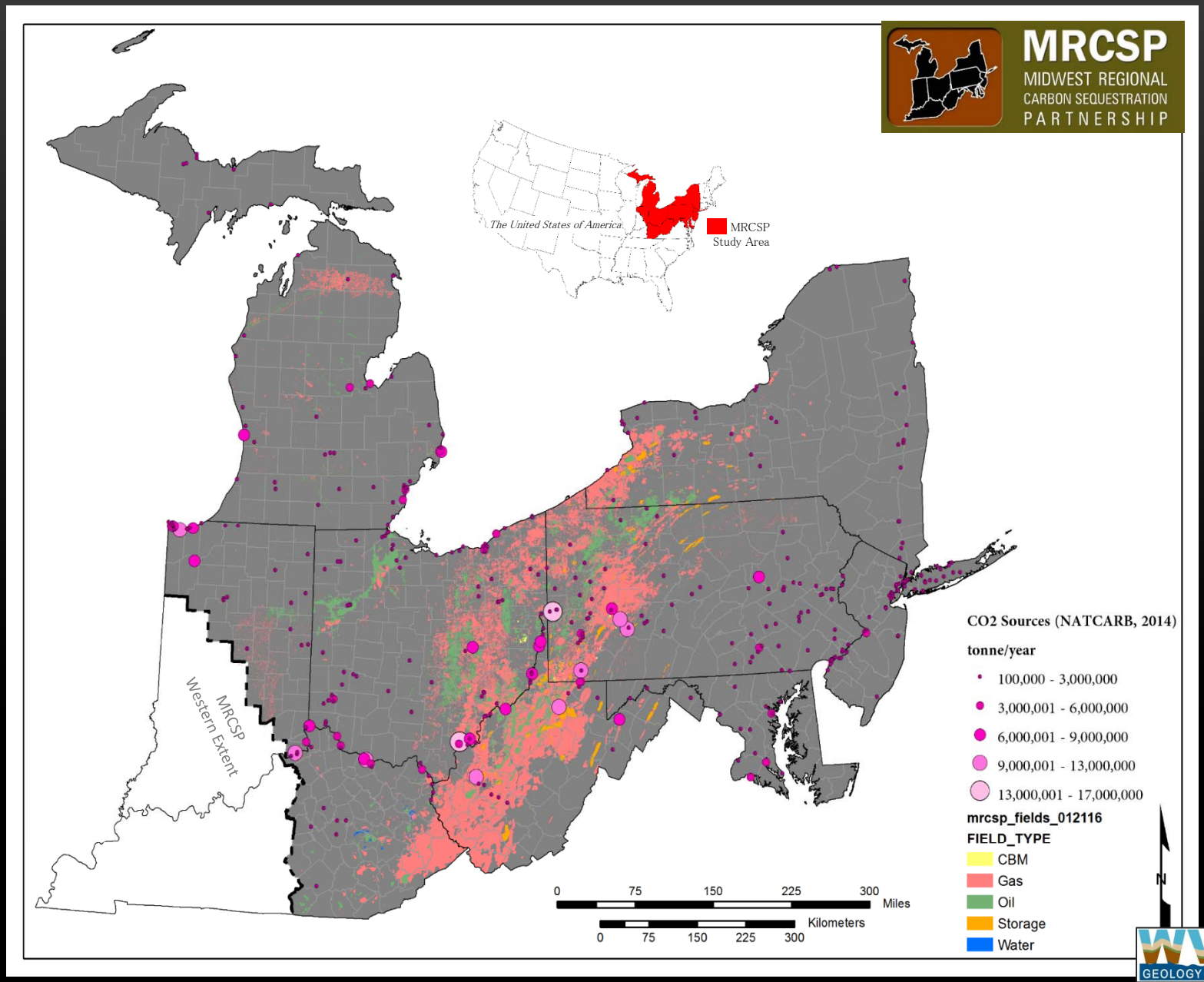
RPSEA Brine Disposal: Conclusions

- N. Appalachian Basin has 2.8 billion bbl brine disposal capacity in existing depleted oil & gas fields (i.e. fields w/ existing Class II wells).
  - ~150 years of disposal, if annual injection rate = ~17.6 million barrels
- Deep saline disposal capacity is estimated at 480 billion barrels
- Approximately 10 bbl brine were disposed per million cubic feet of gas produced
- Injection simulations suggests relatively small zone of influence adjacent to wells
- To download final report, visit: http://www.rpsea.org/files/4828/

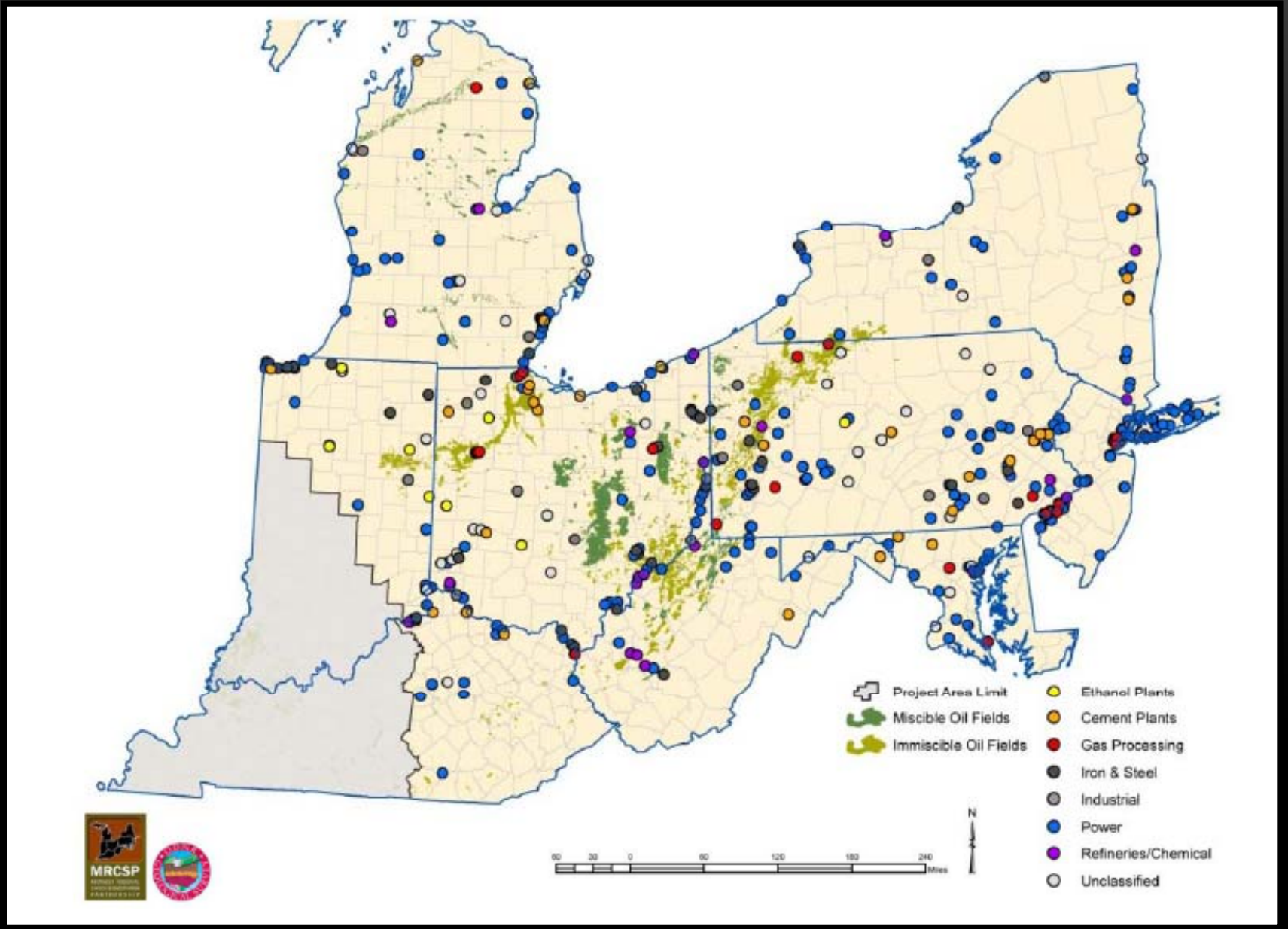
Midwest Regional Carbon Sequestration Partnership (CO_2 EOR)



Midwest Regional Carbon Sequestration Partnership (MRCSP)

- Long-running, US DOE-sponsored research program
- Recently expanded to include coastal plain states (MD, DE, NJ) and enhanced recovery efforts = comprehensive regional characterization of CCUS efforts & opportunities
- WVGES = ranking of oil fields suitable for CO_2-EOR; assisting KGS with ranking of shales for CO_2-EGR potential

Point Source Types and Miscible/Immiscible Oil Fields



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Calculations

1.Storage Capacity = A*h*n*(1-Sw)*p/2200*Ef

where A = field area (ft^2), h = field thickness (ft), n = field porosity, Sw = connate water saturation, p = CO2 density (lb/ft^3), 2200 = conversion factor, Ef = storage efficiency factor

		EOR Efficiency Factor		
Region	States	Min	Mode	Max
Appalachian Basin	OH, E. KY, PA, WV, NY	0.177	0.294	0.539
Michigan/Illinois Basin	MI, IN, W. KY	0.372	0.557	0.680

Ef Min = fraction of OOIP prod during primary & secondary recovery
Ef Mode = fraction of OOIP prod during primary & secondary recovery + "state of the art" CO2 EOR
Ef Max = fraction of OOIP prod during primary & secondary recovery + "next-gen" CO2 EOR

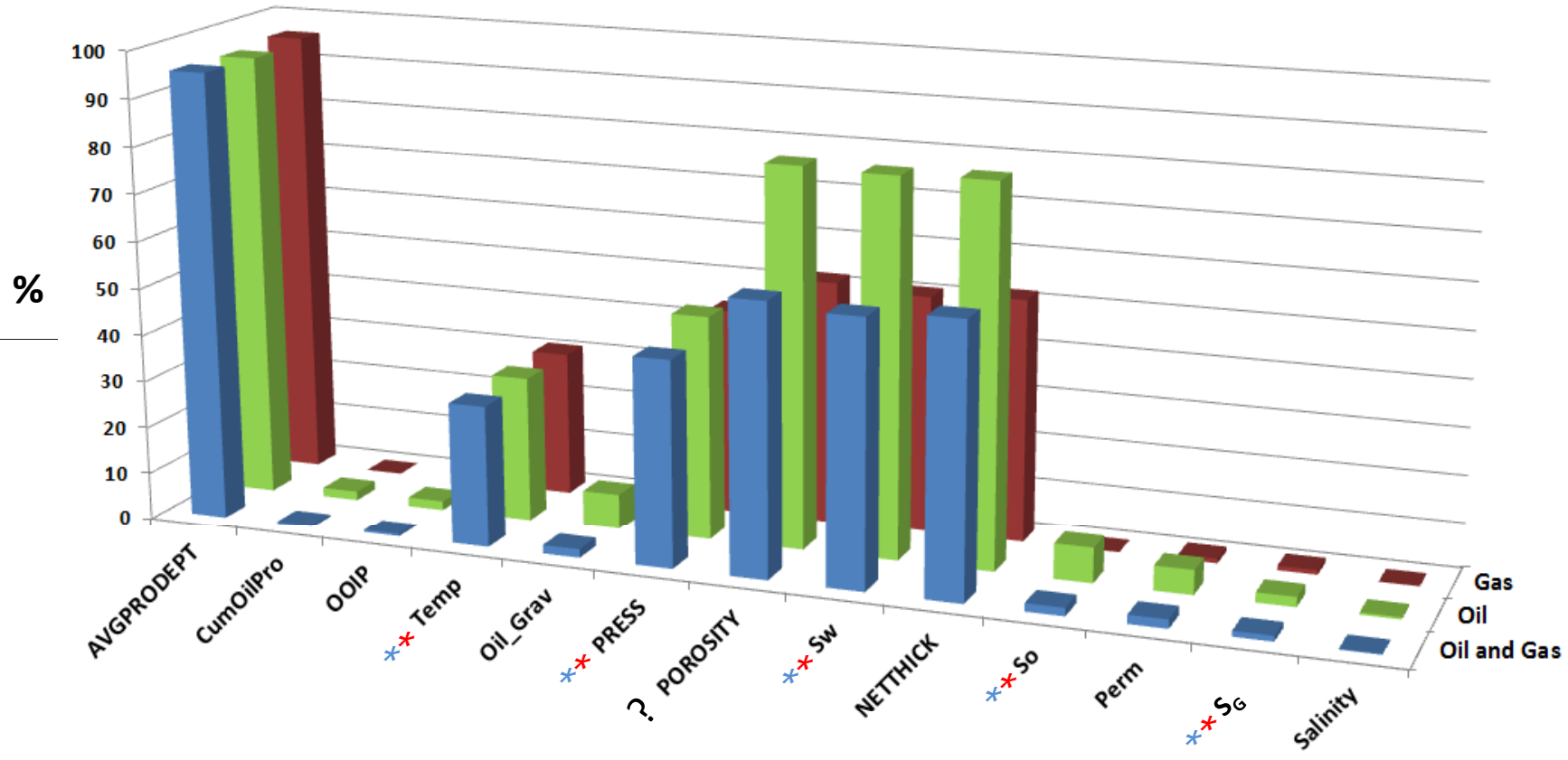
2. Minimum Miscibility Pressure (MMP) = 15.988*Temperature $^{(0.744206 + 0.0011038 * MW\ C5+)}$

where MW C5+ = 4247.98641 * API $^{(-0.87022)}$. MW C5+ is the molecular weight of hydrocarbons containing at least 5 carbon atoms in a single chain (pentane, hexane, etc.), and API is the API gravity of the oil

	A	B	C	D	E	F	G	H	I
1	test_ID	Oil_Grav	Temp_calc	API^-.87022	MWC5+	.0011038*MWC5+	.744206+.0011038*MWC5+	Temp^	MMP
2	20371	55.7000	82.7780	0.0302497571249666	128.5005572	0.141838915	0.886044915	50.0447783900346	800.1159169

If Pi – MMP is a positive value, should be able to reach pressures high enough to attain miscibility

Fields Data Attributes



*COLLECTED **
*CALCULATED **

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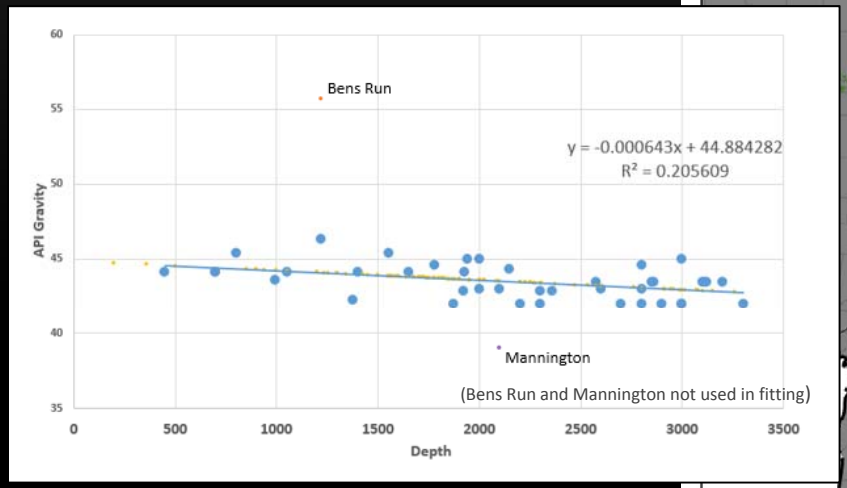
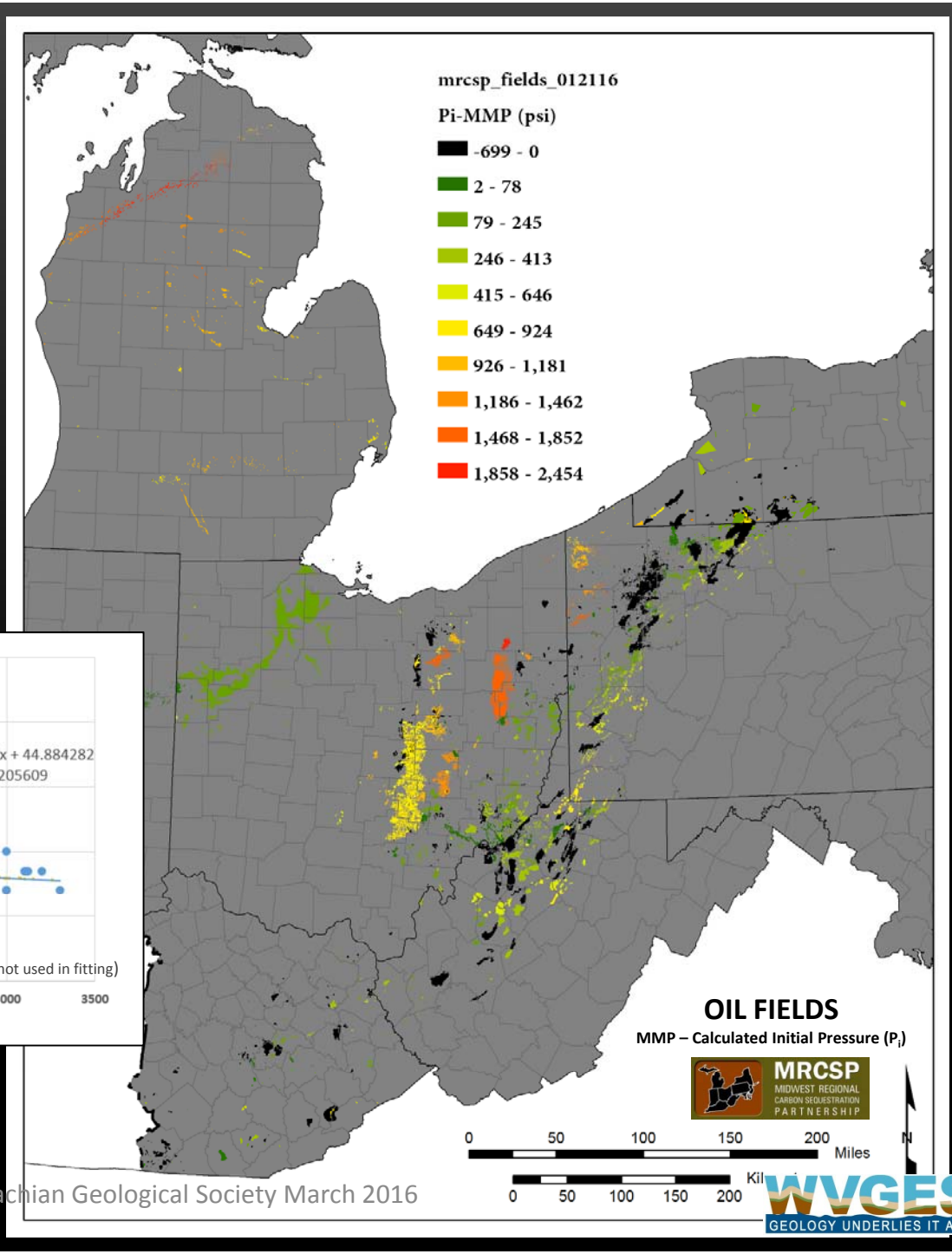
If Pi-MMP is a positive value, flood should attain miscibility
but…
cannot calculate MMP without API Oil Gravity





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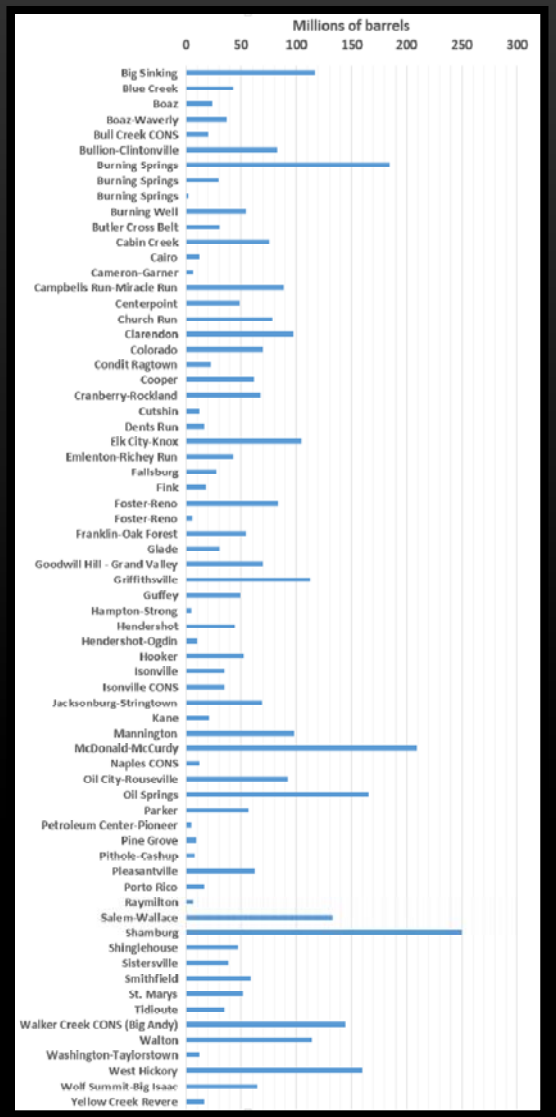
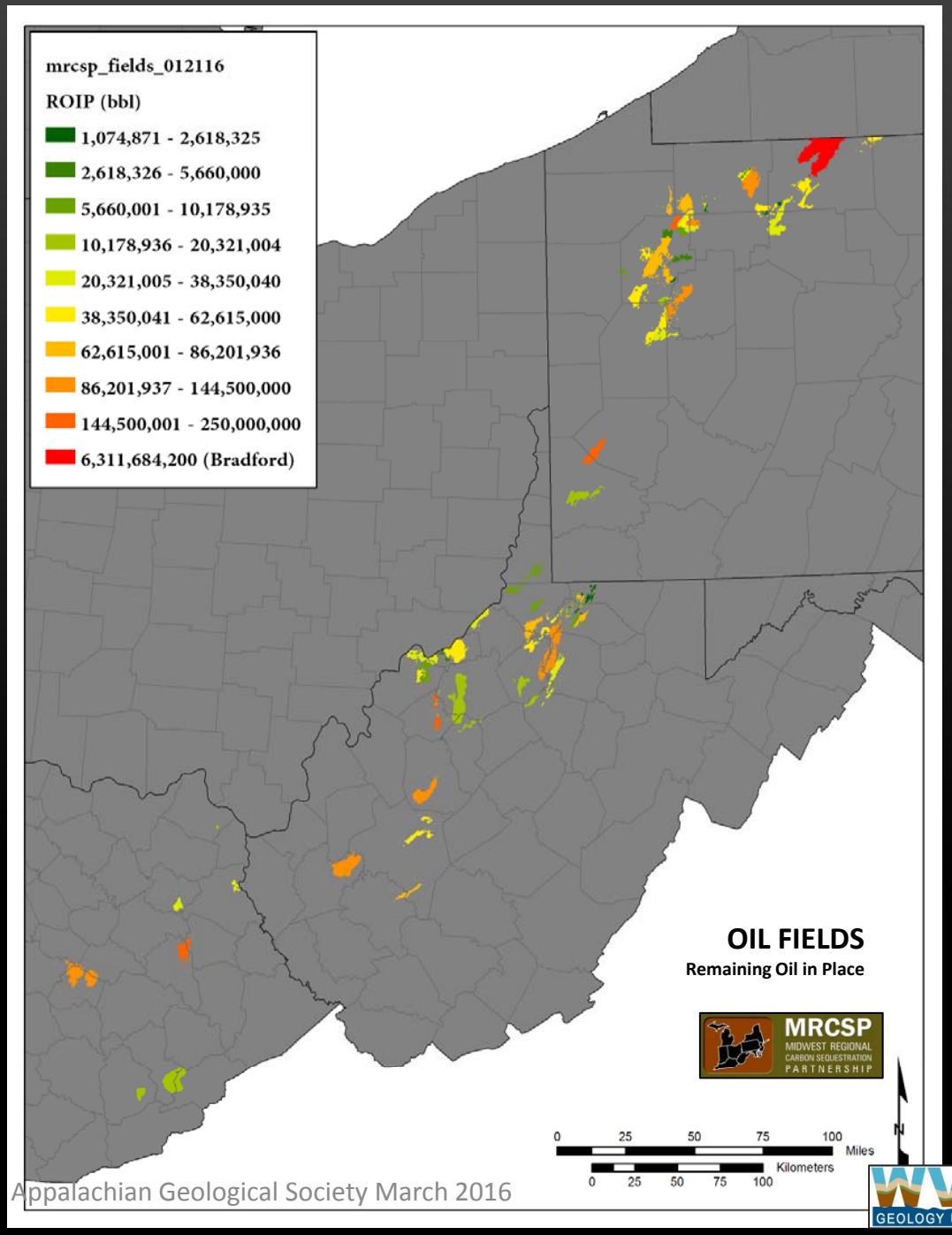
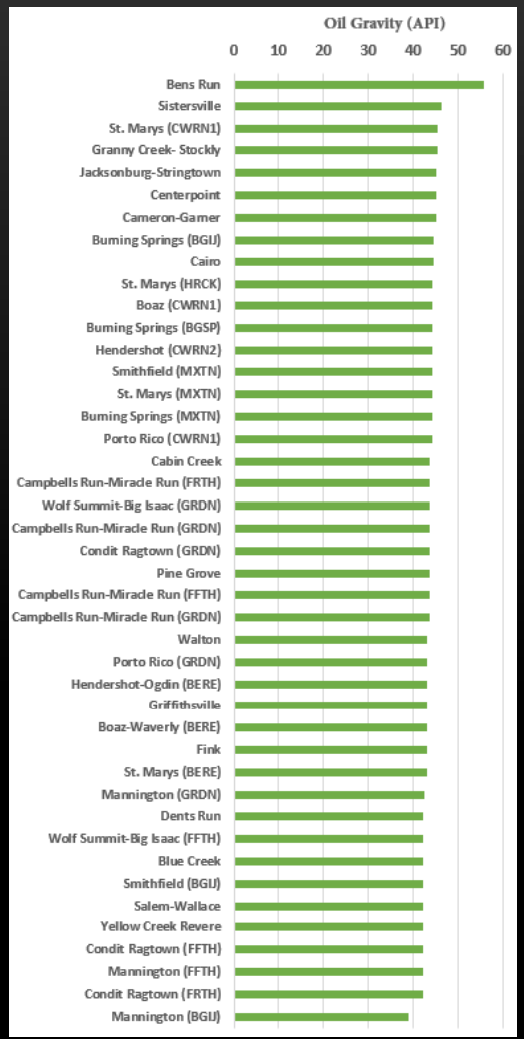
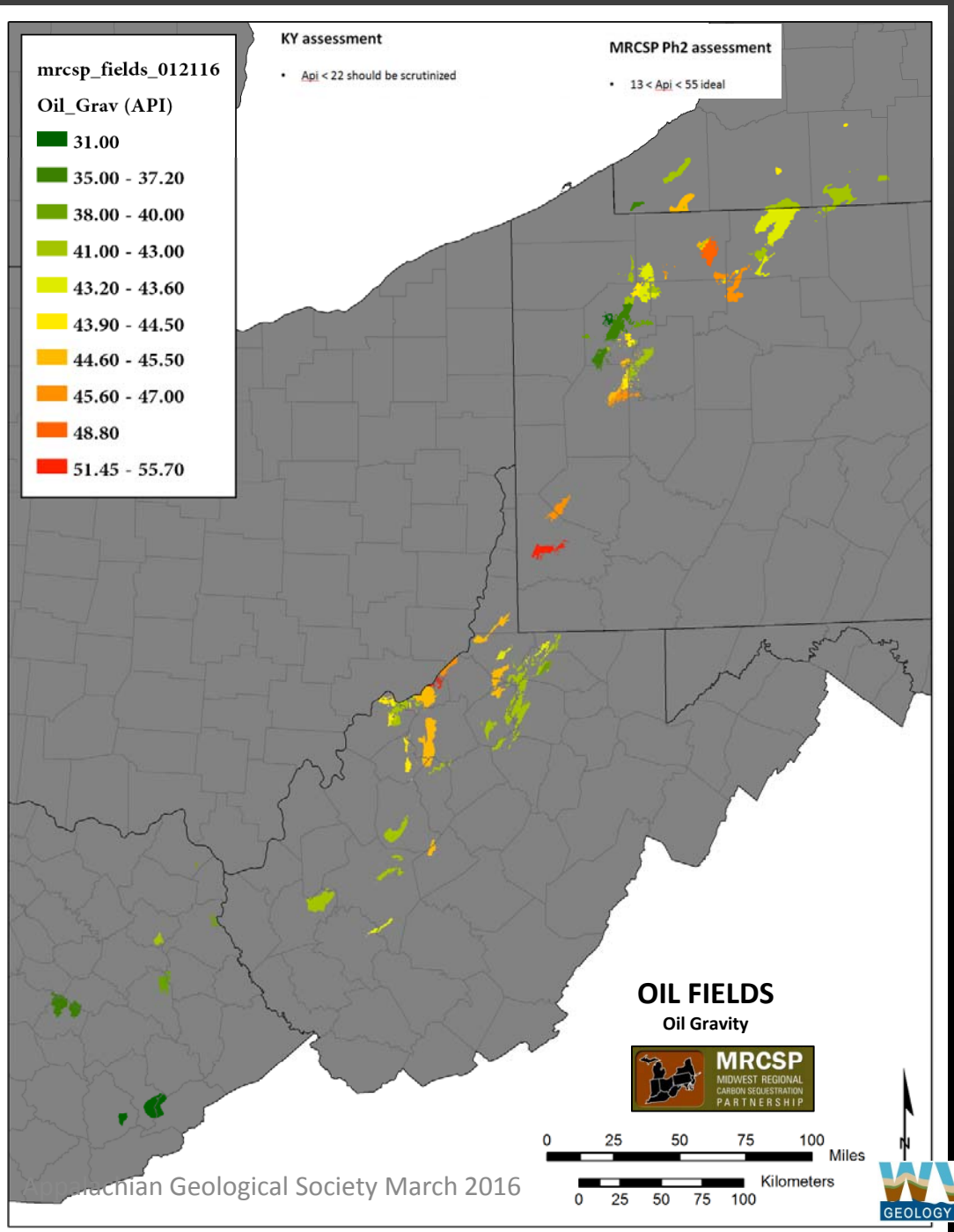
Remaining Oil in Place





Oil Gravity Optimal Range 13-55





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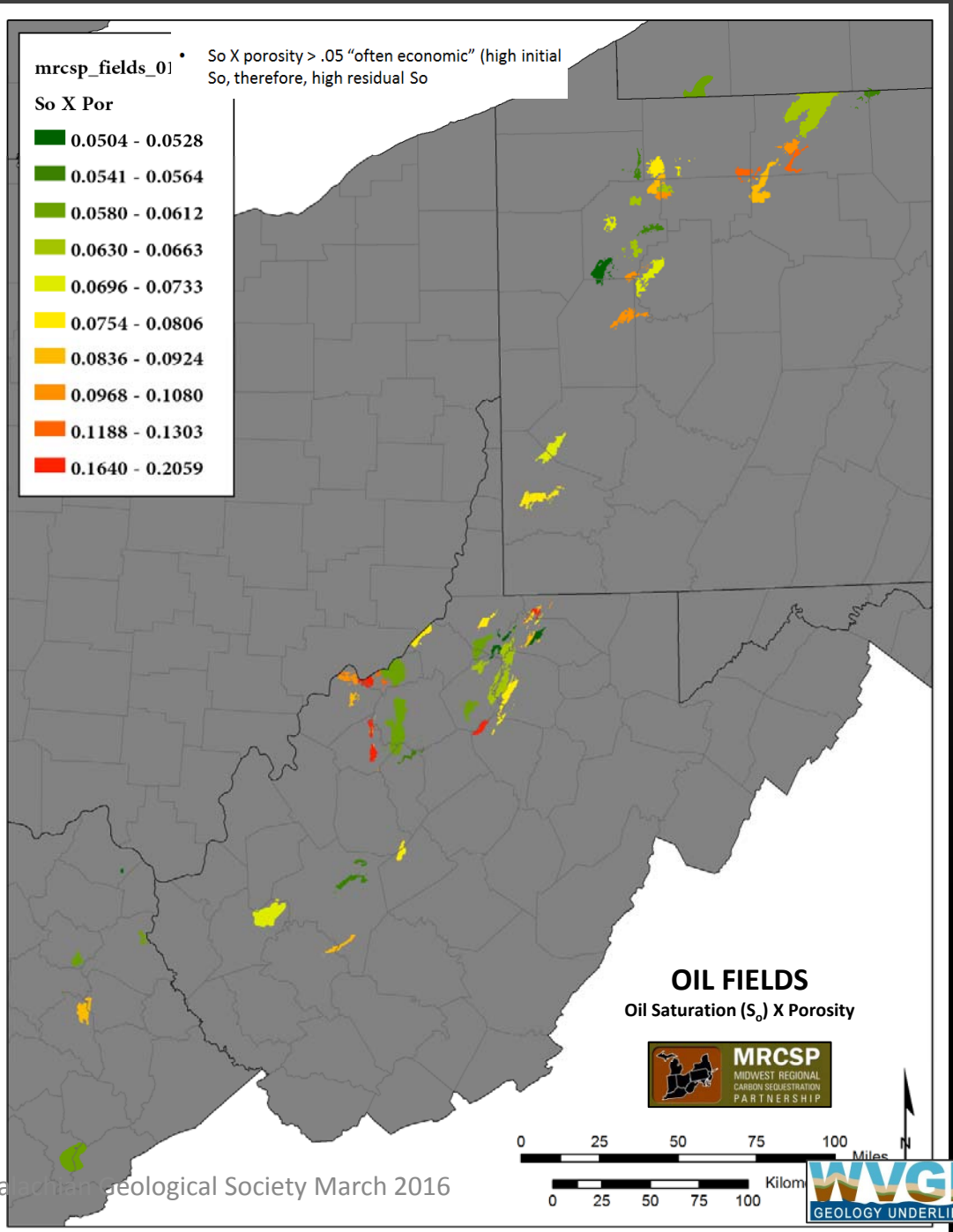
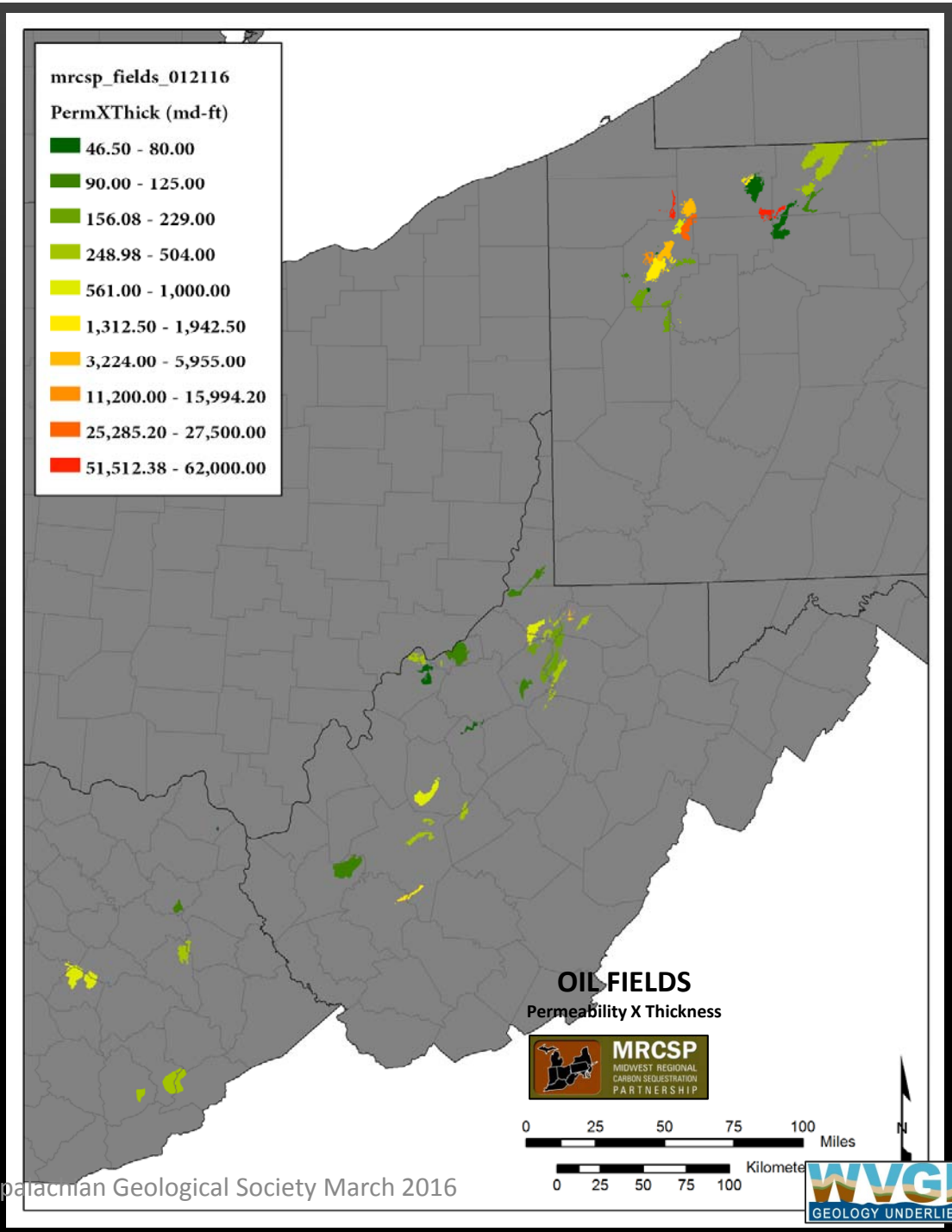
Oil Sat. x Porosity > 0.5 “often economic”

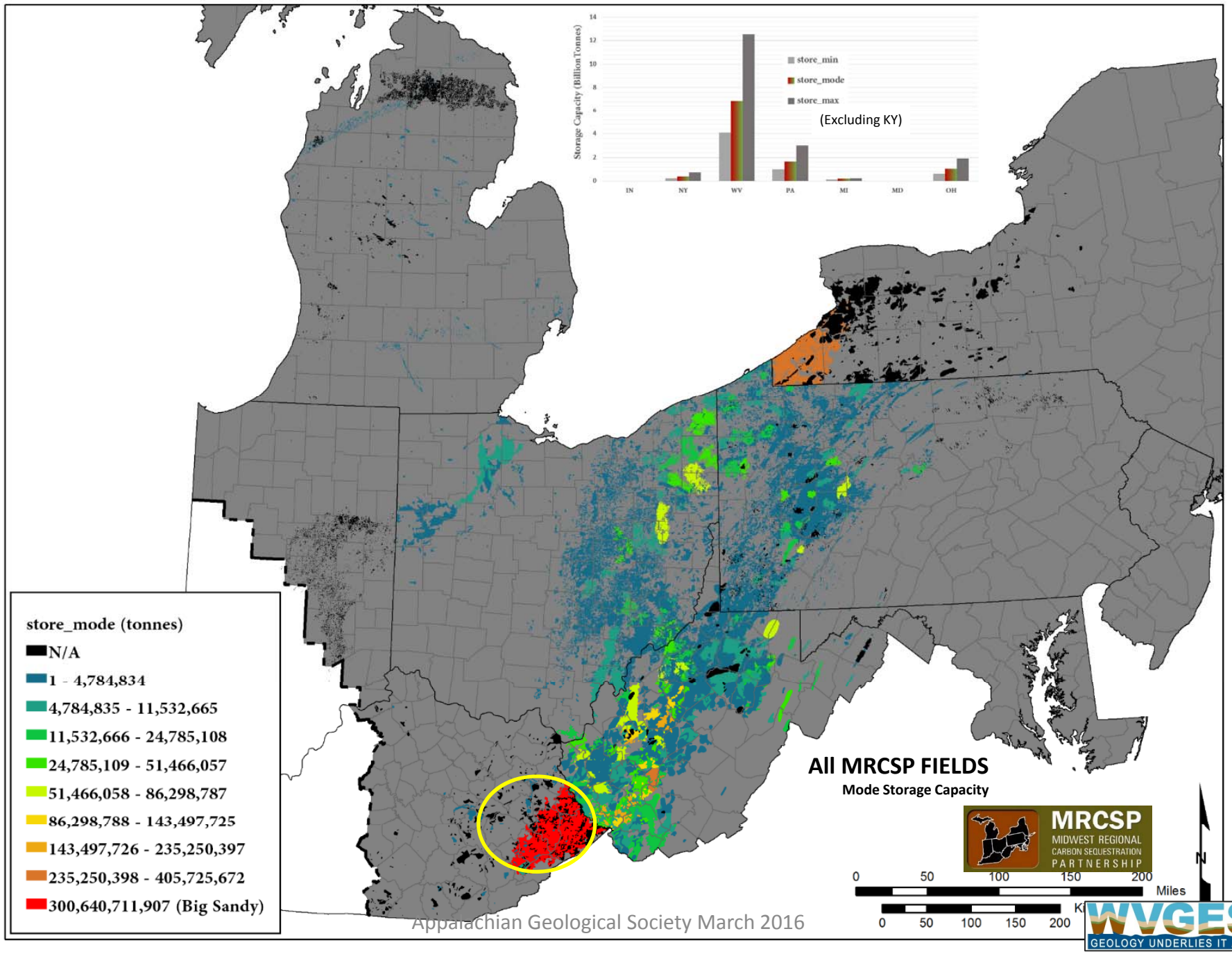


Permeability x Thickness

$K \times h < 10^{-14} m^3$ (33.2427 md/ft) may not have economically viable flow rates

**permeability data are extremely underrepresented in MRCSP dataset





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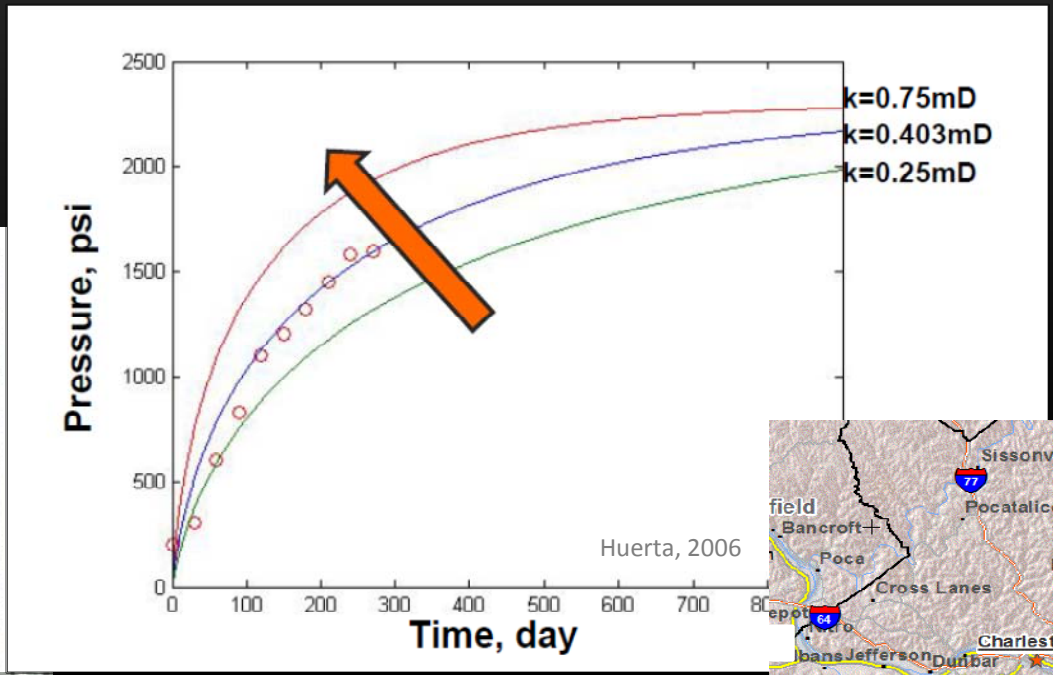
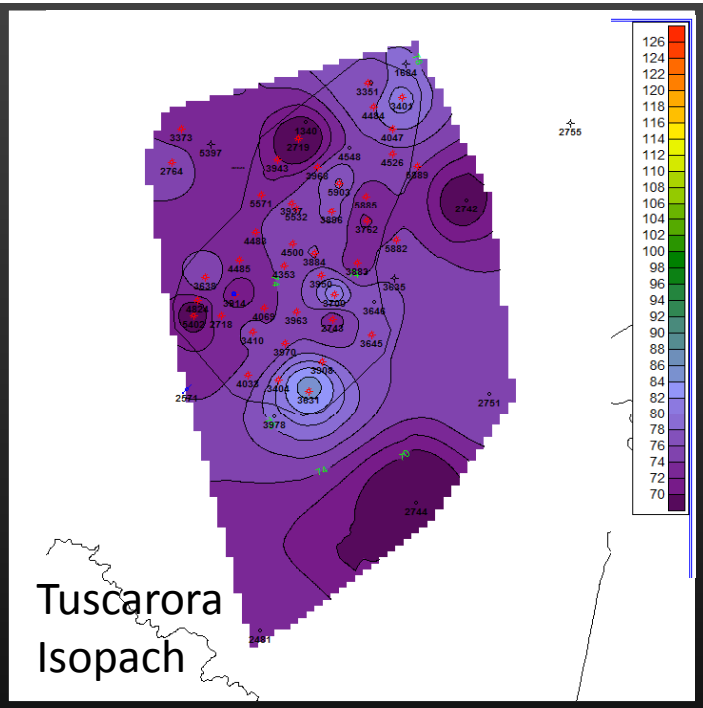
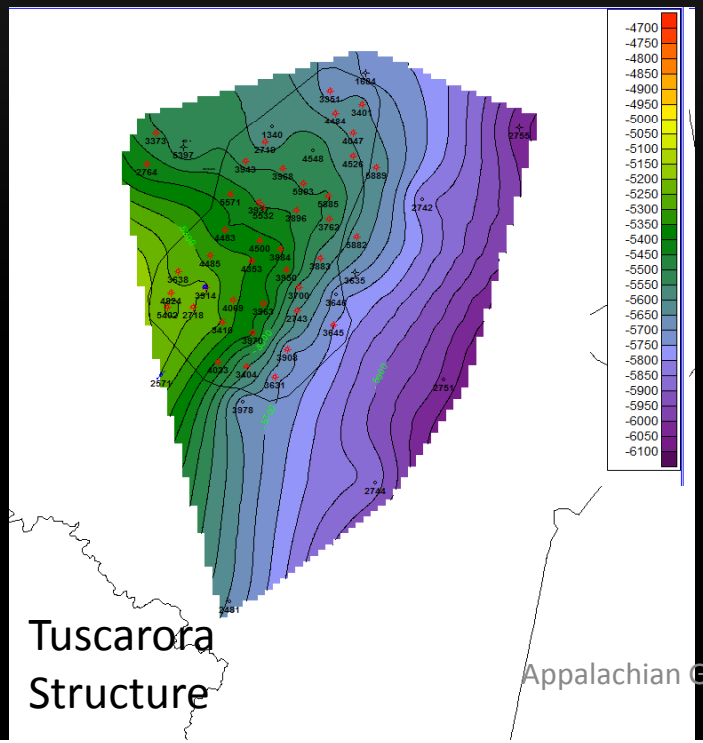
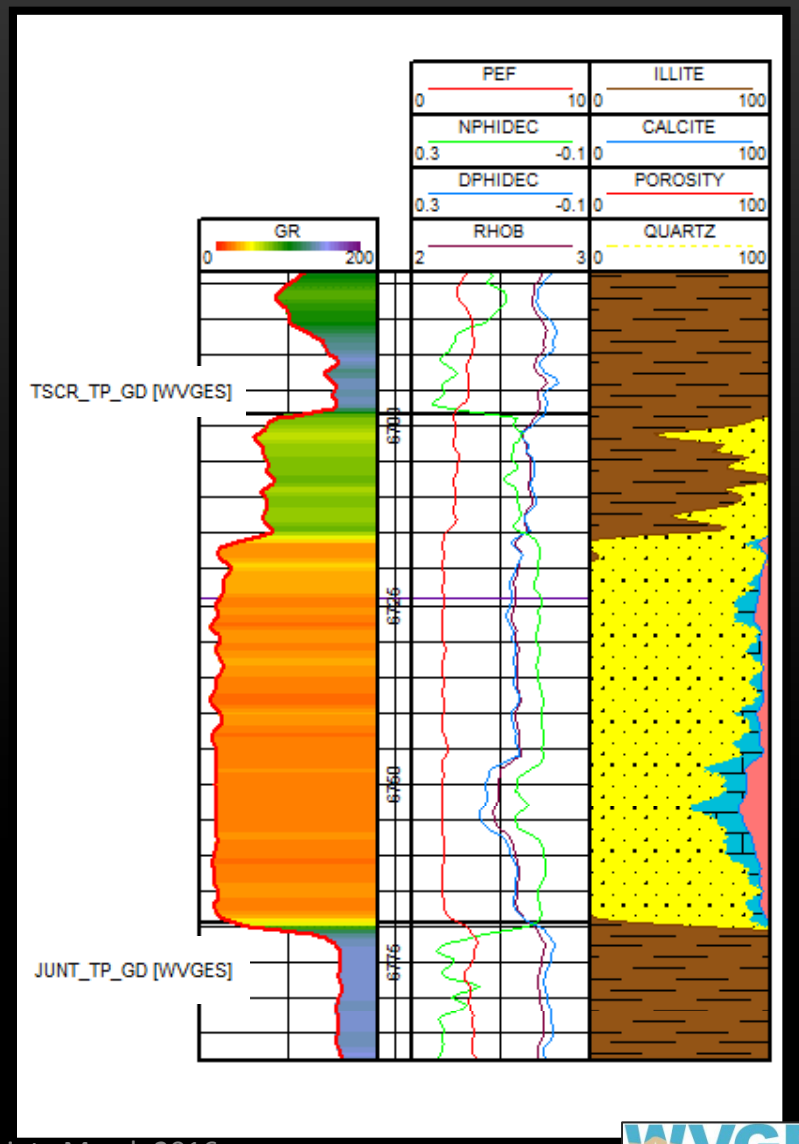
Wellbore Integrity

- Funded by the U.S. DOE/National Energy Technology Laboratory program on technologies to ensure permanent geologic carbon storage
- Sustained casing pressure buildup over time may be analyzed to determine cement permeability, location of leaks, and the nature of leakage processes









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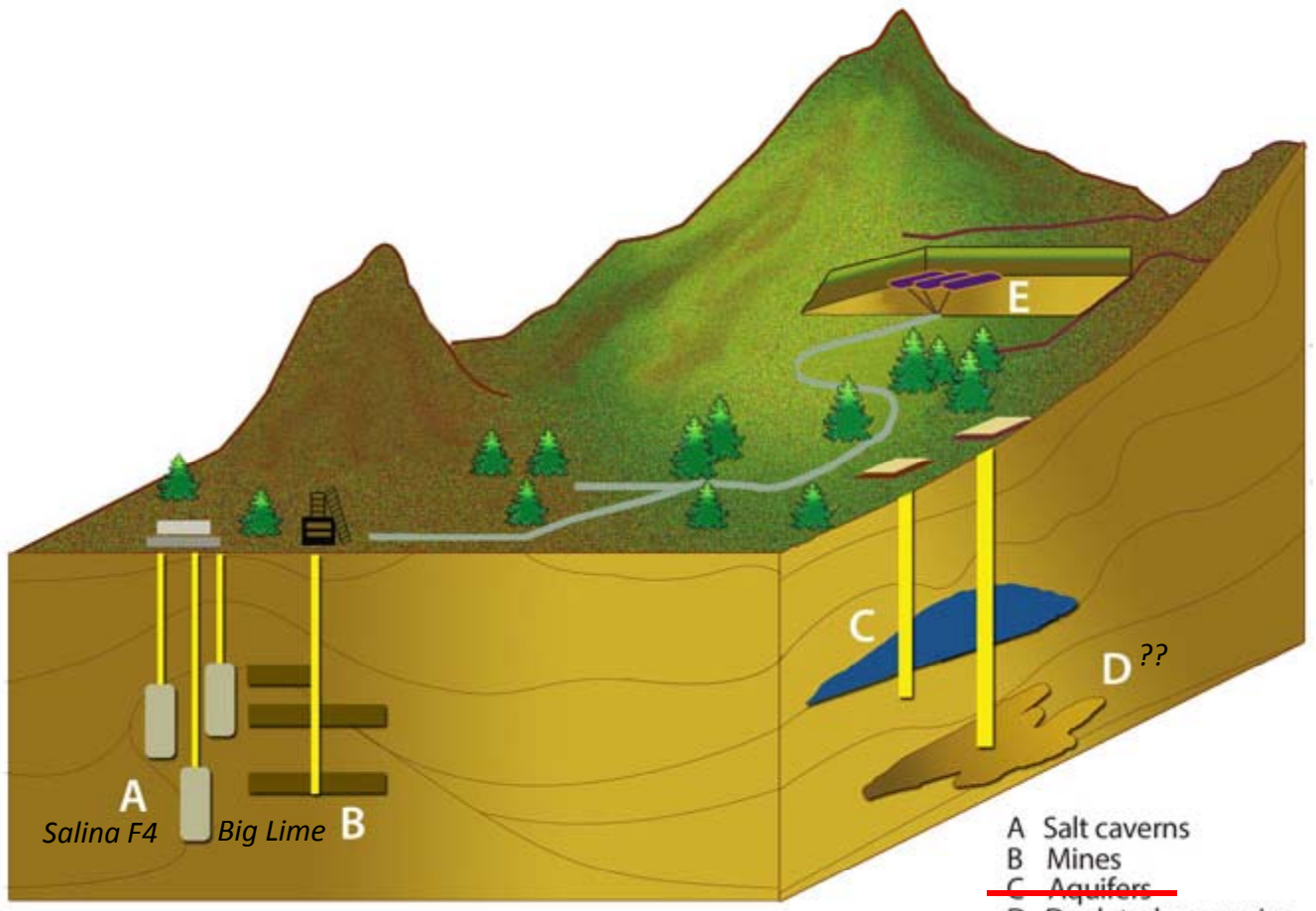
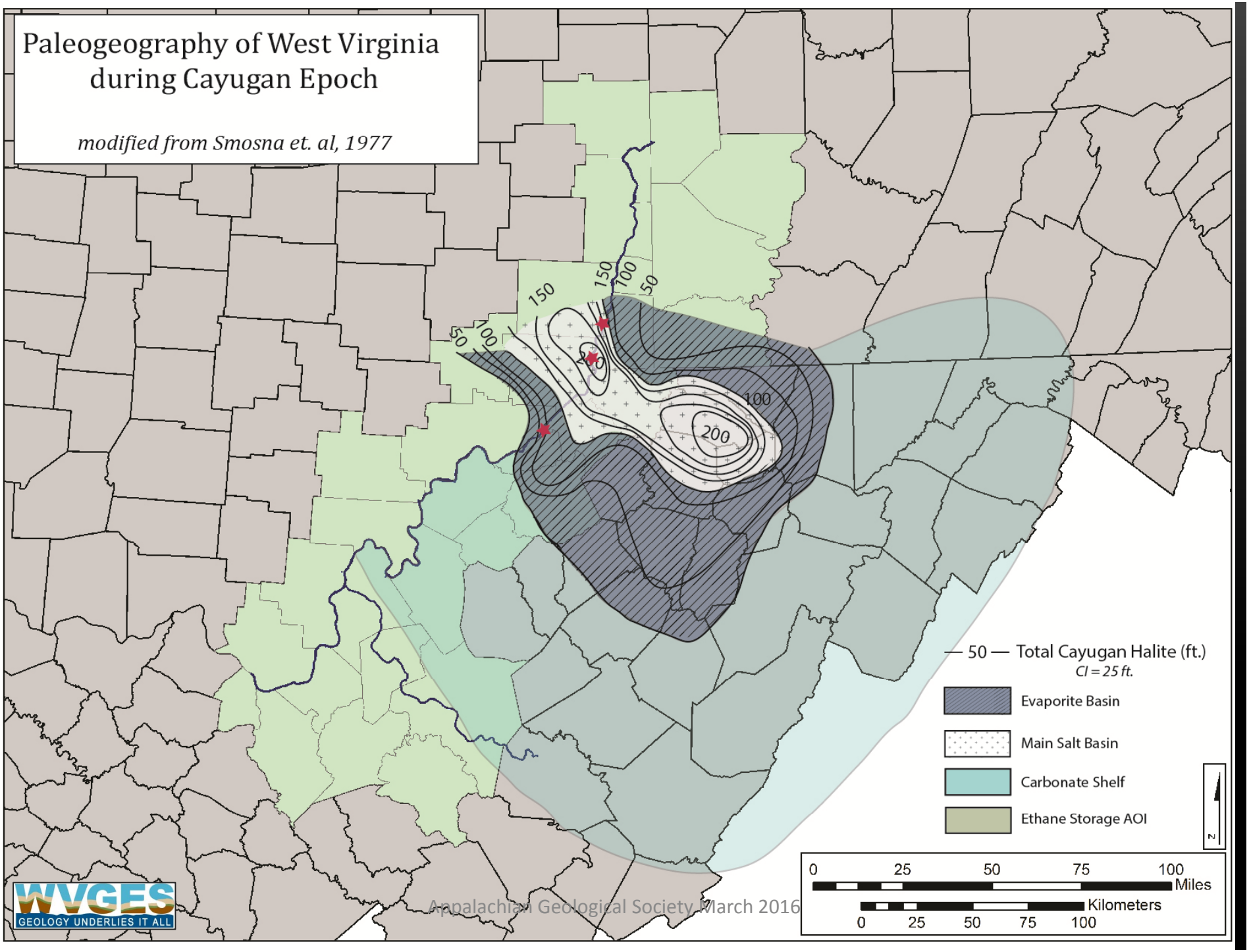
Ethane Pipeline Feasibility Study

- “6-pack” bi-directional pipeline from western PA to eastern KY; proposed route runs along Ohio River
- Potential location of hub for ethane storage
- 3 broad options: Solution caverns, Physical mining of Greenbrier LS, Depleted gas reservoirs

Figure 1. Types of underground natural gas storage facilities



Source: PB-KBB, inc., enhanced by EIA.


Paleogeography of West Virginia during Cayugan Epoch
modified from Smosna et. al, 1977
150
150
100
50
100
50
100
200
50 — Total Cayugan Halite (ft.)
CI = 25 ft.
Evaporite Basin
Main Salt Basin
Carbonate Shelf
Ethane Storage AOI
N
0 25 50 75 100 Miles
0 25 50 75 100 Kilometers
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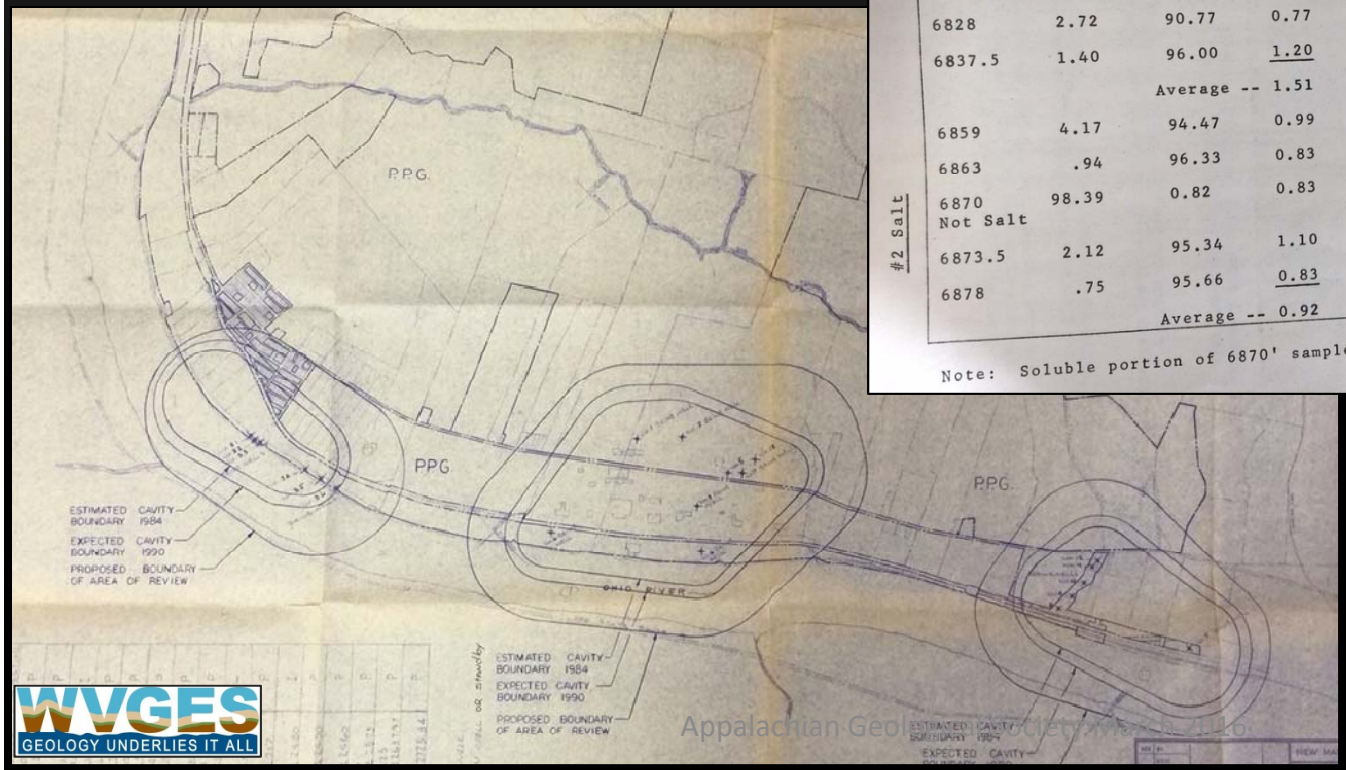
PPG Industries
Natrium, WV

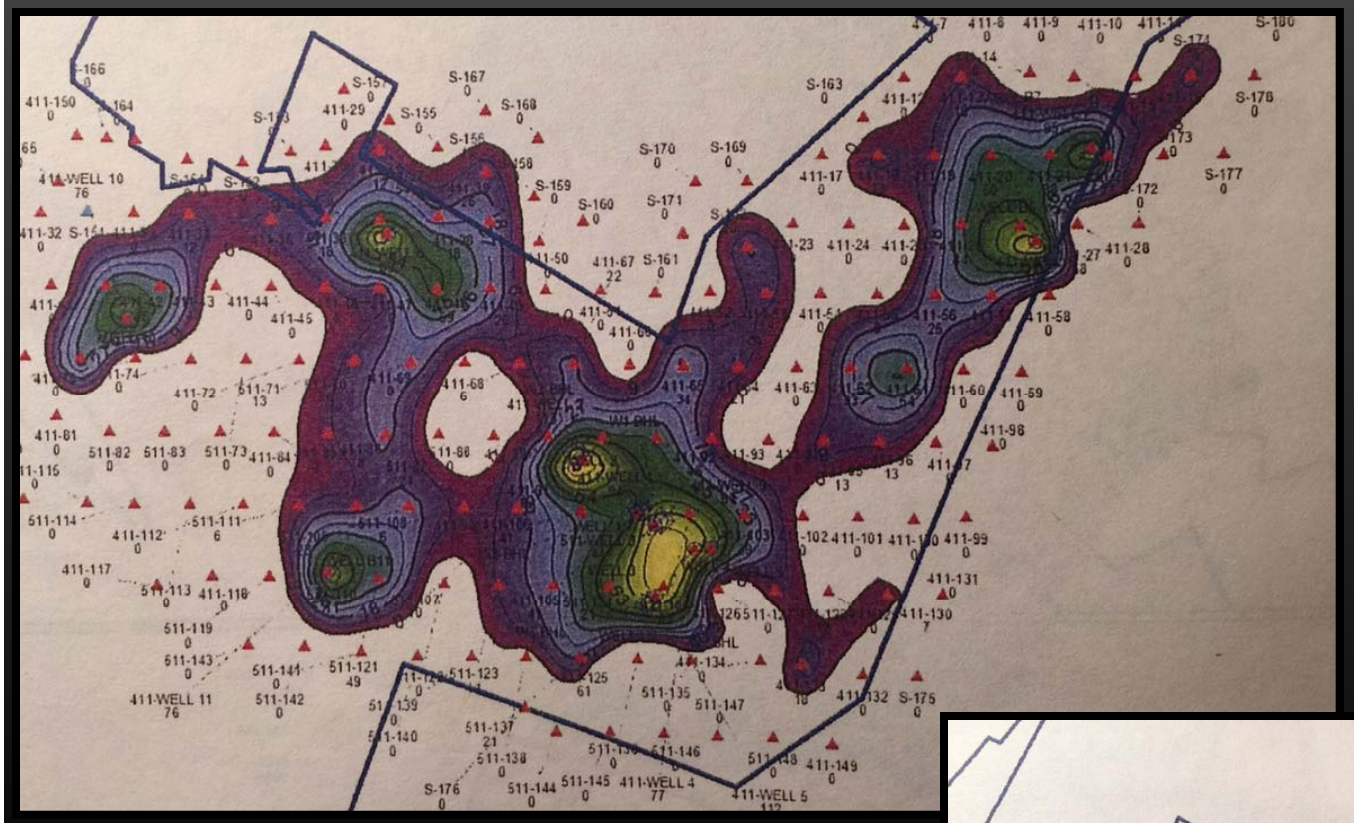
SALT SECTION CHEMICAL ANALYSIS

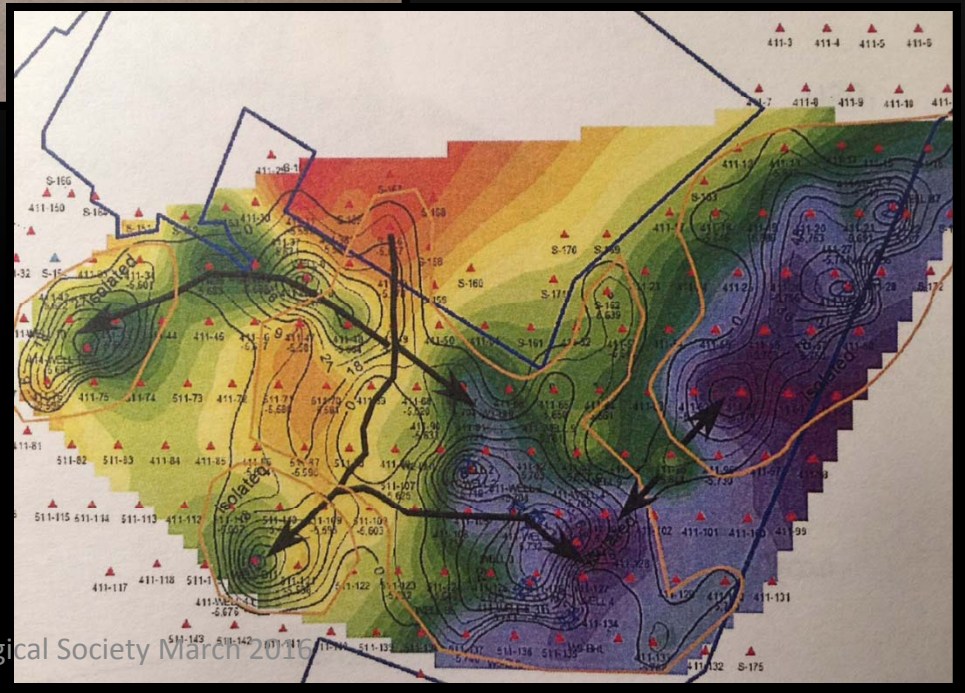
	Log Depths	% H_2O Insoluble	Cl As % NaCl	SO_4 As % Na_2SO_4	% Br_2	% H_2S	% Fe	% NH_3	% I_2	Core Density	CaO
#1 Salt	6820	1.25	96.05	1.98	0.02	0.0003	<.0001	.0005	<.01	2.1689	.66
	6739	4.20	93.91	1.92	0.01	0.0002	<.0001	.0005	<.01	2.1369	.70
	6743	4.97	90.42	1.70	0.01	0.0003	<.0001	.0005	<.01	2.3023	.56
	6753	1.07	96.25	1.07	0.03	0.0004	<.0001	.0005	<.01	2.1838	.32
	6772	1.09	96.08	1.27	0.02	0.0003	.0001	.0005	<.01	2.2978	.42
	6797	12.17	86.95	1.93	0.02	0.0001	<.0001	.0002	<.01	2.2787	.70
	6799	5.81	94.45	1.78	0.02	0.0007	<.0001	.0007	<.01	2.1649	.61
	6828	2.72	90.77	0.77	0.02	0.0002	<.0001	.0005	<.01	2.1011	.21
	6837.5	1.40	96.00	1.20	0.04	0.0002	<.0001	<.0001	<.01	2.1572	.35
			Average --	1.51							
#2 Salt	6859	4.17	94.47	0.99	0.02	0.0008	<.0001	.0010	<.01	2.1434	.33
	6863	.94	96.33	0.83	0.02	0.0004	<.0001	.0167	<.01	2.1962	.25
	6870 Not Salt	98.39	0.82	0.83	0.01	0.0027	<.0001	.0002	<.01	2.1370	.33
	6873.5	2.12	95.34	1.10	0.01	0.0003	<.0001	.0062	<.01	2.1373	.34
	6878	.75	95.66	0.83	0.02	0.0002	<.0001	.0005	<.01	2.0872	.22
			Average --	0.92							

Note: Soluble portion of 6870' sample can be computed to: $CaSO_4$ 0.79% on sample basis
NaCl .79%
KCl .04%



4” diameter core; chemical analyses and maps from UIC permit applications





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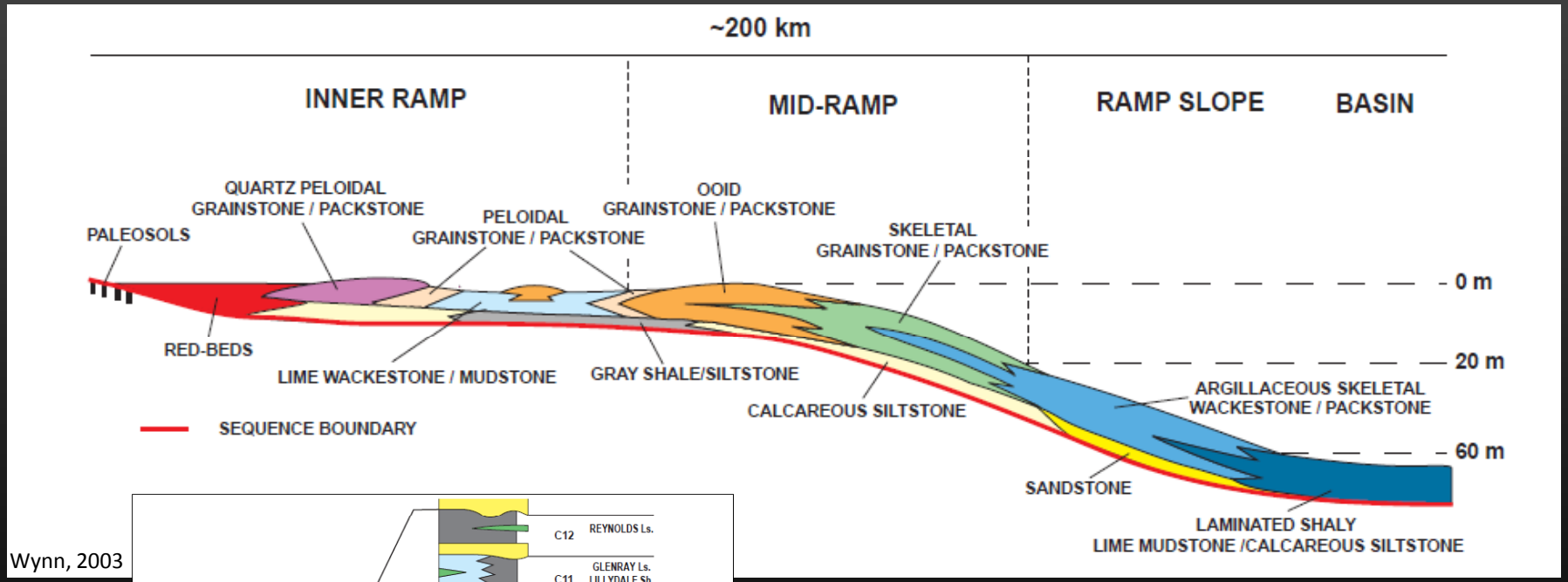
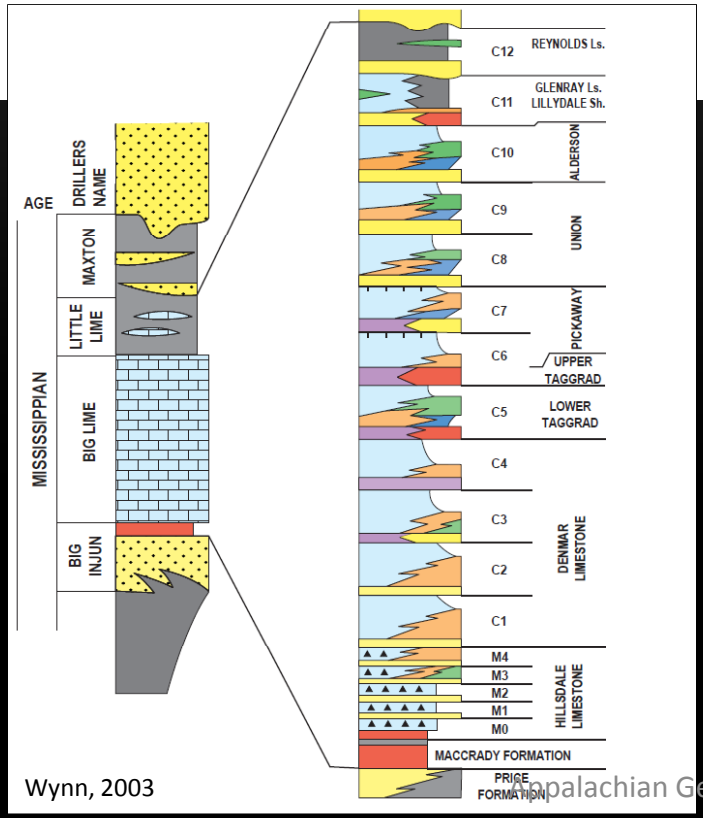


Wynn, 2003



Wynn, 2003

Storage Option 2: Physical Mining of Greenbrier Limestone

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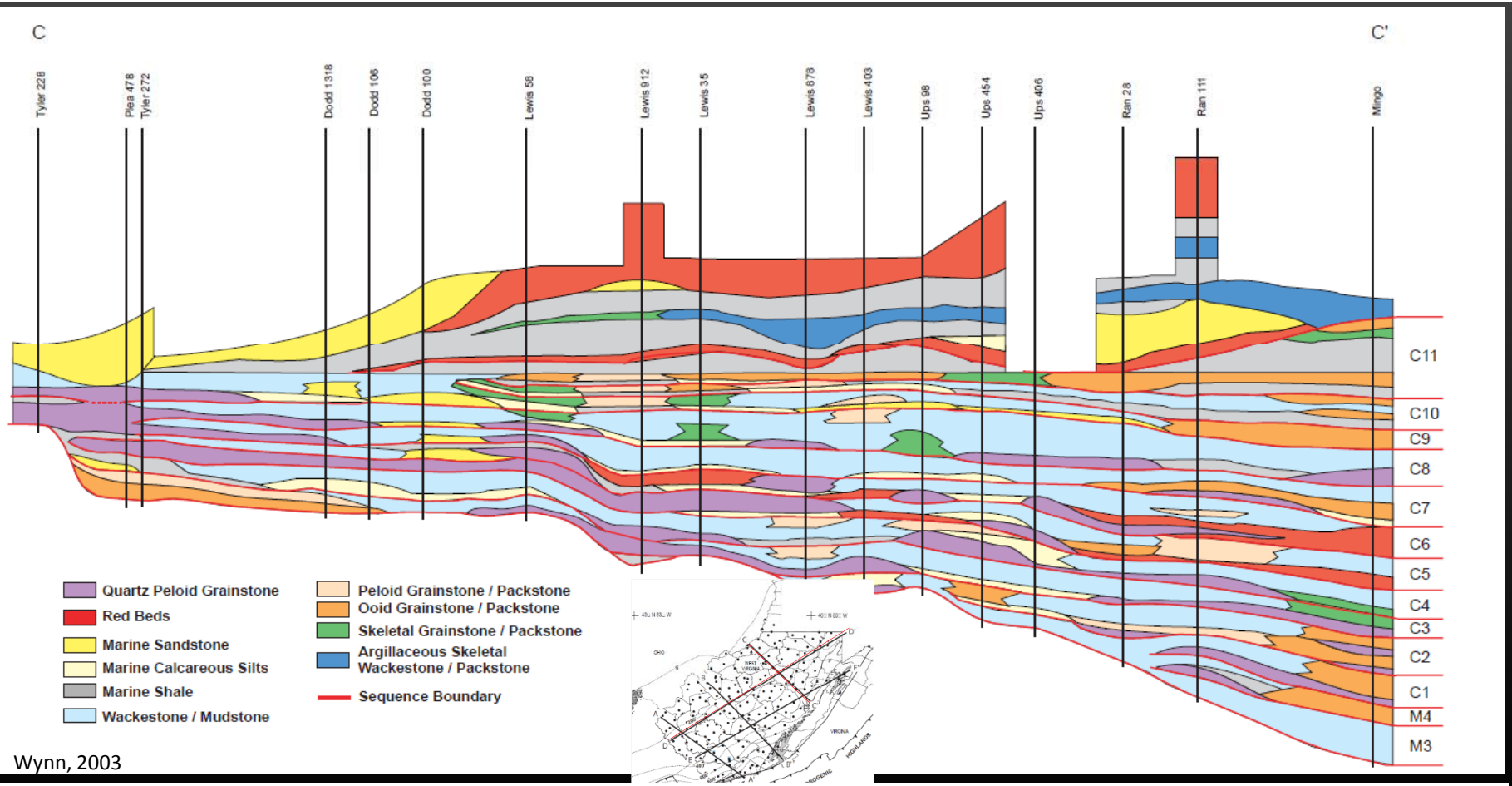
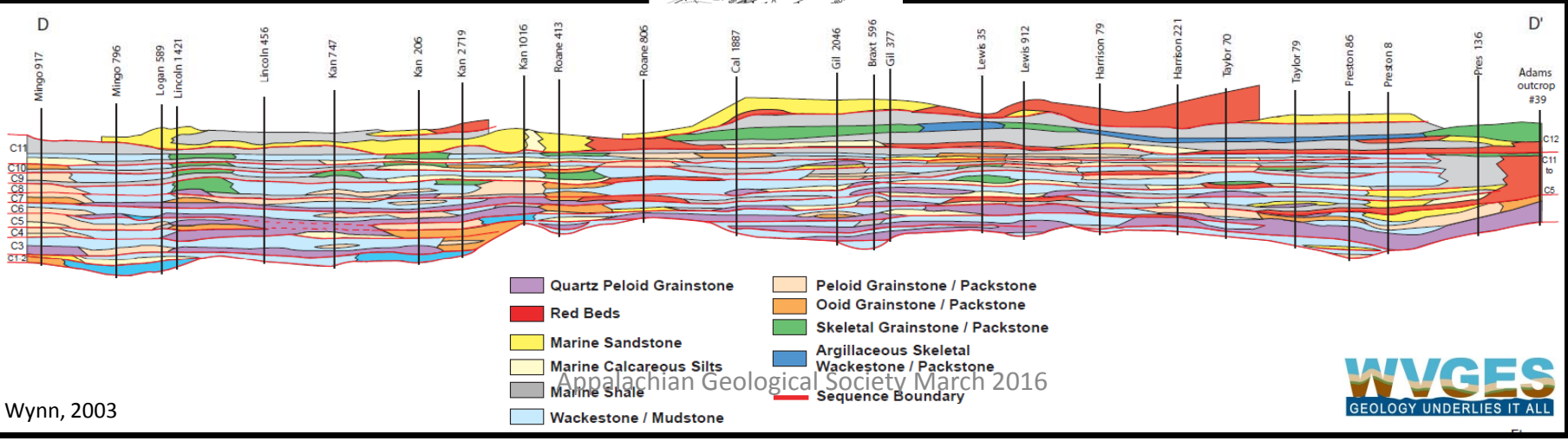


Wynn, 2003



Wynn, 2003

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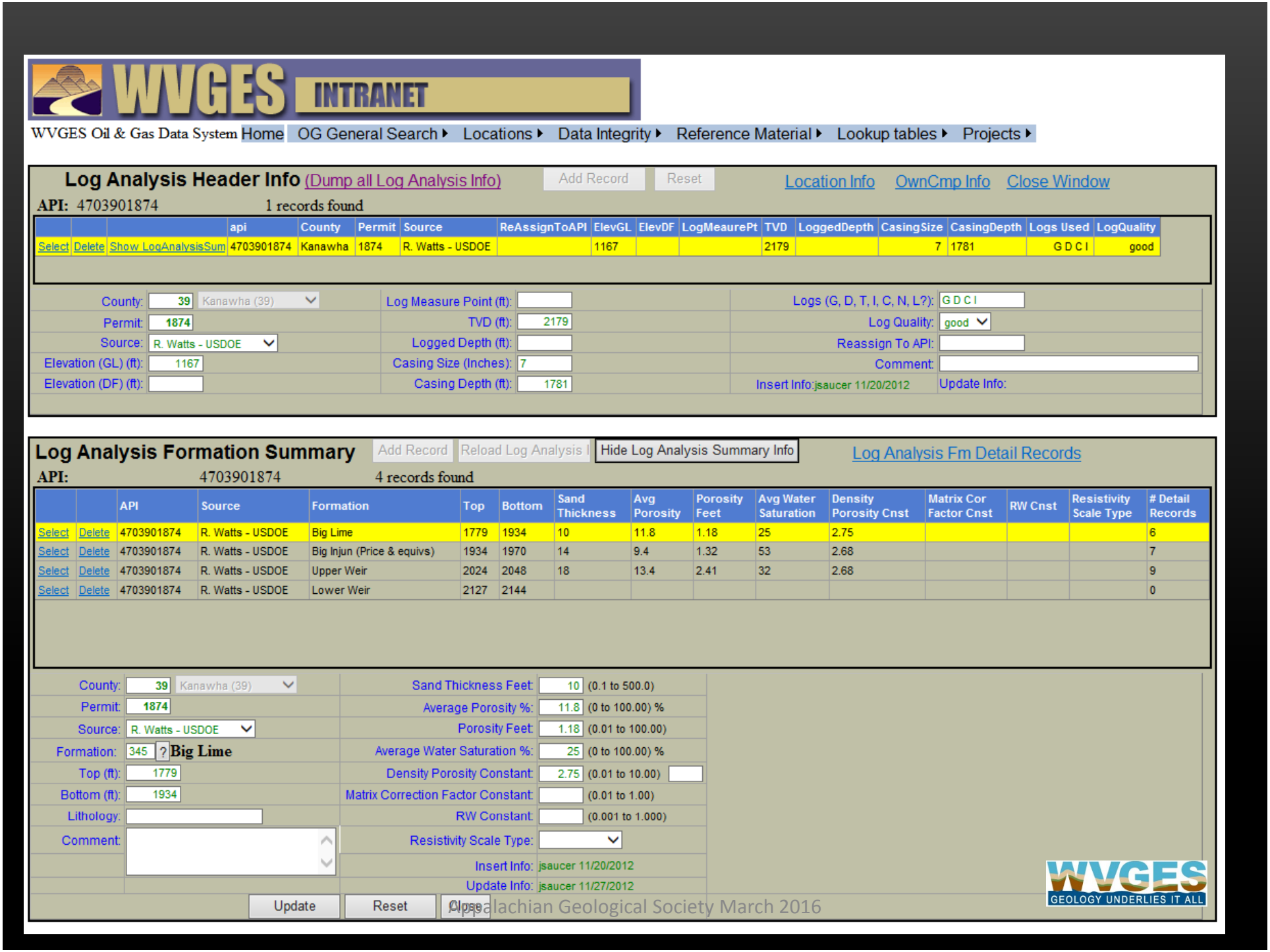
WVGES INTRANET
WVGES Oil & Gas Data System Home OG General Search Locations Data Integrity Reference Material Lookup tables Projects
Log Analysis Header Info (Dump all Log Analysis Info) Add Record Reset Location Info OwnCmp Info Close Window
API: 4703901874 1 records found
Select Delete Show LogAnalysisSum 4703901874 Kanawha 1874 R. Watts - USDOE 1167 2179 7 1781 G D C I good
County: 39 Kanawha (39)
Permit: 1874
Source: R. Watts - USDOE
Elevation (GL) (ft): 1167
Elevation (DF) (ft):
Log Measure Point (ft):
TVD (ft): 2179
Logged Depth (ft):
Casing Size (Inches): 7
Casing Depth (ft): 1781
Logs (G, D, T, I, C, N, L?): G D C I
Log Quality: good
Reassign To API:
Comment:
Insert Info:jsaucer 11/20/2012
Update Info:
Log Analysis Formation Summary Add Record Reload Log Analysis I Hide Log Analysis Summary Info Log Analysis Fm Detail Records
API: 4703901874 4 records found
Select Delete 4703901874 R. Watts - USDOE Big Lime 1779 1934 10 11.8 1.18 25 2.75 6
Select Delete 4703901874 R. Watts - USDOE Big Injun (Price & equivs) 1934 1970 14 9.4 1.32 53 2.68 7
Select Delete 4703901874 R. Watts - USDOE Upper Weir 2024 2048 18 13.4 2.41 32 2.68 9
Select Delete 4703901874 R. Watts - USDOE Lower Weir 2127 2144 0
County: 39 Kanawha (39)
Permit: 1874
Source: R. Watts - USDOE
Formation: 345 ? Big Lime
Top (ft): 1779
Bottom (ft): 1934
Lithology:
Comment:
Sand Thickness Feet: 10 (0.1 to 500.0)
Average Porosity %: 11.8 (0 to 100.00) %
Porosity Feet: 1.18 (0.01 to 100.00)
Average Water Saturation %: 25 (0 to 100.00) %
Density Porosity Constant: 2.75 (0.01 to 10.00)
Matrix Correction Factor Constant: (0.01 to 1.00)
RW Constant: (0.001 to 1.000)
Resistivity Scale Type:
Insert Info: jsaucer 11/20/2012
Update Info: jsaucer 11/27/2012
Update Reset Close
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Fracture Dissolution of Carbonate Rock: An Innovative Process for Gas Storage

FINAL TECHNICAL REPORT

August 1, 2002 – October 30, 2006

James W. Castle[1], Principal Investigator
Ronald W. Falta[1], Co-Investigator
David Bruce[2], Co-Investigator
Larry Murdoch[1], Co-Investigator
Scott E. Brame[1], Research Associate
Donald Brooks[3], Consultant

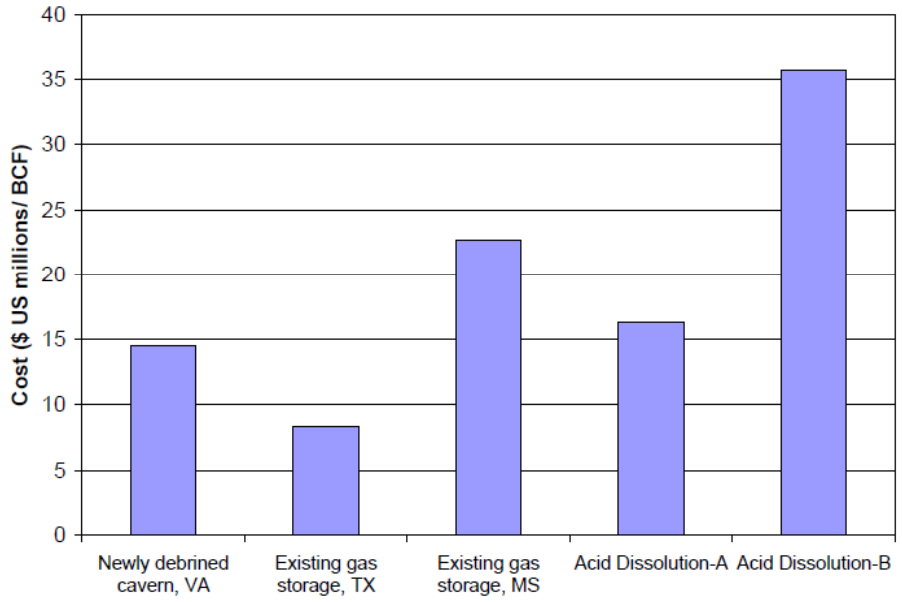
[1]Department of Geological Sciences, Clemson University, Clemson, SC
[2]Department of Chemical Engineering, Clemson University, Clemson, SC
[3]DB Consulting, Millington, NJ

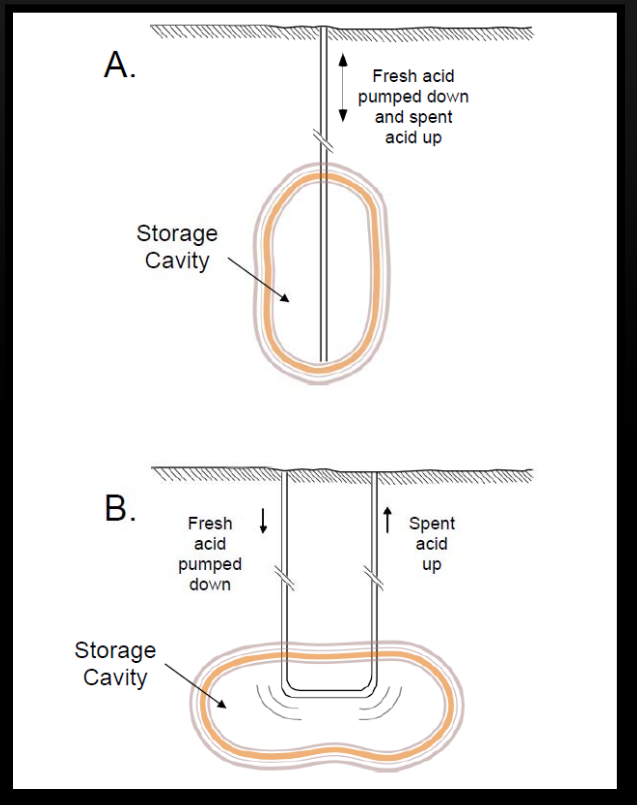
January 30, 2007

DE-FC26-02NT41299

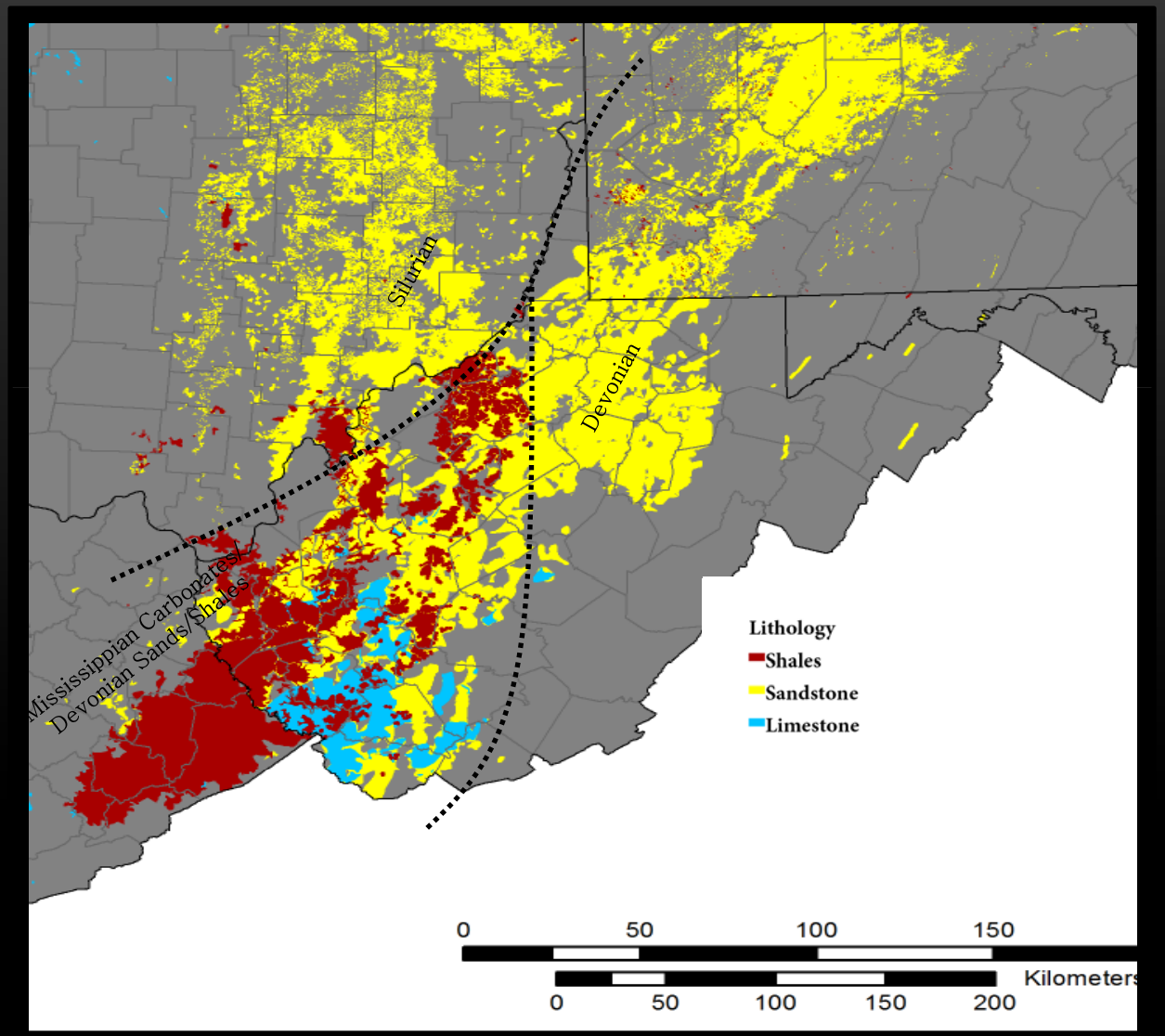
Submitted by:

Sample	Initial Sample Weight (g)	Post Dissolution Results			
		Dried (100°C) Weight (g)	Insoluble (%)	Calcined (700 °C) Weight (g)	Combustible (%)
Lewis-57	53.135				
Green-6	23.8297	2.155	9.0		
Harr79-HDG	34.0793	6.9736	20.5	6.6807	0.9
Harr-79SAL	32.7239				
8792	31.2792	1.0143	3.2	0.9494	0.2
Jack-1366	21.5574	0.3859	1.8	0.3854	0.002
Hamp-12	23.8199	1.2488	5.2		
Wetzel-408	23.7258	7.4959	31.6		
8959R	32.4899	3.1142	9.6		





Option 3: Depleted Gas Fields



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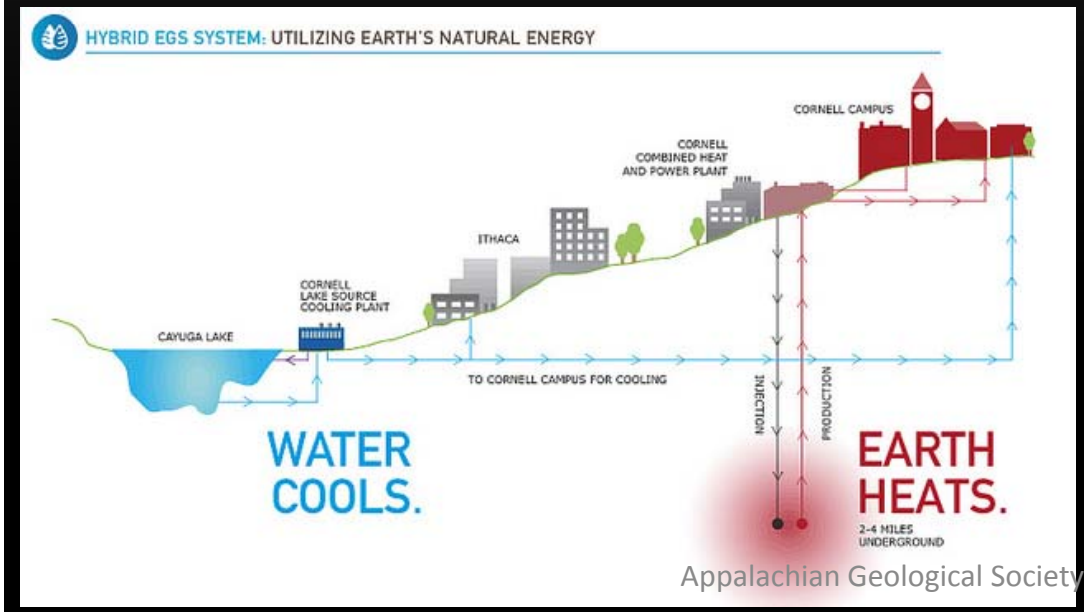
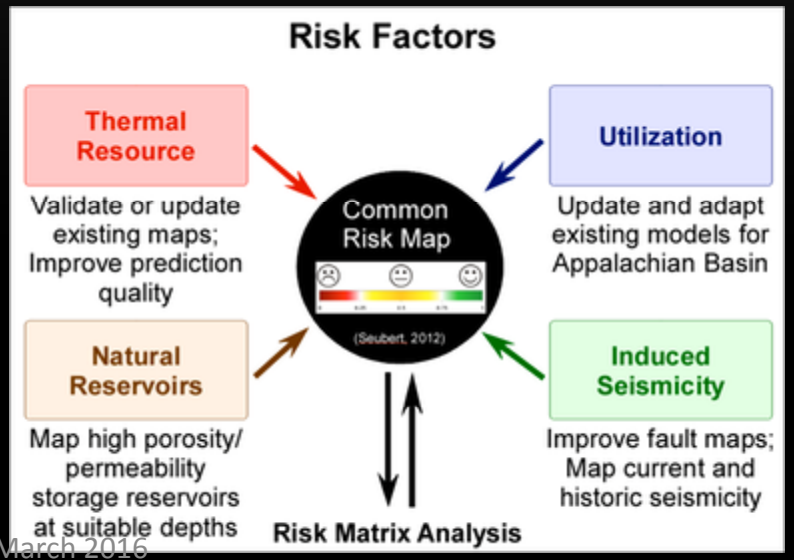
Low-temperature Geothermal

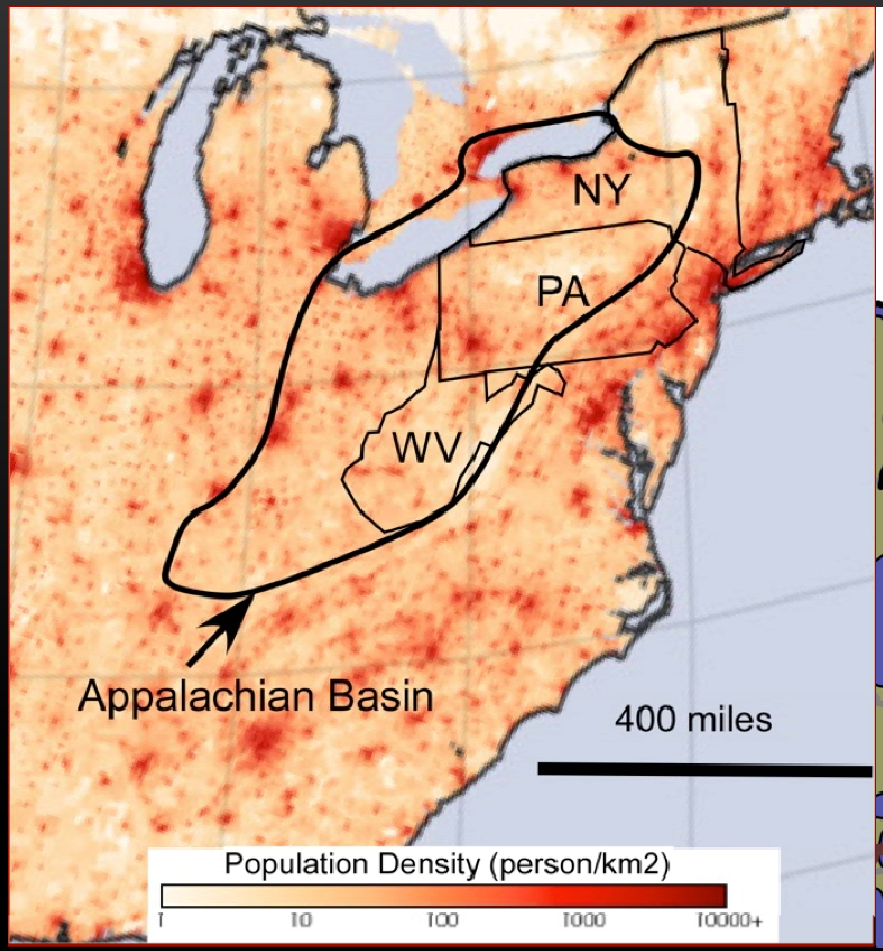
- Cornell University/WVU/Southern Methodist University
- Low-temperature applications in the Appalachian Basin
  District heating, greenhouses, livestock, laundries, etc.
- Phase 1: Risk Assessment (Complete)
- Potential Targets in WV: Tuscarora Sandstone (northern WV)
  and others??

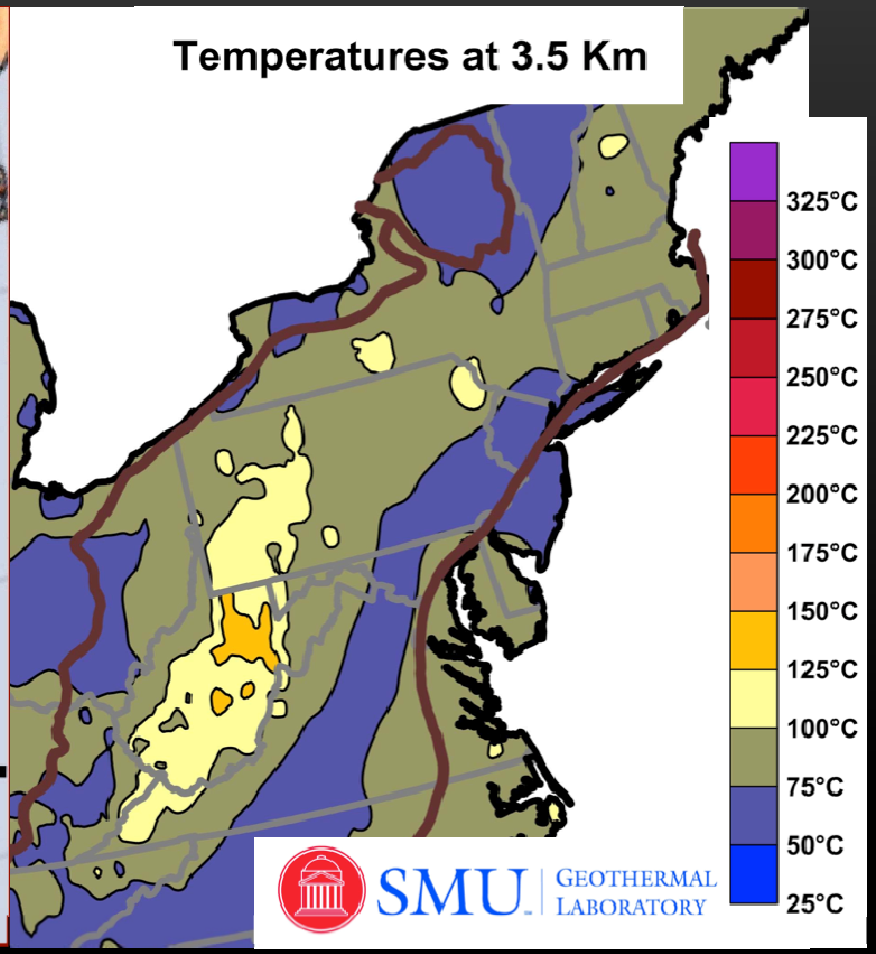
****Currently seeking non-producing wells slated to be plugged (to measure equilibrated BHTs) ****



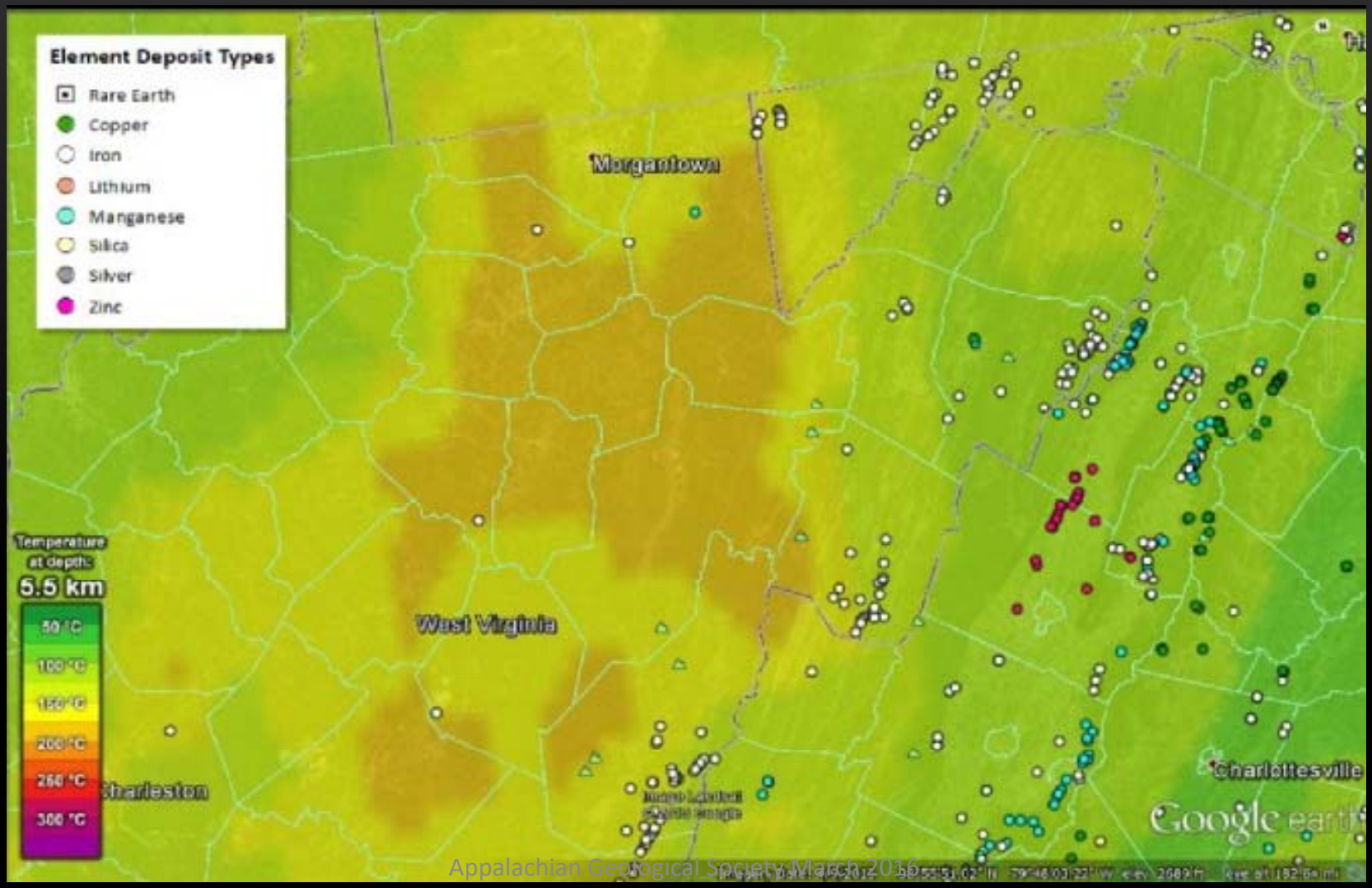


Low-temperature Geothermal

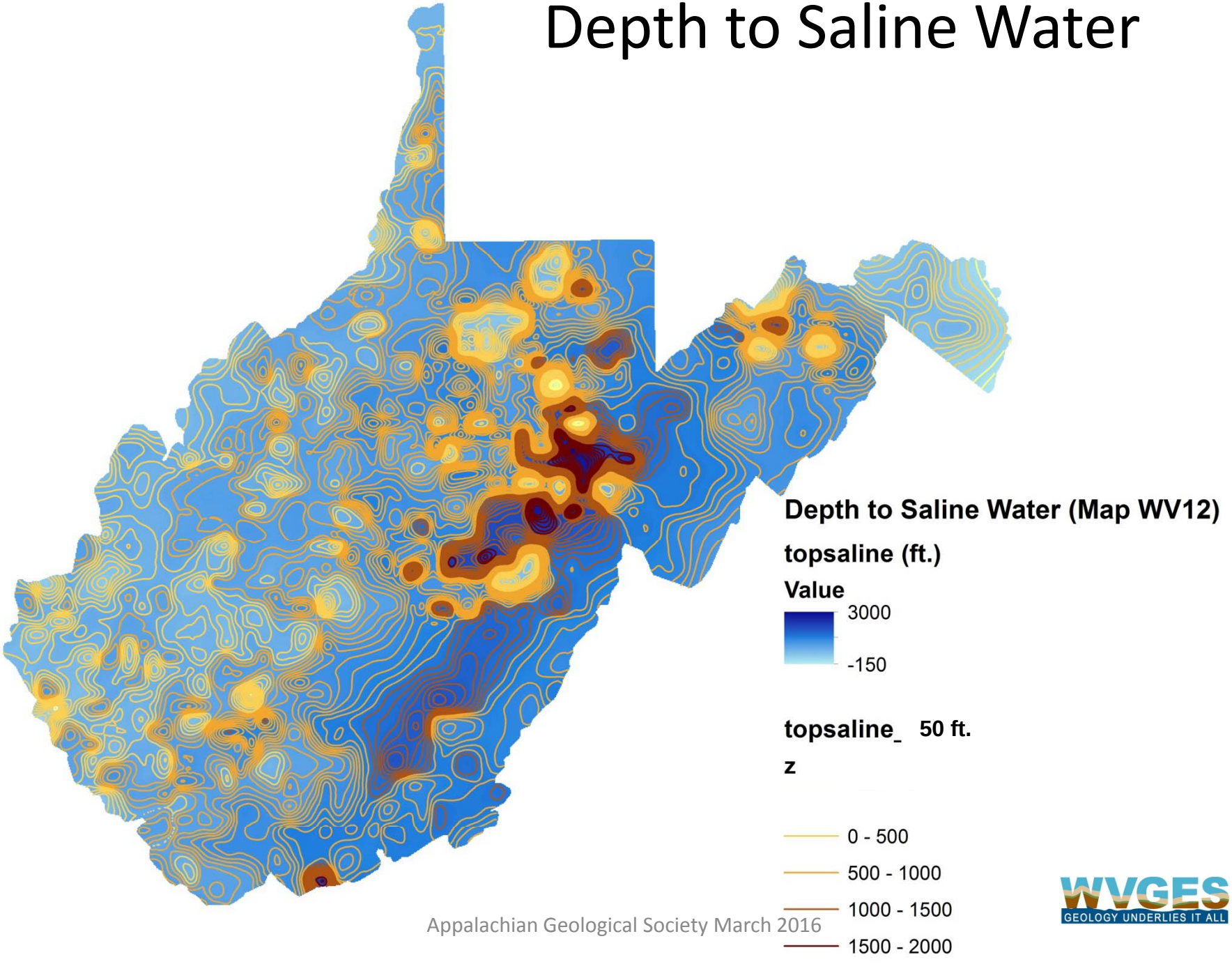




Geothermal Anomalies and Strategic/Rare-Earth Elements



Depth to Saline Water



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USGS Data Preservation

- Implements bar code technology to systematically archive and catalog WVGES well cuttings and core samples
- Box information and location are linked to the existing Oil and Gas database
- Sample analyses and results will be linked to wells at the box level
- New boxes for Sandhill well

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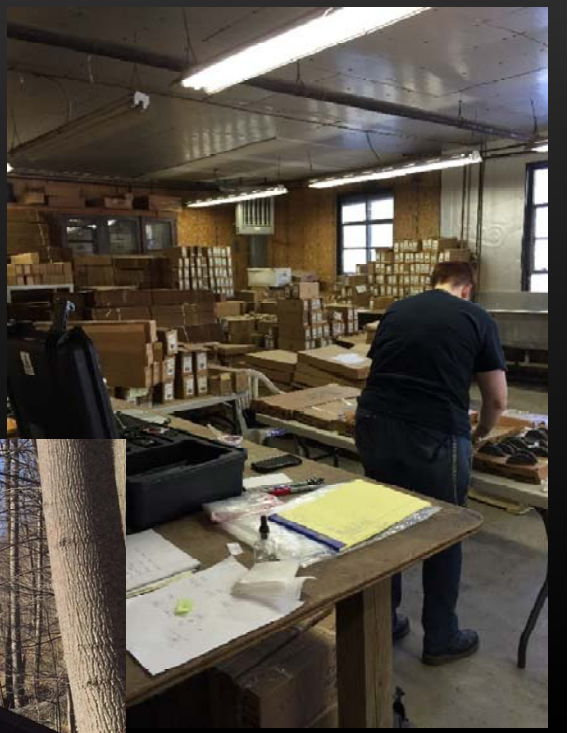
Existing WVGES sample repository is at capacity; new storage facility is being prepared



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Recent Acquisitions via WVGES Sampling Policy

- Rogersville Shale XRD and RockEval (Wayne, Jackson, Calhoun counties)
- Big Injun porosity and permeability (Roane and Clay counties)

Coming Soon

- Berea to Sunbury porosity/perm/shale TOC
- Utica maturity (Marion and Preston counties)
- Utica XRF + (Wood County)

Special thanks to Cabot Oil and Gas for new boxes for RTC cores!

Thank You!

- Oil and Gas Program Staff: Philip Dinterman, Eric Lewis, Gary Daft, Pat Johns
- IT Program Staff: Mary Behling, Susan Pool, John Saucer, John Bocan, Samantha McCreery, Matthew Seese, Steve Munro

Special Assists from Drs. Hohn and McDowell

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