Sixth Annual Conference on Carbon Capture & Sequestration

Session 4-B Sequestration and Coal Seams

Geological Carbon Sequestration (GCS) Potential Upper Silurian to Middle Devonian Strata Michigan Basin, USA

Dave Barnes[1], Bill Harrison[1], Amanda Wahr[1], Phil Jagucki[2], and Neeraj Gupta[2]

1. Michigan Geological Repository for Research and Education (MGRRE) and Department of Geosciences, Western Michigan University, Kalamazoo, Michigan 49008
2. Battelle, Columbus, Ohio, USA

Sixth Annual Conference on Carbon Capture & Sequestration

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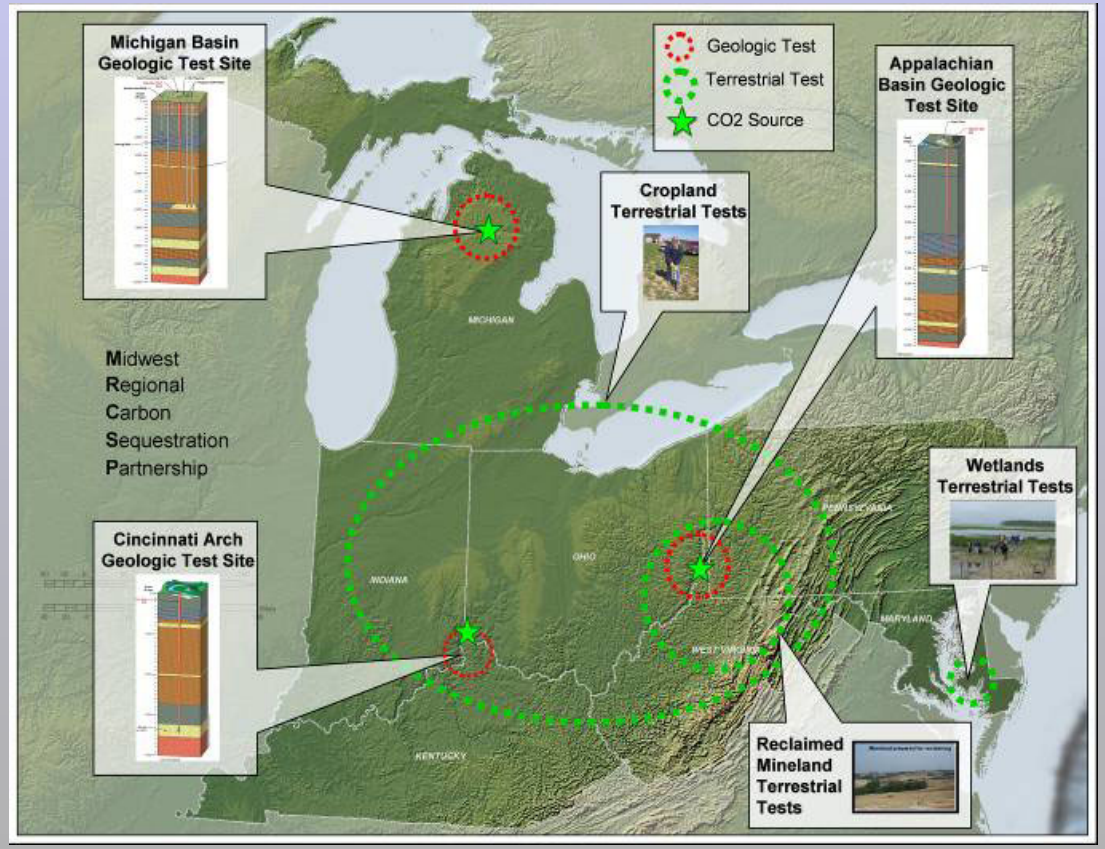
Project Context

- MRCSP is one of seven U.S. DOE/NETL Regional C Seq. Partnerships.
- Eight-state region of IN, KY, MD, MI, NY, OH, PA, and WV.
- Phase I Launched, fall 2003; Phase II commenced October 2005.
- Michigan Basin site is one of three geologic test sites.

MRCSP
MIDWEST REGIONAL
CARBON SEQUESTRATION
PARTNERSHIP



See: Sminchak, and others, this meeting

MRCSP Regional GCS Potential

Phase I Results

- Three significant saline reservoir GCS targets were identified in the Michigan basin totaling >200Gt GCS potential :
  - Cambrian Mt. Simon Sandstone,
  - Middle Ordovician St. Peter Sandstone, and
  - Upper Silurian to Middle Devonian strata of the Sylvania Sandstone, Bois Blanc Formation, and related strata ***~15Gt GCS potential***

State	Saline	10% Saline	Coal	10% Coal	Shales	10% Shales	Oil & Gas	10% Oil & Gas	Total	10% Total
Eastern Indiana	807.1	80.7	0	0	0	0	0.14	0.01	807.3	80.7
Eastern Kentucky	108.7	10.9	0.21	0.02	16.8	1.7	6.5	0.65	132.3	13.2
Maryland	95.1	9.5	0	0	0.09	0.009	0	0	95.2	9.5
Michigan	2,160.8	216.1	0	0	41.8	4.2	0.48	0.05	2,203.1	220.3
Ohio	373.4	37.3	0.37	0.04	85.0	8.5	4.2	0.4	462.9	46.3
Pennsylvania	756.0	75.6	0.81	0.08	120.4	12.0	7.6	0.8	884.9	88.5
West Virginia	411.1	41.1	1.1	0.11	189.5	19.0	6.2	0.6	607.9	60.8
Total	**4,712.2**	**471.2**	**2.5**	**0.25**	**453.6**	**45.4**	**25.1**	**2.5**	**5,193.4**	**519.3**

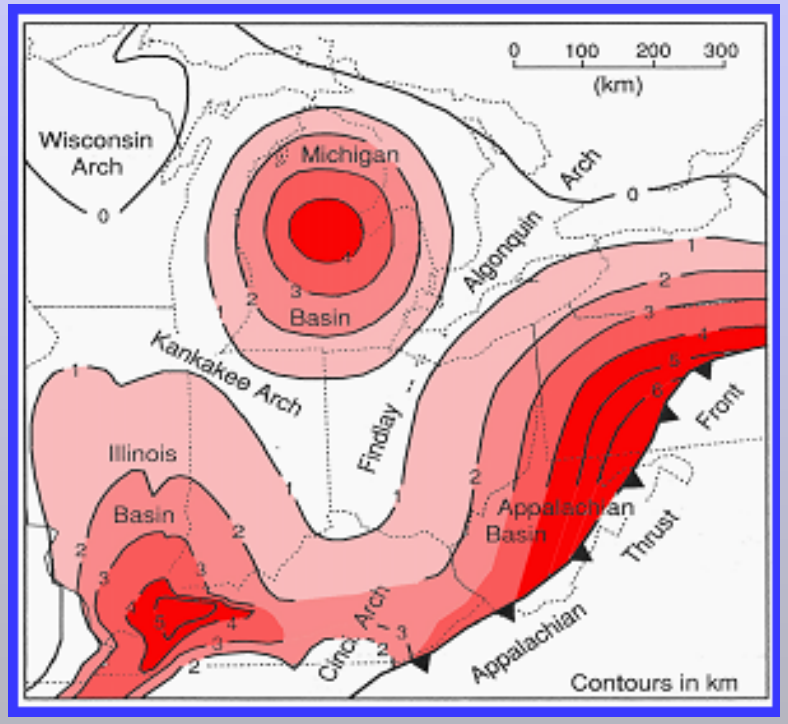
Estimated CO_2 storage capacity by reservoir type and state (in gigatonnes).

From: Wickstrom et al, 5th Ann Conf Carb Seq, DOE/NETL, 2006

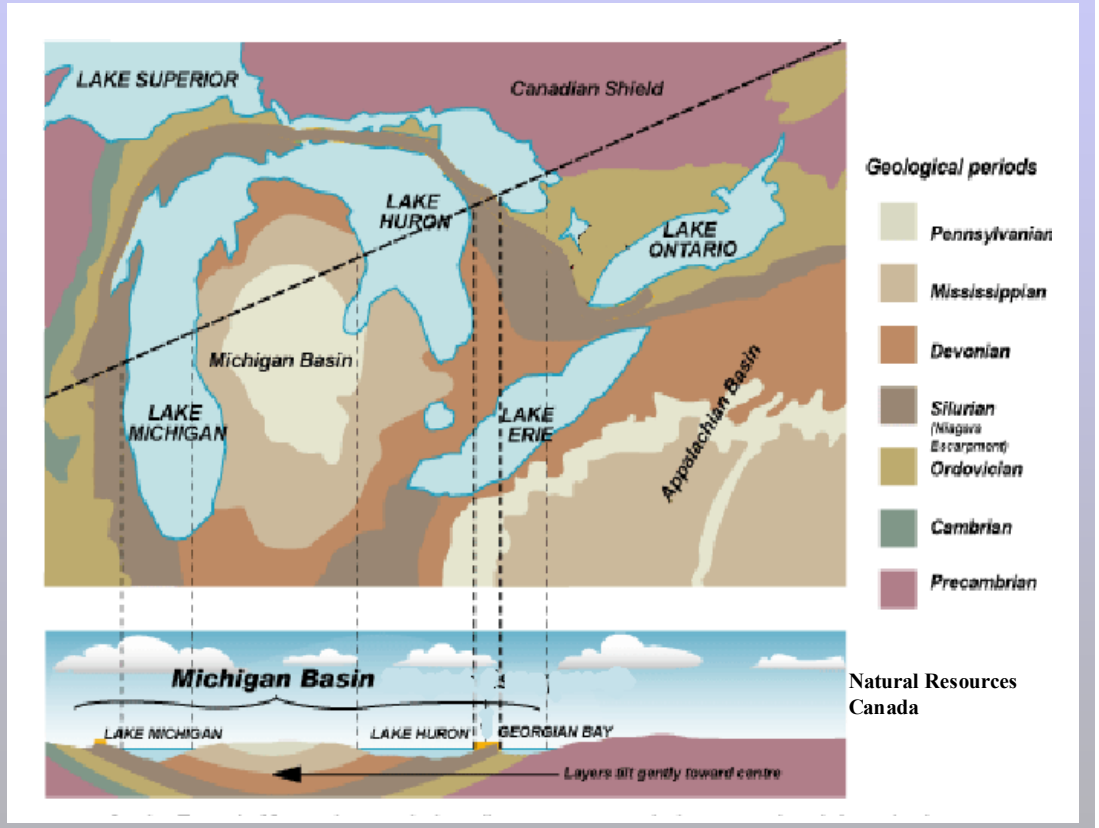
Sequestration Target	Porosity (%)	Density (g/cc)	Gas Content (scf/ton)	Area (mi²)	Total (GT)	10% of Total
Oil and Gas Fields					25.1	2.51
Waste Gate Formation	10			1,342	43.8	4.38
Net Coal		1.32	100	25,578	2.5	0.25
Antrim and Ohio shales		2.62	42.9	109,043	453	45.3
Needmore Shale		2.62	42.9	850	0.5	0.05
Sylvania Sandstone	10			25,324	151.1	15.11
Oriskany Sandstone	10			37,313	194.3	19.43
Medina/Tuscarora SS	8			72,328	705.3	70.53
St. Peter Sandstone	10			41,796	881.3	88.13
Rose Run sandstone	8			57,493	492.7	49.27
Potsdam Sandstone	2			9,298	17.1	1.71
Conasauga Formation	2			24,973	42.5	4.25
Rome trough sandstone	1			18,452	12.3	1.23
Mt. Simon Formation	8			85,916	2,171.8	217.18
Total					**5,193.5**	**519.35**

Summary of estimated CO_2 storage capacity by geologic interval or reservoir type (in giga tonnes).

Michigan Basin Geological Province

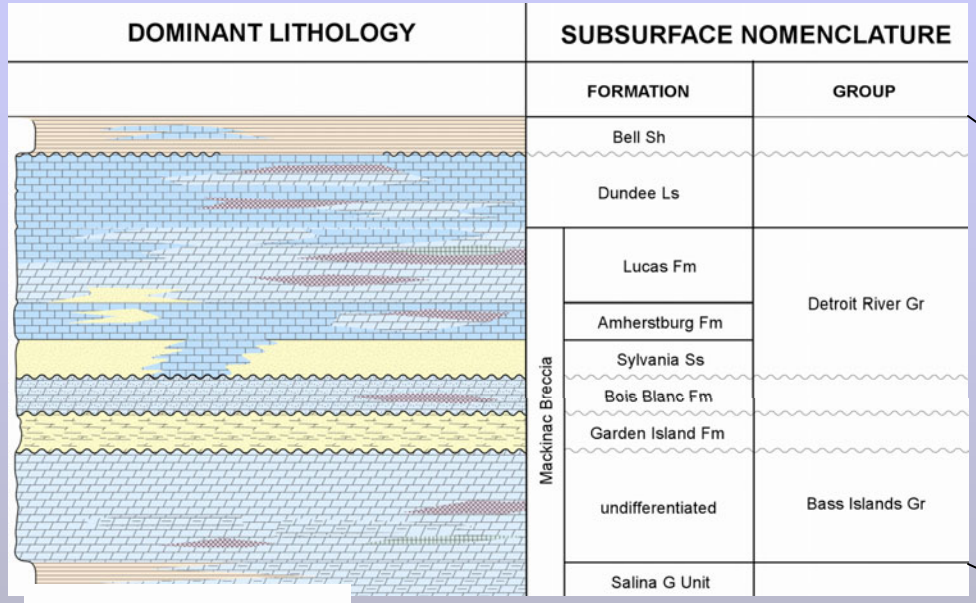


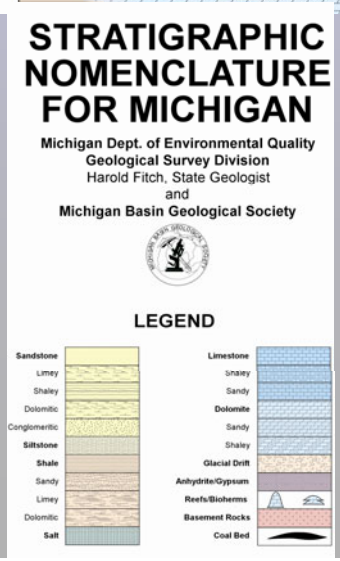
Total Phanerozoic in km; after Howell & van der Pluijm, 1990



- ~260,000 km^2 (100,000 mi^2)
- Up to 4800 m (16,000 ft)
- Mostly Paleozoic sedimentary strata

Middle Silurian-Middle Devonian Stratigraphy – Western MRCSP

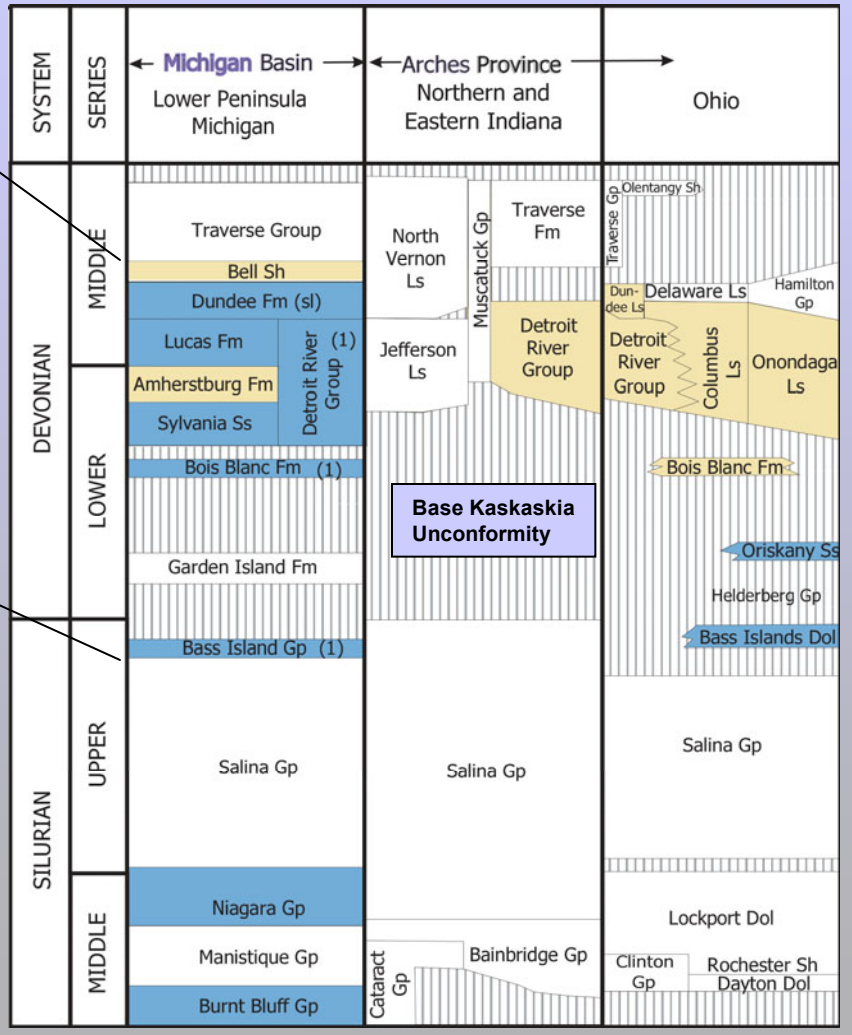




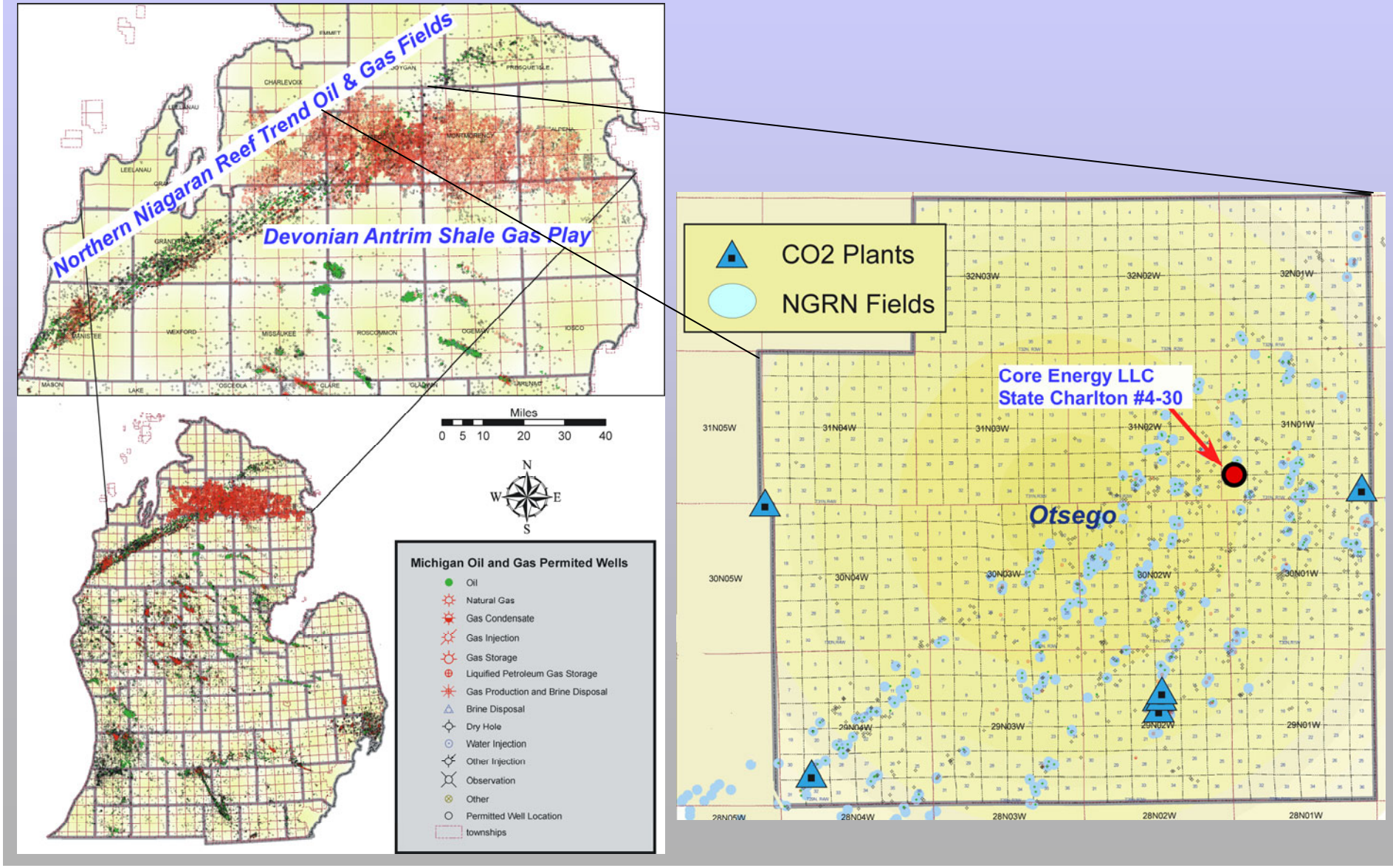
Sequestration Targets

Caprock Units

(1) Contains both Sequestration Targets and Caprock Units

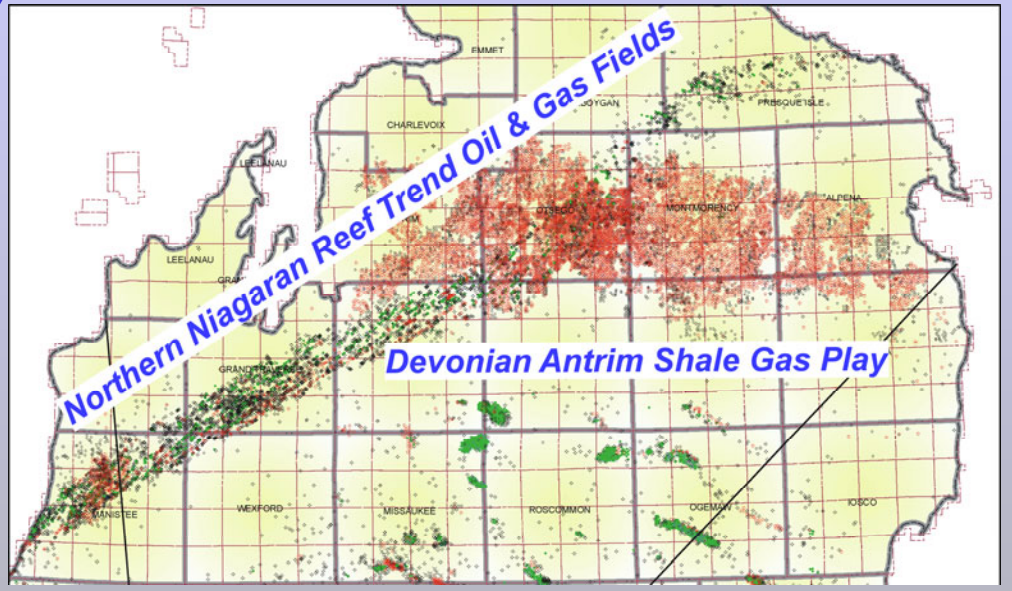


Michigan Pilot Injection Test Well
Otsego Co., Michigan



CO_2 Supply & Existing Subsurface Data

- ***Devonian Antrim Gas Play***
  ~ 2.5TCF cum; 5TCF estimated total recovery
  - Antrim gas CO_2 content ~15-30%
  - CO_2 removed at local gas processing plants
  - ~500-700BCF (30-40Mt) additional CO_2 emissions



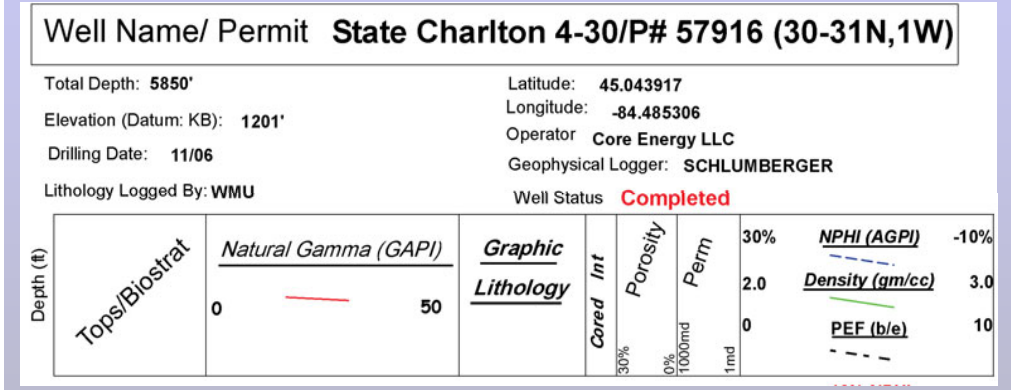
- ***Northern Niagaran (Silurian) Reef Trend***
  - 2000 wells in over 1000 northern reef trend oil and gas fields from reservoirs at depths of 5,000’ to 7,000’

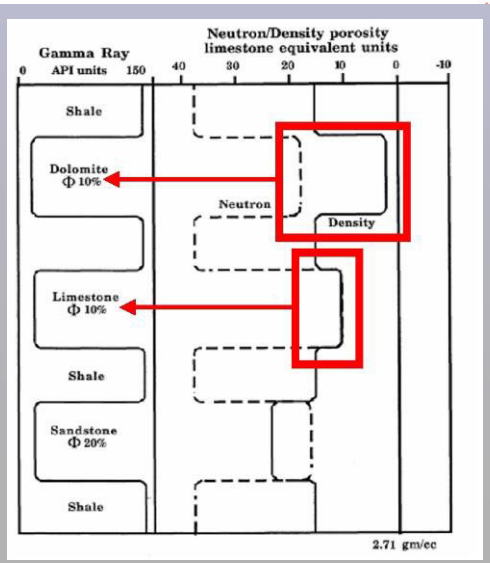
CO_2 Supply Considerations

- Core Energy LLC, is currently taking CO_2 from Otsego Co. gas processing plant emissions stream
  - Currently used for Niagaran CO_2 /EOR
- Core is capable of handling up to ~650 metric tons per day (11 mmcf/day) of CO_2 in their compression and pipeline facilities

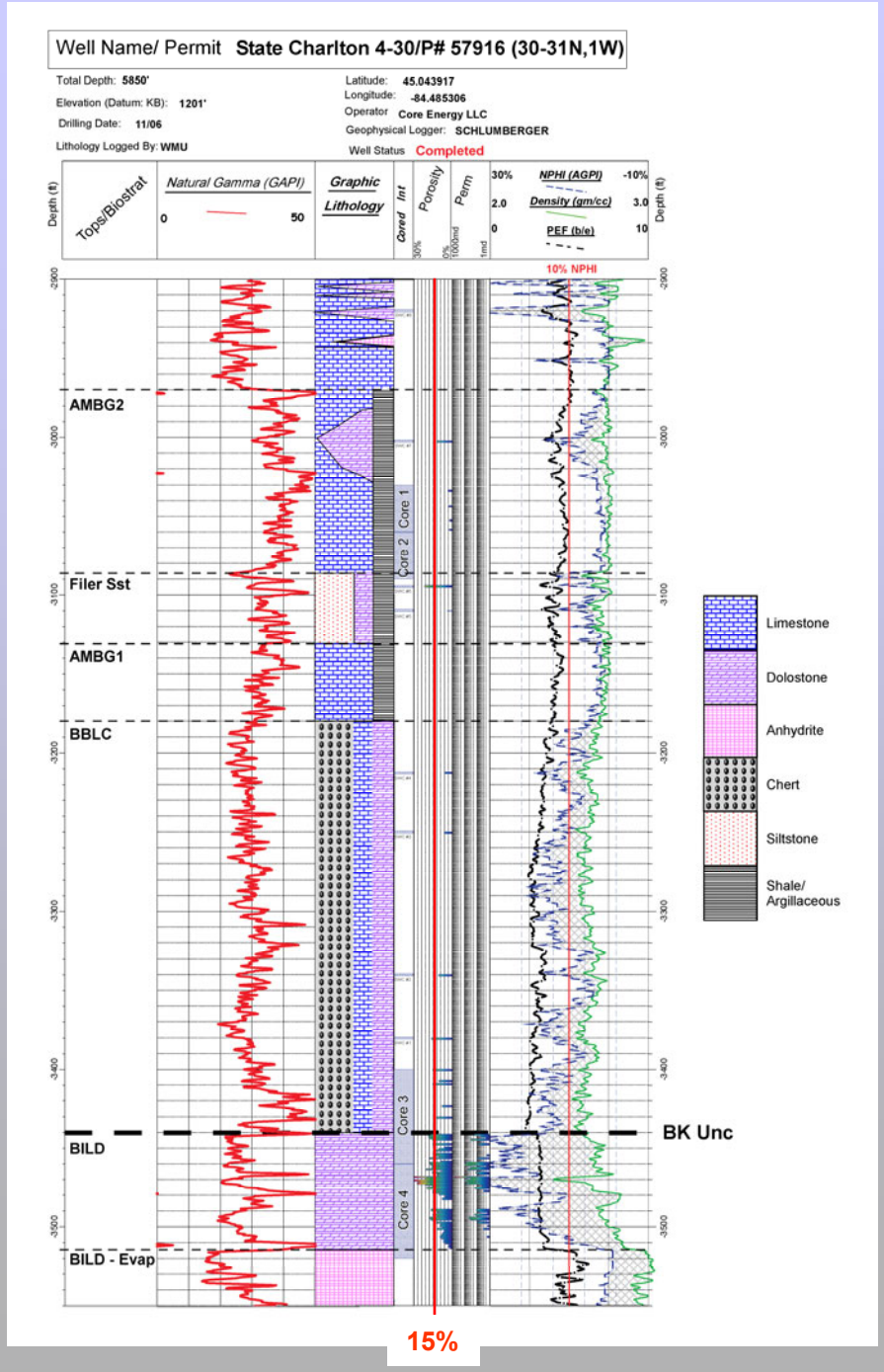
See: Sminchak, and others, this meeting

Analysis of Stratigraphic, Conventional Core, and Log Data in the State-Charlton #4-30

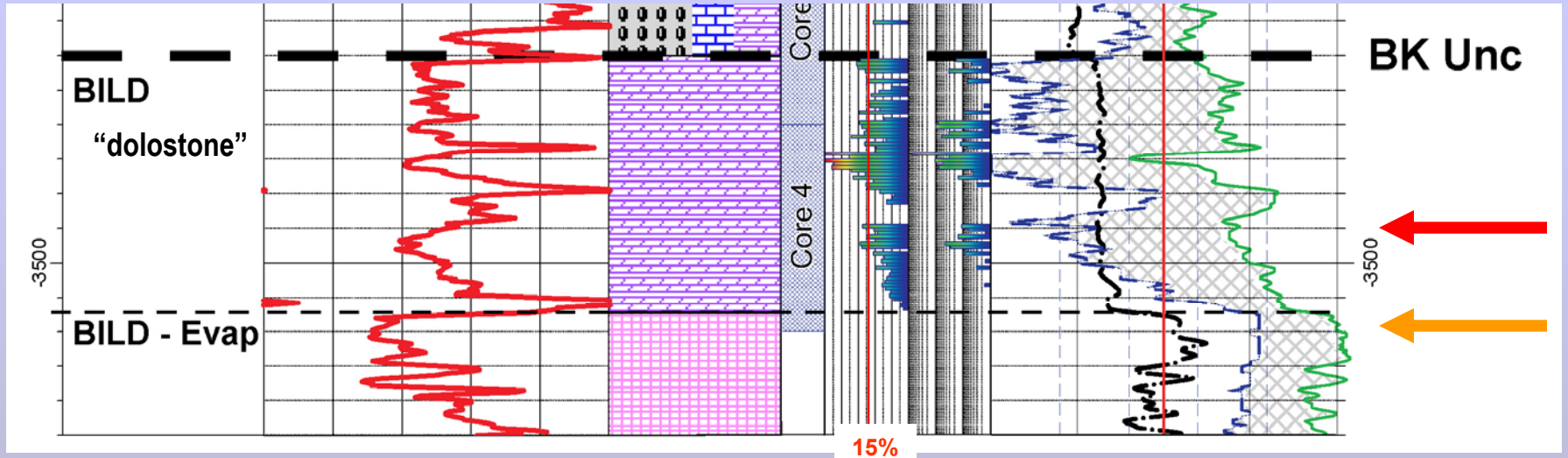


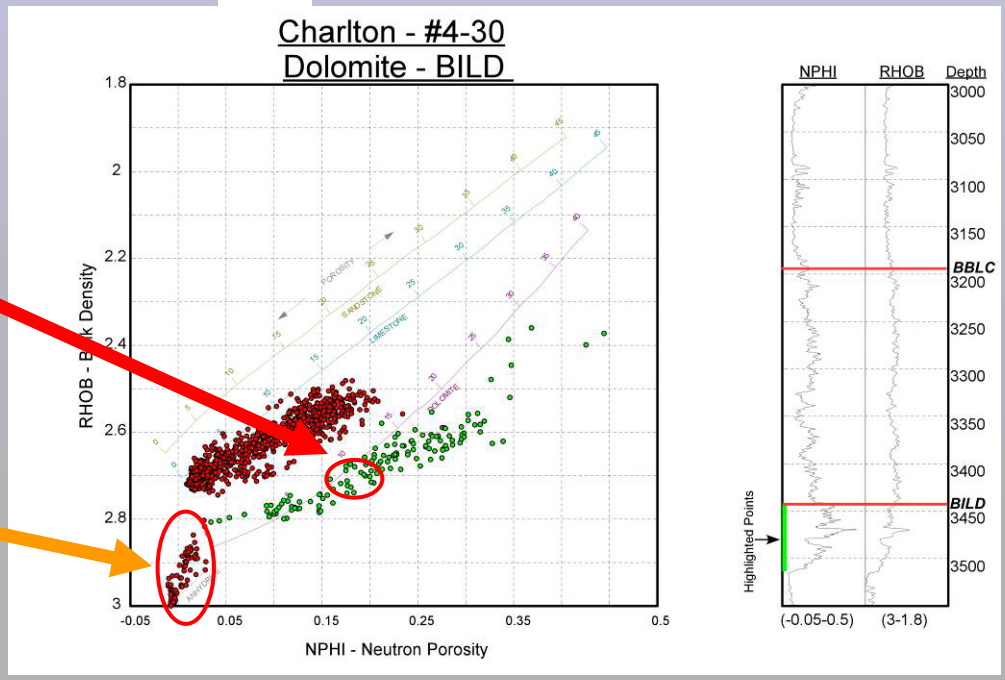


Doveton, 1986

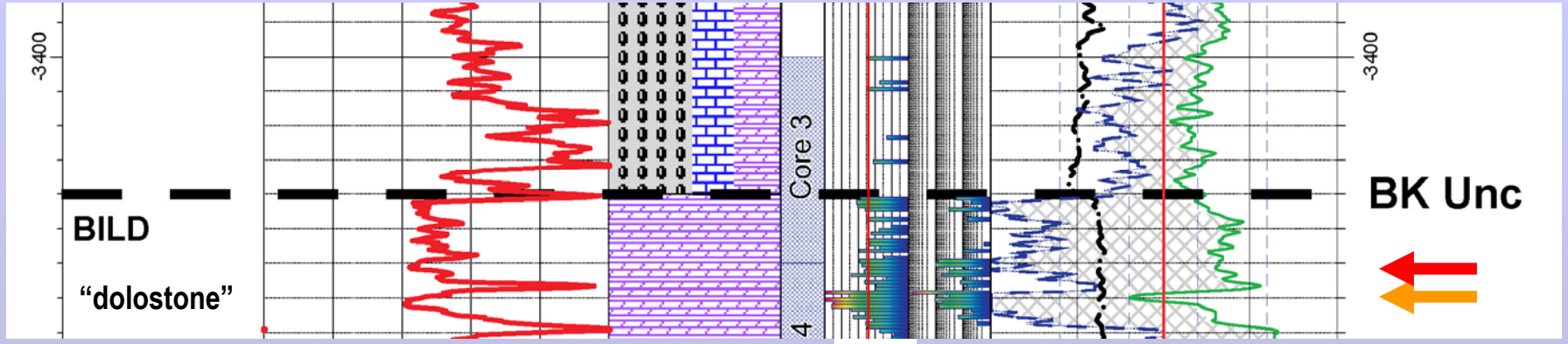


Upper Silurian Bass Islands Gp



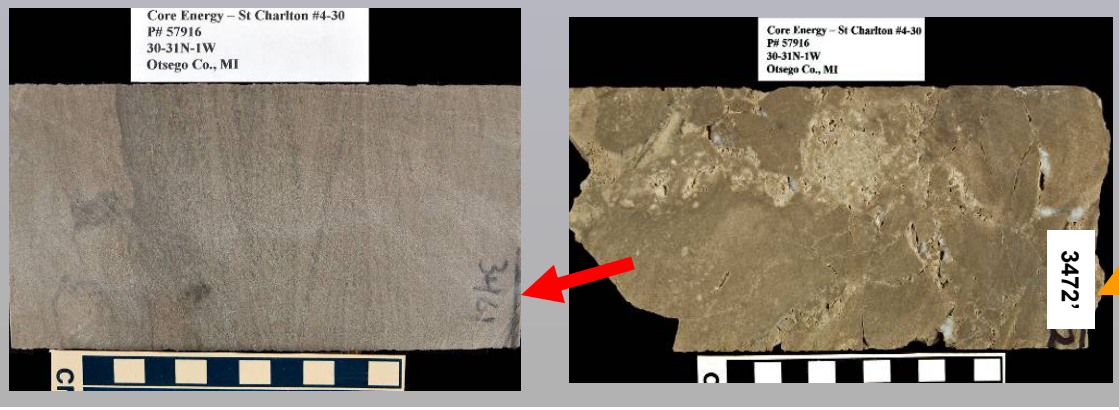


Base Kaskaskia Unconformity



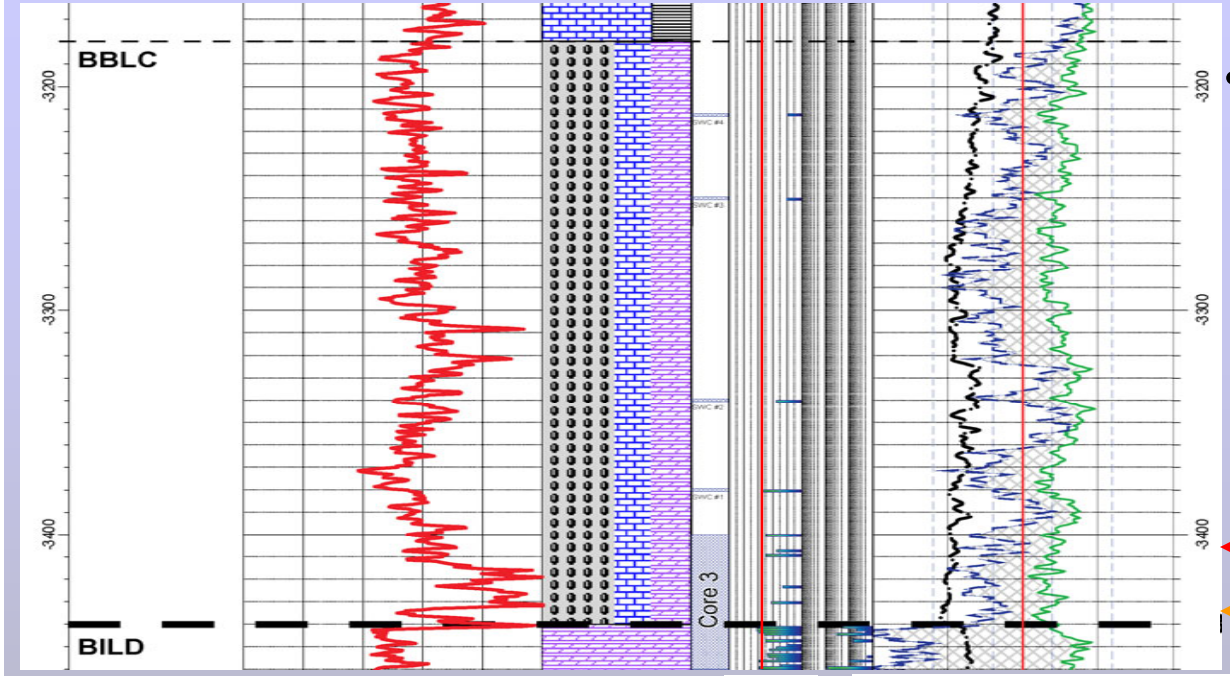
- *Bois Blanc Fm (BBLC)*
  - Fossil lag - Marine Flooding Srfc and transition to BBLC above

- *Base Kaskaskia Unc.*



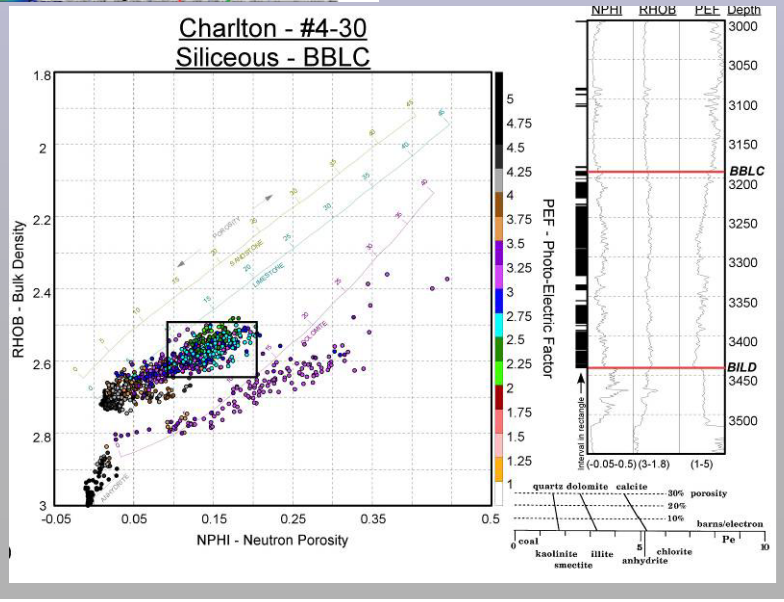
- *Bass Islands (BILD) "dolostone":*
  - Restricted marine; sub-tidal, intertidal to sabhka dolostone facies
  - Karst? Breccias

Lower Devonian Bois Blanc Fm

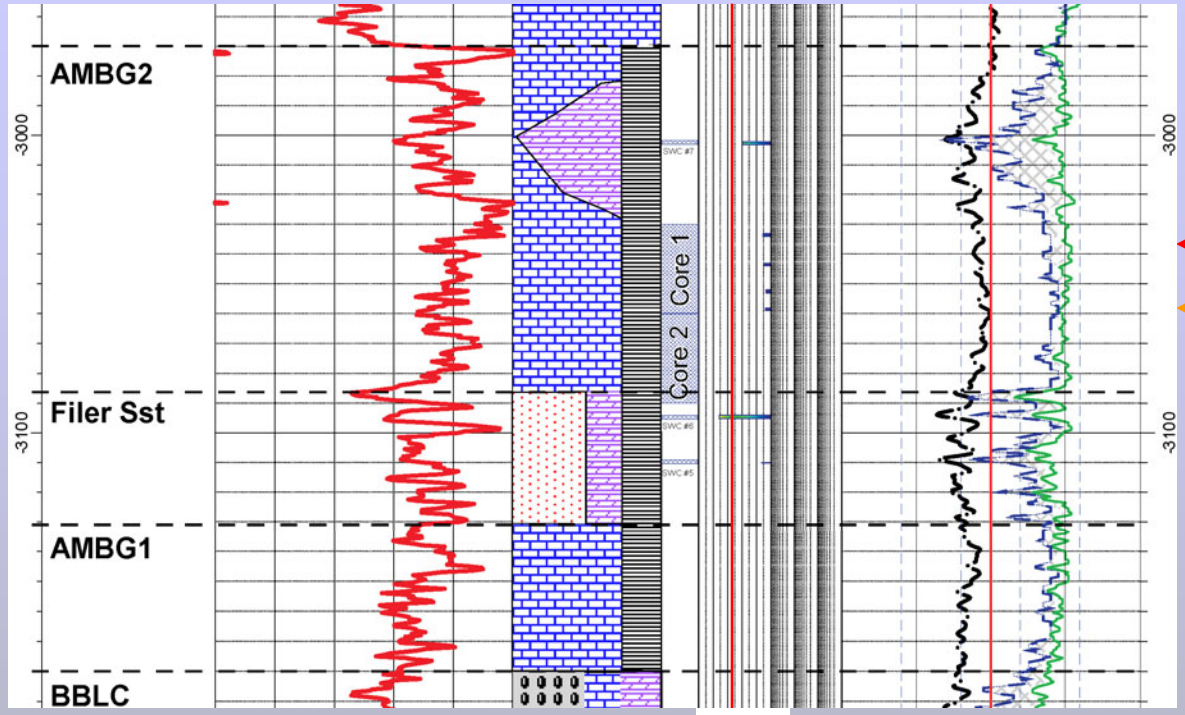


- *Bois Blanc Fm (BBLC)*
  - complex mixture of sparsely fossiliferous, moderately burrowed, chert-rich limestone, cherty dolomitic limestone and dolostone
  - Moderate (micro)porosity

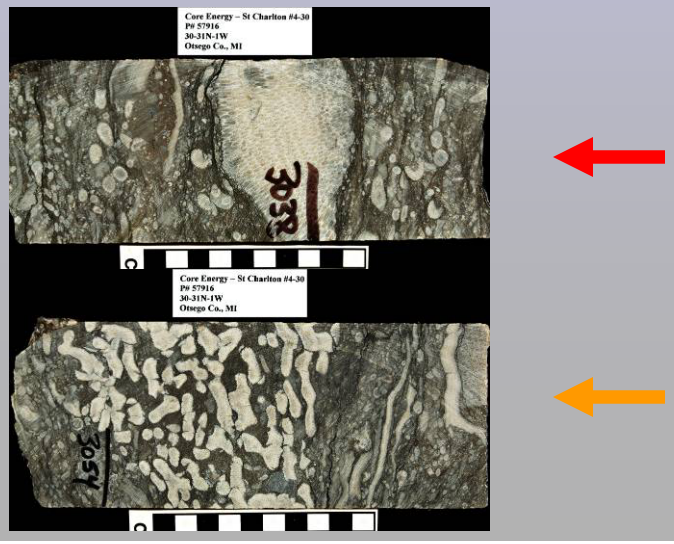
15%



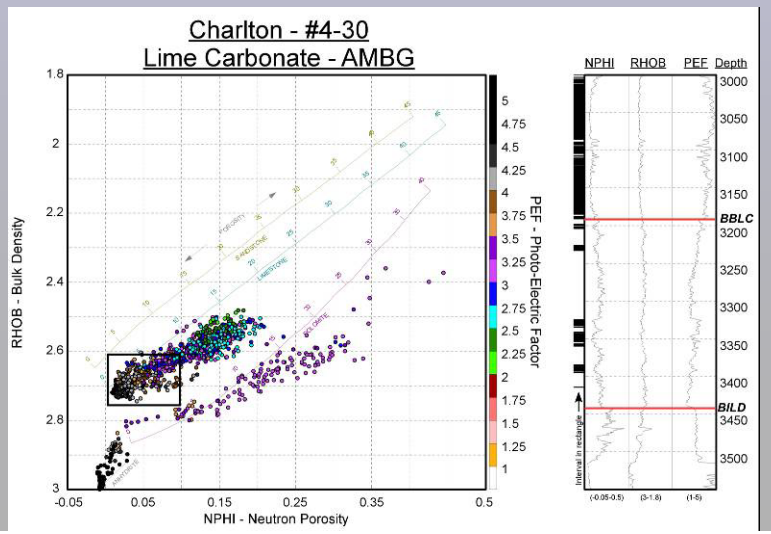
Lower Devonian Amherstburg Fm



- *Amherstburg Fm (AMBG)*
  - fossiliferous, dense, skeletal lime wackestone to mud-rich lime packstone
  - Abundantly fossiliferous
  - Low Porosity
- Filer Sst Tongue
  - Local calc sst, thins to the south & east
  - Mod Ø, low K

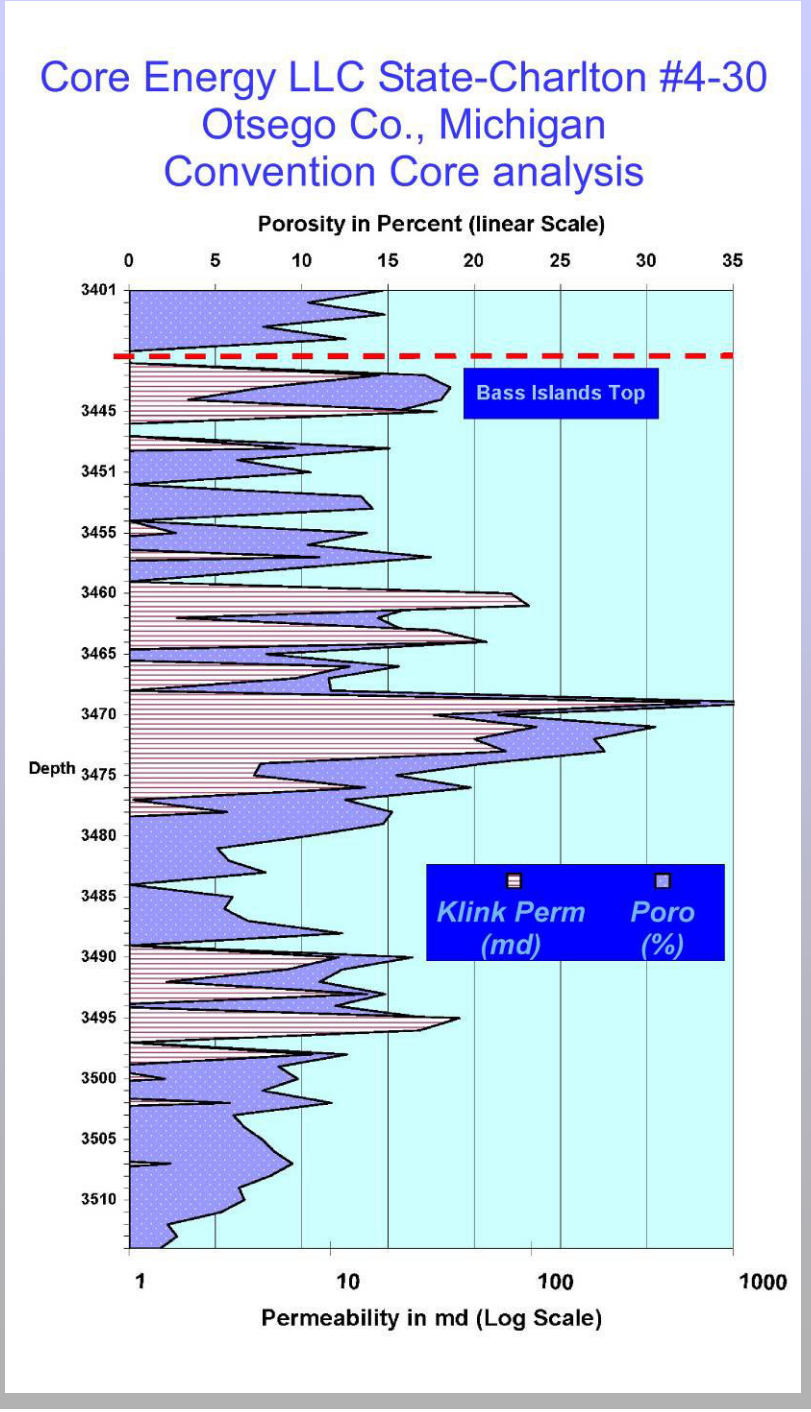


15%



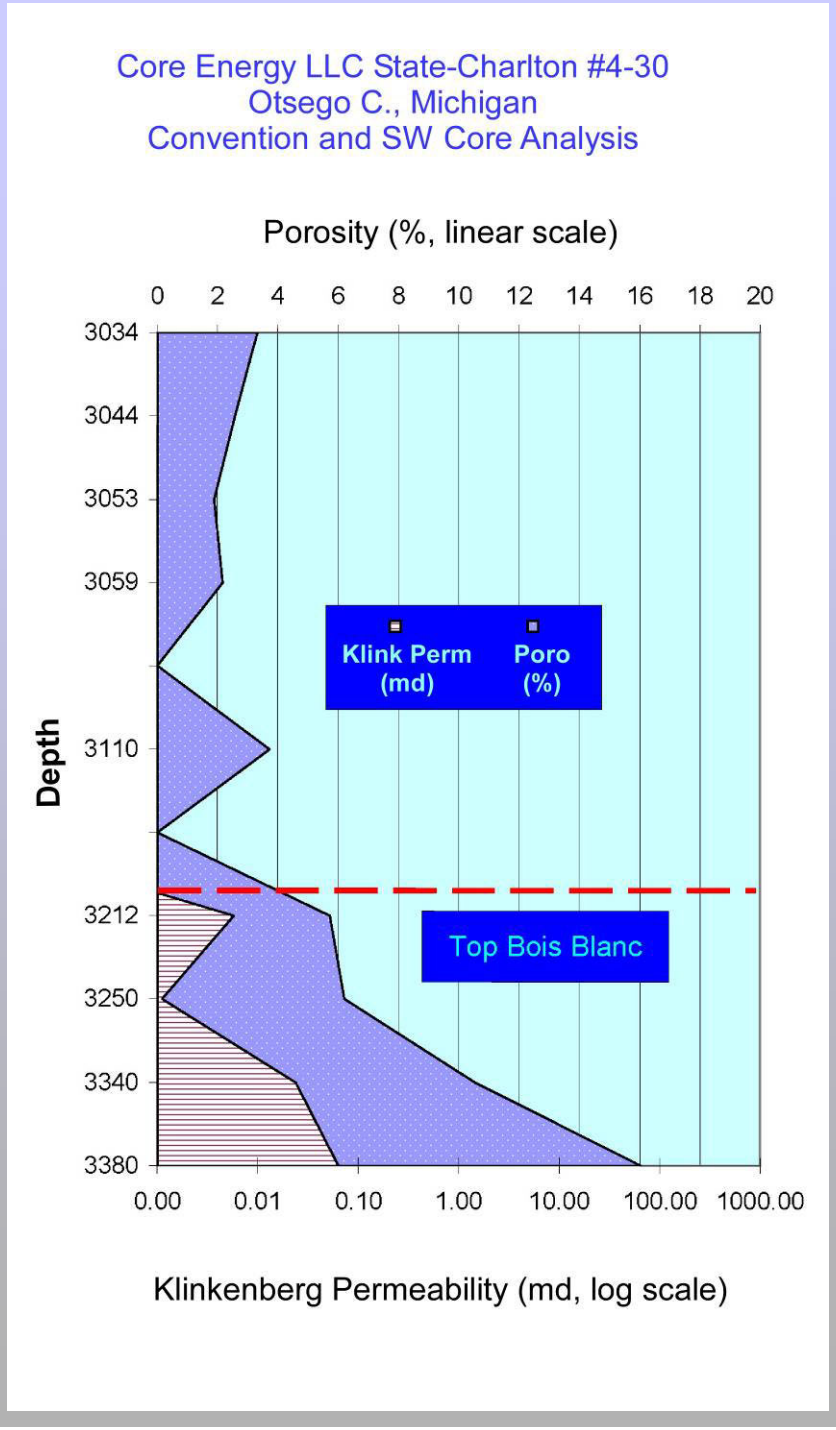
Saline, GCS Reservoir Quality

- ***Bass Islands "dolomite"***
  - Variable Ø to 30%
  - Average Ø ~ 14% (n=54)
  - Variable K to 100md
  - Average K ~25md (n=54)
- ***Bois Blanc Fm***
  - Variable Ø to 15%
  - Average Ø ~ 12% (n=5)
  - Consistent K < 1md
  - Average K ~ 0.1 (n=5)

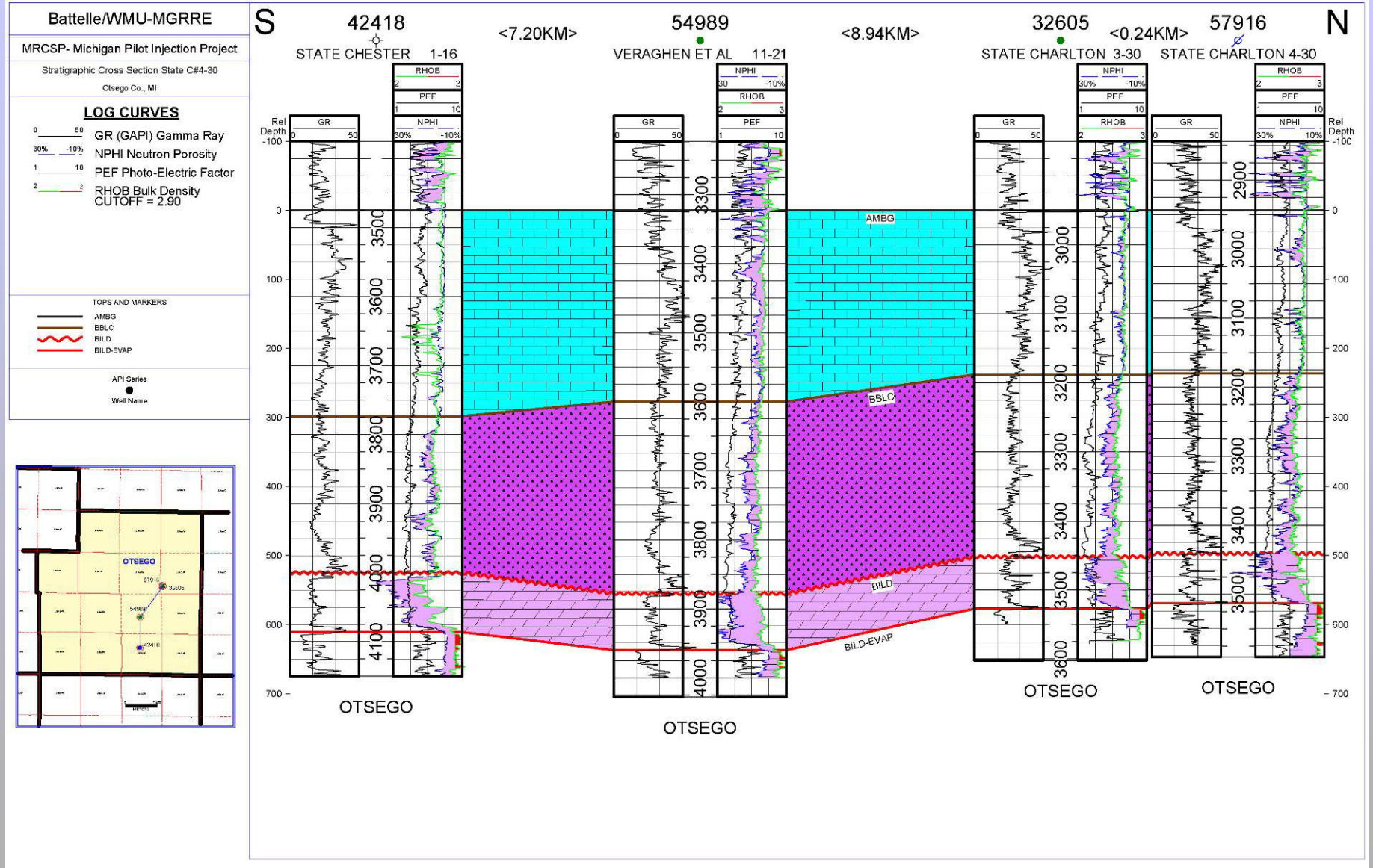


Saline, GCS Caprock Quality

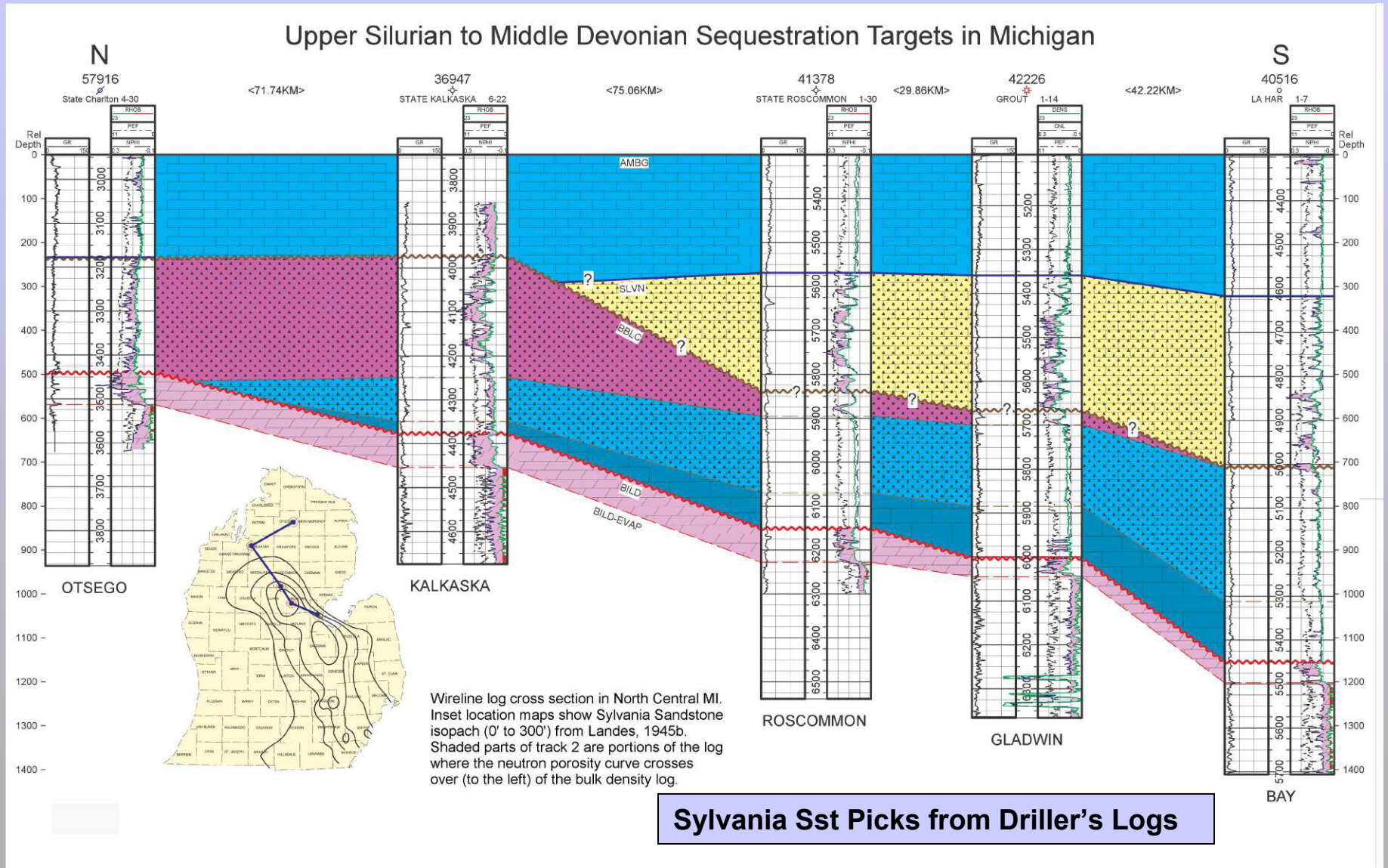
- ***Amherstburg Fm***
  - Consistent Ø < 4%
  - Average Ø ~ 2.5% (n=4)
  - Consistent K << 0.01md
  - Average K << 0.01md (n=4)



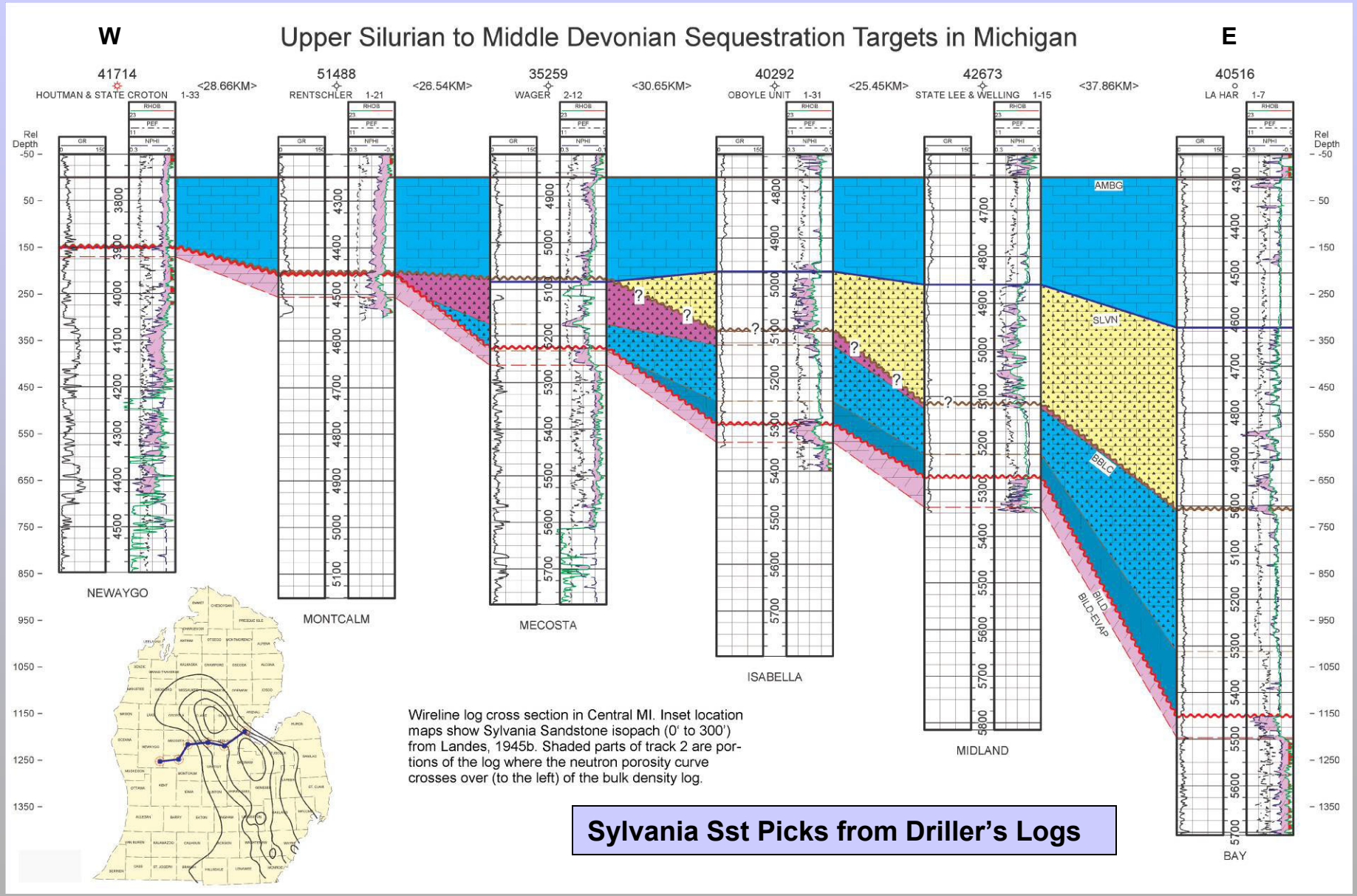
Otsego Co., MI Stratigraphic X-Section



MI N-S Regional Stratigraphic X-Section



MI W-E Regional Stratigraphic X-Section

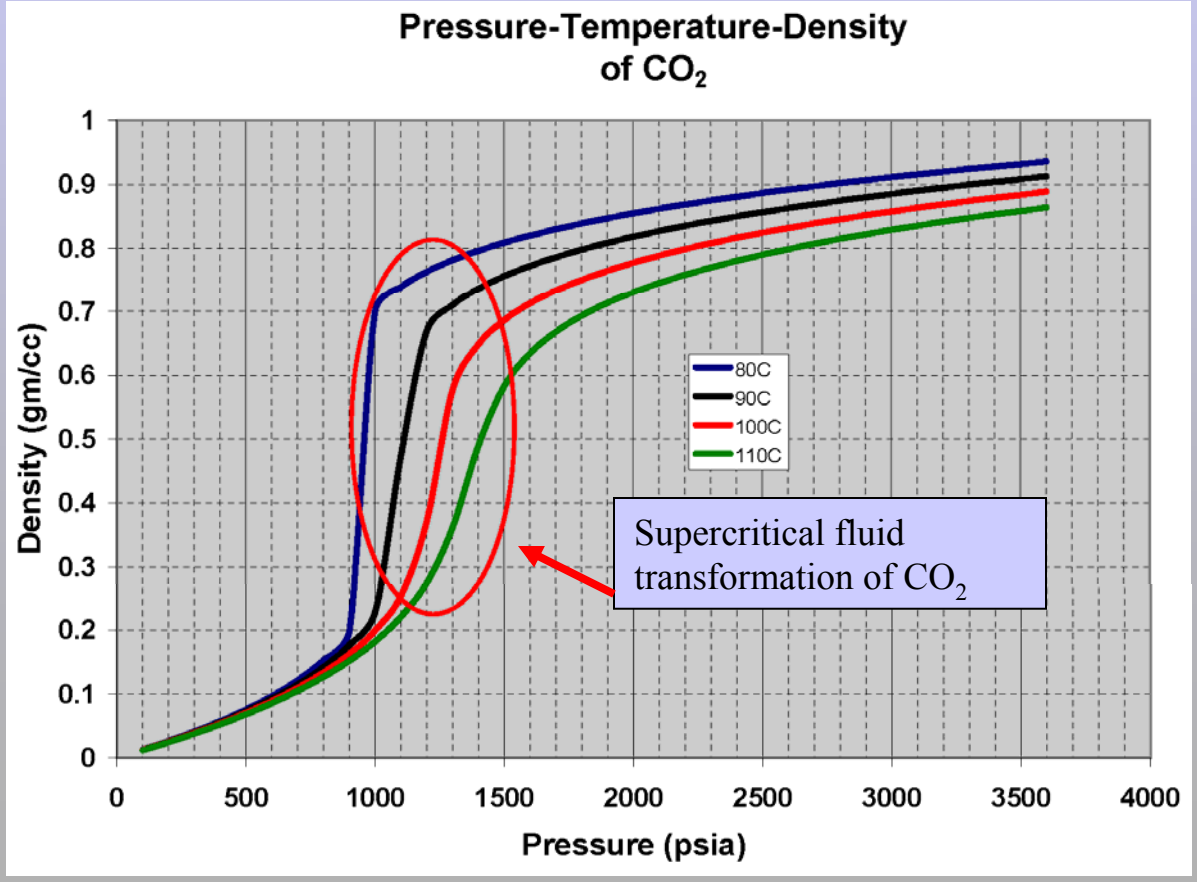


Wireline log cross section in Central MI. Inset location maps show Sylvania Sandstone isopach (0' to 300') from Landes, 1945b. Shaded parts of track 2 are portions of the log where the neutron porosity curve crosses over (to the left) of the bulk density log.

Sylvania Sst Picks from Driller's Logs

P-T Considerations for Supercritical-Displacement CO_2 Sequestration in the Michigan Basin

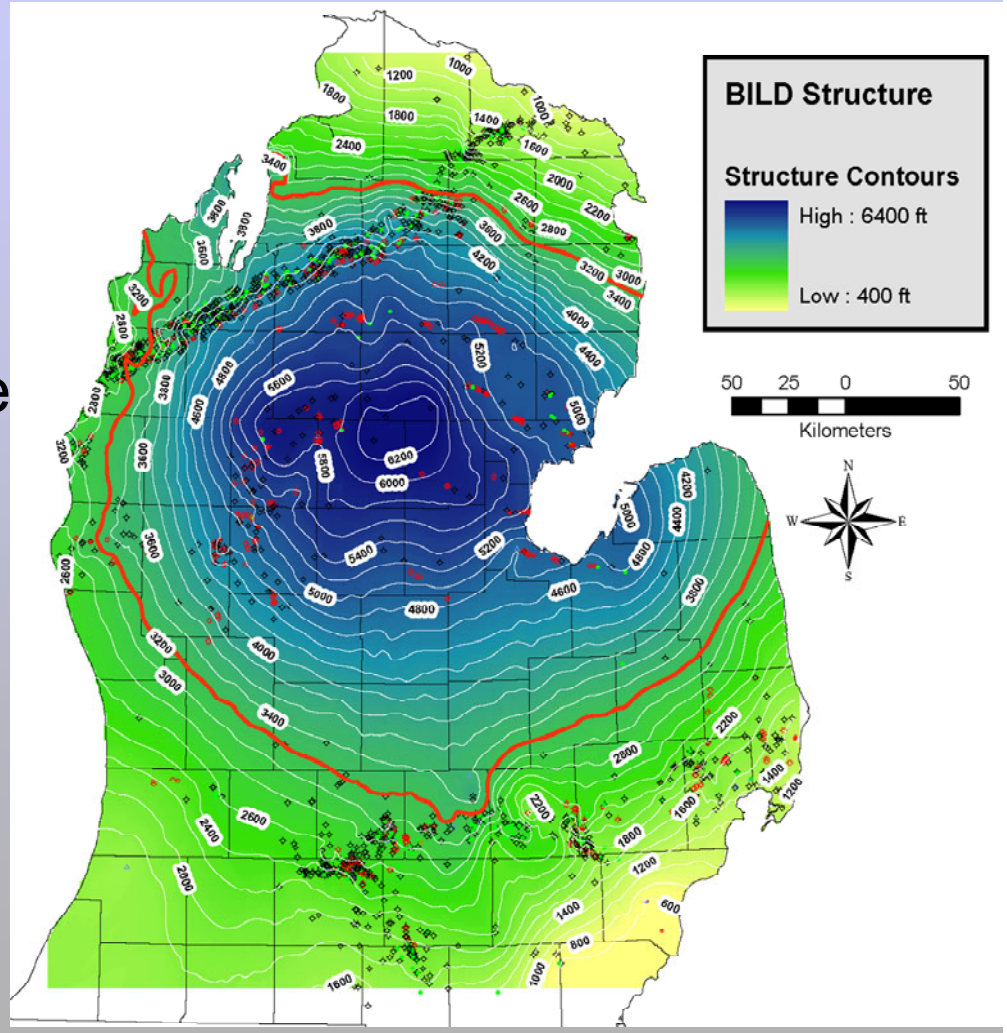
- ***Geothermal Gradient*** ~20°C/km (21°F/1000ft) + 15° surface temp
  → **@1km ~34°C (100°F)**
- ***Hydrostatic Gradient*** ~0.46lbm/ft
  → **@1km ~1500psia**



Pressure/Density relationships of several naturally occurring fluids from R.T. Johns (ed), ***Practical Aspects of CO_2 Flooding***

Measure Depth Structure Contours MSMD GCS Saline Reservoir Targets

- Top Bass Islands “evap”
  - Red contour indicates approximate depth to critical point CO_2 pressure



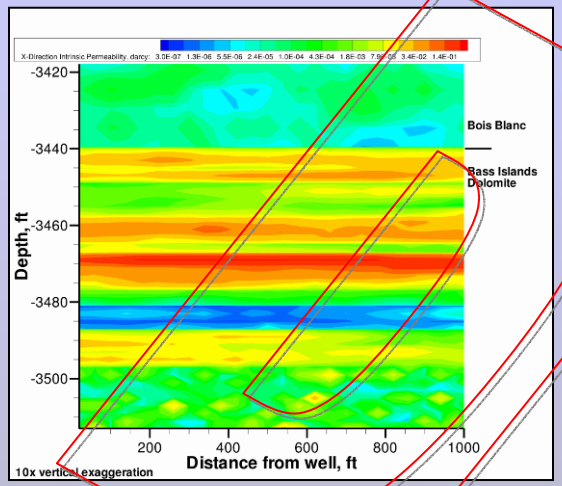
Preliminary Michigan Basin GCS Volume Calculations; Bass Islands "dolomite"

- Estimate of areal extent
  - *46.5 x $10^9 m^2$ [~500 x 10^9 ft^2]*
- Average stratigraphic thickness
  - *~15 m [50ft], from regional cross sections*
- Average Ø
  - *15% from conventional core and wire-line log analysis*
- CO_2 density at critical point pressure
  - *641 kg/m^3 [40lbm/ft^3]*
- Displacement storage efficiency
  - *2-10%*

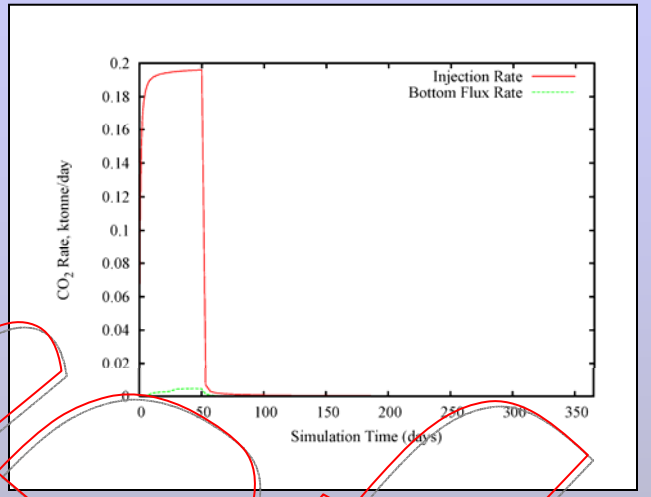
- ***1.4 - 6.8 Gt CO_2 state-wide***
- ***310-1544 metric tons of CO_2 per hectare (125-625 metric tons per acre)***

MRCSP Michigan Basin Test Site: Preliminary Reservoir Simulations For Pilot-Scale Injection Using STOMP-CO_2 Code

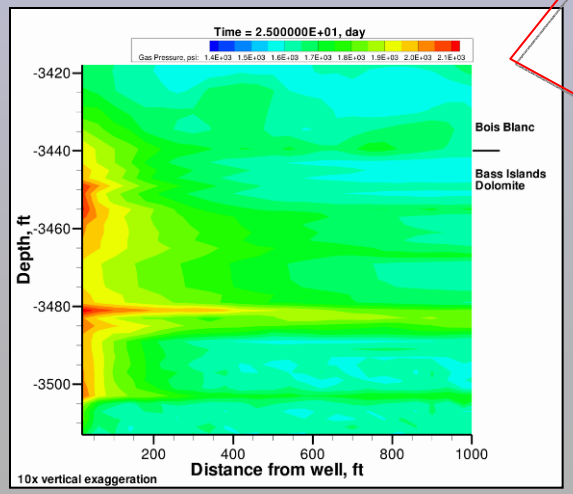
Permeability Distribution



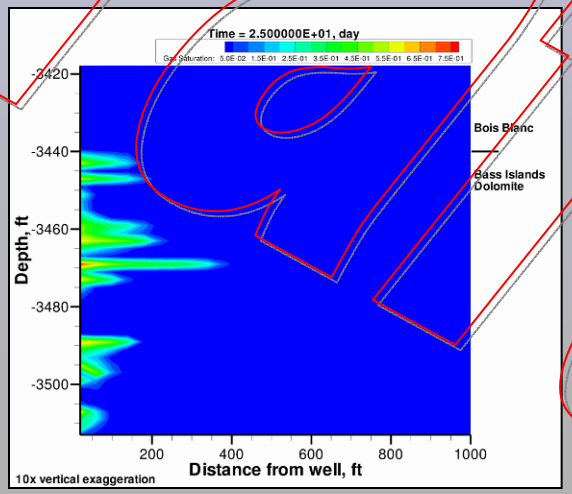
Injection Schedule



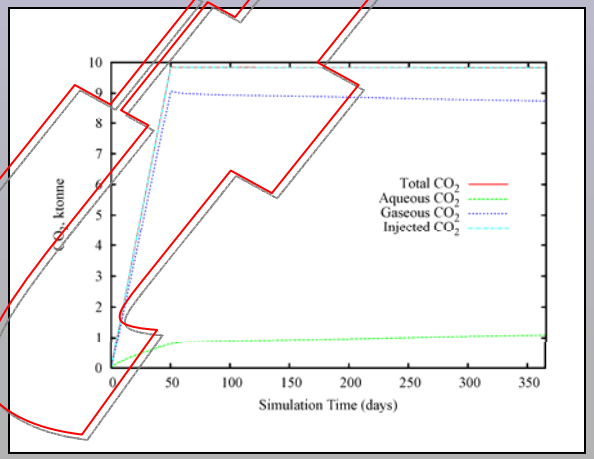
Pressure



CO_2 Saturation



Phase Behavior



(Simulations by - Diana Bacon, Battelle)

Thank You!

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