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**Michigan Basin, MRCSP
Otsego Co. Geologic Field Test Site**

Presented By: Neeraj Gupta, Battelle

*Regional Carbon Sequestration Partnerships
Initiative Review Meeting
December 12-13, 2007, Pittsburgh, PA*



**Michigan Basin- Otsego County
Test Site Project Team**



Abed Houssari, Becky Cook, Steve Rawlings, and others



Dave Barnes, Bill Harrison, Sue Grammer



Dave Ball, Neeraj Gupta, Phil Jagucki, Joel Sminchak, Danielle Meggyesy, Judith Bradbury, Bob Janosy, Jackie Gerst, Diana Bacon, Mark Kelley, Bruce Sass, and others



Lynn Brickett, Charlie Byrer, Art Wells, Dave Wildman



Robert Mannes, Joe Herpst, and Jane DeVeaux



Mark Zoback and Laura Chiamonte



Dwight Peters

*Additional Contributions by Numerous Other MRCSP Team Members
Outreach support by Sarah Wade, AJW Inc.*

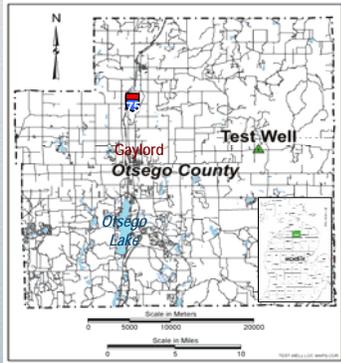
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Michigan Basin- Otsego County Test Site



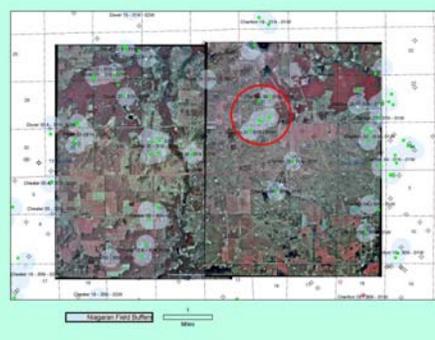
- Charlton 30/31 field, S. Dover/N. Chester Township, Otsego County, Michigan
- The location is at Core Energy gas fields in the vicinity of a DTE gas processing plant outside of Gaylord, Michigan
- Michigan Basin has significant sequestration potential



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Michigan Basin- Otsego County Site



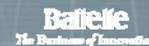
- Near DTE gas processing plant
- Gas produced from Antrim Shales
- 8-mile CO₂ pipeline for EOR in deeper Niagaran Reefs



- State-Charlton 30/31 Field
- Natural gas produced from Antrim gas play at depths of 1100-1500 ft.
- Oil production from deeper Niagaran Reefs at a depth of 5000-6000 ft.



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Michigan Basin CO₂ Source



- CO₂ available from DTE gas processing plant
- Antrim Shale gas contains 15-30% CO₂ and is removed in amine based separation process
- Relatively pure CO₂ (99%) stream
- CO₂ periodically used for EOR floods in Niagaran Reef oil fields



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Michigan Basin- Public Outreach



- Winter 2006: Coordinated with partners DTE Energy, Core Energy and Western Michigan University in planning interactions and developing informational materials to introduce the project and describe future drilling and other activities
- Summer 2007: Conducted an Open House for nearby residents in collaboration with DTE Energy, Core Energy and Western Michigan University, including a series of exhibits, seismic video and take-home materials, as well as opportunities for one-on-one discussions with technical staff

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Site Characterization- Test Well Drilling



- Test well drilled October 30 – November 22.
- Total depth = 5,800 ft into Niagaran Reefs.
- Target zone of interest was 3200-3500 ft.



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Site Characterization- Test Well Drilling



- 180 ft of full core collected across injection zone and caprock.
- Full suite of wireline logs run in target interval.



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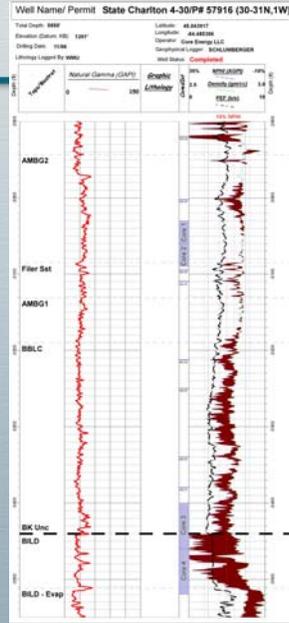
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Site Characterization- Test Well Drilling

- Injection Target = Bass Islands Dolomite
- Total Storage Interval = Upper Bass Islands-Bois Blanc
- Confining Layer = Amherstburg



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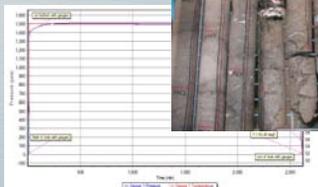


Site Characterization- Core Tests and Well Tests

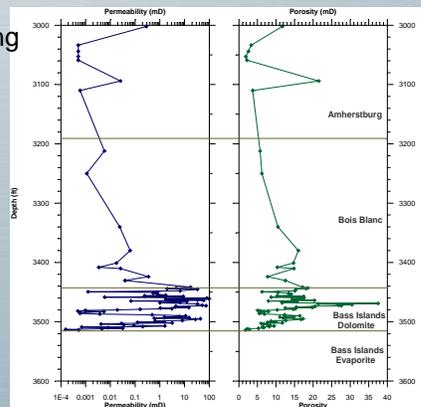
- Primary target = Bass Islands Dolomite.
- Containment layers: Bois Blanc - Amherstburg-Lucas anhydrite-carbonate formations
- Swab reservoir test data from monitoring well confirms permeability at ~4-18 mD.

Depth = 3441-3515 ft.
Avg. Porosity = 13%
Avg. Permeability = 22.6 mD.

Bass Island Rock Core



Swab Test Data



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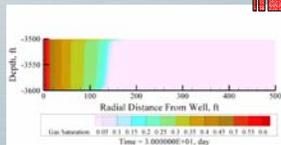
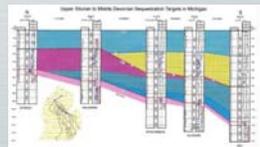
STOMP_{CO2} Reservoir Simulations



- STOMP_{CO2} simulations were completed based on test well data.
- Results will be calibrated to test data to improve model capabilities.

MRCSP Michigan Basin State-Charlton 30/31 Field Test Site

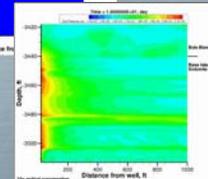
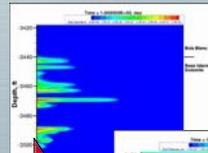
Preliminary Modeling Based on Regional Data



Site Drilling and Testing



Site Specific Modeling



Next step....calibrate to field monitoring data

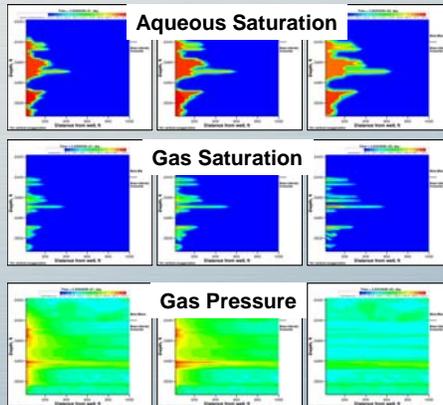
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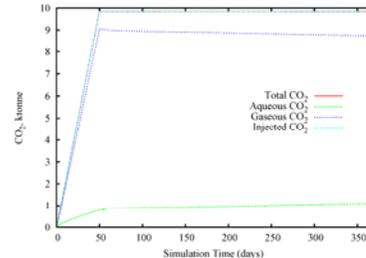
STOMP_{CO2} Reservoir Simulations



- STOMP_{CO2} results used for MMV program, permit support, site closeout strategy, and many other items.
- Results will be calibrated to test data to improve model capabilities.



Bass Islands Dolomite CO₂ Phase Behavior



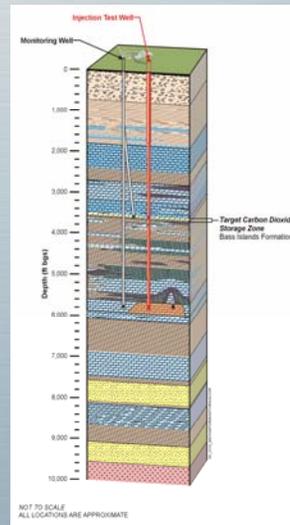
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Injection System



- CO₂ injection testing and monitoring plan for the Otsego County site is to inject a fairly significant volume of CO₂ (10,000 tonnes) because a clear source is available from nearby gas processing plant.
- This should allow for more meaningful monitoring of the injected CO₂ such as cross-well seismic and acoustic emissions.



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MMV Program



Well Monitoring

Pressure

Temperature

Acoustic Emissions

Rutledge, et al. "Faulting Induced by Forced Fluid Injection..." BSA, Vol. 34, No. 5, P 1617-1630, 2004.

Wireline Monitoring

Figure Courtesy of Schlumberger

Brine Chemistry and Fluid Sampling

Government Required Monitoring
 Research Monitoring

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Injection System



- CO₂ to be routed from compression facility via “white frost” pipeline to the injection site.
- A flow line from the main pipeline to State-Charlton 4-30 well has been installed. Flow line will be equipped with a CO₂ flow meter.
- Pressure/temperature gauges will be installed in injection and monitoring well.



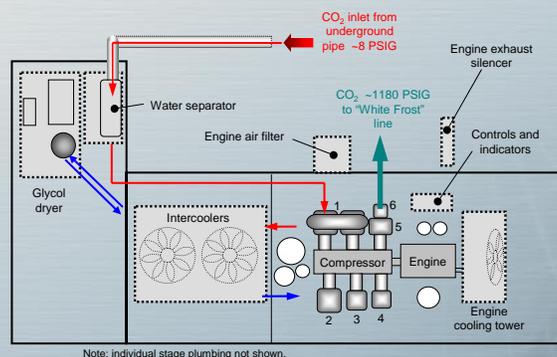
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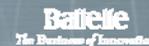
Michigan Site Compression



- Compressor site layout (one unit shown)



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Michigan Site Compression



1



2



3



4

- (1) CO₂ source from amine capture system (DTE's Turtle Lake Gas Processing Facility).
- (2) Inlet pipe at ~8 PSIG entering compression building from the underground pipeline.
- (3) Water separator to remove liquid.
- (4) Suction pressure control valve.

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Michigan Site Compression



5



6



7



8

- (5) Intake water separator shown for first stage.
- (6) First stage compression utilizes two throws. After compression flow goes to intercooler.
- (7) Intercooler as viewed from bottom. The fan is visible.
- (8) Subsequent 2nd, 3rd, and 4th stage compression. Each has an intake water separator, and intercooling is performed between each stage.

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Michigan Site Compression



9

10

11

- (9) Triethylene glycol contactor tower for dehydrating after 5th stage
- (10) The 5th and 6th stages are combined on one throw. The final ~1180 PSIG flow goes to:
- (11) The "White Frost" supercritical pipeline. (A pig kicker is on the left, the pipeline is on the right.) The pipeline goes to an oil processing facility, from where a slipstream is taken for injection into the MRCSP well.

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Michigan Site Compression



- **Compressor type:** Ariel reciprocating separable compressor
- **Compression design:** 6 stages on a 6 throw compressor. The first stage uses two throws in parallel. Stages 2 to 4 each use one throw. Stages 5 & 6 are combined into one throw.
- **Drive:** Caterpillar natural gas engine, 2250 hp, water-air cooling tower
- **Intercooling:** Gas to air heat exchanger after every compression stage. Heat exchangers are together inside an air tower driven by two large axial fans.
- **Drying:** Water separator at suction pipe, water separators before each compression stage, TEG (triethylene glycol) contact tower after 5th stage.
- **Inlet:** ~8 psig, 70-80°F
- **Outlet:** ~1180 psig, 85-95°F
- **Flow rate:** 5.0 MMSCFD per unit (million standard cubic feet per day), only a small portion goes into the MRSCP well

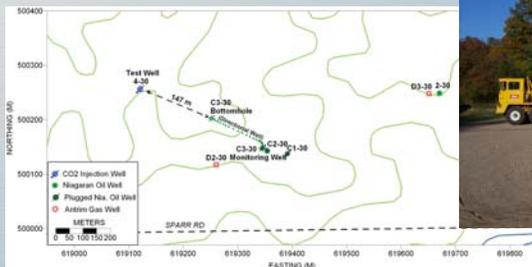
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Monitoring Wells

- C3-30A will be used as a monitoring well for acoustic emissions, crosswell seismic, downhole pressure/temp. gauges, and fluid sampling
- 2-30 will also be used as a monitoring well for acoustic emissions.



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Crosswell Seismic Survey

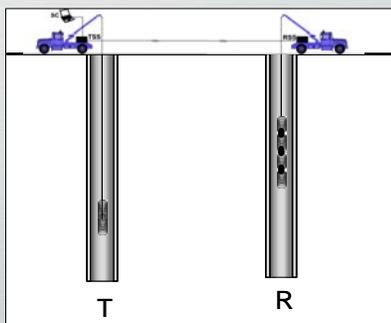


Figure Courtesy of Schlumberger

- Geophysical technique conducted with receivers down one well completed in the injection reservoir and sources down another creating an image between the two wells
- Measures the change in velocity due to the presence of CO₂ with a possible resolution of approximately 10 feet

- Subsequent survey will be compared to the initial survey to track the movement of the CO₂.

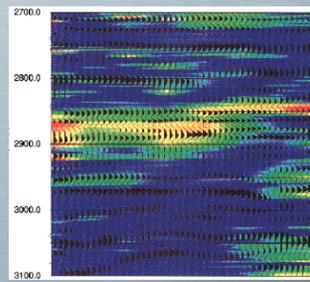


Figure from Lazaratos and Marion, The Leading Edge, 3/97

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Crosswell Seismic Current Status



- Baseline survey was performed October 21-23, 2007
- Initial look at data parameters shows promising results
- Processed data will be finished in December



Parameter	Preliminary Value
velocity	19,000 ft/s
wavelength	16-192 ft
best case scenario resolution	4 ft

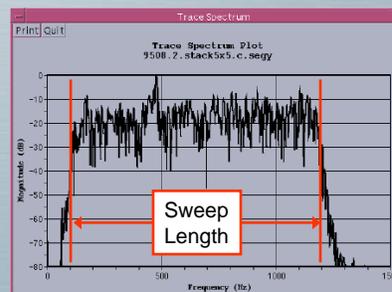
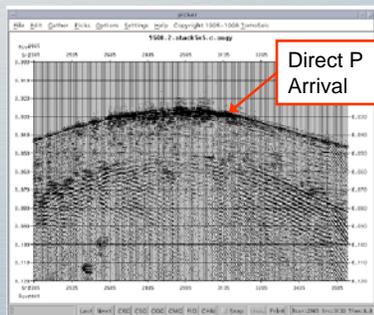
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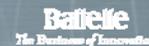
Raw Crosswell Seismic Data



- Data quality appears excellent
 - High signal to noise ratio indicated by clear first arrivals
 - Entire sweep (100-1200 Hz) was recovered at high magnitude



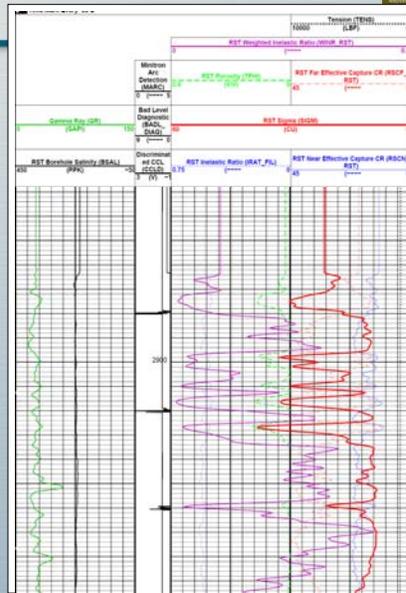
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Reservoir Saturation Tool



- Baseline survey performed at MRCSP's Michigan Test Site
- Tool run in both Sigma (capture cross-section) and C/O (carbon to oxygen ratio) modes
- Field data appears to be adequate for repeat survey
- Data is currently being processed
- Some surprising results seem to indicate higher salinity/TDS than originally expected
 - Fluid sample analysis is being conducted to confirm these results



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Acoustic Emissions

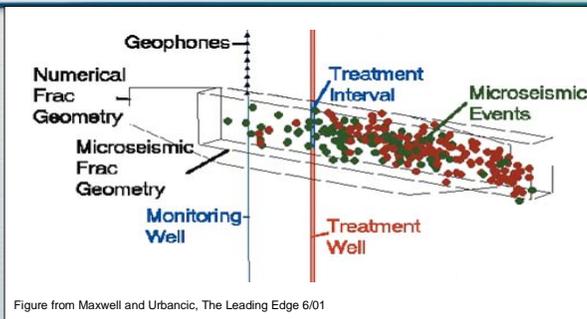


Figure from Maxwell and Urbancic, The Leading Edge 6/01

- Geophysical technique that employs a passive, permanent, downhole hole array that continuously records data Records and locates the small micro-seismic events caused by the CO₂ plume moving through the rocks
 - Can be used to monitor caprock integrity (ie. No events occurring in the caprock imply no CO₂ is present)?
 - Can be used to monitor the movement of CO₂ in the injection zones

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Geomechanical Analysis



- We've been working with Stanford University to develop a geomechanical model



- Data from the wireline Formation MicroImager tool, sonic logs and regional formation testing help determine the stress orientation at the site.
- This will help to track the CO₂ plume and predict stability

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Michigan Test Site Tracers



- The Michigan site has multiple sources of CO₂, which would make surface detection techniques very difficult.
- NETL is utilizing perfluorocarbon tracers (PFTs) at the wellhead and monitor points for leak detection.



16 SVE Points at Michigan Basin Site



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Permitting Track



- Working closely with US EPA Region V Underground Injection Control program and State of Michigan
- Class V UIC permit application submitted in April 2007.
- No technical issues found by EPA.
- Public comment period during mid-July to August 23, 2007
 - Received one comment regarding land/mineral rights and trespass issues
 - US EPA provided a written response noting that these issues are outside the UIC permit.
- Permit "Final" on September 23, 2007
 - An Appeal was filed with the Environmental Appeals Board, US EPA Headquarters
 - Region V provided a response to EAB by November 3, 2007
 - Based on precedents, the anticipated outcome is that the Board will not accept the appeal for a decision
 - This appeal provides an important example of a major institutional issues to be encountered by every site

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Status for the Michigan Basin Site



- Site characterization (complete)
- Permitting (pending)
- Test Well Drilling/retrofitting (complete)
- Baseline Monitoring (complete)
- Injection testing and monitoring
- Post injection and closure

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