



EERC

EERC Technology... Putting Research into Practice

The Plains CO₂ Reduction (PCOR) Partnership

Beaver Lodge Field Validation Test Overview

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Pittsburgh, PA

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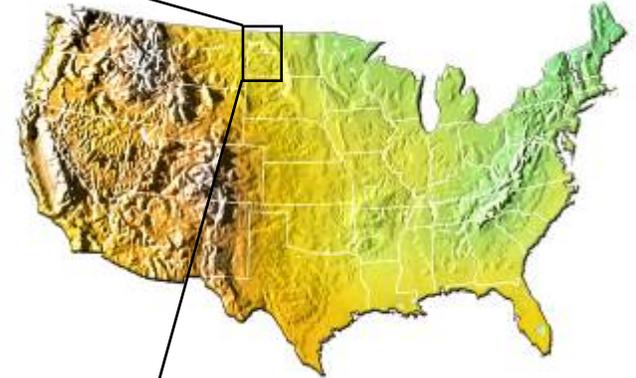
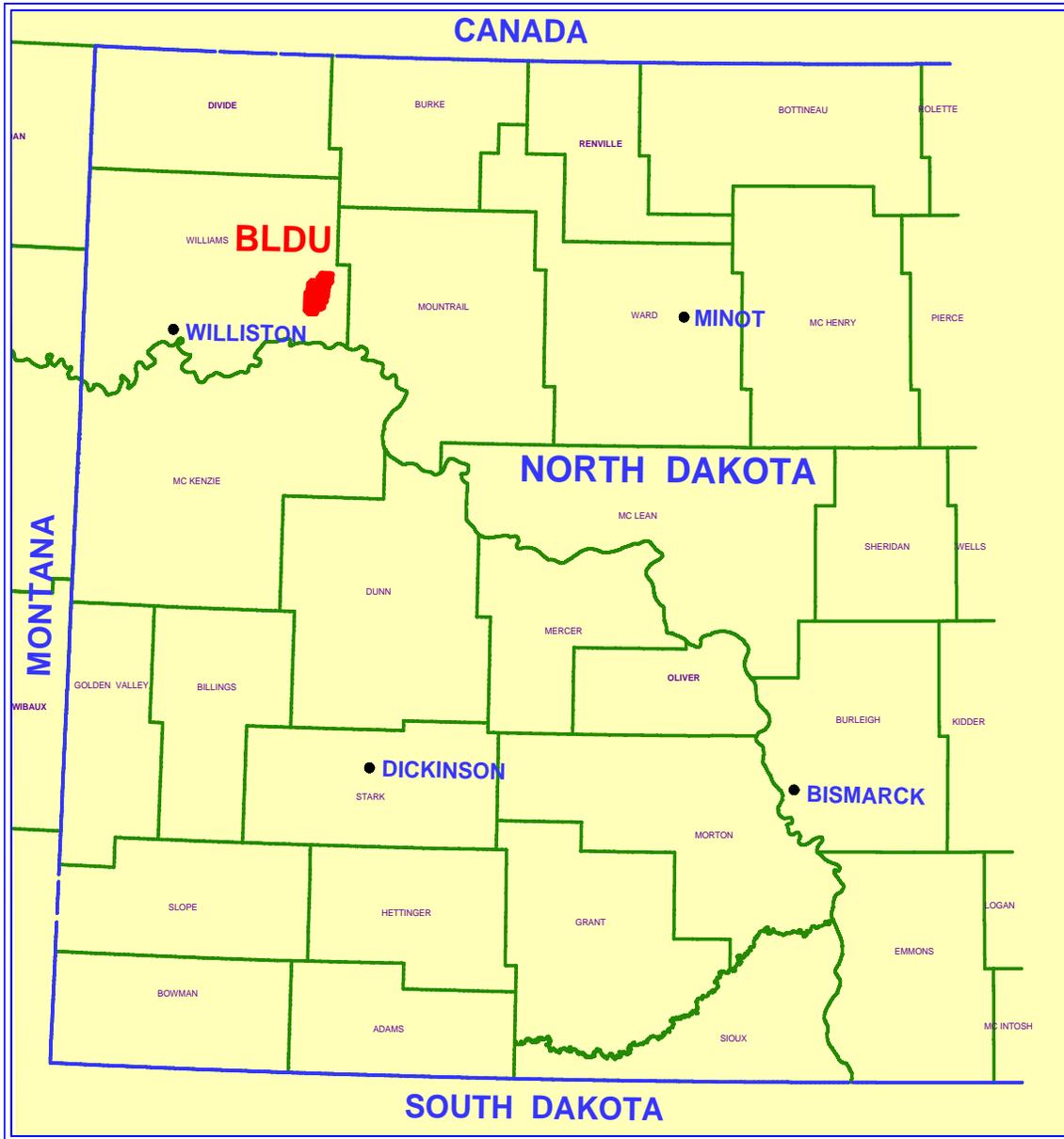


Beaver Lodge, North Dakota



- CO₂ in a deep oil reservoir – CO₂ will be injected into an oil-bearing zone at great depth in the Beaver Lodge oil field.
- Minimum of 3000 tonnes of CO₂ will be injected during demo period.

Regional Location



It is a multi-pay field producing from at least 10 separate horizons.

Beaver Lodge Demonstration

- The target formation in this project is the Devonian Duperow Formation.
- It is the most prolific producing interval of the multiple producing horizons in the field.

ERA	AGE OF FORMATION		CENTRAL WILLISTON BASIN	
Cenozoic	Tertiary	Pliocene	Flaxville	
		Miocene		
		Oligocene	White River	
		Eocene	Golden Valley	
		Paleocene	Tongue River Sentinel Butte	
Mesozoic	Cretaceous	Upper	Hell Creek Fox Hills Pierre	
		Middle	Niobrara Carlile Greenhorn Belle Fourche Mowry	
		Lower	Newcastle / Skull Creek Dakota Fuson Lakota Morrison Swift	
	Jurassic		Ellis Group Rendon Piper	
		Tri.	Spearfish	
	Paleozoic	Permian	Ochoa	Minnekahta Opeche
			Guadalupe	
			Leonard	
		Penn.	Wolfcamp	Minnelusa
			Virgil	
Missouri				
Des Moines				
Atoka				
Morrow				
Chester				
Miss.		Meramec	Amesden Heath-Oster-Kibbey Viert	
		Osage	Charles	
		Kinderhook	Mission Canyon Lodgepole Bakken	
Devonian		Upper	Three Forks Noble Duperow Scott Bluff	
		Middle	Dayton Bay Prairie Winnepedosis Ashm	
Sil.		Caraga Niagara Alexandria	Interlake	
Ord.		Richmond Big Lake Treston	Cleveland	Guntion Stony Mountain
	Chazy-Stones River Beekmantown		Red River Winnipeg	
Camb.	Upper		Deadwood	
	Middle			
	Lower			
			Pre-Cambrian	

Beaver Lodge Demonstration

- The Duperow Formation is carbonate rock.
- Reservoir is primarily dolomite.
- It consists of a series of distinct shallowing upward cycles usually culminating in anhydrite deposition.



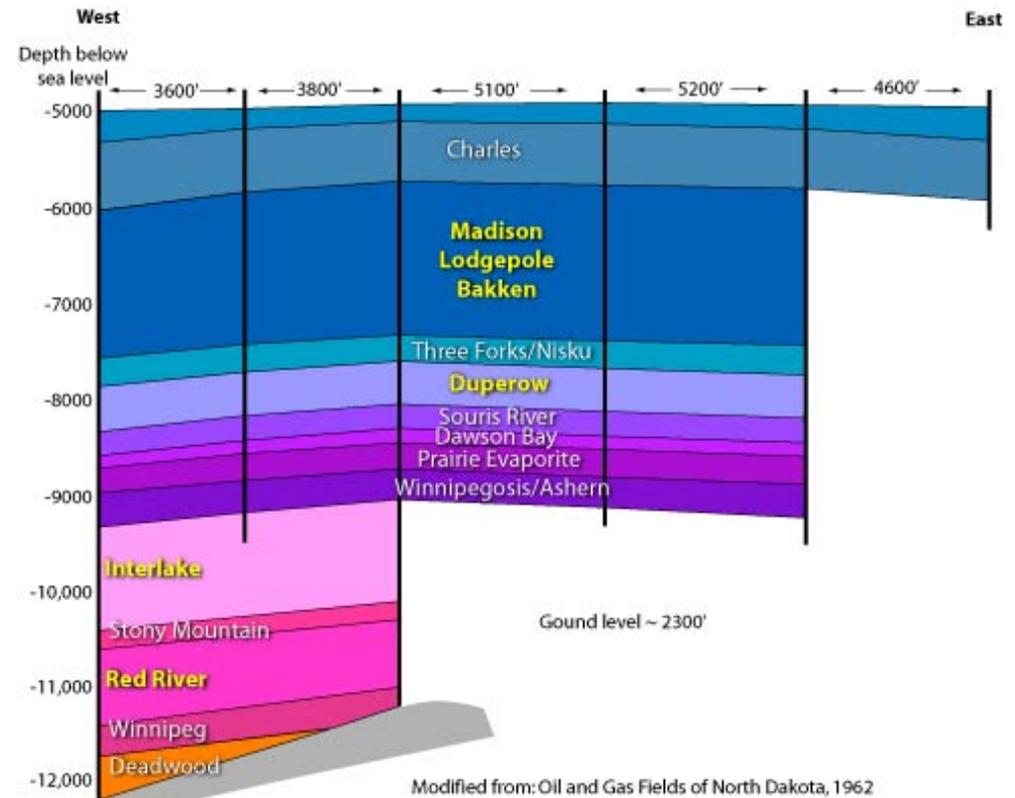
Beaver Lodge Field – Duperow Reservoir Characteristics

- Structural trapping mechanism with a secondary stratigraphic component.
- Average Pay Thickness = 43'
- Average Porosity = 13.7%
- Average Permeability = 3.6 md
- Average Water Saturation = 21%
- Injection Depth = 10,000'
- Reservoir Pressure = 3942 psig
- Reservoir Temperature = 249 degrees F
- Salinity = 329,000 ppm
- Estimated CO₂ Storage Capacity = 170 MMT



What Are We Going to Characterize?

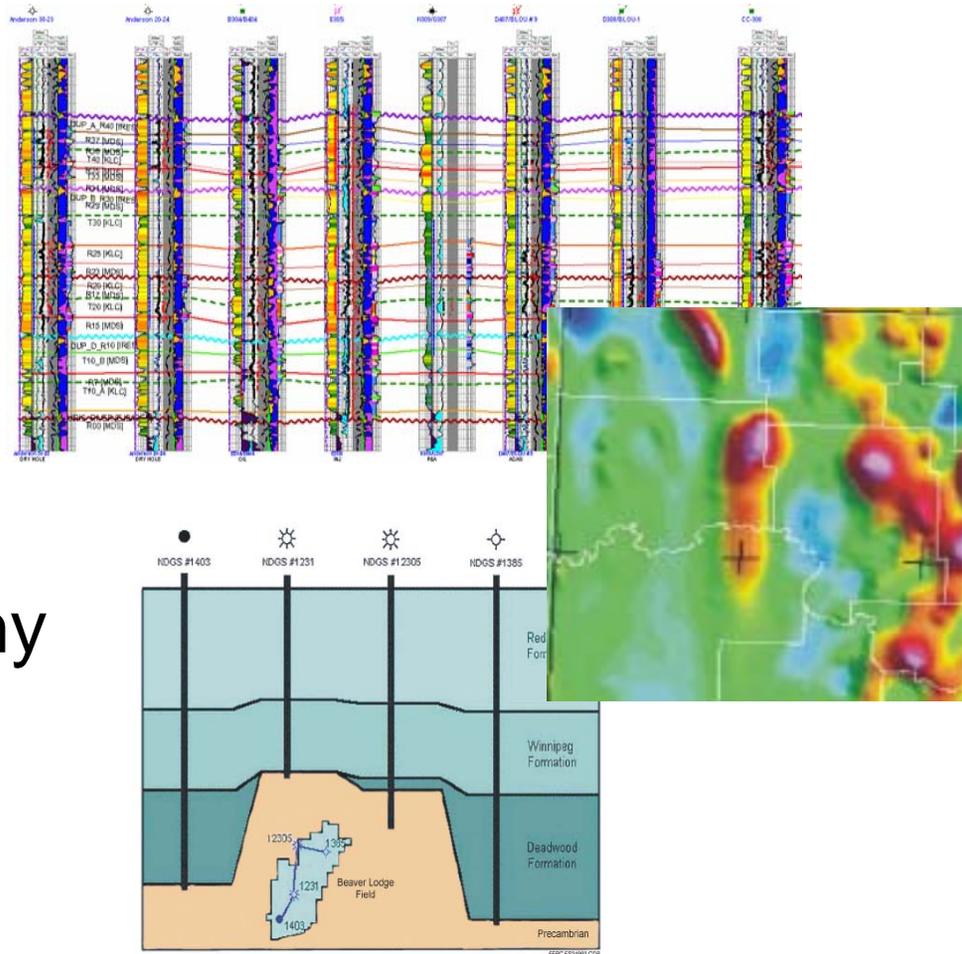
- Geology
- Hydrogeology
- Reservoir
- Cap Rock & Seal
- Production history



Baseline characterization for demonstration sites should be done at **small, medium, and large scales**.

Key Elements of Geology & Hydrogeology

- Tectonic features
- Hydrodynamics
- Detailed stratigraphy



Figures courtesy Amerada Hess & North Dakota Geological Survey

Key Elements of Reservoir

- Rock properties
 - Mineralogy
 - Porosity
 - Permeability
 - Transmissivity
- Fluid compositions
 - Oil
 - Water
 - Gas
- Geomechanical properties
- Pressure regime

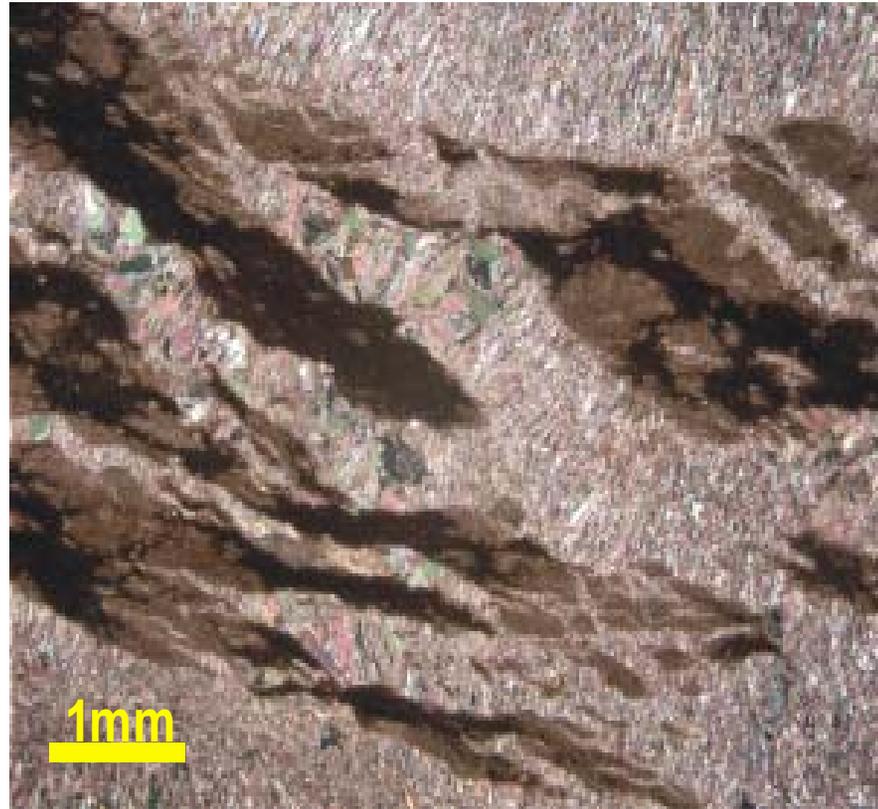


Figure courtesy Saskatchewan Industry & Resources

Key Elements of Cap Rock & Seal

- Rock properties
 - Mineralogy
 - Porosity
 - Permeability
 - Transmissivity
- Geomechanical properties
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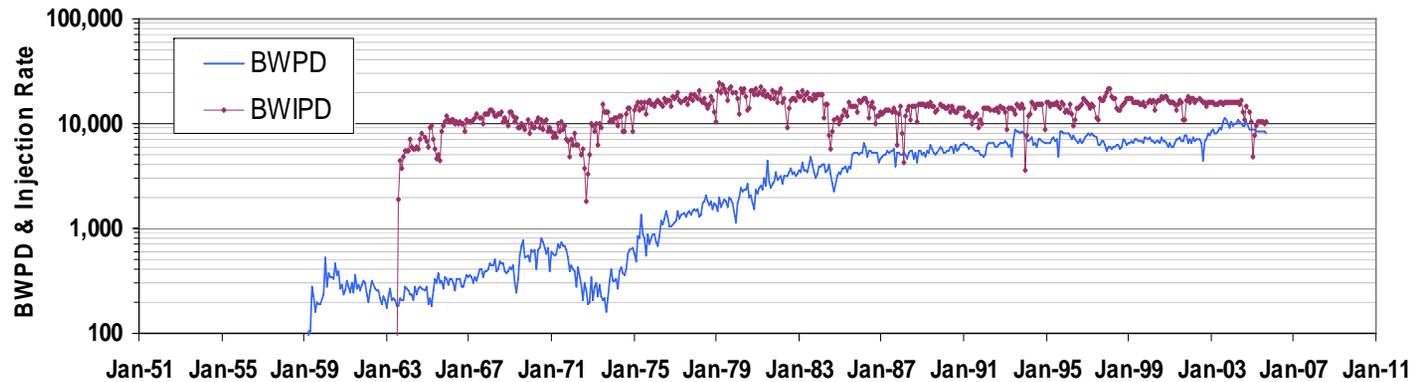


Figure courtesy Saskatchewan Industry & Resources

Production & Operational History

- Oil
- Gas
- Water
- Pressure

Water production & injection rates



Oil production rates

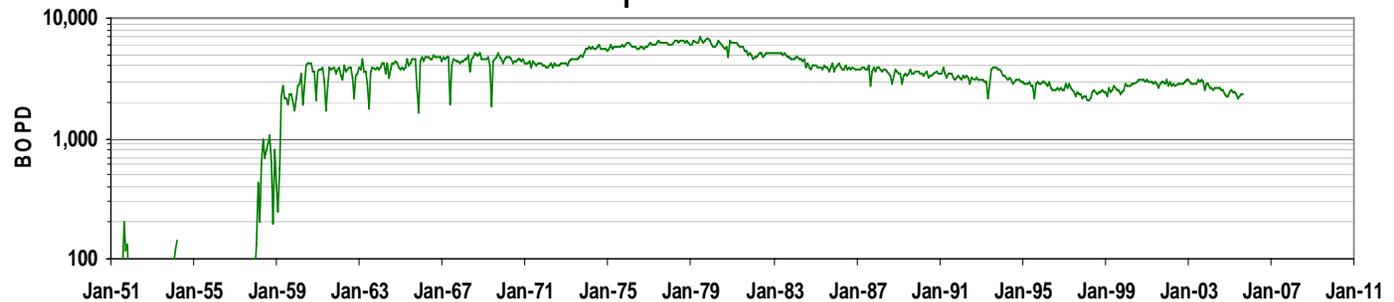


Figure courtesy Amerada Hess

Approaches to Site Characterization of Oil Fields

IEA Greenhouse Gas Storage Project (Weyburn Phase I)

“Trail Blazer” approach:

- Gather as much data as possible using a variety of techniques.
- Large multi-disciplinary team representing industry, government, academia, and consulting expertise.
- Strong emphasis on geophysical data to monitor the CO₂ plume.
- Tremendous data availability for Weyburn field.

PCOR Partnership Beaver Lodge Field Demonstration

“Pioneer” approach:

- Apply the lessons learned from Weyburn and Frio.
- Smaller multi-disciplinary team.
- Emphasis on reservoir dynamics and monitoring well data.
- Limited (but ample) data availability.

Toolboxes

Weyburn Phase I

- Core
- Well logs
- Geosphere & biosphere fluid samples (historic & new)
- Seismic (historic & new)
- Aeromagnetic (historic & new)
- Reservoir modeling (historic & new)
- Aerial photo interpretation
- Soil gas survey

PCOR Partnership

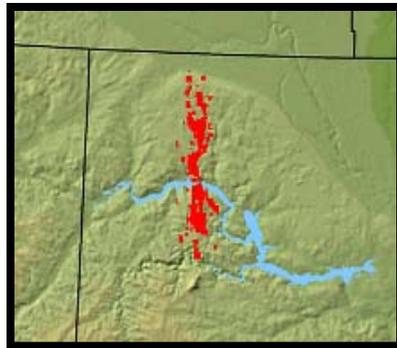
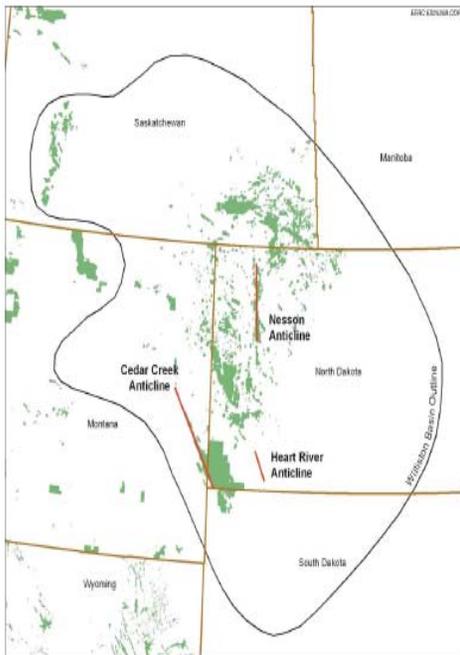
Phase II Beaver Lodge

- Core
- Well logs
- Geosphere & biosphere fluid samples (historic & new)
- Seismic (historic)
- Reservoir modeling (historic & new)
- Soil gas survey

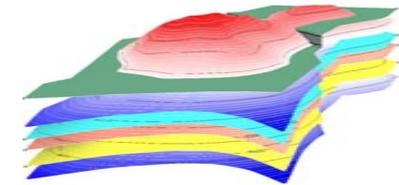
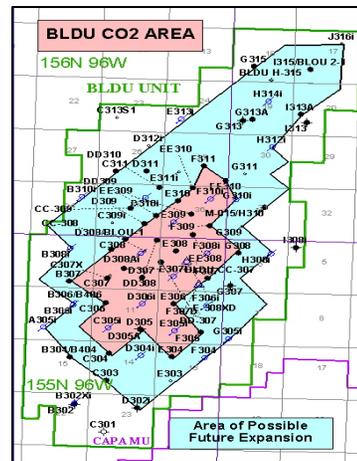


Scales of Evaluation

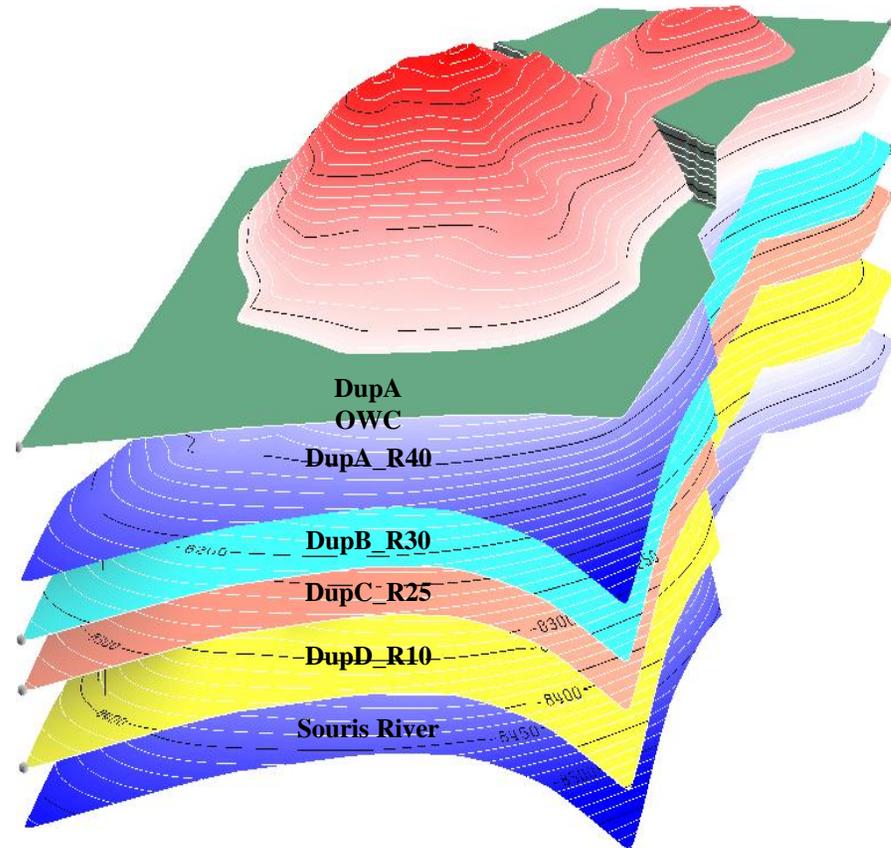
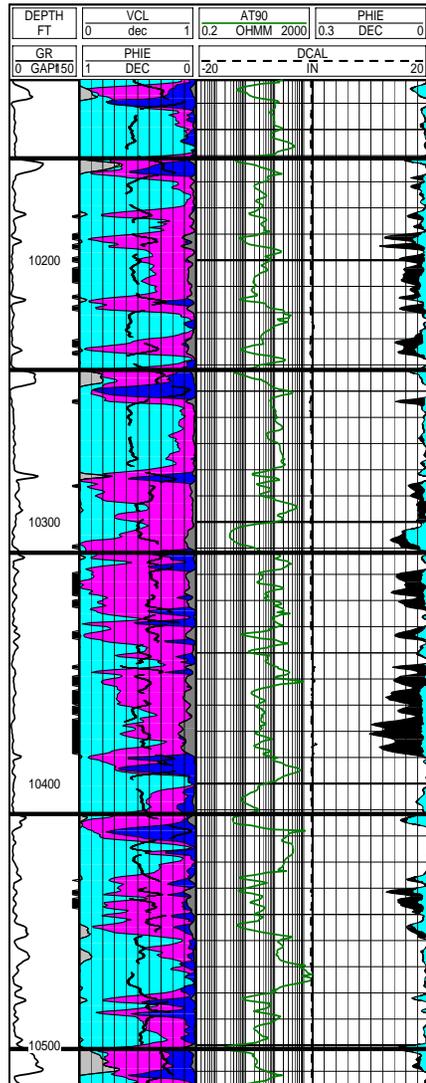
- To evaluate potential near- and long-term effects, the Beaver Lodge Demonstration will be evaluated on a multi-scale basis.



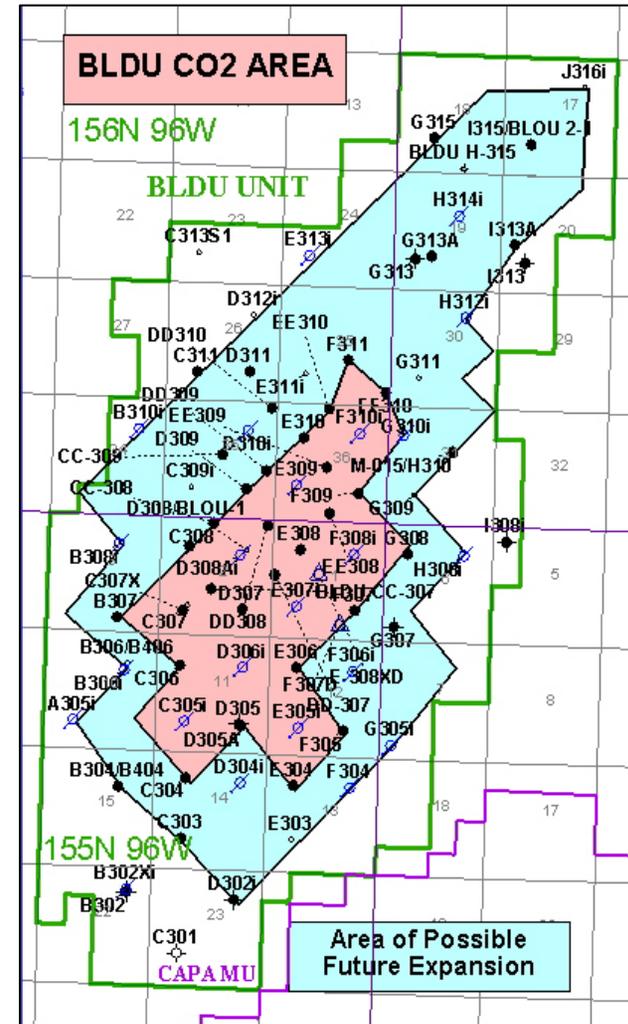
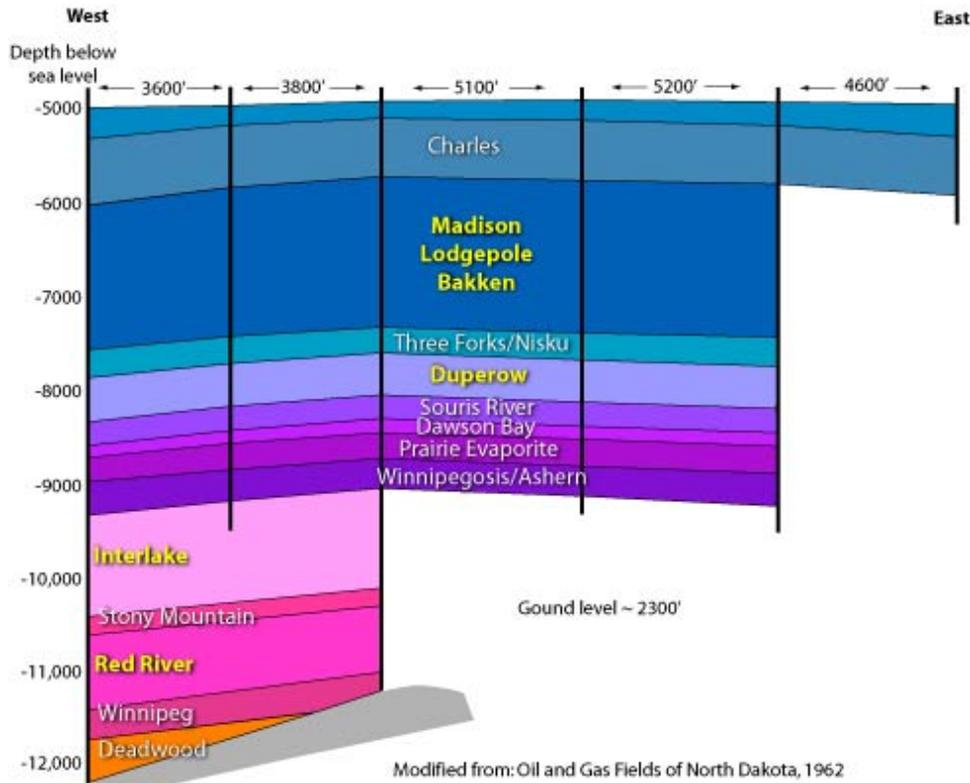
- Local scale (reservoir)
- Field scale
- Sub-regional scale
- Regional scale



Reservoir Scale – Devonian Duperow



Field Scale – Beaver Lodge Oil Field



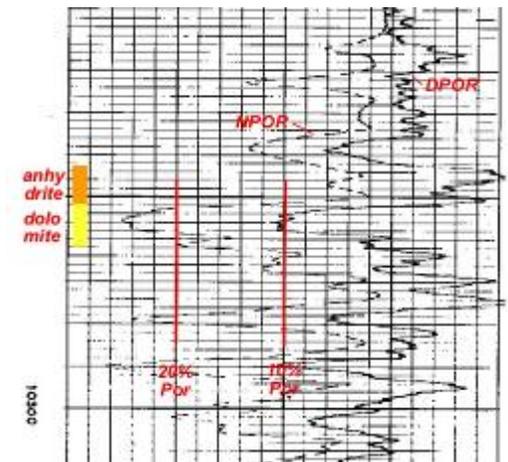
Sub-Basin Scale – Nesson Anticline



Aeromagnetic anomaly map showing basement structure of the Nesson Anticline.

Beaver Lodge Activity Thus Far

- Initiated BLDU CO₂ pilot study
- Updated reservoir simulation model
 - Refined grid: 450'x 450' cells
 - Added 83 layers; 168,000 cells
 - Matched recent history
 - Investigated 5-pt and 9-pt solutions
- Evaluating CO₂ vs. waterflood scenarios
- Evaluating CO₂ availability issues
- Conducting economic evaluations
- Developing full-field depletion plan



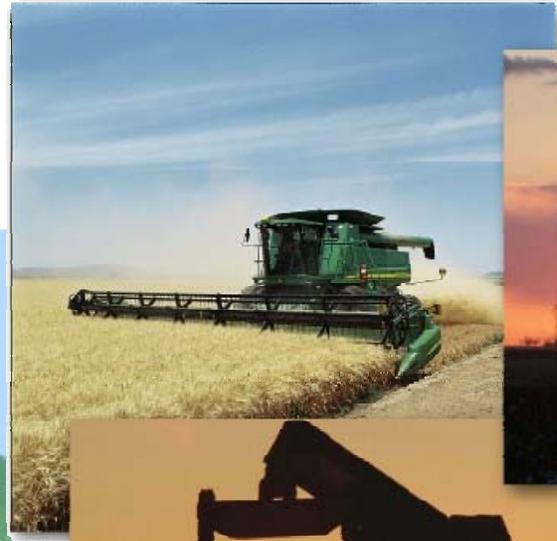
Summary

- **Technical challenge – impact of reservoir conditions on EOR and sequestration**
- **Commercial challenges – well costs, CO₂ costs, CO₂ availability**
- **Mitigating factor – high oil prices**
- **Technical advantage – experienced CO₂ operator**
- **Environmental aspect - beneficial use of CO₂**



Figures courtesy Amerada Hess

Thanks!



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