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Plains CO_2 Reduction (PCOR) Partnership Update

Regional Carbon Sequestration Partnerships Annual Review Meeting
Sheraton Station Square
October 5, 2010

Ed Steadman and John Harju

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

PCO2R Partnership

Phase III Demonstration Tests

Fort Nelson Carbon Capture and Storage (CCS) Project

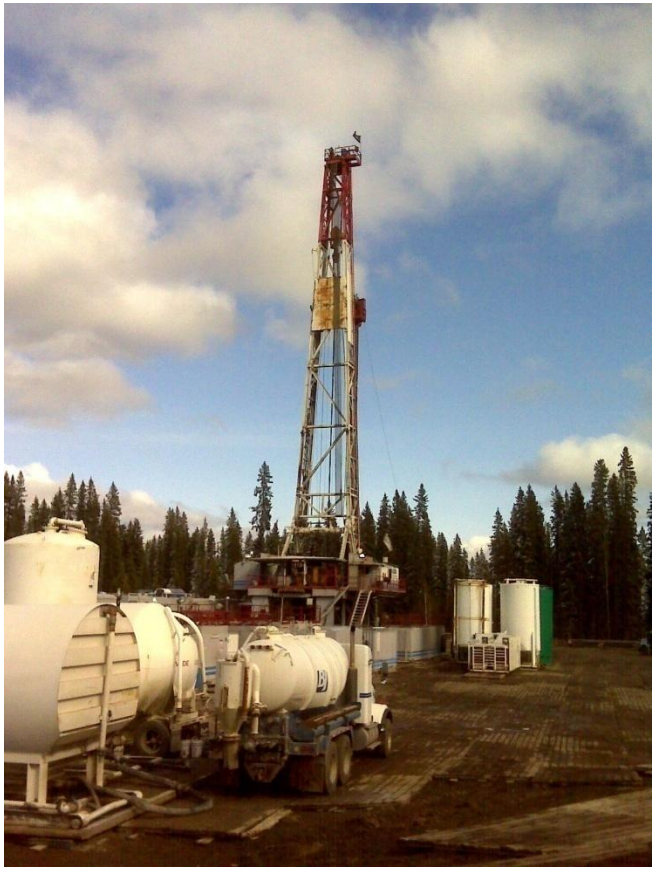
Fort Nelson CCS in a Deep Saline Formation

Drill rig and camp site near Fort Nelson, British Columbia, Canada

Spectra Energy SM

Phase III Fort Nelson Goals

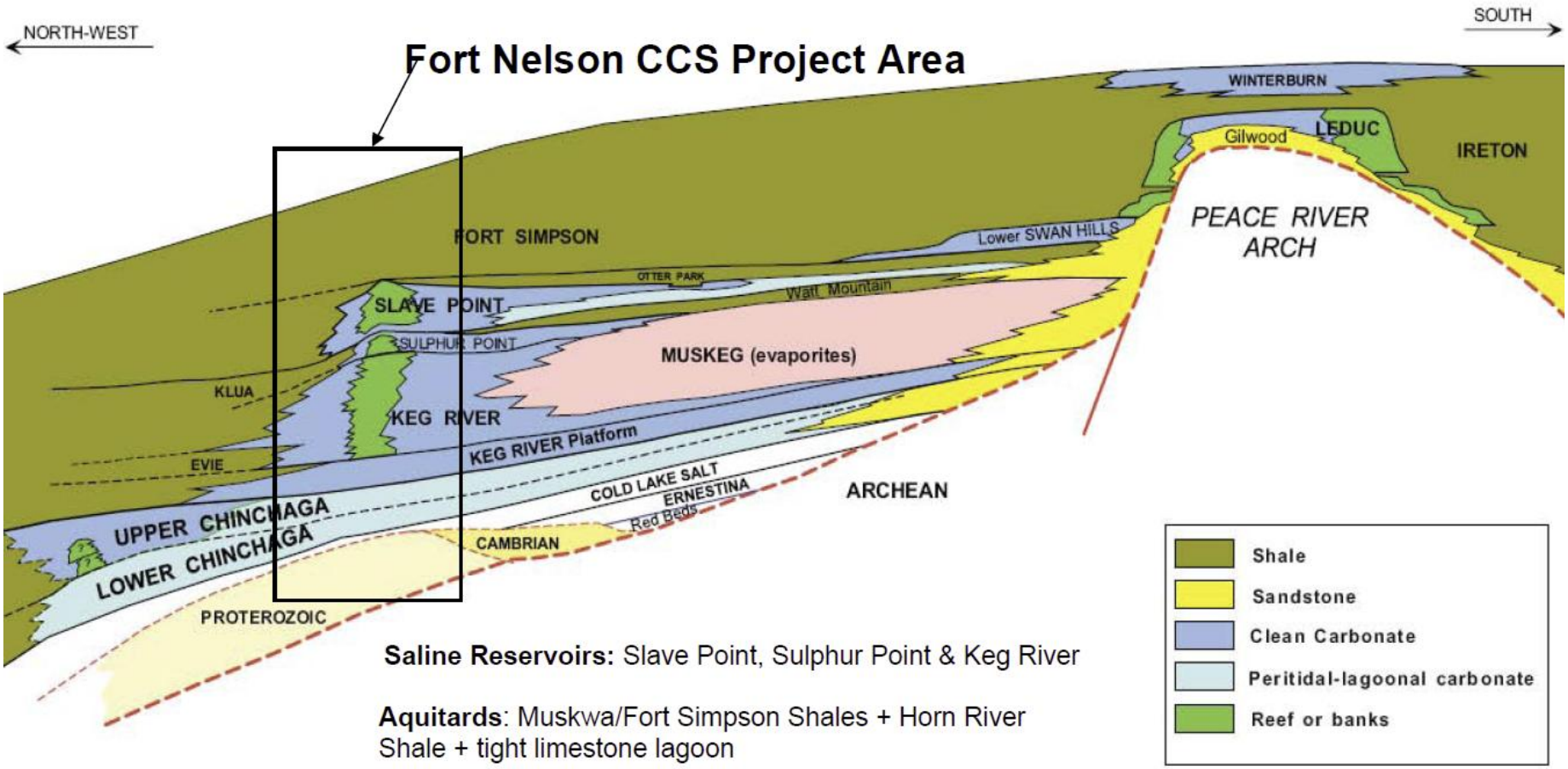
- Verify and validate the technical and economic feasibility of using brine-saturated carbonate formations for large-scale carbon dioxide (CO_2) injection.
- Demonstrate that robust monitoring, verification, and accounting (MVA) of a brine-saturated CO_2 sequestration project can be conducted cost-effectively.



Fort Nelson Gas Plant

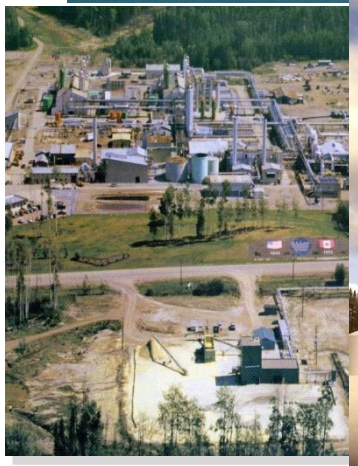
- Fort Nelson Gas Plant
  - 1 Bcf/d raw gas-processing capacity – largest facility of its kind in North America.
  - Spectra Energy gathering and processing assets are strategically positioned in the growing Horn River Basin, processing both conventional and unconventional shale gas resources.
  - The proposed Fort Nelson CCS project is a potential solution to mitigate CO_2 emissions as shale gas production grows.

Fort Nelson Site Geology



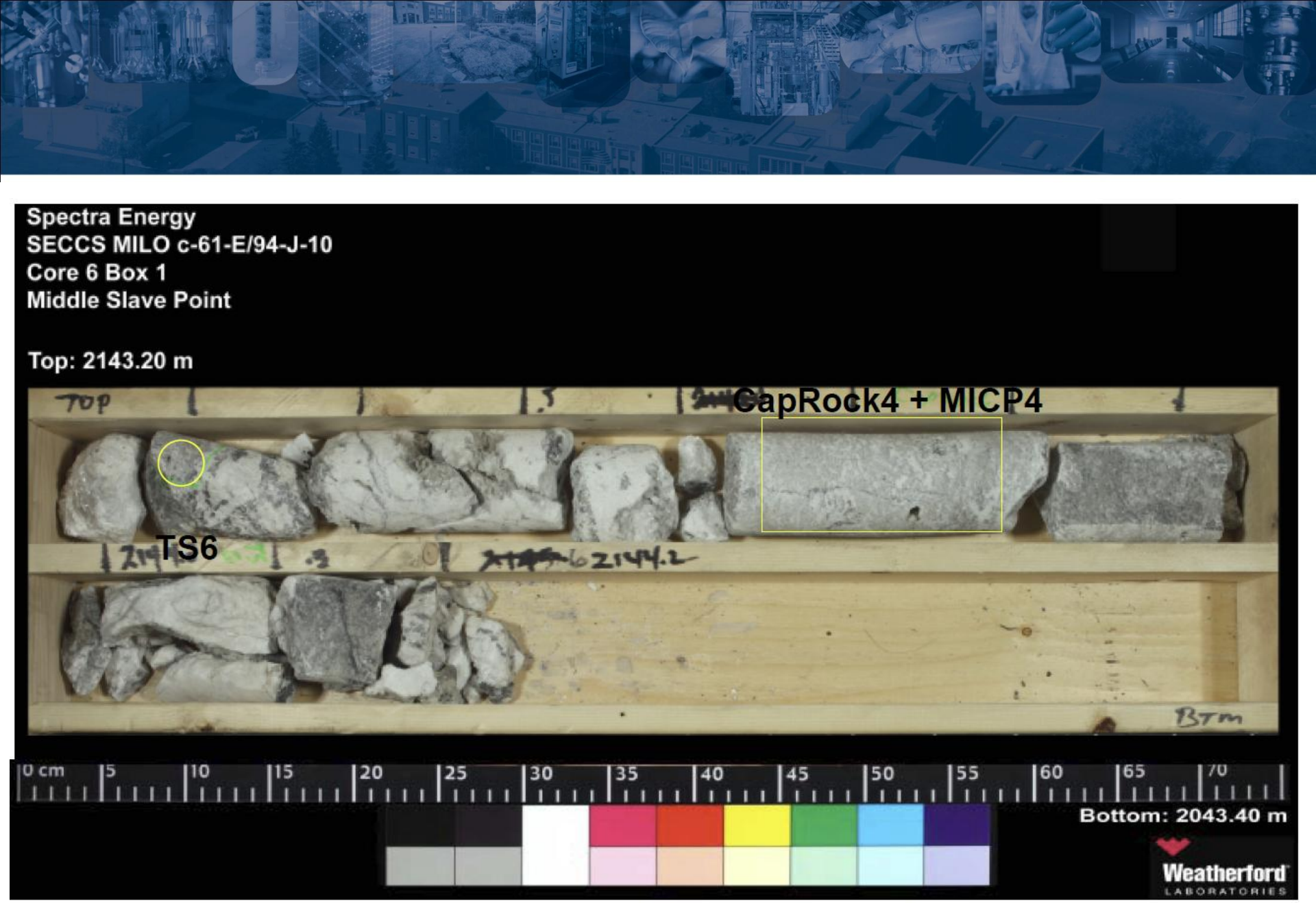
Phase III Fort Nelson – Current Status

- An exploration well was drilled spring 2009. The well was reentered and additional logs were collected in the winter drilling season 2009−2010.
- An additional well is planned for winter drilling season 2010−2011.
- The PCOR Partnership has provided a preliminary risk management plan (RMP), and we are developing an integrated RMP, modeling, and MVA program.



Samples Selected for Core Work

*MP = Mechanical Properties; **Cap Rock = Cap Rock Integrity Evaluation Test;
***MIPC = Mercury Injection Capillary Pressure Test


Spectra Energy
SECCS MILO c-61-E/94-J-10
Core 6 Box 1
Middle Slave Point
Top: 2143.20 m
CapRock4 + MICP4
TS6
Bottom: 2043.40 m
Weatherford
LABORATORIES

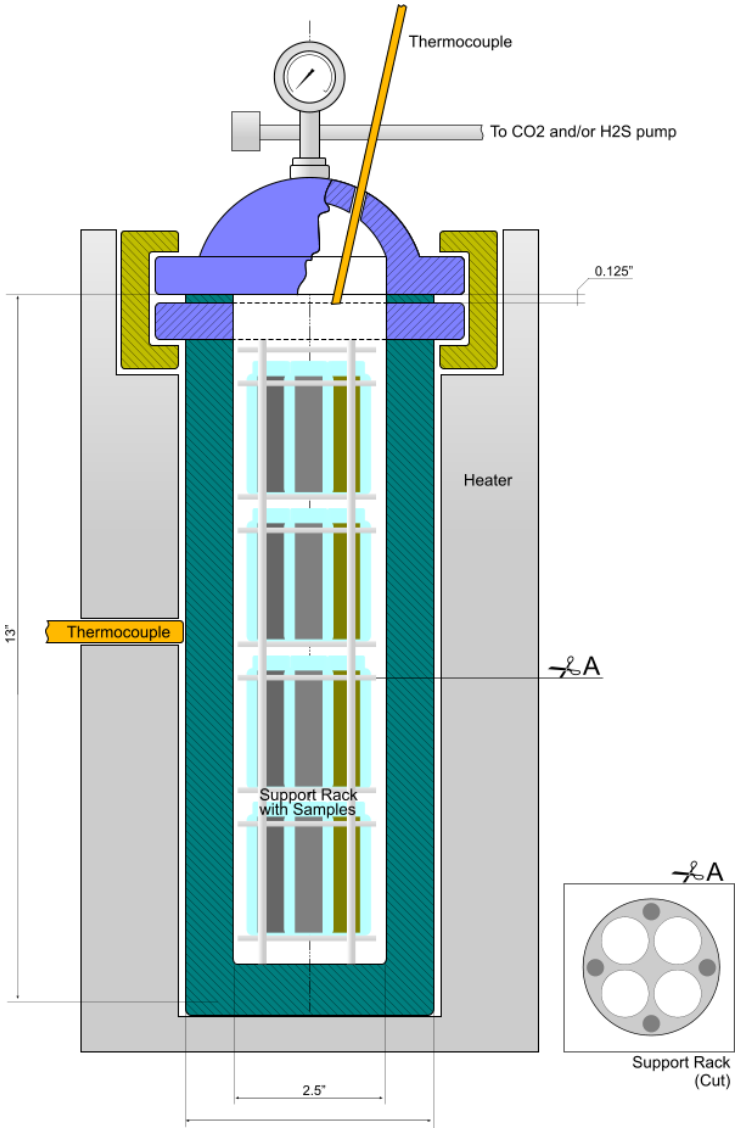
Fort Nelson Geochemical Evaluation (performed tasks)

- Mineralogical analysis
  - Core cuttings were analyzed with x-ray diffraction (XRD) and QEMSCAN.
- Laboratory tests
  - Two sets of 12 samples from 6-foot-depth intervals (1960–2200 m) were exposed to pure CO_2 and sour gas in a high-pressure and temperature chamber under reservoir conditions.
  - Mineralogical and fluid sample analysis of reacted samples was performed.
- Numerical geochemical modeling:
  - Results of the laboratory experiment are evaluated and compared with the simple 2-D homogeneous reservoir-scale numerical modeling.

High-Pressure CO_2–H_2S Chamber Experiments

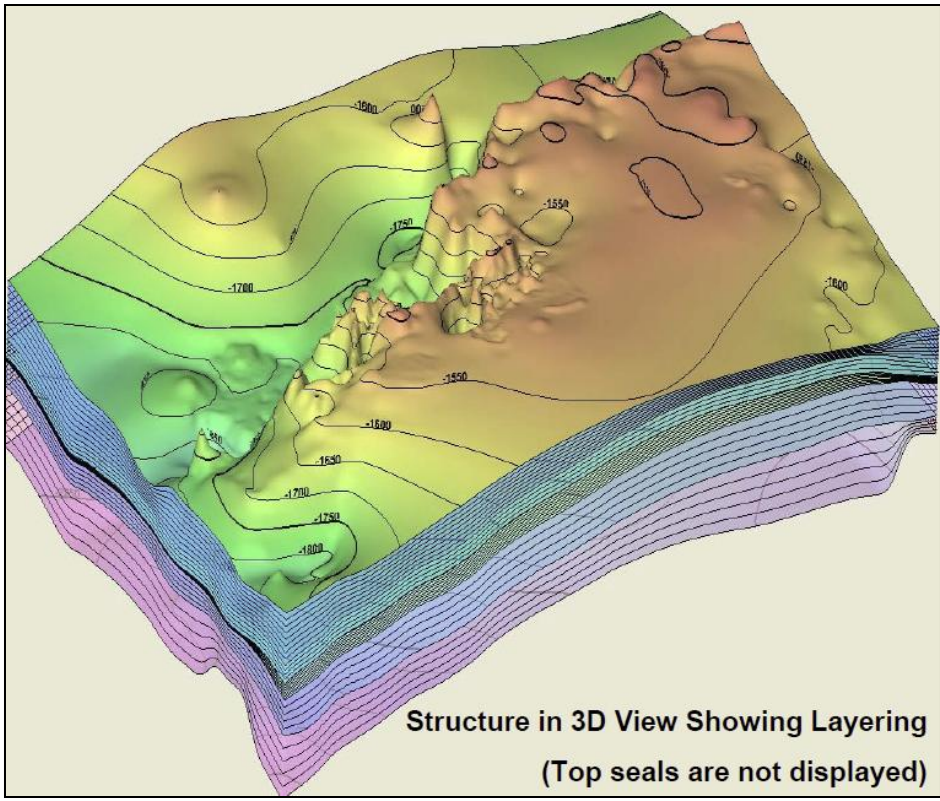
Two scenarios were considered: pure CO_2 and a mixture of CO_2 and H_2S for Fort Nelson sample cuttings from different depth intervals (1960–2200 m)

CO_2 and H_2S Pressure:	2.1 MPa (3000 psi)
CO_2 Partial Pressure:	100 and 95 mole %
H_2S Partial Pressure:	0 and 5 mole %
Temperature:	100 C (212 F)
Mass of Sample:	3–4 g (cuttings and powdered)
Saturation Conditions:	Synthetic brine NaCl, 10% by weight
Time of Exposure:	4 weeks
Depths Tested:	1960–2,200 m
Sampling Interval:	6 feet



Fort Nelson CCS: Characterization of Slave Point and Sulphur Point Saline Reservoirs

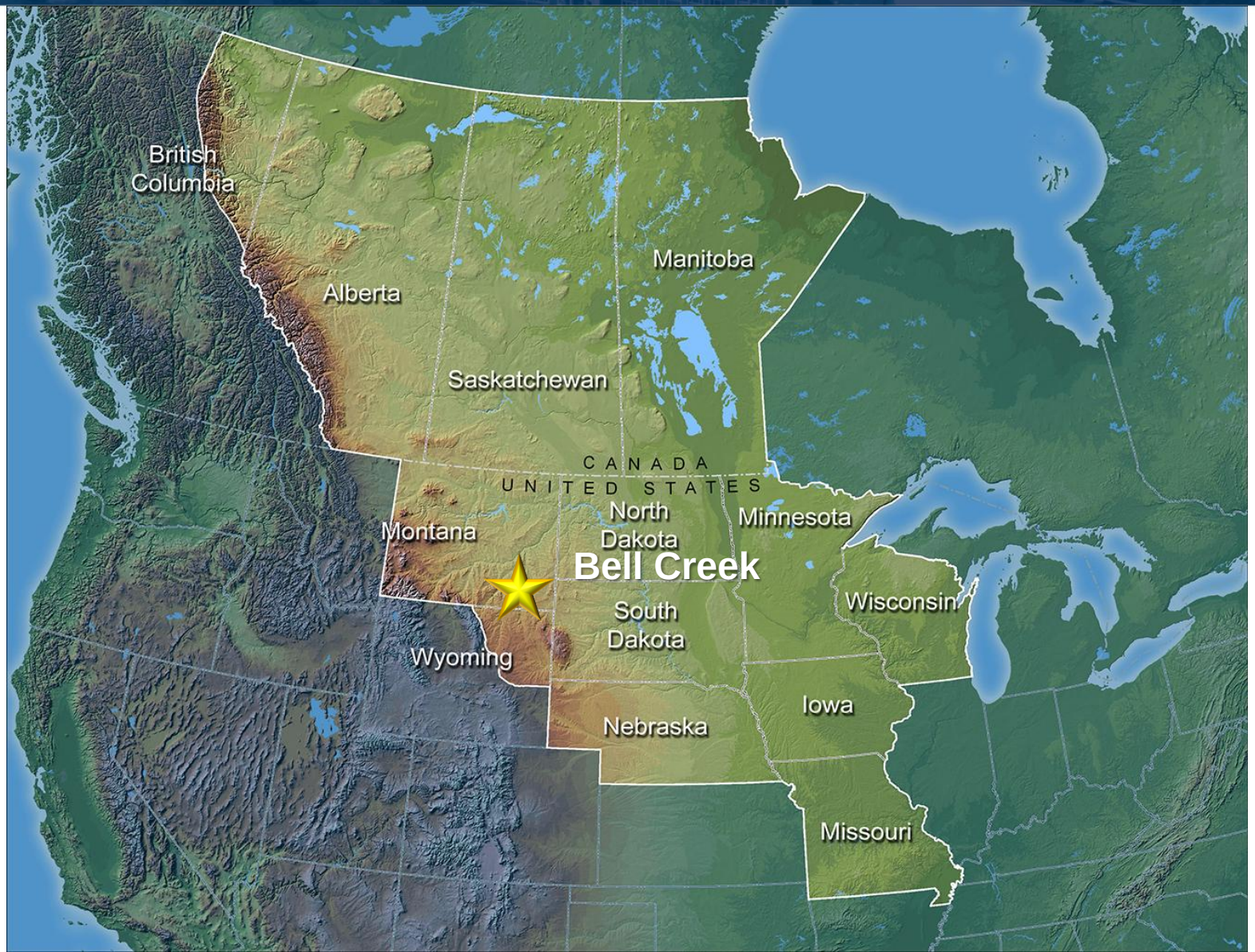
- Required storage capability:
  - Hydrogeology – supports capacity.
  - Modeling >50-yr injection.
- Permeability and injection capability
  - 300 mD + permeability (in situ testing).
  - Low number of injection wells required.
  - Good pressure dissipation.
- Excellent containment:
  - Stable tectonics.
  - >1800 ft impervious shale cap rock.
  - No leakage into lateral and top seals.
  - Postinjection – large pressure falloff in 10 years and reduces to near preinjection pressures in 40 years.



Fort Nelson – Next Steps

- Develop commercial model
- Drill second test well (approvals in place)
- Perform 3-D seismic survey (approvals in place)
- Complete geological, lab, geomechanical, and geochemical analyses
- Update geological and dynamic models
- Update risk assessment
- Design MVA
- Commence CCS scheme approval process with British Columbia Oil and Gas Commission
- Potential to have project in service by 2014

Bell Creek EOR Project

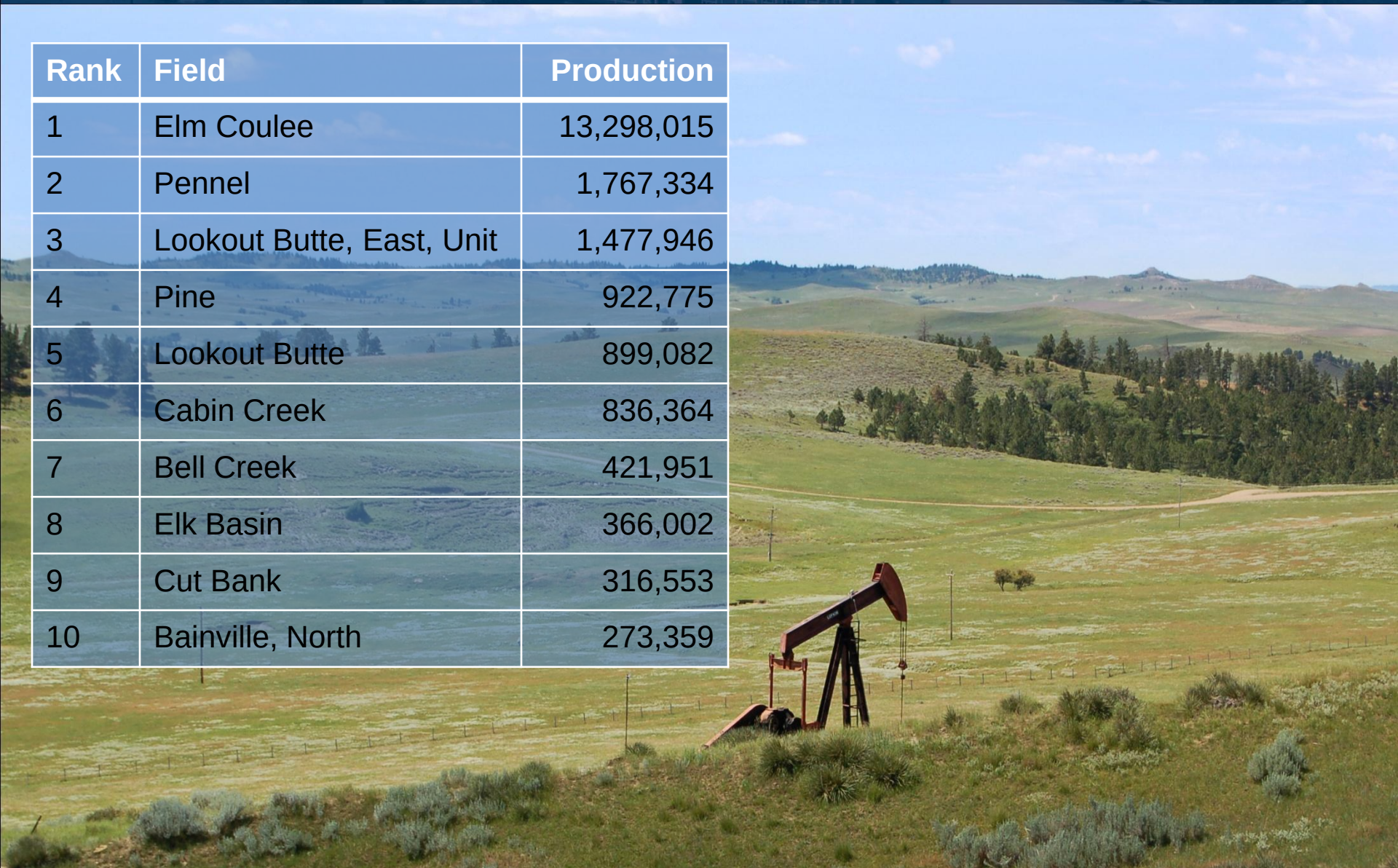



BELLECREEK

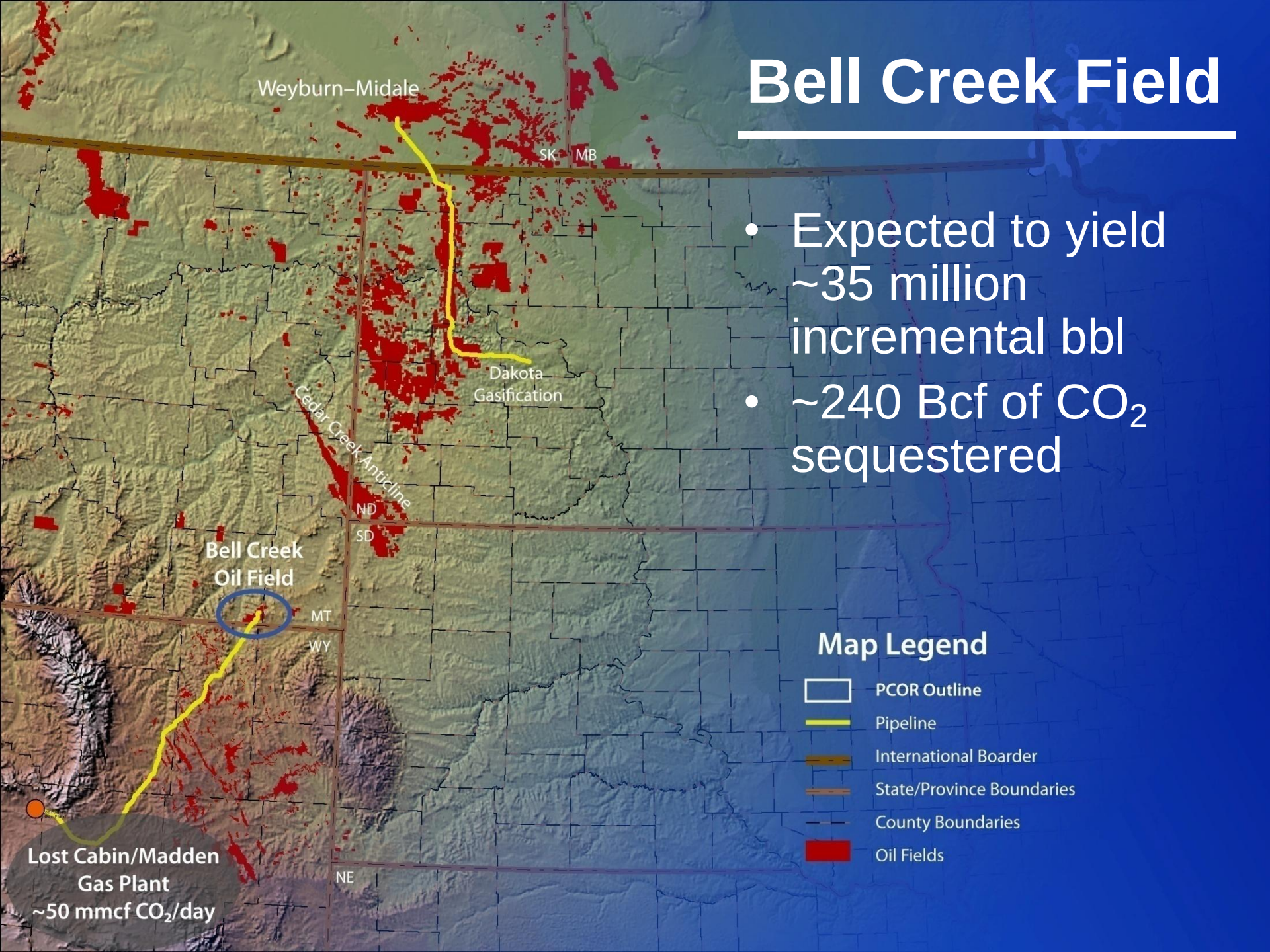

ENTERING
MONTANA

Top Montana Oil Fields 2009

Rank	Field	Production
1	Elm Coulee	13,298,015
2	Pennel	1,767,334
3	Lookout Butte, East, Unit	1,477,946
4	Pine	922,775
5	Lookout Butte	899,082
6	Cabin Creek	836,364
7	Bell Creek	421,951
8	Elk Basin	366,002
9	Cut Bank	316,553
10	Bainville, North	273,359



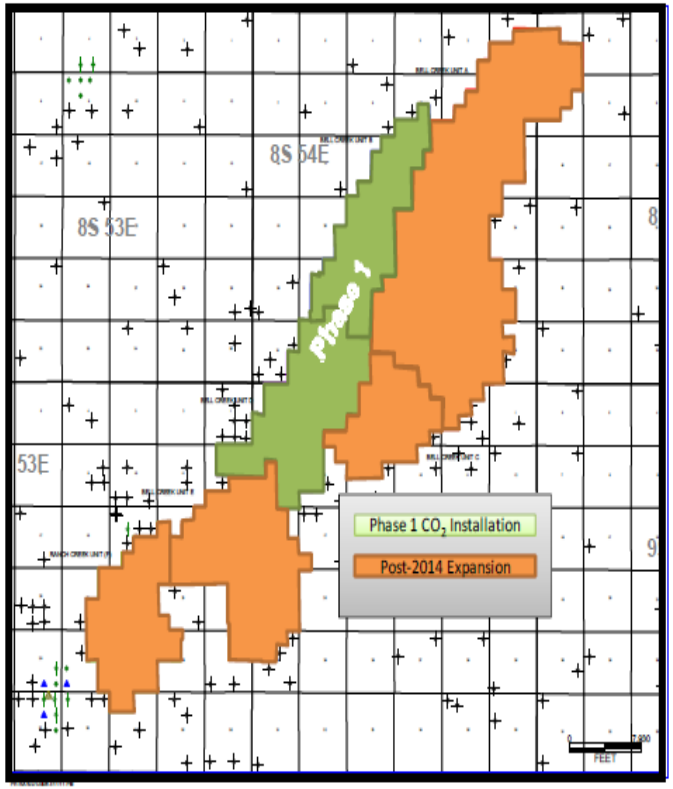
Bell Creek Field



- Expected to yield ~35 million incremental bbl
- ~240 Bcf of CO_2 sequestered

Bell Creek Field

- Discovered in 1955
- Delta/channel deposits in the Muddy/Newcastle Sandstone
- High porosity/ permeability
- 15 x 3.5 miles
- 350 MMbbl OOIP
- Planned CO_2 injection 2011–2025

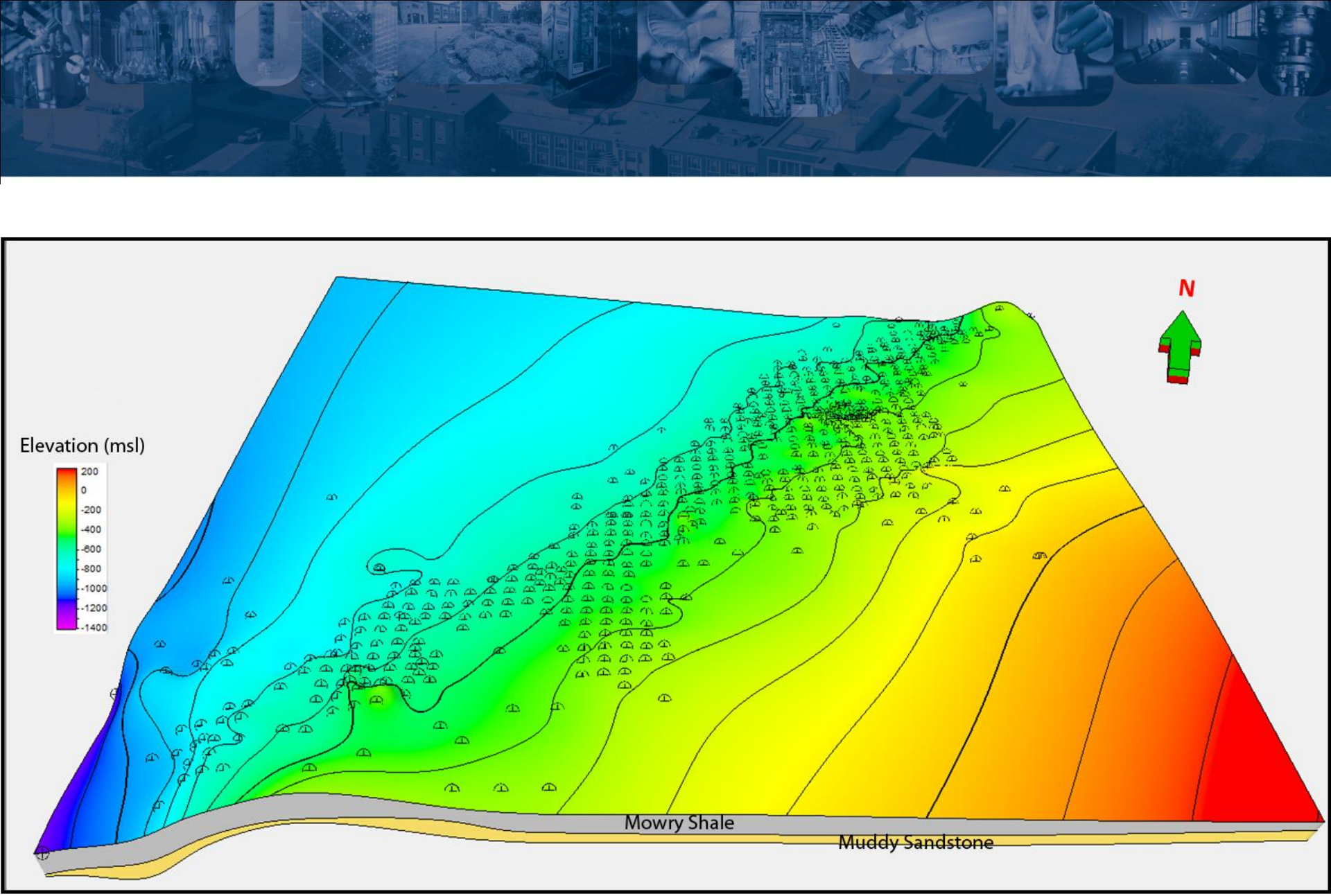


Source: Encore

- Reservoir Parameters:
  - API gravity: 33 -41°API
  - Depth: 4500'
  - Flood Pressure: 2300 psi
  - Temperature: 108 °F
  - Porosity: average = 24%
  - Permeability : average= 900 md
  - Gross Thickness: 25-30 feet
  - Original Oil-In-Place: 350 MM barrels
  - Remaining Oil-In-Place : 221 MM barrels
  - Minimum Miscibility Pressure: 1250 – 1850 psi
  - 40-acre spacing – 5-spot pattern
- Bell Creek CO_2 injection will be installed in multiple phases between 2011 and 2025

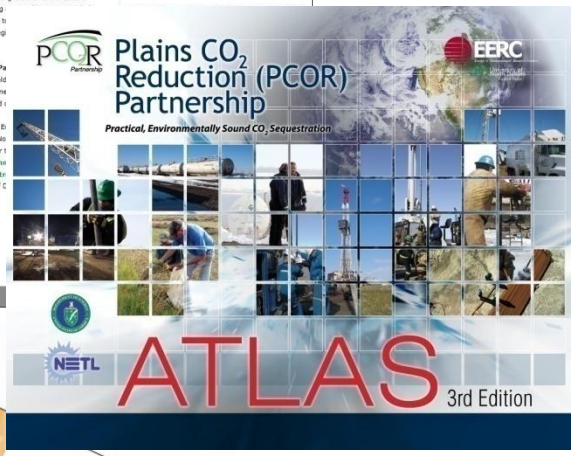
Depositional Setting

- Deposited as channels, deltas, and bars from eroding Black Hills.
- The system has been compared to the Gulf Coast.


N
Elevation (msl)
200
0
-200
-400
-600
-800
-1000
-1200
-1400
Mowry Shale
Muddy Sandstone

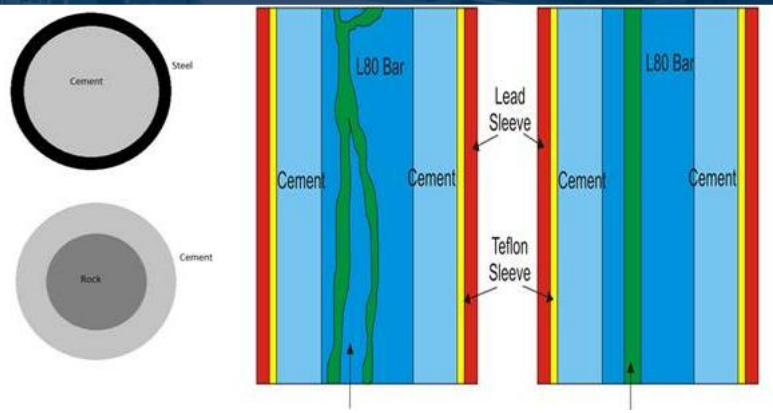
PCOR Partnership Outreach Support

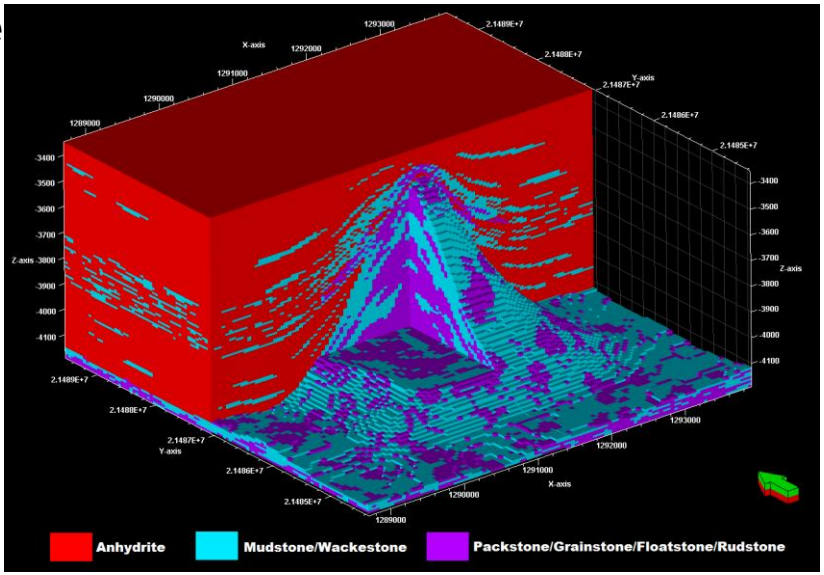
- 65-page regional sequestration atlas
- Fact sheets on key topics and projects
- A variety of PowerPoint presentations
- Public Web site with streaming and downloadable materials
- Sequestration documentaries (television broadcasts, Web streaming, and DVDs)
- Video clips
- Technical reports



Zama Add-On Work

- **Cement integrity study**
  - Cement bond integrity
  - Basic casing corrosion and failure testing
  - Dissolution rate of cement and increase in cement permeability
- **Static and dynamic modeling**
- **Acid gas-phase behavior and rock interactions**
  - Acid gas solubility in brine
  - Acid gas molecular diffusion and reaction rate studies
  - CO_2/H_2S phase behavior
- **VSP-type seismic survey and logging suites**
- **Continued MVA activities**
  - Fluid sampling
  - Pressure sampling
  - Tracer injection
  - Fluid injection and production monitoring

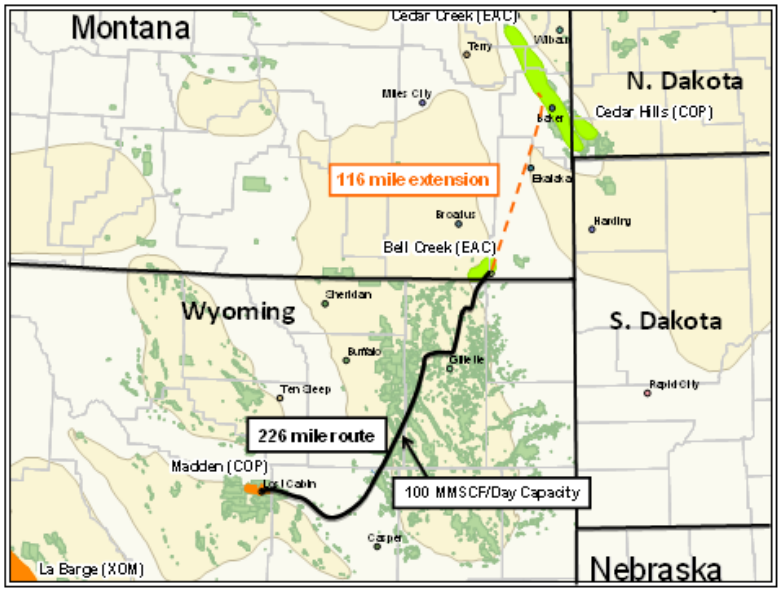




PCOR Partnership 2003 – Present

Phase III Status

We are moving ahead with both the Bell Creek and the Fort Nelson demonstrations.



Conclusion

The PCOR Partnership region has huge CCS potential!

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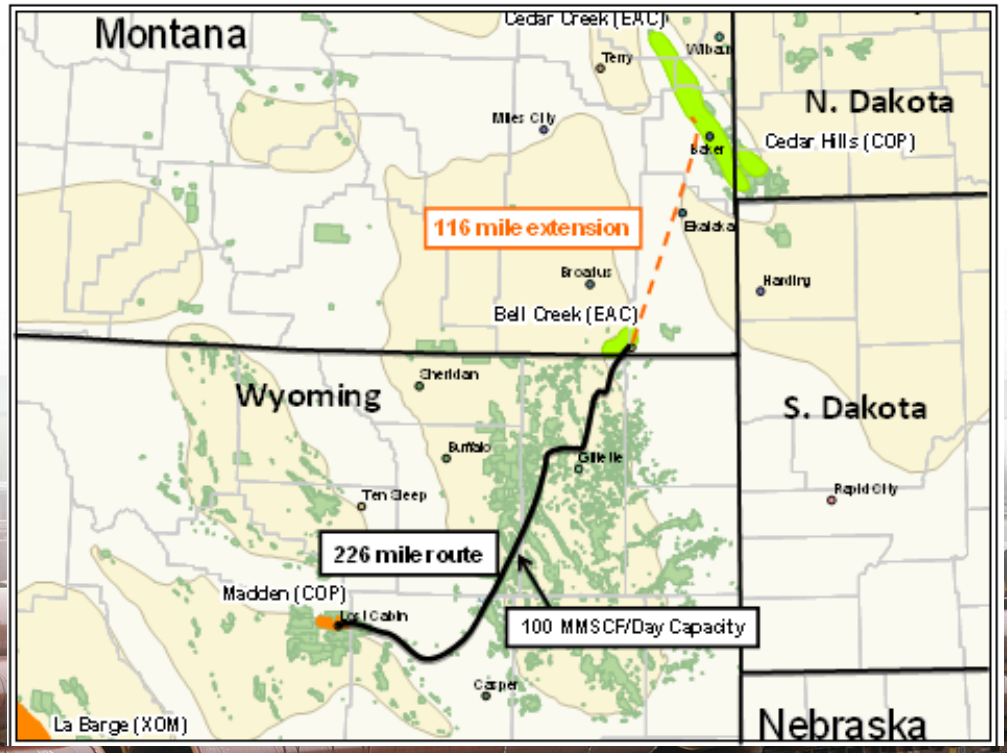
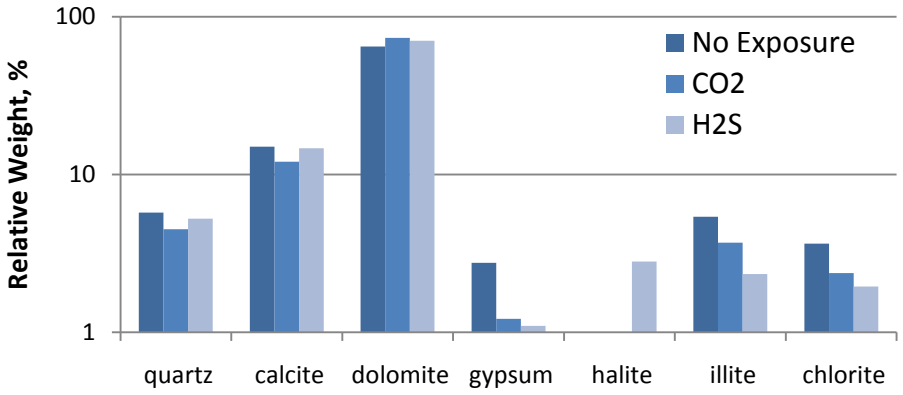
Bell Creek CO_2 Project

- Constructing a CO_2 transport pipeline from the Lost Cabin Gas Plant to the Bell Creek Field.

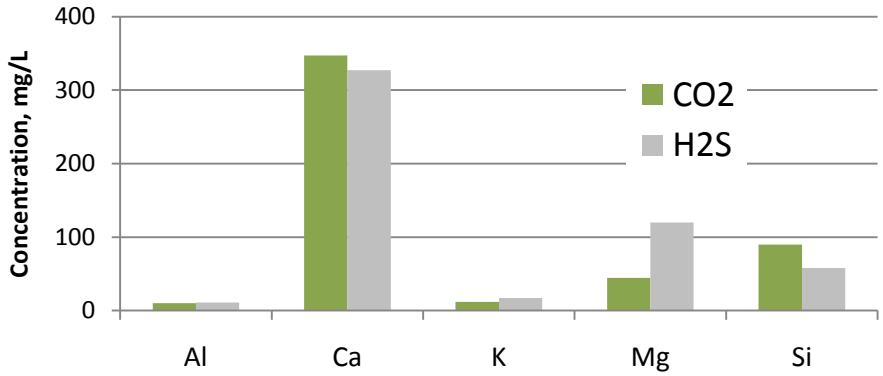


Experimental Results (2054 m)

Mineralogical Changes (XRD)



Changes in Ca, Mg, and Si Concentrations in Brine



Zama Continuation

- The Zama site is ideal to continue research activities for the following reasons:
  - An excellent partnership with the field operator, Apache Canada Ltd., exists.
  - The unique geological setting with respect to the isolated nature and geometry of pinnacle reef structures simplifies containment of injected gas.
  - Injection of acid gas is ongoing and will continue as an EOR scheme.
  - The lithology is characteristic of much of the central interior of North America, including the Williston and Powder River Basins.