Overview of Carbon Dioxide Capture and Sequestration

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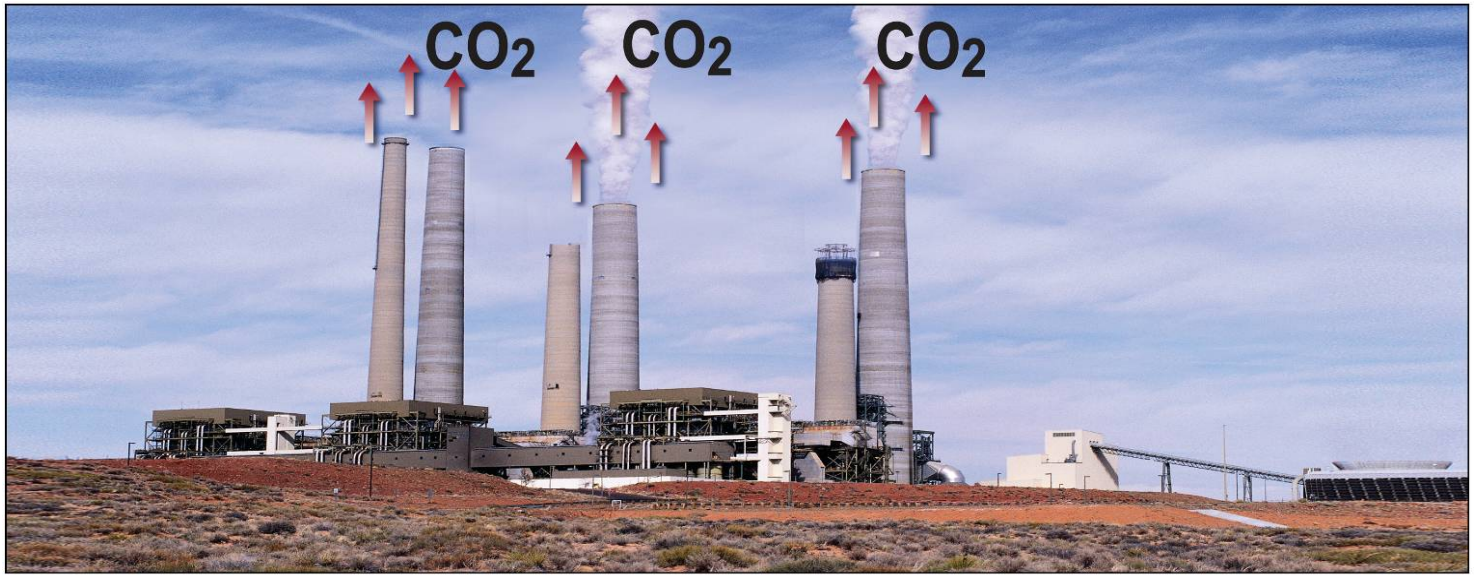
Summary

- **Why is it important?**
  - Fossil fuels will continue to be the major source of energy for the foreseeable future
  - Without CCS it will be difficult to meet emissions reduction targets of 50 to 80% by 2050
- **How much sequestration capacity is available?**
  - Estimates indicate sufficient capacity for sequestering emissions for over the next century
  - Experience and research will improve reliability
- **Will it leak back to the atmosphere and how will we know?**
  - Seals providing a permeability and capillary barrier can retain buoyant fluids for geologic time scales
  - Careful site selection and operations with regulatory oversight
  - Many monitoring methods are available – with more to come

What is Carbon Dioxide Capture and Storage and Why is it Important?



- Carbon dioxide capture and sequestration technology can slow global warming by reducing carbon dioxide emissions into the atmosphere
- Applicable to the 60% of global emissions that come from stationary sources such as power plants
- Necessary to achieve the rapid and sustained carbon dioxide emission reductions over the next 50 to 100 years

Carbon Dioxide Capture and Geologic Sequestration is a Four Step Process

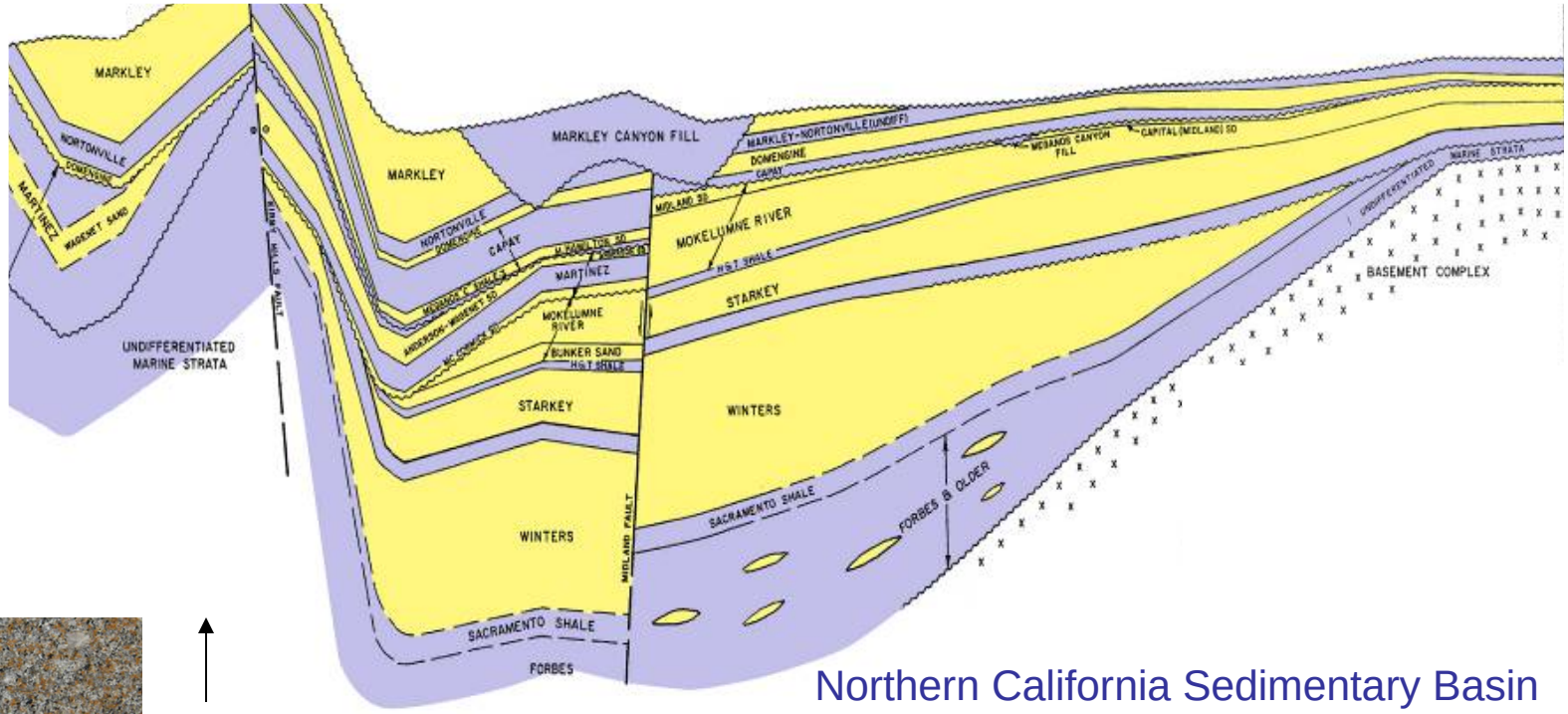
- How much sequestration capacity do we have?
- Will it leak back out?

Capture → **Compression** → **Pipeline Transport** → **Underground Injection**

Types of Rock Formations Suitable for Geological Sequestration

Deep sedimentary basins are suitable for CO_2 sequestration.

100 miles



Northern California Sedimentary Basin

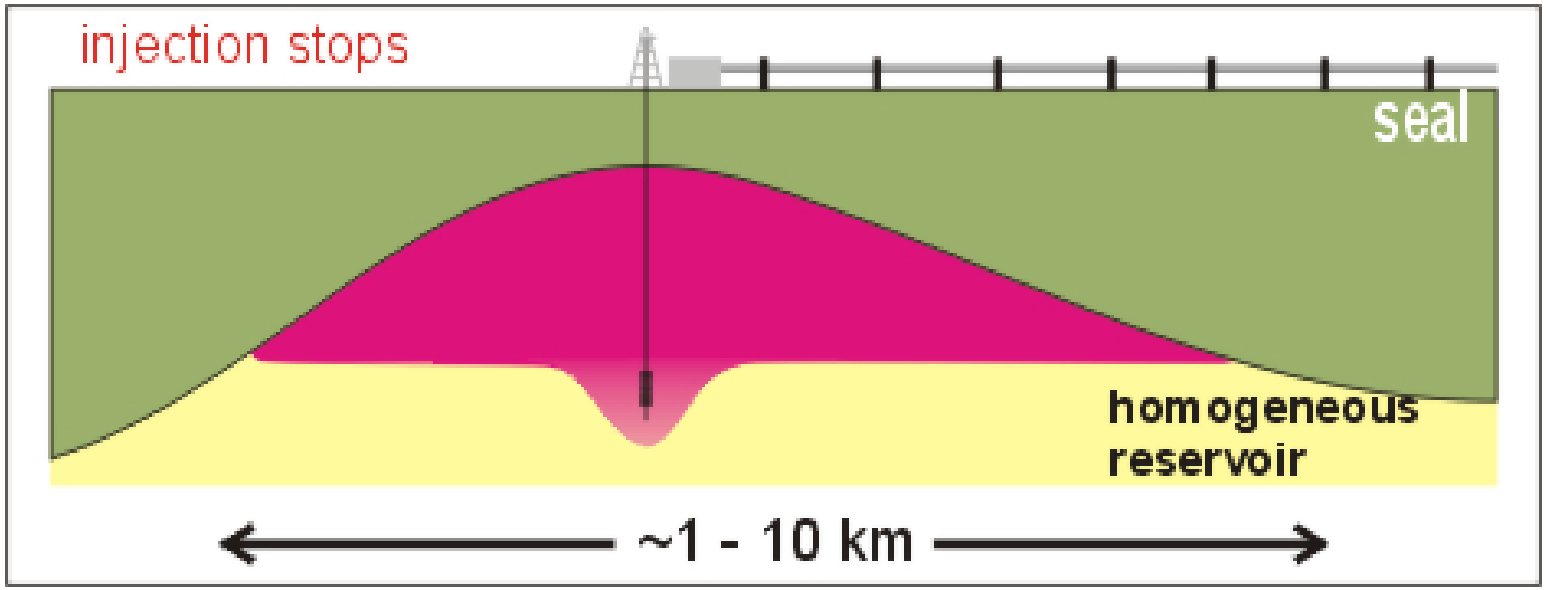
Sandstone

1 inch

Example of a sedimentary basin with alternating layers of sandstone and shale.

Basic Concept of Geological Sequestration of CO_2

- Injected at depths of ~ 1 km or deeper
- Primary trapping
  - Beneath seals of low permeability rocks



Courtesy of John Bradshaw

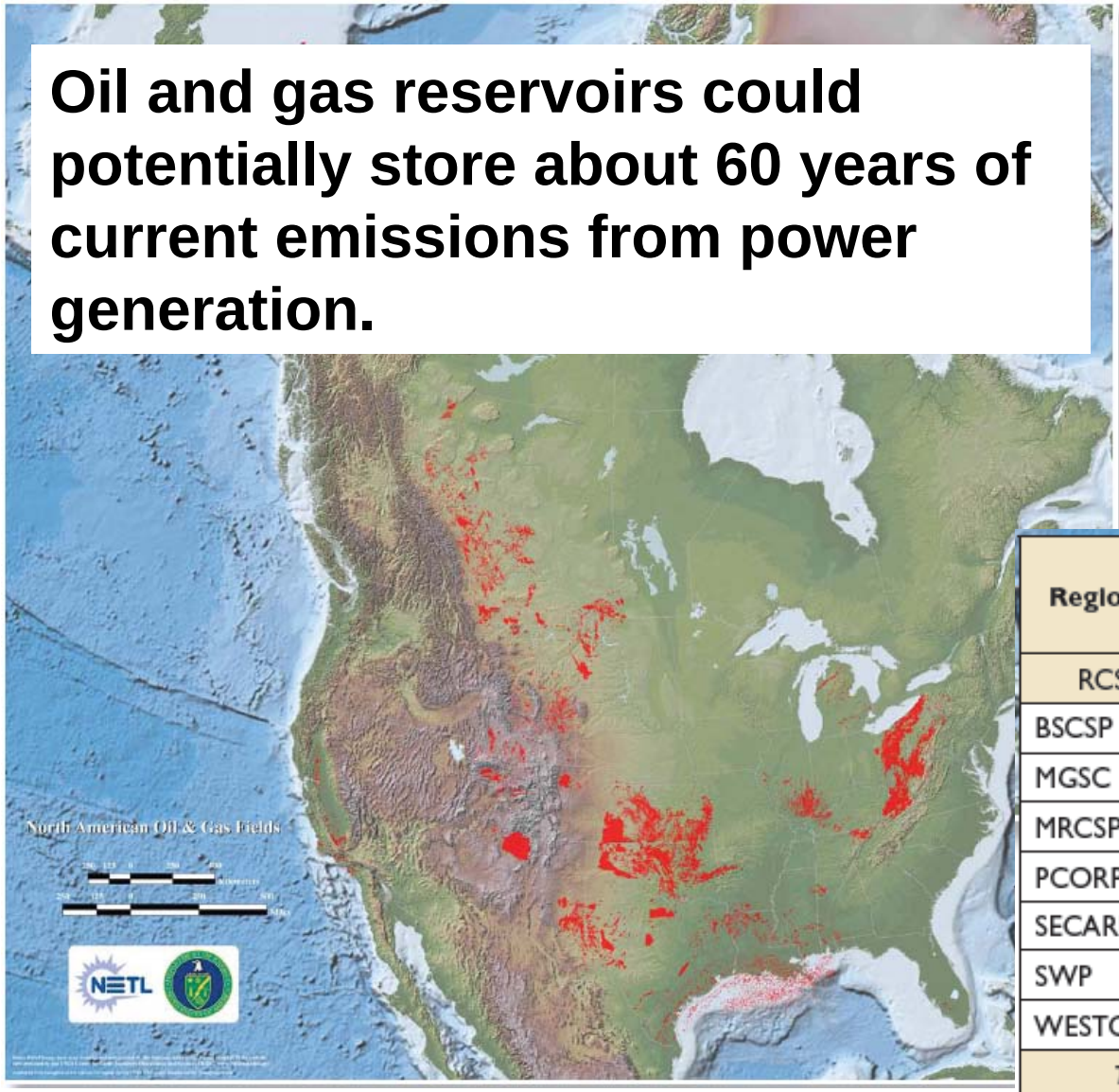
- Secondary Trapping Mechanisms
  - Dissolution, residual gas trapping, and mineralization

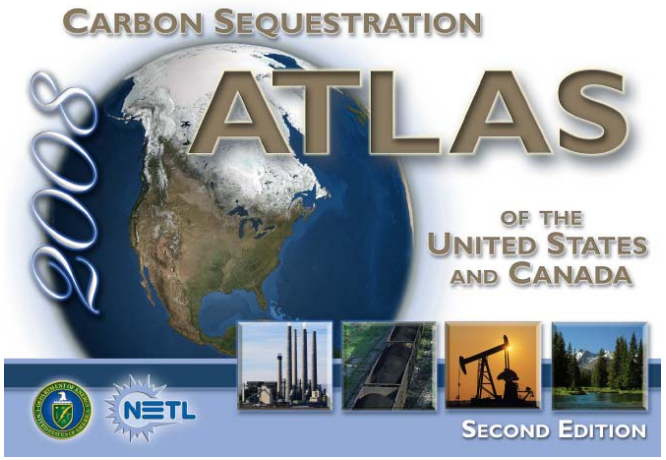
Sequestration Site Selection Criteria

Overburden	Known condition of active and abandoned wells Presence of multiple secondary seals
Seal	Geographically extensive Low permeability and high capillary entry pressure Stable and sealed faults and fractures High mechanical strength
Sequestration Formation	Deeper than 800 m Not a source of drinking water Satisfactory permeability Sufficient sequestration volume Hydrologically isolated from drinking water aquifers Large with open boundaries

North American Sequestration Resources in Oil and Gas Reservoirs

Oil and gas reservoirs could potentially store about 60 years of current emissions from power generation.

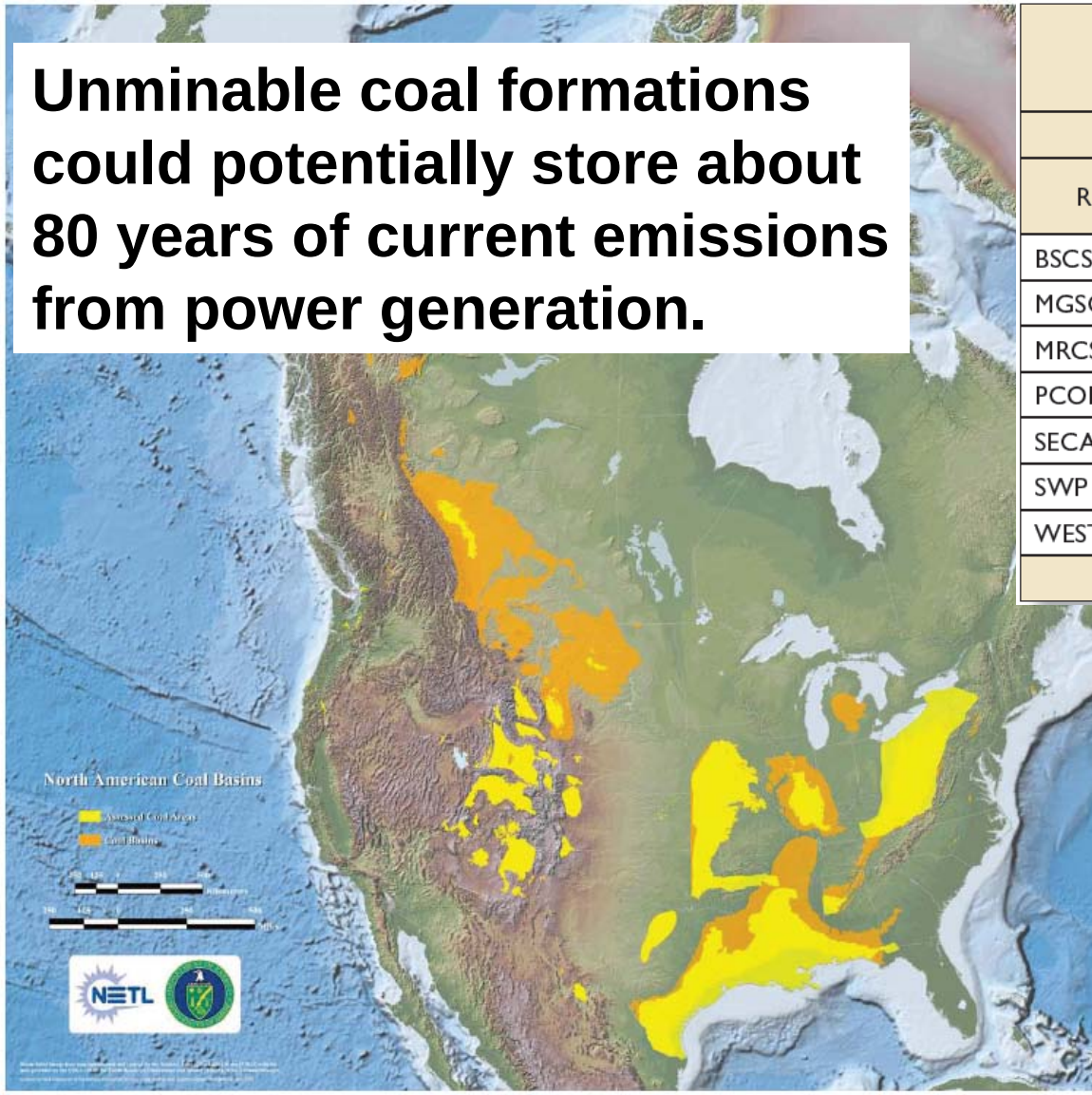




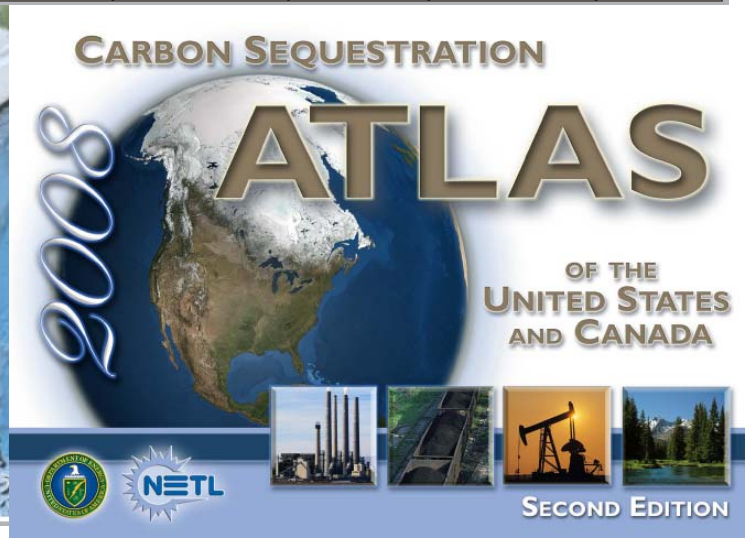
CO_2 Resource Estimates by Regional Carbon Sequestration Partnership for Oil and Gas Reservoirs		
RCSP	Billion Metric Tons	Billion Tons
BSCSP	1.5	1.6
MGSC	0.4	0.4
MRCSP	8.4	9.3
PCORP	24.1	26.5
SECARB	27.1	29.9
SWP	62.3	68.7
WESTCARB	5.8	6.4
TOTAL	129.6	142.9

North American Sequestration Resources in Coal Beds

Unminable coal formations could potentially store about 80 years of current emissions from power generation.



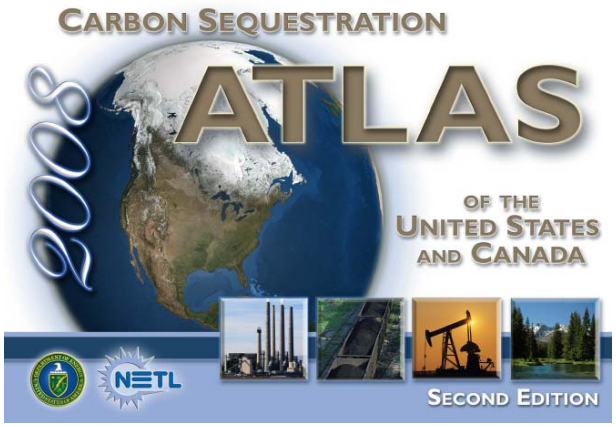
CO_2 Resource Estimates by Regional Carbon Sequestration Partnership for Unmineable Coal Seams				
	Low		High	
RCSP	Billion Metric Tons	Billion Tons	Billion Metric Tons	Billion Tons
BSCSP	12.1	13.3	12.1	13.3
MGSC	1.7	1.8	2.4	2.6
MRCSP	0.8	0.9	0.8	0.9
PCORP	10.7	11.8	10.7	11.8
SECARB	57.8	63.7	82.8	91.3
SWP	0.7	0.8	1.8	2.0
WESTCARB	86.8	95.7	86.8	95.7
TOTAL	170.6	188.0	197.3	217.5



North American Sequestration Resources in Saline Aquifers

Saline aquifers could potentially store more than 1,000 years of current emissions from power production.

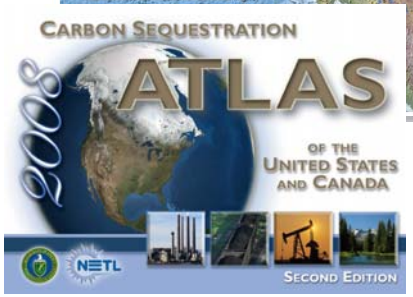
CO_2 Resource Estimates by Regional Carbon Sequestration Partnership for Saline Formations				
	Low		High	
RCSP	Billion Metric Tons	Billion Tons	Billion Metric Tons	Billion Tons
BSCSP	460.9	508.0	1,831.5	2018.9
MGSC	29.2	32.1	116.6	128.6
MRCSP	117.8	129.8	117.8	129.8
PCORP	185.6	204.6	185.6	204.6
SECARB	2,274.6	2,507.3	9,098.4	10029.3
SWP	10.7	11.8	42.6	47.0
WESTCARB	204.9	225.9	817.3	900.9
TOTAL	3,283.6	3,619.5	12,209.8	13459.0



Key Technical Issues About Capacity in Saline Aquifers

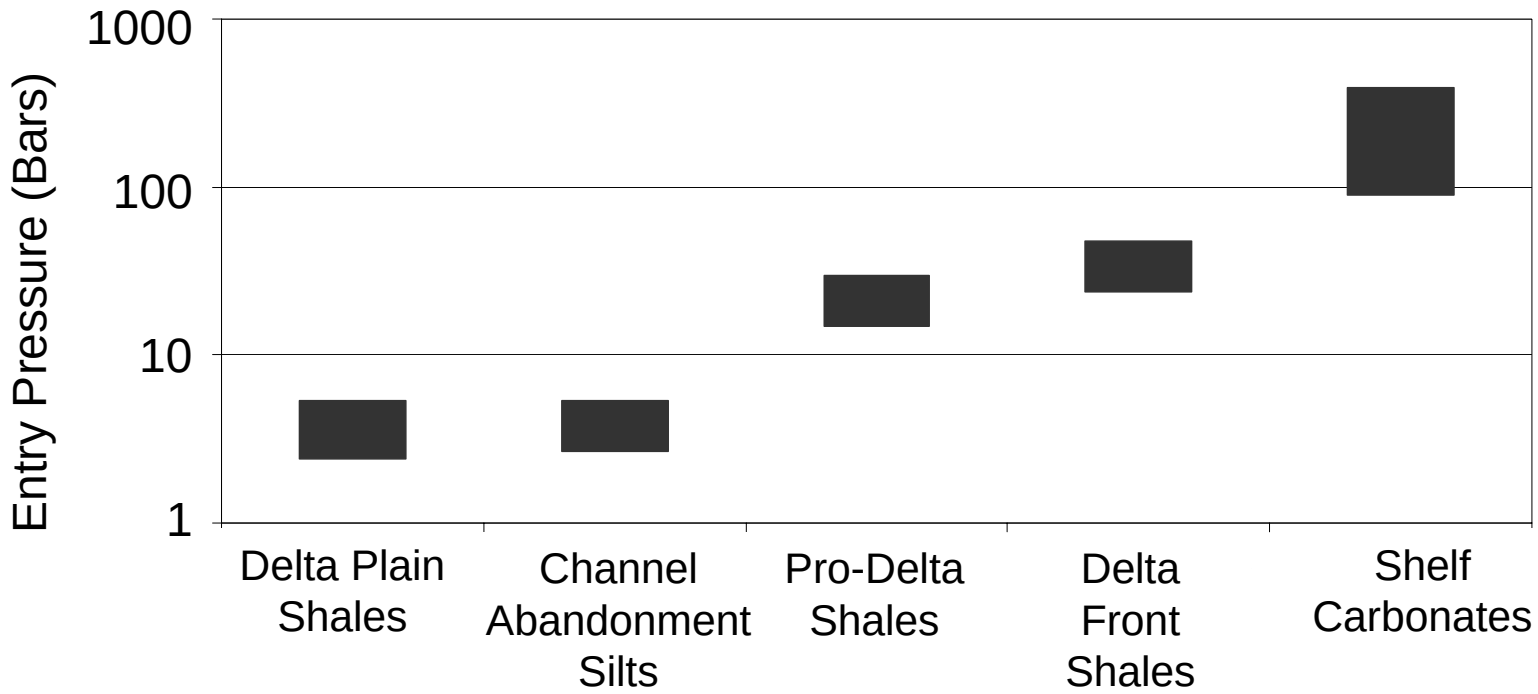
- **Continued refinement of capacity estimation methodology**
  - **Current approach is based on a fraction of the pore space**
  - **Limited by injection pressure?**
  - **Limited by seal continuity?**
- **Storage resource to storage reserve?**

Prospective Saline Aquifers



Seal Rocks and Trapping Mechanisms

- **Seal rock geology**
  - **Shale, clay, anhydrite, carbonates**
- **Two trapping mechanisms**
  - **Permeability barriers to CO_2 migration**
  - **Capillary barriers to CO_2 migration**



Lessons Learned from Natural Gas Storage and Waste Disposal

- **Major sources of leakage through seals**
  - **Injection wells**
  - **Abandoned wells**
  - **Undetected faults and fractures in the seal**
  - **Damage to seal from hydraulic fracturing**
  - **Inadequate monitoring**
- **These were all adequately addressed through regulation**
  - **Permits for siting and injection operations**
  - **Well completion standards**
  - **Injection pressure limits**
  - **Routine monitoring and reporting**

S.M. Benson (2005) "Lessons Learned from Natural and Industrial Analogues," *Carbon Dioxide Capture for Storage in Deep Geologic Formations—Results from the CO2 Capture Project*, *Vol. 2: Geologic Storage of Carbon Dioxide with Monitoring and Verification*, Elsevier Publishing, UK, p. 1133-1141.

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