Favorable Stratigraphic Conditions for Carbon Sequestration Exist in the Rocky Mountain Basins*

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Abstract

The United States Geological Survey (USGS) was directed by the 2007 Energy Independence and Security Act (Public Law 110-140) to assess the potential geologic storage resources for carbon dioxide (CO_2) within the United States. The USGS, following its published, wholly probabilistic methodology for this national assessment, began these assessments in the Rocky Mountain States in the Fall of 2010. The basic unit of assessment for the USGS methodology is the Storage Assessment Unit (SAU), which consists of a storage formation and an overlying regional seal formation. The SAUs are defined by geologic criteria, primarily based on depth, rock properties, and regional extents of the storage and seal formations. The methodology requires that the storage formation be between 3,000 and 13,000 ft below ground surface. This minimum required depth ensures that CO_2 will be supercritical. Within the Rocky Mountain basins, a significant portion of the Mesozoic section (such as the Dakota Sandstone), fits within this interval. However, when rock properties indicate that CO_2 could be stored at depths greater than 13,000 feet, a separate deep SAU is assessed. The areal extent of the storage formation and overlying seal are required to be continuous and regional in extent. Most Rocky Mountain basins contain thick laterally extensive marine shales like the Pierre Shale or Mowry Shale that would inhibit flow to superjacent strata. In some cases, the stratigraphy includes the potential for multiple or stacked seals. During the assessment, the seal is evaluated for leakage potential and a minimum seal thickness is defined. This minimum seal thickness must exist over the extent of the storage formation and no portion of the SAU may exist where the seal is too thin or nonexistent. A final consideration is the salinity of the water within the pore space of the storage formation; based on available salinity data and geologic models, estimates are made as to how much of the SAU contains water that has less than 10,000 parts per million total dissolved solids. Much of the stratigraphic section in the Rocky Mountain area is composed of porous and permeable sedimentary rock, though much of the rock contains low salinity waters. The USGS Carbon Sequestration assessments have shown that the stratigraphy of the Rocky Mountain basins is conducive to potential CO_2 sequestration, with some restrictions.

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Outline for Presentation

- Introduction
- Overview of legislation
- Geologic sequestration model
- Methodology
- Assessment examples from Rocky Mountain basins
- Summary

USGS

Energy Independence and Security Act 2007

TITLE VII—CARBON CAPTURE AND SEQUESTRATION

Subtitle B—Carbon Capture and Sequestration Assessment and Framework

SEC. 711. CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT.

(b) METHODOLOGY— …shall develop a methodology for conducting an assessment under subsection (f), taking into consideration—

(1) the geographical extent of all potential sequestration formations in all States;

(2) the capacity of the potential sequestration formations;

(3) the injectivity of the potential sequestration formations;

(4) an estimate of potential volumes of oil and gas recoverable by injection and sequestration of industrial carbon dioxide in potential sequestration formations;

(5) the risk associated with the potential sequestration formations; and

(6) the work done to develop the Carbon Sequestration Atlas (USDOE, 2010) of the United States and Canada that was completed by Department of Energy (DOE).

(c) COORDINATION—

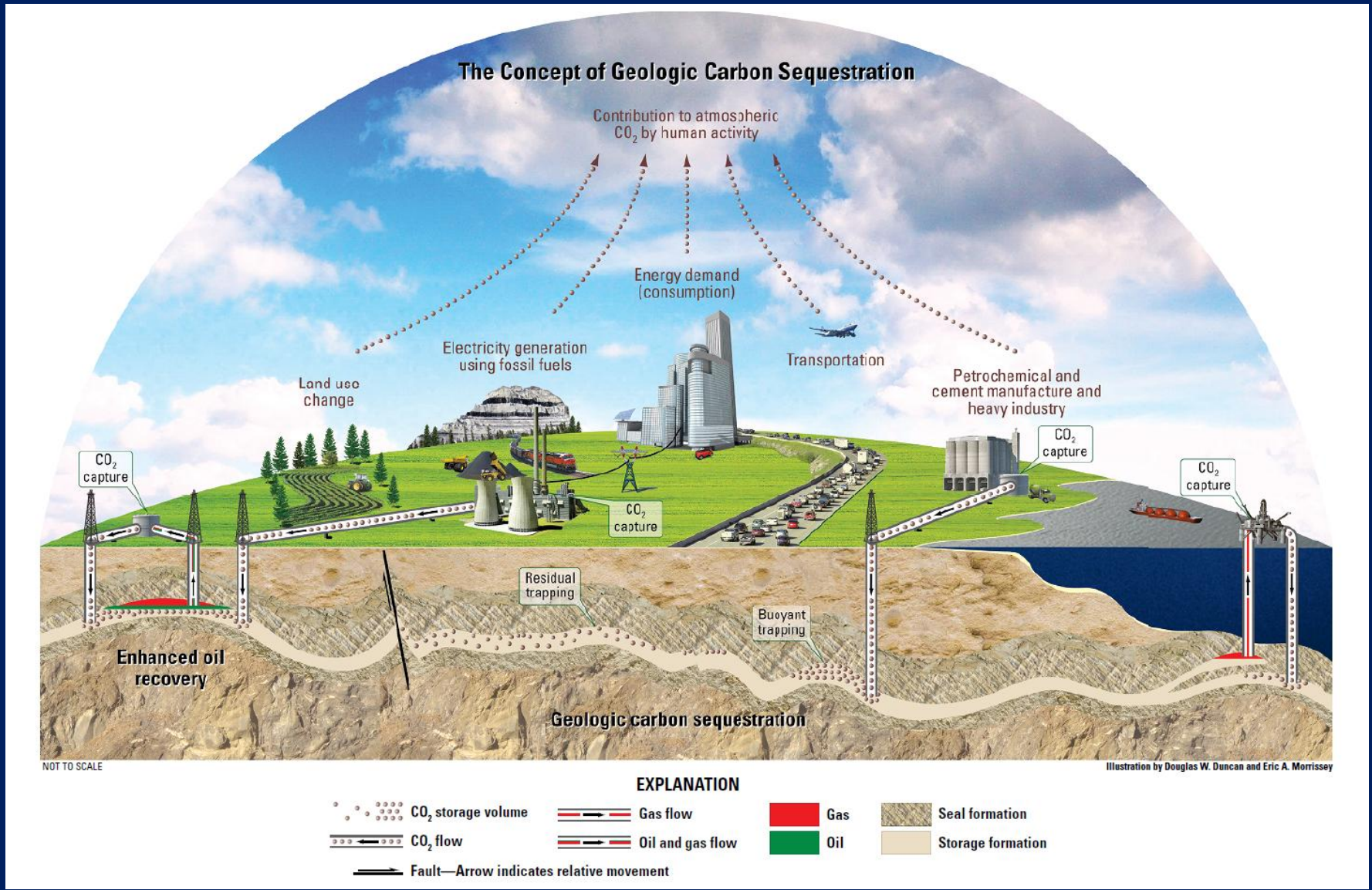
(1) Federal Coordination

(2) State Coordination

For more information on the Energy Independence and Security Act 2007
See: https://www.federalregister.gov/articles/2010/07/08/2010-16236/energy-independence-and-security-act-pub-l-110-140

USGS

What is Geologic CO_2 Sequestration?



USGS

(Duncan and Morrissey , 2011)

USGS Assessment Methodology for Geologic CO_2 Storage Capacities

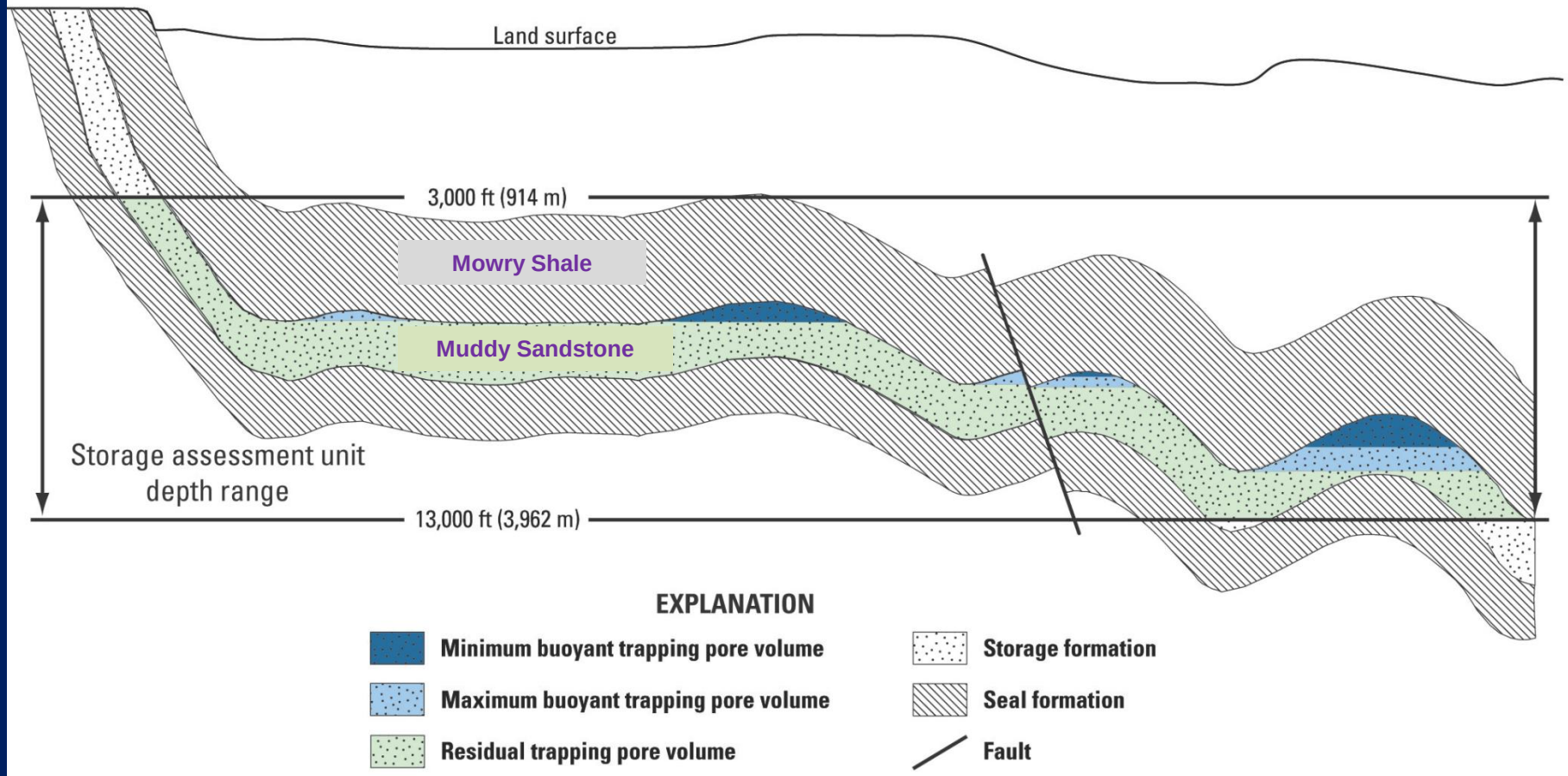
- The USGS assessment focuses on CO_2 injected at depths of 3,000 to 13,000 ft (deeper if rock properties indicate potential storage resources)
- CO_2 (pressurized and supercritical at depths > 3000 ft) is buoyant and displaces existing water, oil, or gas
- Storage formation must have an overlying seal to retain buoyant CO_2
- USGS assessment methodology addresses buoyant and residual trapping
- Salinity of groundwater in storage formation must be >10,000 ppm TDS per Environmental Protection Agency (EPA) regulations (U.S. EPA, 2008)
- Assessment results provide probabilistic ranges of storage capacities

USGS

(Modified from Warwick, written comm., 2012 NETL CCUS)

Schematic Storage Formation Model

Storage Assessment Unit, Cross Section



(Modified from Brennan and others, 2010)

USGS

Salinity of water in storage formation must be > 10,000 ppm TDS per EPA regulations

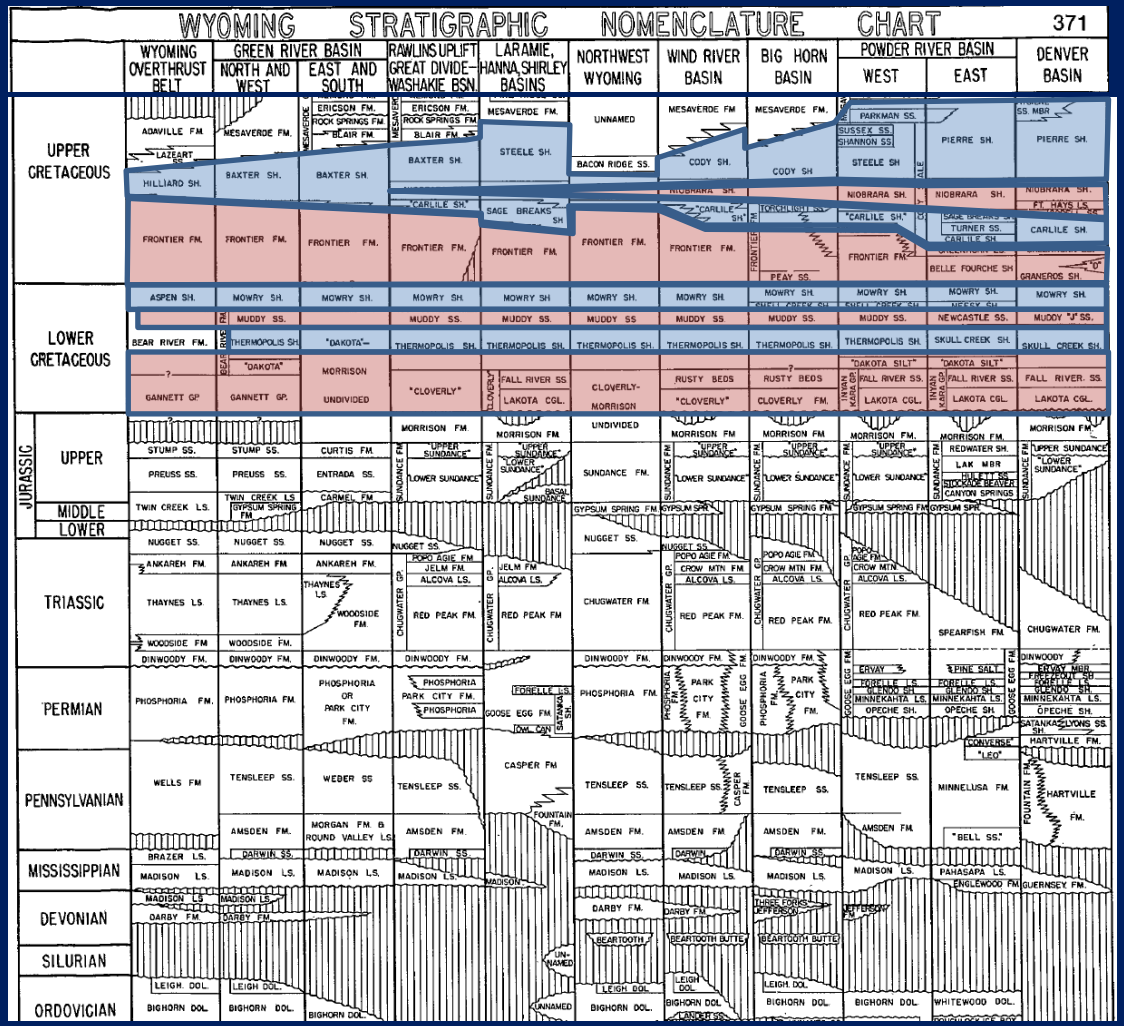
What are Favorable Conditions for Potential CO_2 Storage?

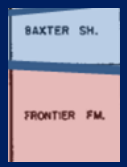
- Storage Assessment Unit (SAU) with a minimum depth of 3,000 feet below the surface
- A storage formation with reservoir-quality rock properties
- Storage formation must have a robust overlying seal that is…
  - Impermeable
  - Regionally extensive
  - Maintains a minimum thickness (e.g. 75’)

USGS

Rocky Mountain Basin Stratigraphy

- Laramide Orogeny -- formed and preserved structural basins
- Alternating storage unit/seal stratigraphy
- Western Interior Seaway → sea level changes (Regional)
- Ancestral Rockies, erosion



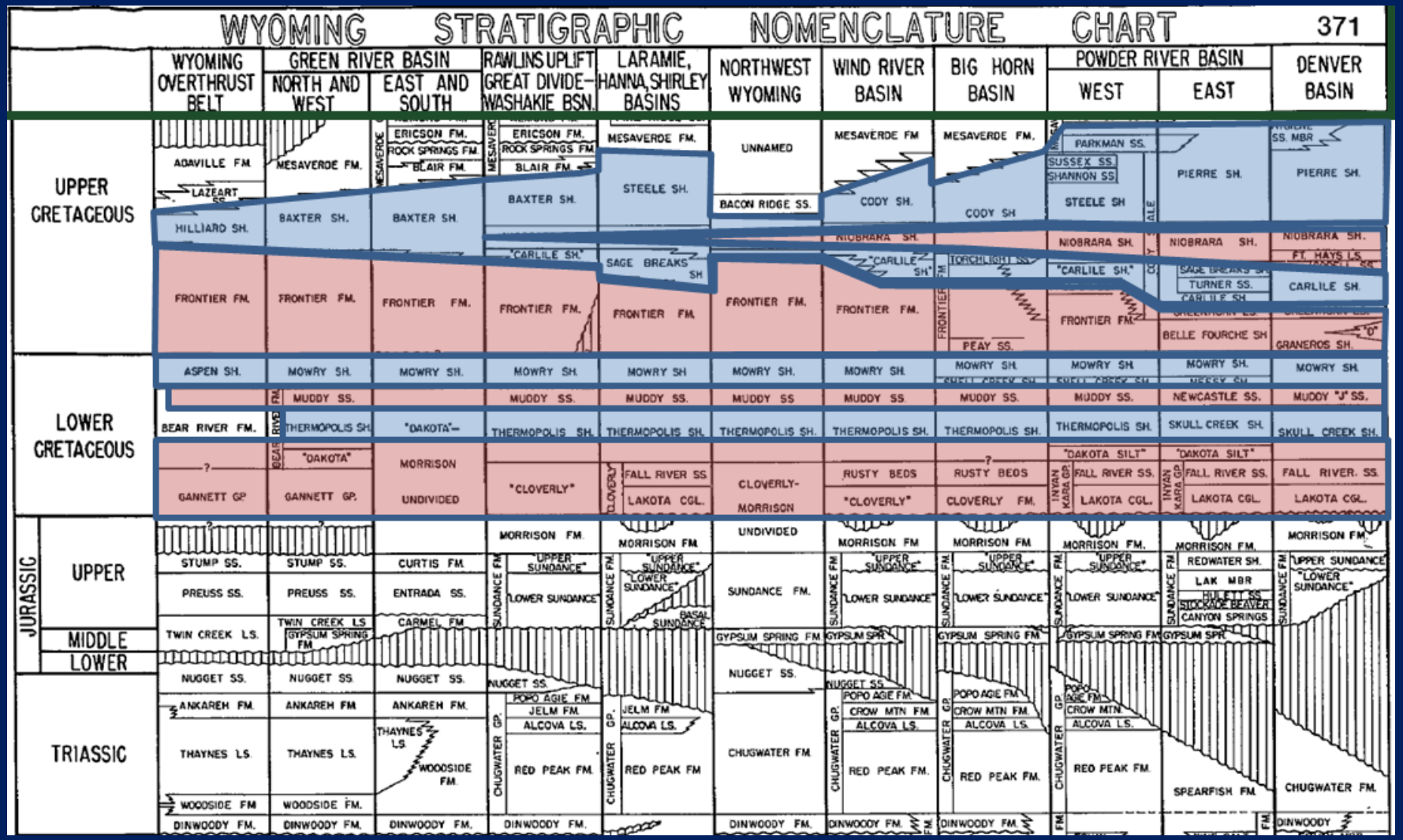


= Regional Seal

= Reservoir

(Wyoming Geological Association, 1969)

Examples of Cretaceous seals and reservoirs



BAXTER SH. = Regional Seal

FRONTIER FM. = Reservoir

USGS

(Wyoming Geological Association, 1969)

Denver Basin in Colorado, Wyoming and Nebraska

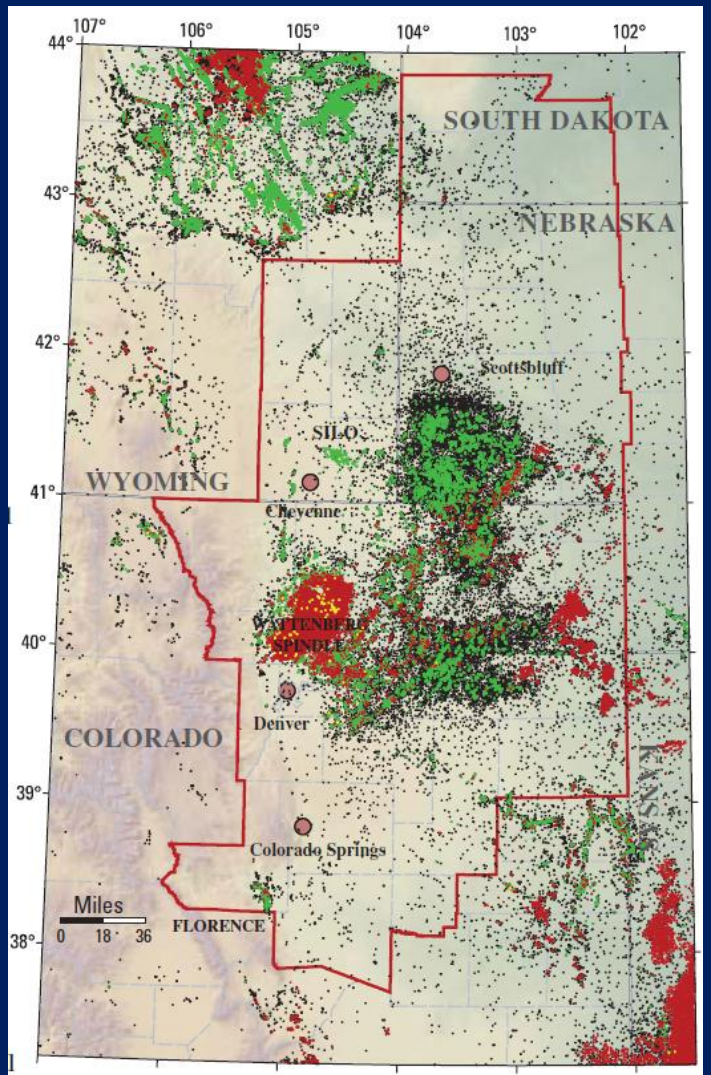


Figure 1. The Denver Basin Province (red line) of Colorado, Kansas, Nebraska, South Dakota, and Wyoming. Shown are oil (green), gas (red), oil and gas (yellow) and nonproductive (black) wells.

(Higley and others, 2002)

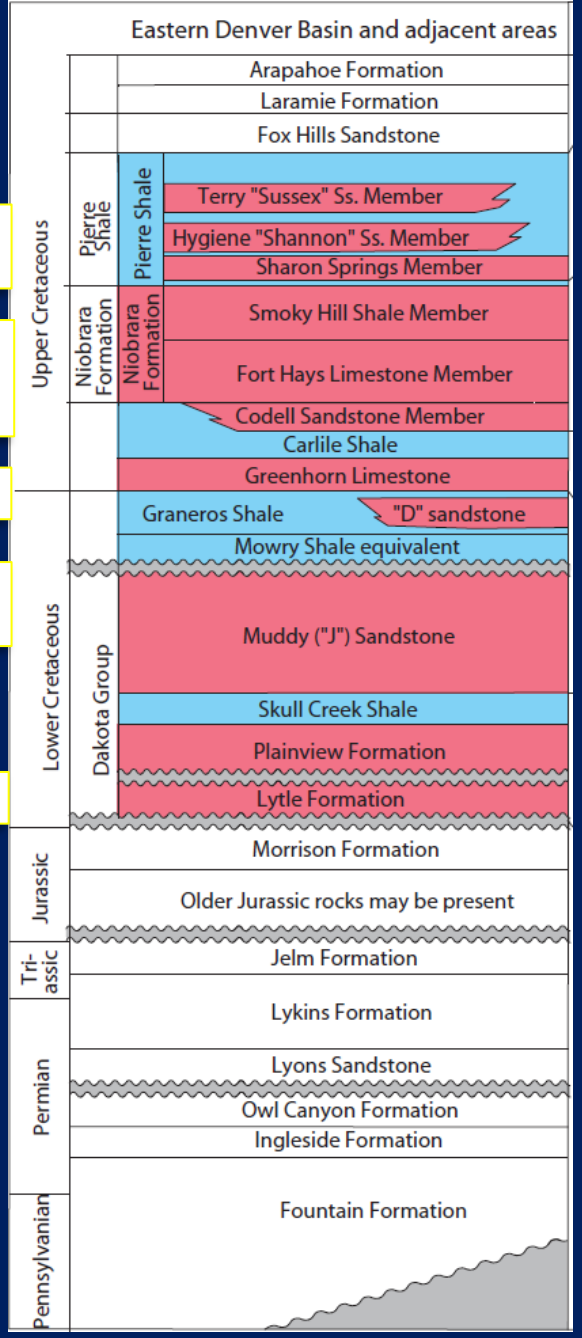
Pierre Shale and sandstone members

Niobrara Formation, Codell Sandstone Member

Greenhorn Limestone

Muddy ("J") Sandstone and "D" sandstone

Lytle and Plainview Formations



Regional seal (blue) and reservoir (red)

(Modified from Higley and Cox, 2007)

USGS

San Juan Basin, New Mexico and Colorado

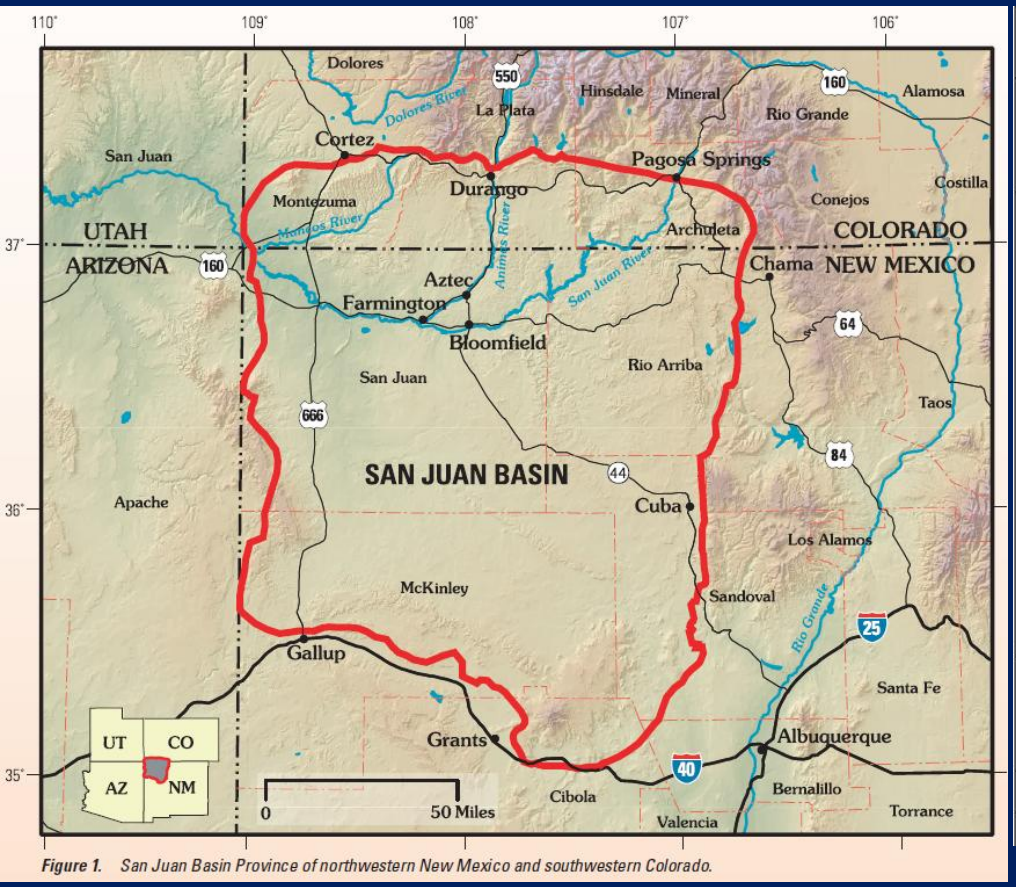
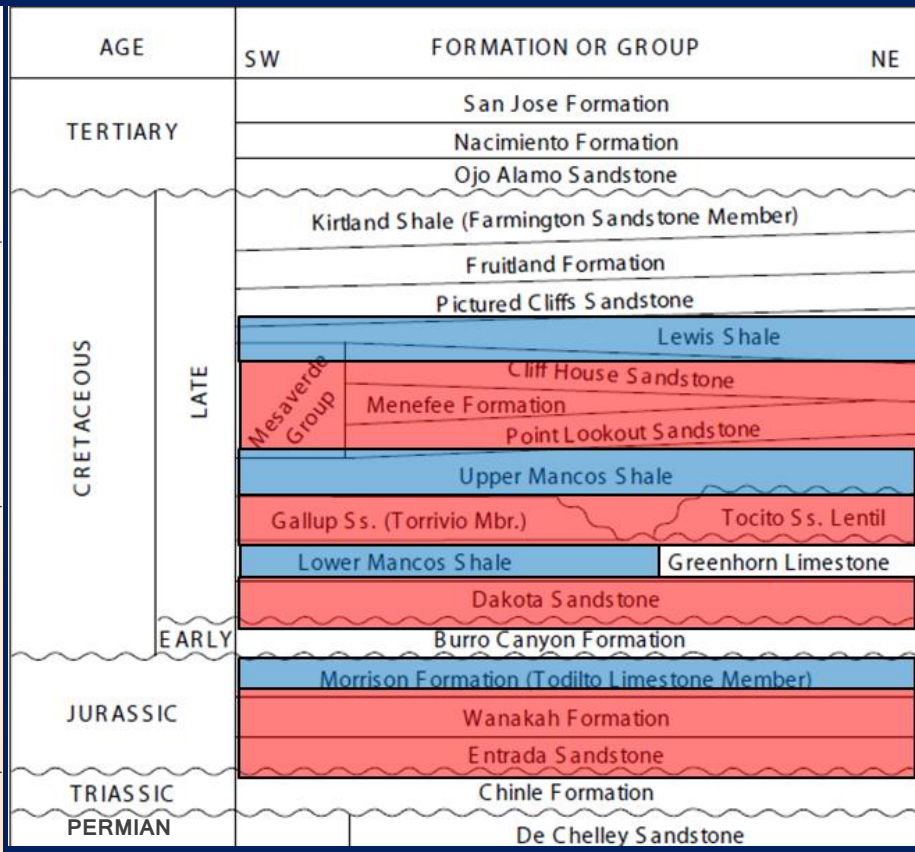


Figure 1. San Juan Basin Province of northwestern New Mexico and southwestern Colorado.

(USGS, San Juan Basin Province Assessment Team, 2002)



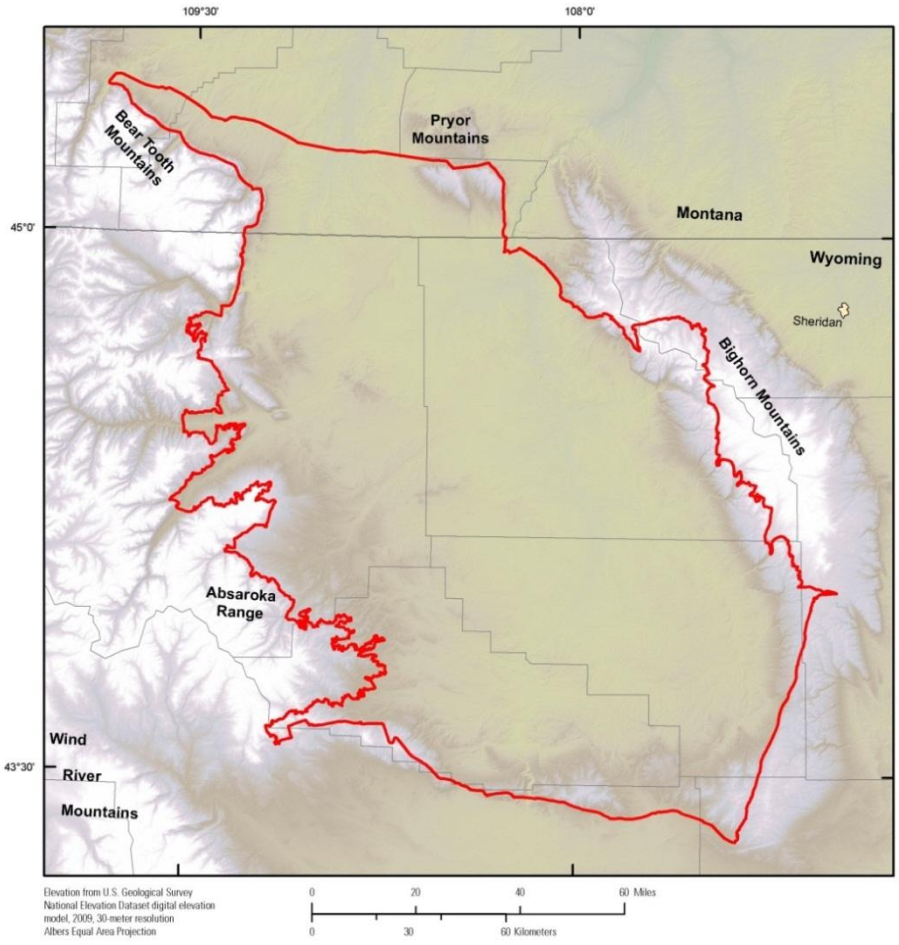
(Huffman, 1995)

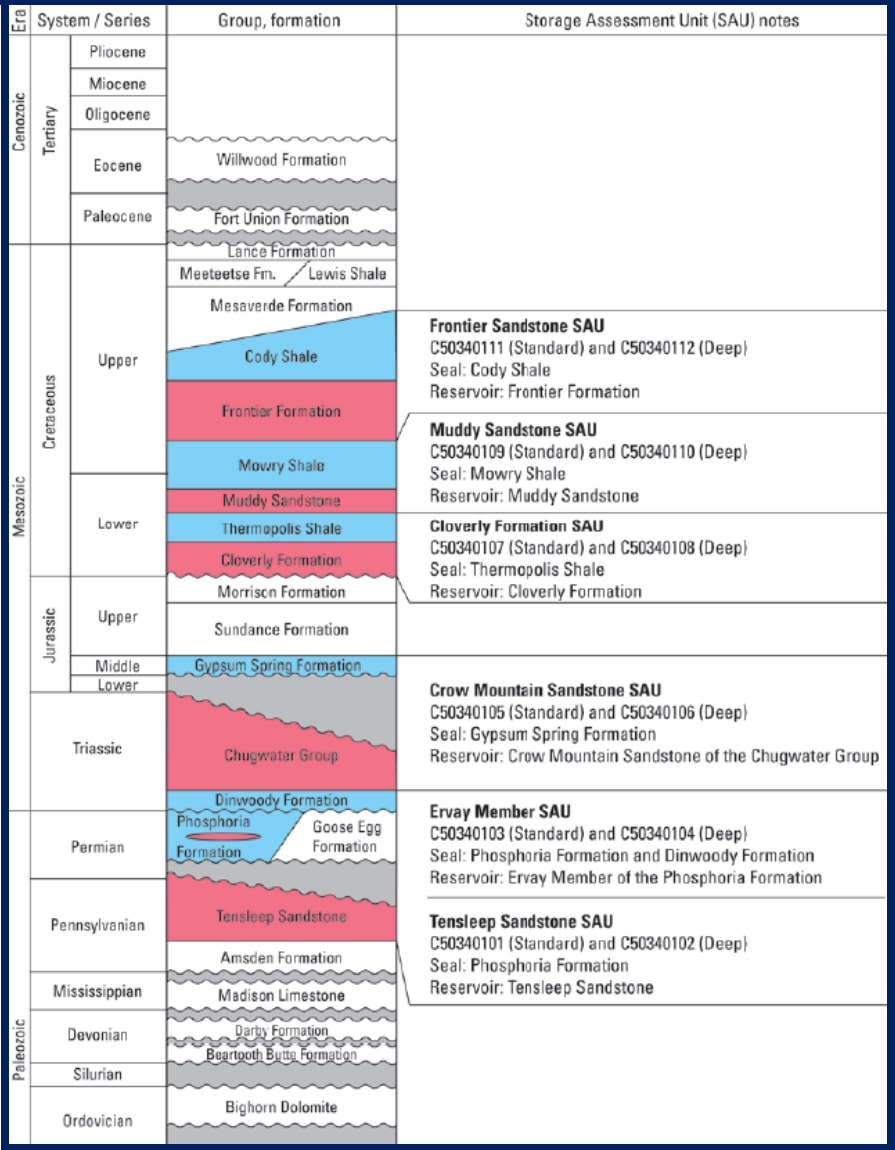
Regional seal (blue) and reservoir (red)

1) Mesaverde Group w/ Lewis Shale seal
2) Gallup Ss. with upper Mancos Shale seal
3) Dakota Ss. with lower Mancos Shale seal
4) Entrada Ss. with Todilto Member (evaporite) seal

USGS

Bighorn Basin, Wyoming and Montana



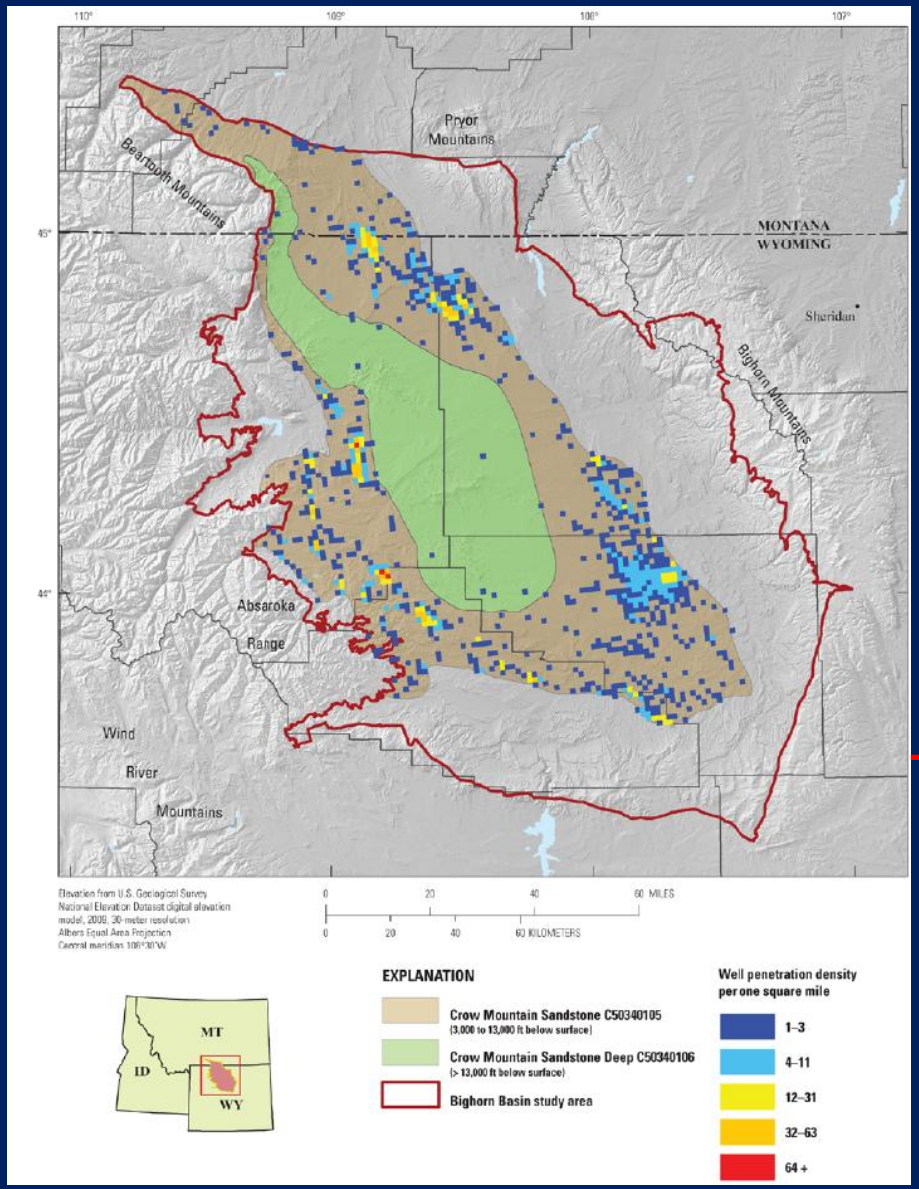


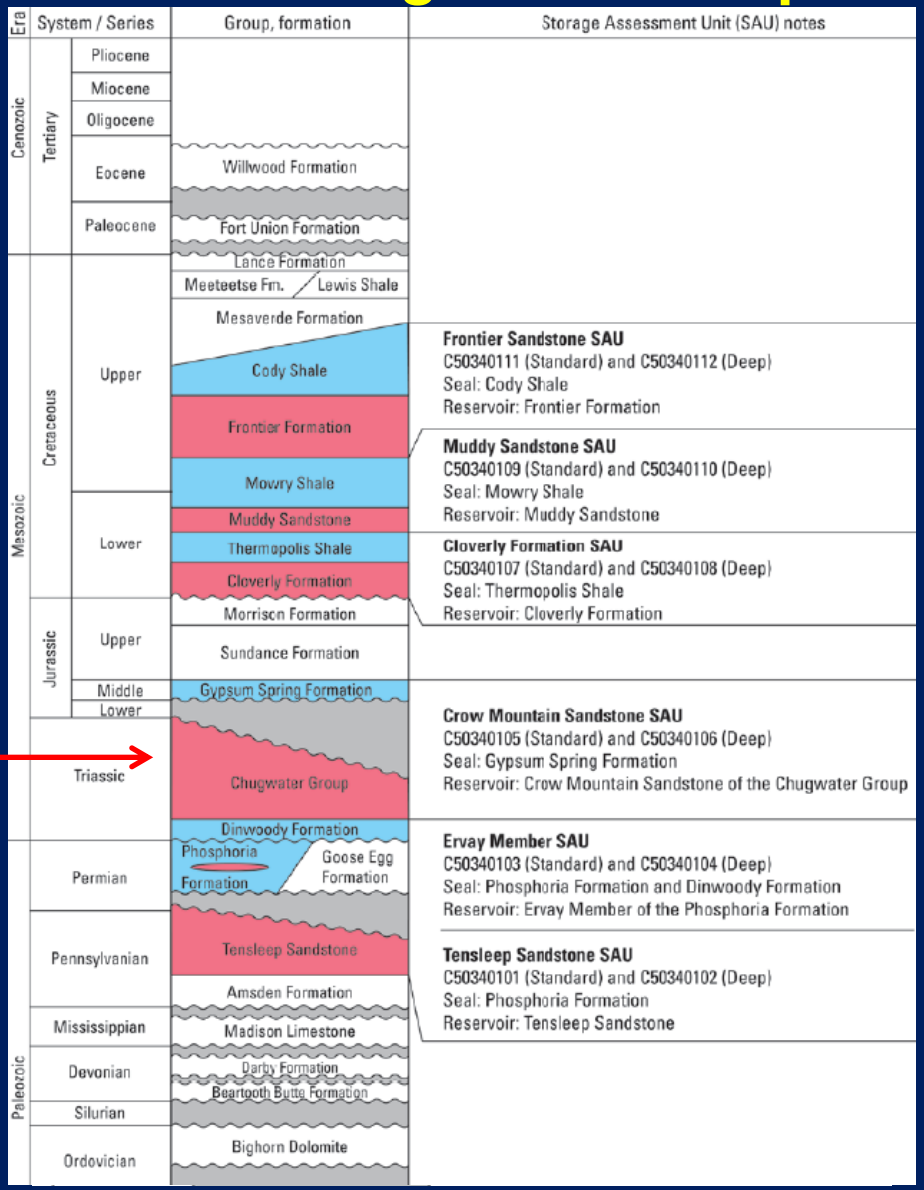
Regional seal (blue) and reservoir (red)

- *6 standard SAUs and 6 deep SAUs were assessed*

(Covault and others, 2012)

Triassic Crow Mountain Sandstone of Chugwater Group

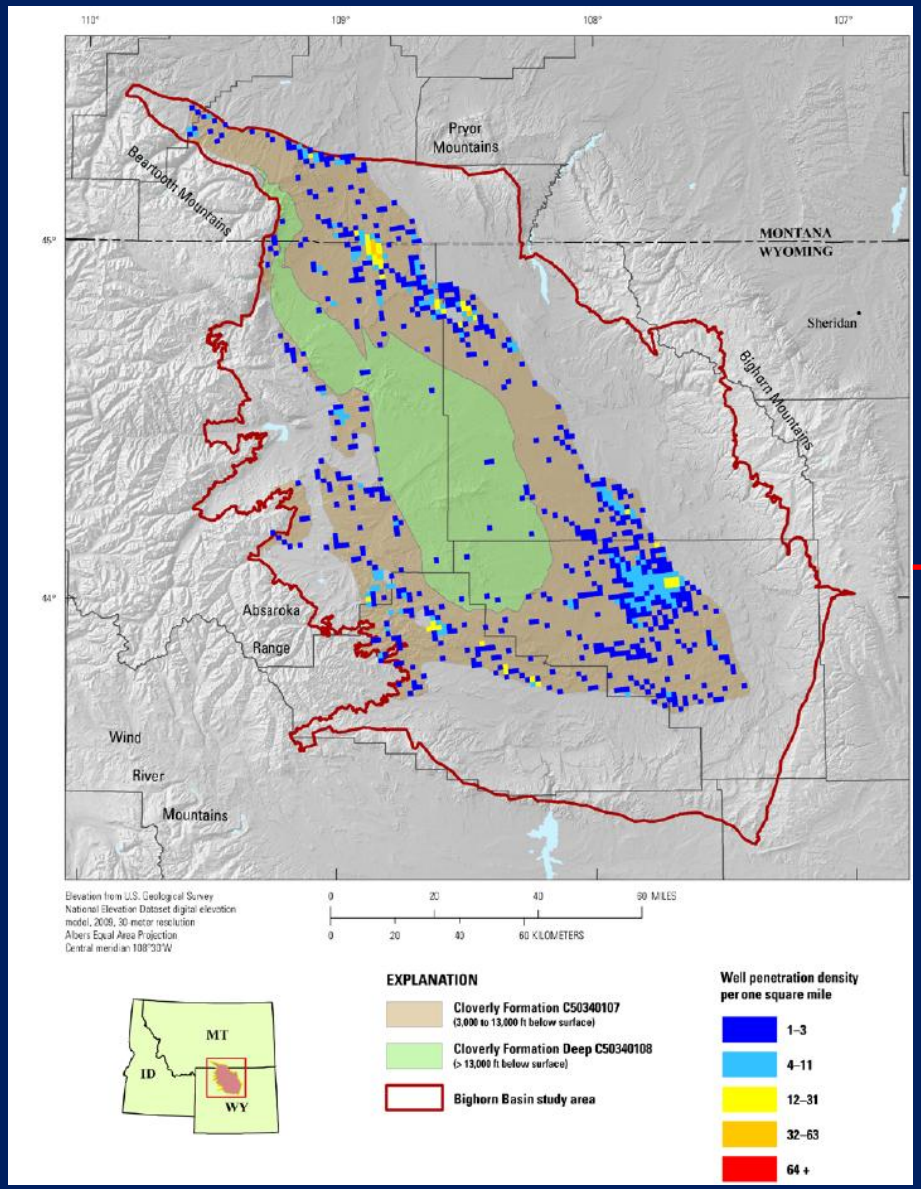


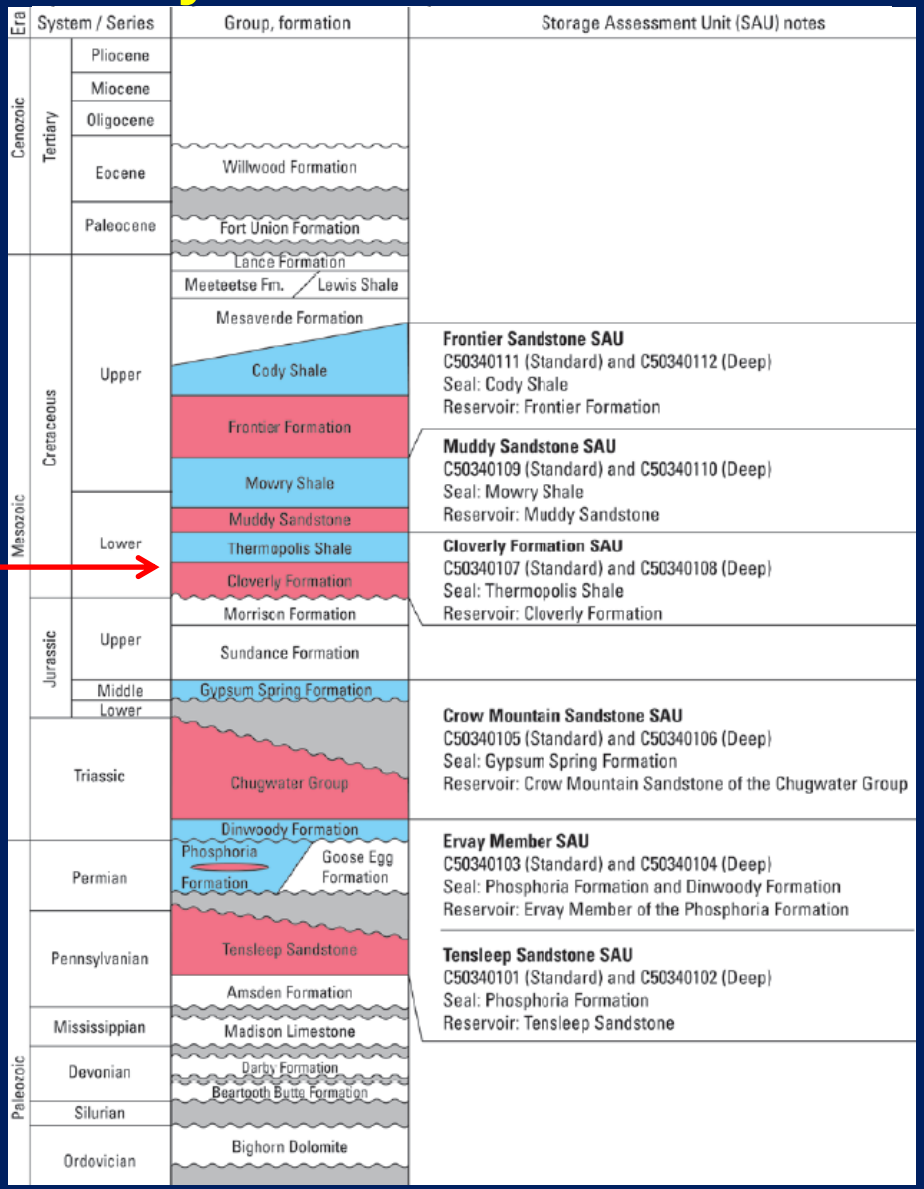


(Covault and others, 2012)

Seal is impermeable Gypsum Spring Formation (80–200 ft thick).

Lower Cretaceous Cloverly Formation

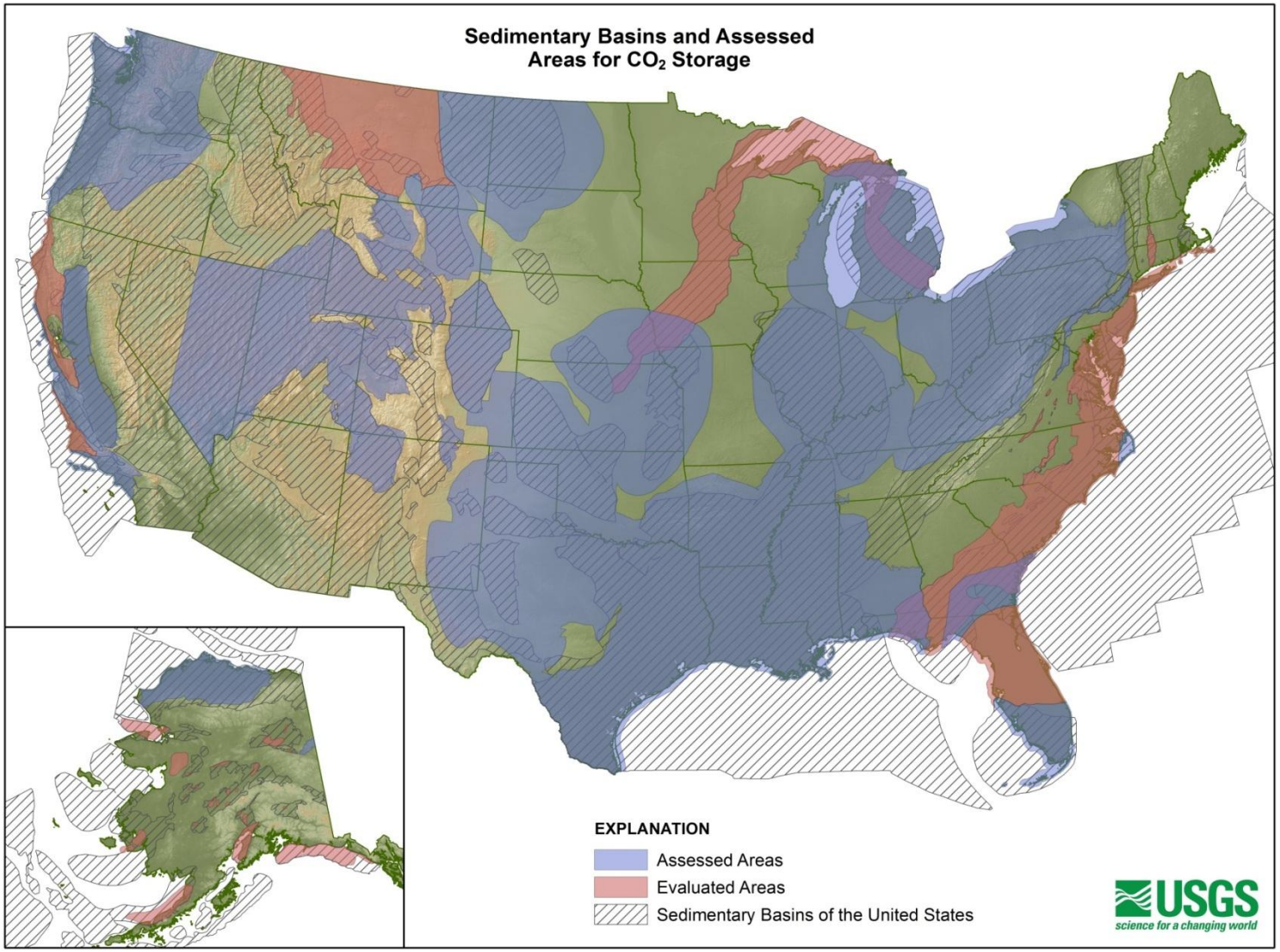




(Covault et al., 2012)

Seal is Thermopolis Shale (up to 230 ft thick).

USGS National Sequestration Assessment Summary



USGS

…36 basins assessed containing 200+ SAUs

Summary

- Most Rocky Mountain basins contain rocks formed in a multitude of depositional environments
- The USGS national assessment has shown that many units meet the criteria of the CO_2 storage assessment methodology and may be suitable as potential CO_2 storage formations
- The USGS CO_2 storage assessment methodology can estimate the technically accessible CO_2 storage resource at a variety of levels of uncertainty across a formation
- The assessment process has been completed; final products are expected in 2013

USGS

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Also on the web at:

http://energy.usgs.gov

http://rmgsc.cr.usgs.gov/carbon_seq/

http://energy.er.usgs.gov/health_environment/co2_sequestration/

USGS

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