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WESTCARB Regional Partnership

Sealing Characteristics of Shale

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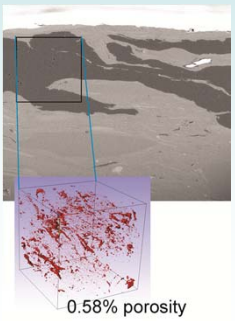
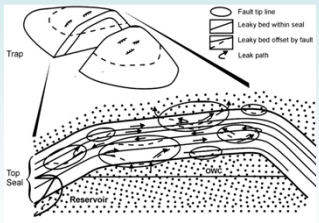
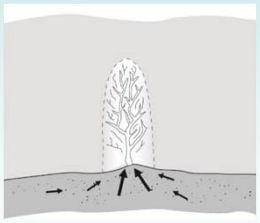
What governs transport at specific sites: pore networks or “seal bypass systems”? And how is this effectively determined?



(Heath et al., 2011)

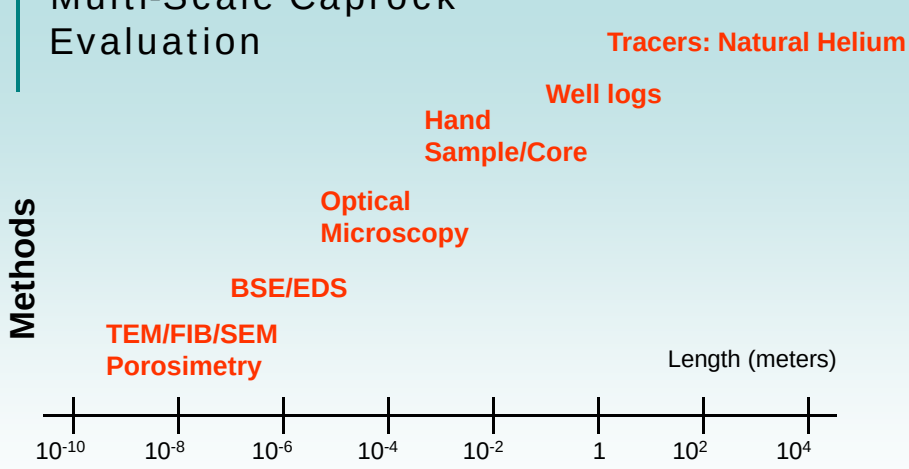


(Ingram and Urai, 1999)



(Cartwright et al., 2007)

Multi-Scale Caprock Evaluation



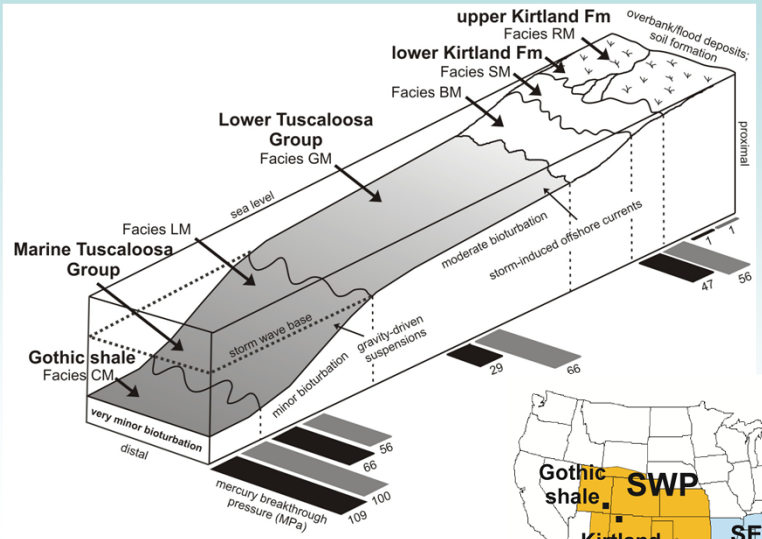
Nanoscale: pore networks & surfaces

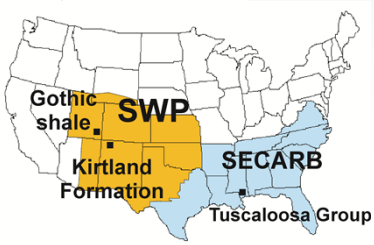
Microscale: large pores and microfractures

Mesoscale: core, outcrop, well logs, fractures

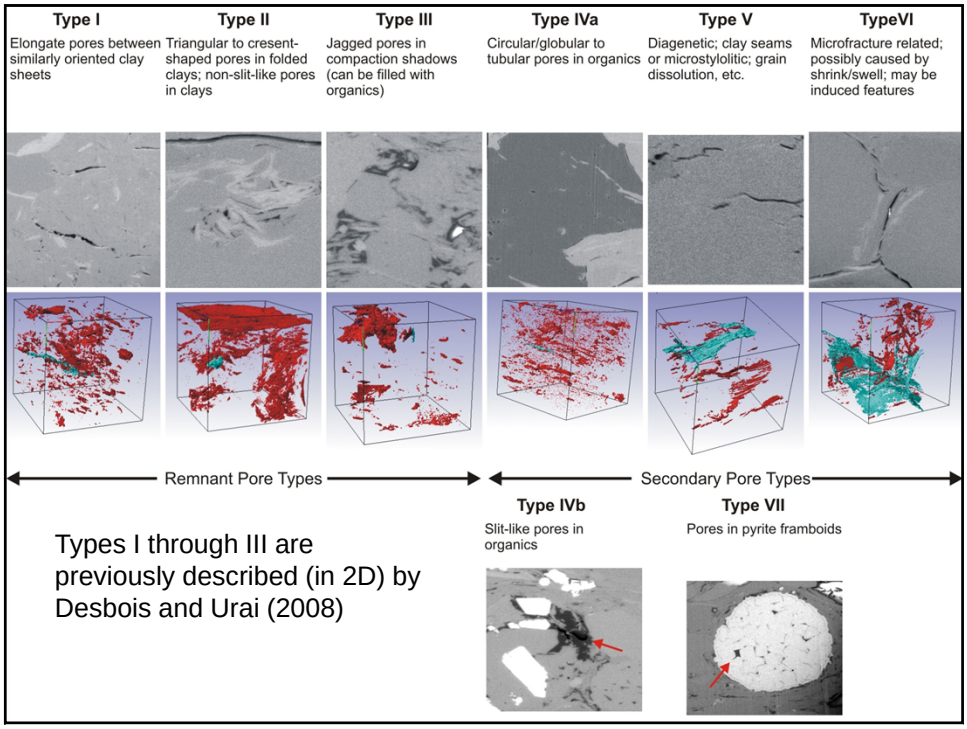
Macroscale: Formation/ reservoir

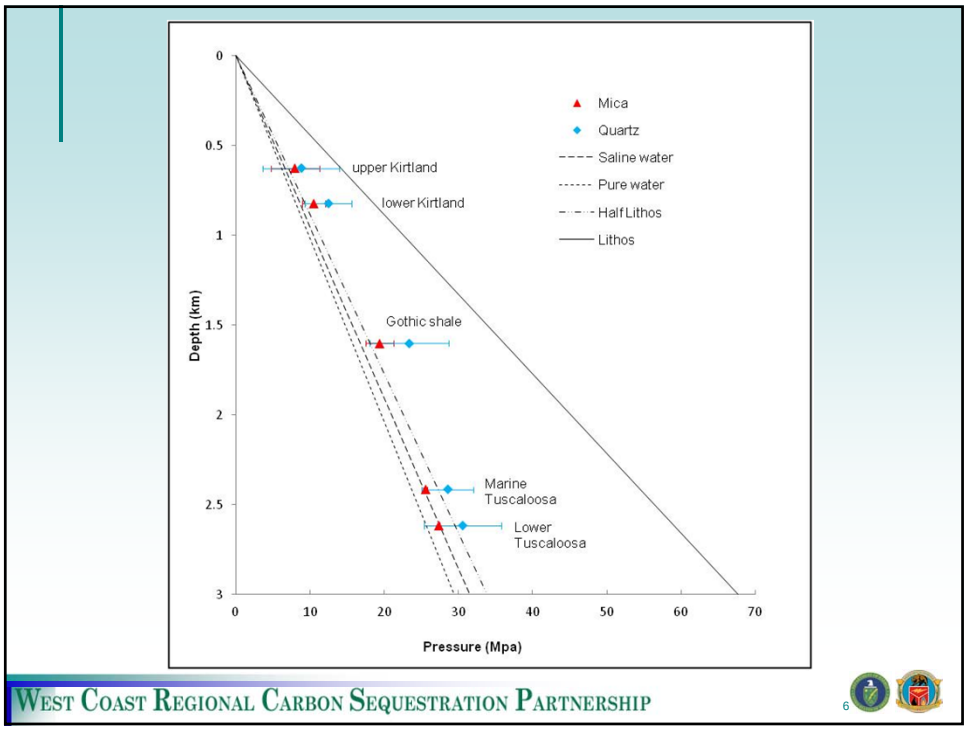
Small-Scale First: Breakthrough Pressure & Sequence Stratigraphy





(modified from Schieber, 1999)


Type I
Elongate pores between similarly oriented clay sheets
Type II
Triangular to cresent-shaped pores in folded clays; non-slit-like pores in clays
Type III
Jagged pores in compaction shadows (can be filled with organics)
Type IVa
Circular/globular to tubular pores in organics
Type V
Diagenetic; clay seams or microstylolitic; grain dissolution, etc.
TypeVI
Microfracture related; possibly caused by shrink/swell; may be induced features
Remnant Pore Types
Secondary Pore Types
Types I through III are previously described (in 2D) by Desbois and Urai (2008)
Type IVb
Slit-like pores in organics
Type VII
Pores in pyrite framboids


Mica
Quartz
Saline water
Pure water
Half Lithos
Lithos
upper Kirtland
lower Kirtland
Gothic shale
Marine Tuscaloosa
Lower Tuscaloosa
Depth (km)
Pressure (Mpa)
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
70
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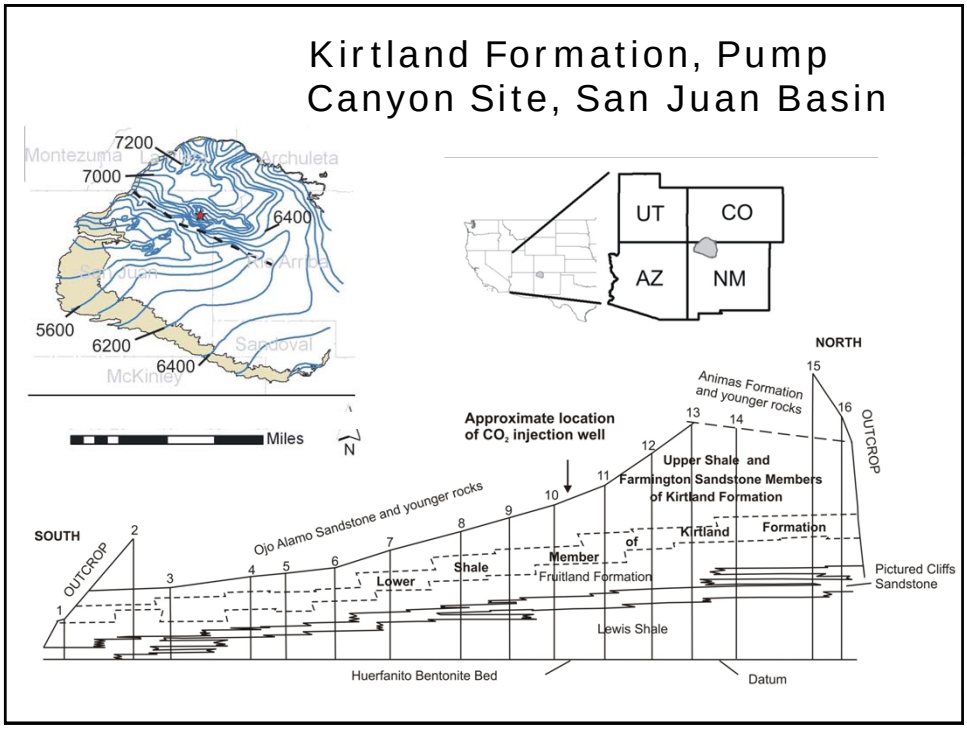
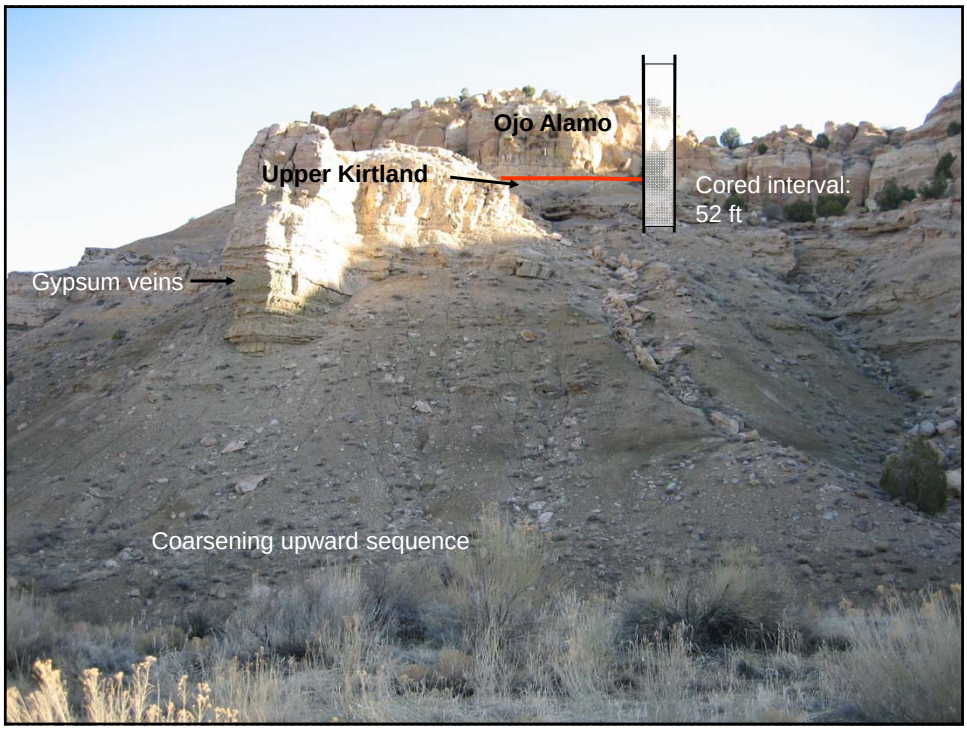
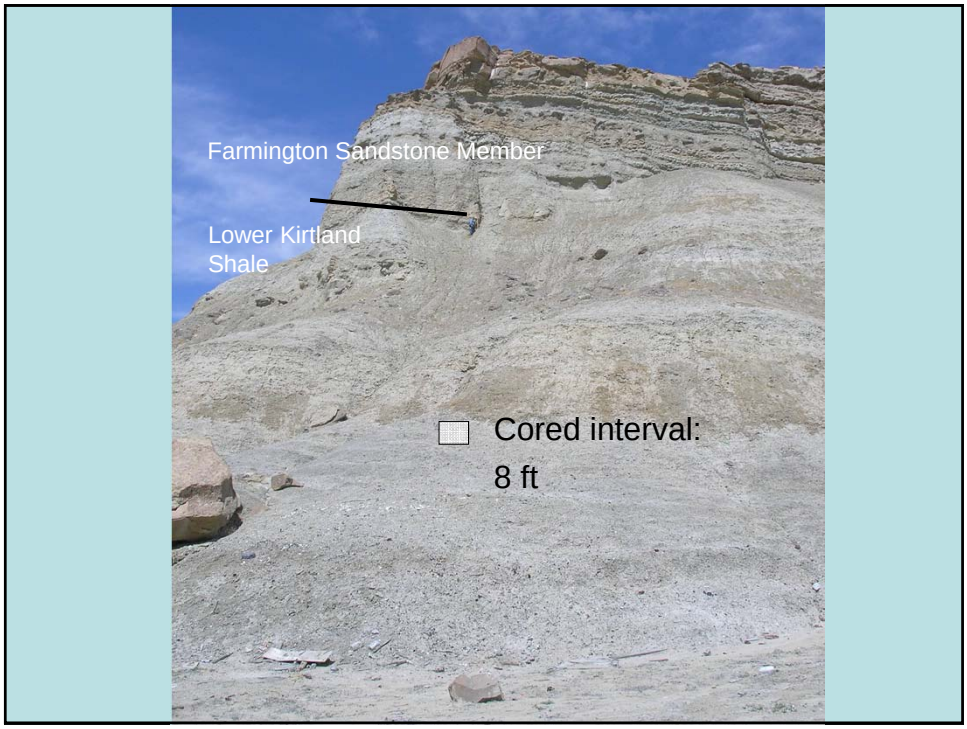
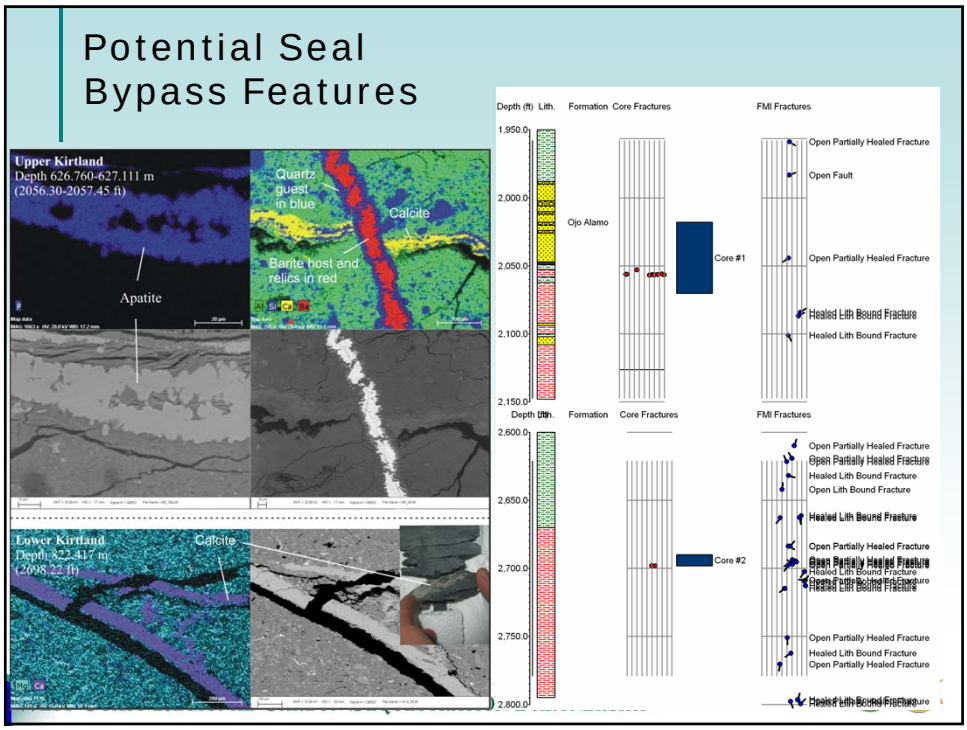
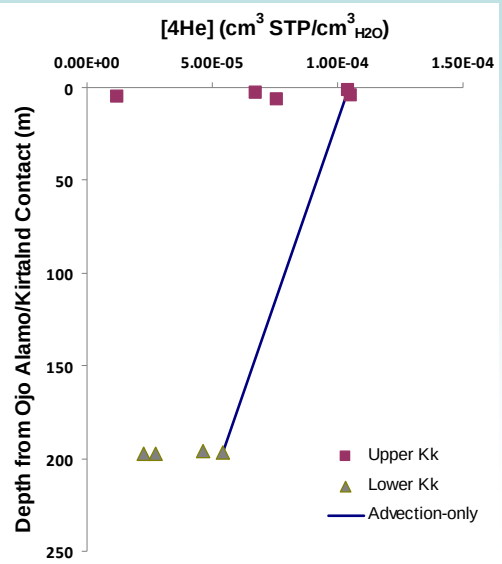

Kirtland Formation, Pump Canyon Site, San Juan Basin
7200
7000
6400
5600
6200
6400
Montezuma
Archuleta
Sandoval
McKinley
Miles
N
UT
CO
AZ
NM
NORTH
SOUTH
OUTCROP
Animas Formation and younger rocks
Approximate location of CO_2 injection well
Upper Shale and Farmington Sandstone Members of Kirtland Formation
Ojo Alamo Sandstone and younger rocks
Kirtland Formation
Member
of
Fruitland Formation
Lower Shale
Pictured Cliffs Sandstone
Lewis Shale
Huerfanito Bentonite Bed
Datum


Ojo Alamo
Upper Kirtland
Cored interval: 52 ft
Gypsum veins
Coarsening upward sequence

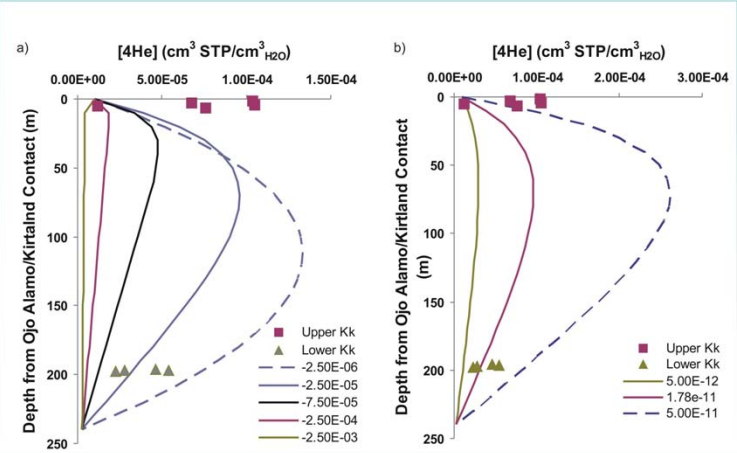

Farmington Sandstone Member
Lower Kirtland Shale
Cored interval:
8 ft


Potential Seal Bypass Features
Upper Kirtland
Depth 626.760-627.111 m
(2056.30-2057.45 ft)
Apatite
Quartz guest in blue
Calcite
Barite host and relics in red
Lower Kirtland
Depth 822.417 m
(2698.22 ft)
Calcite
Depth (ft)
Lith.
Formation
Core Fractures
FMI Fractures
1,950.0
2,000.0
2,050.0
2,100.0
2,150.0
Ojo Alamo
Core #1
Open Partially Healed Fracture
Open Fault
Open Partially Healed Fracture
Healed Lith Bound Fracture
Healed Lith Bound Fracture
2,600.0
2,650.0
2,700.0
2,750.0
2,800.0
Core #2
Open Partially Healed Fracture
Healed Lith Bound Fracture
Open Lith Bound Fracture
Healed Lith Bound Fracture
Open Partially Healed Fracture
Open Partially Healed Fracture
Healed Lith Bound Fracture
Open Partially Healed Fracture
Healed Lith Bound Fracture
Open Partially Healed Fracture

1D Advection-Only Model



1D Advection-Diffusion Model



Major Findings and Conclusions

Pore Network Scale

- Distal depositional environments, deep burial, and organics contribute to high capillary-breakthrough pressure caprocks
- Pore-lining composition is not typically directly indicated by XRD
- Paucity of knowledge on wettability of typical pore-lining phases for CO_2/brine systems limits prediction of capillary sealing
- Will CO_2-organic interactions alter sealing quality?

Core and Well Log Scale

- Fractures identified in core and FMI; mineralization is common that includes potentially reactive phases (carbonates)
- Connectivity indicated by mineralization, but permeability is difficult to ascertain

Major Findings and Conclusions

Formation Scale

- Abundant potential seal bypass features exist within the Kirtland Formation – fractures, discontinuities (also see work by Tom Wilson), and methane saturations
- Need for assessment of connectivity
- Of the total helium-4 produced since deposition, a large portion still resides in the pore fluids
- Inventory of helium suggests low fluid flux
- Some gas stripping processes occurred, possibly *in situ*, but the helium content is still high
- Helium generally supports lack of a strong bypass system

Recommendations

- Carefully plan locations of fluid sampling for natural tracers in caprock and reservoir to support model testing
- For assessing fracture connectedness:
  - Measure isotopes of fracture mineralization
  - Evaluate cross seal flow with helium and other tracers (e.g., methane)
- Characterize fracture types in core to augment FMI logs:
  - Sandia is developing discrete fracture modeling at the outcrop scale to estimate potential CO_2 and/or brine fluxes through fracture networks in caprock
- Preserve core against drying

EXTRA SLIDES

Kirtland Formation Pump Canyon Site San Juan Basin

Kirtland Formation lies above the world's largest coalbed methane play