Characterizing Seal Bypass Systems at the Rock Springs Uplift, Southwest Wyoming, Using Seismic Attribute Analysis*

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Abstract

If carbon storage is to be implemented at a potential storage site at the Rock Springs Uplift (southwest Wyoming), there are significant challenges to overcome regarding sealing assessment. Specifically, identifying the potential for leakage of CO_2 along natural bypass systems such as faults and fractures. This study evaluates the integrity of strata at a University of Wyoming test well (RSU #1 049–047–07154) using a 25 square mile 3-D survey adjacent to the well. Specifically, we focus on determining potential seal bypass systems using multiple seismic attributes. Two groups of seal bypass systems were recognized within the seismic survey bounds: (1) dispersed sets of orthogonal deformation bands and faults, and (2) isolated fractures and chimneys likely associated with karst collapse features. Deformation bands are associated with folding of the Paleozoic strata and are arranged in patterns related to regional structural deformation. Fracture analysis reveal that lineaments within the study area strike northeast-southwest and northwest-southeast. This observation is consistent with joint orientation in surface outcrops. Isolated, vertically oriented fractures that originate in the Mississippian Madison Limestone were interpreted on coherency horizon slices and within the Rock Integrity attribute volume. These features may result from karst processes such as dissolution, hydrothermal alteration, tectonism, or a combination of these processes.

Continuous spectral analysis of wireline logs from the RSU #1 well were used to describe porosity heterogeneity at an intermediate scale of several feet to tens of feet. We found that spectrograms generate useful information that can be utilized for identification of intervals with variable reservoir/sealing capacity within a formation. The amplitude and distribution of spectral

peaks appears to correspond with the relative effectiveness of confining layers. Based on the above data, multiple sealing lithologies were identified at the study site though some were associated with seal bypass systems. Additional unknowns include compartmentalization of the reservoirs along fault boundaries and the risk factors for induced seismicity along existing faults and fractures. Hence, it is of great importance to choose reliable rock properties for simulation modeling and, if possible, increase the amount of available subsurface data.

References Cited

Cartwright, Joe, Mads Huuse, and Andrew Aplin, 2007, Seal bypass systems: AAPG Bulletin, v. 91, p. 1141-1166.

Downey, M.W., 1984, Evaluating seals for hydrocarbon accumulations: AAPG Bulletin, v. 68, p. 1752-1763.

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Characterizing seal bypass systems at the Rock Springs Uplift, southwest Wyoming using seismic attribute analysis

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Presented at the 2015 ICE AAPG, Denver

Seismic Evaluation of Seals at a CCUS site; Interpreting Seal Bypass Systems

Seal Bypass Systems

Definition: Cartwright et al., 2007 (modified from Downey, 1984) "*recognition that some high-quality seals may be breached episodically or semipermanently by a range of geological structures that we collectively term "seal bypass systems.*"

Objective

Characterize seal bypass systems and related processes at a potential CCUS characterization site in southwest Wyoming

Method

Reflection continuity analysis of seismic data correlated with regional geologic history

- Curvature
- Coherency
- Amplitude
- Gradients

Spectrogram Analysis

Regional Geologic Studies

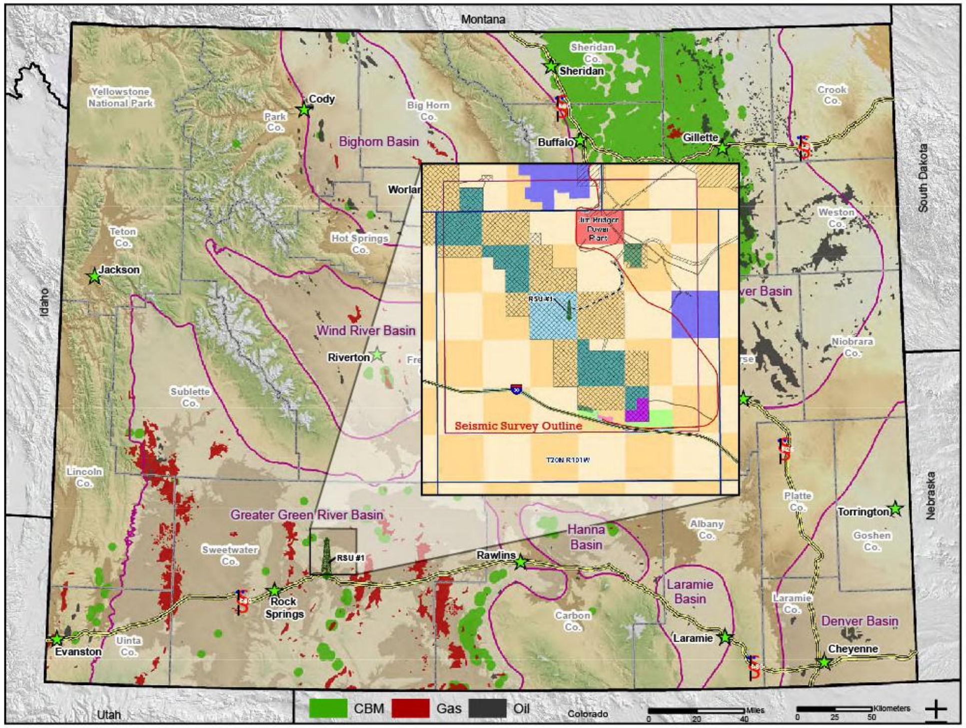
Summary

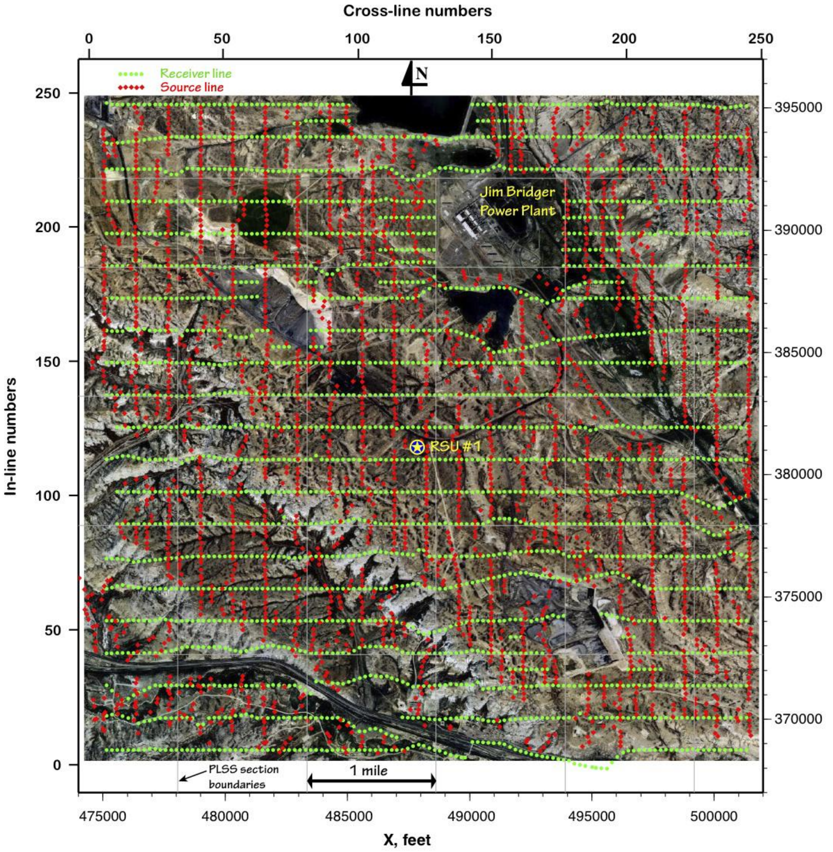
There are two identified seal bypass systems, one dominant and one dispersed (structural deformation and karstification)

Cartwright, Joe, Mads Huuse, and Andrew Aplin. "Seal bypass systems." AAPG bulletin 91.8 (2007): 1141-1166.

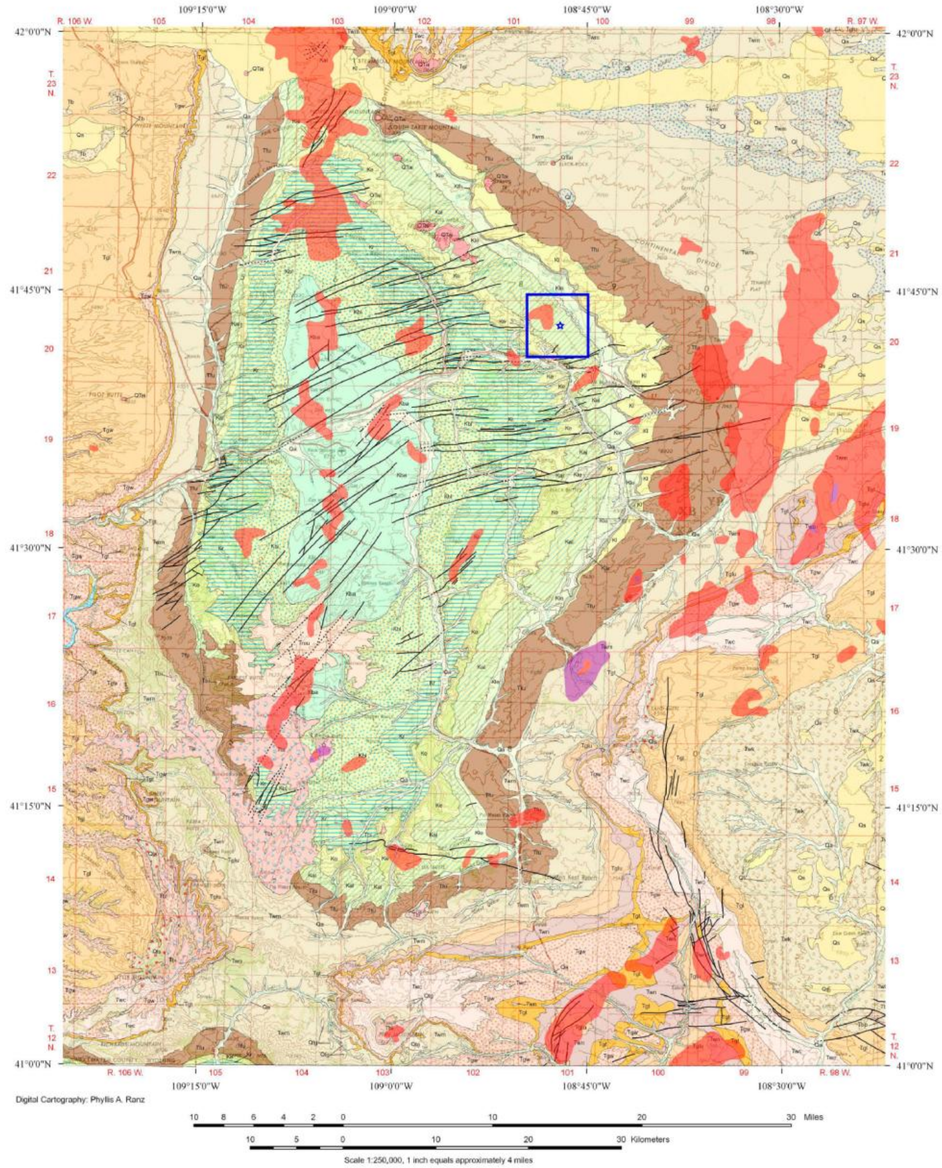
Downey, M. W., 1984, Evaluating seals for hydrocarbon accumulations: AAPG Bulletin, v. 68, p. 1752– 1763.

Study Site and Seismic Survey

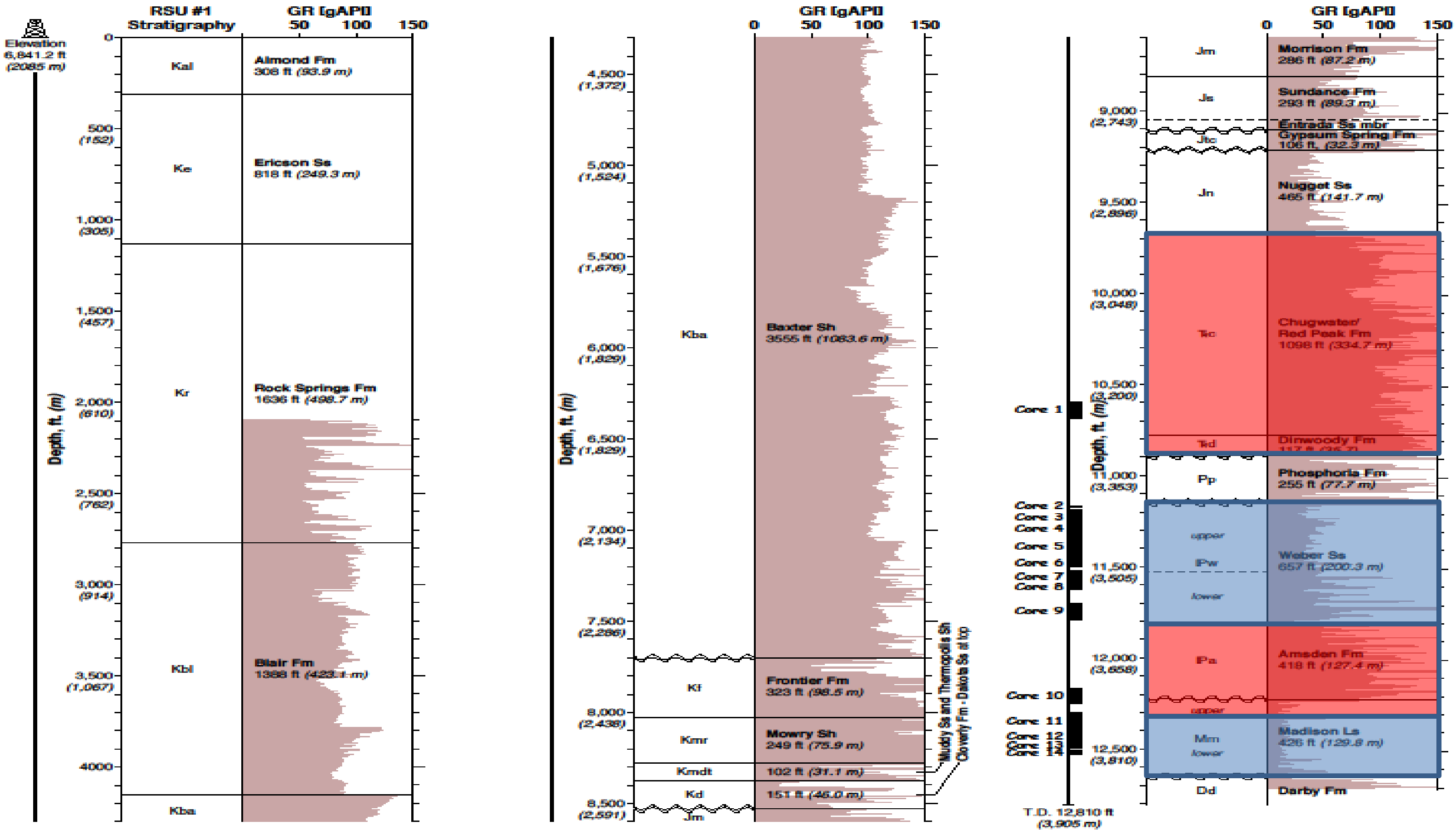




Regional Geology: the Rock Springs Uplift



Stratigraphic Section at the Study Site

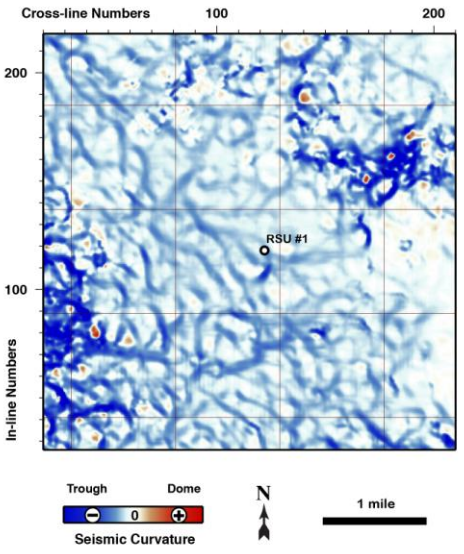


Seal
Reservoir

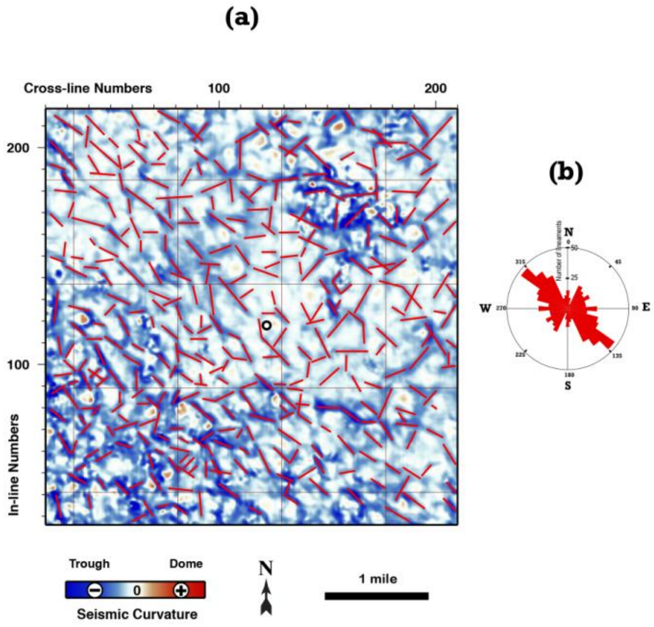
Seal Bypass System: Structural Deformation

Curvature Analysis: Interpreting Fold, Joint, and Fracture Systems in Horizon Slices

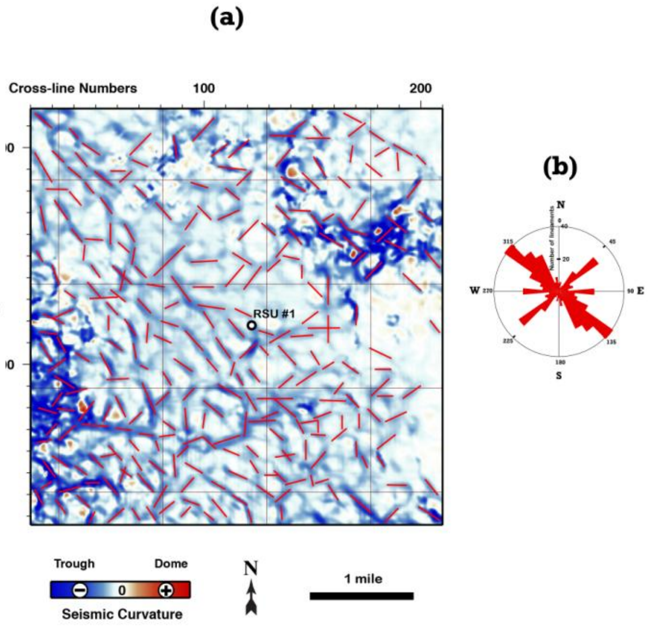
Preliminary Analysis



Interpreted Slices (1 and 2)



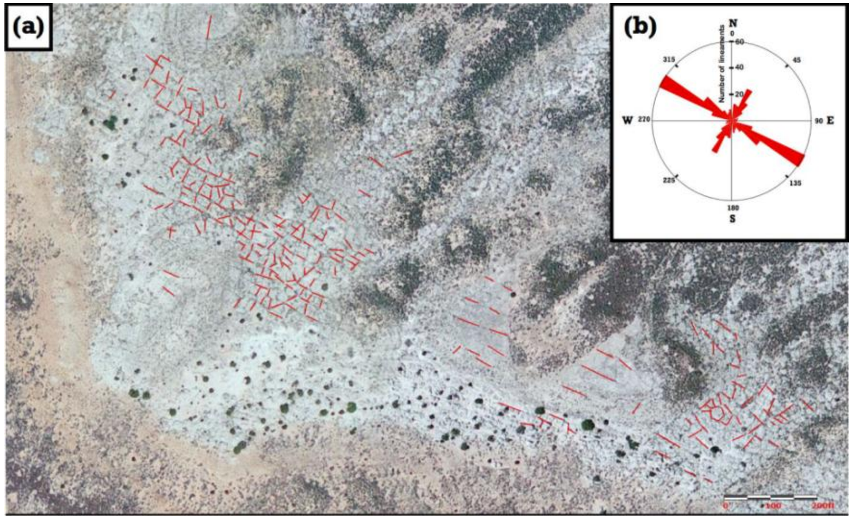
1. Triassic seal



2. Madison reservoir

Seal Bypass System: Structural Deformation

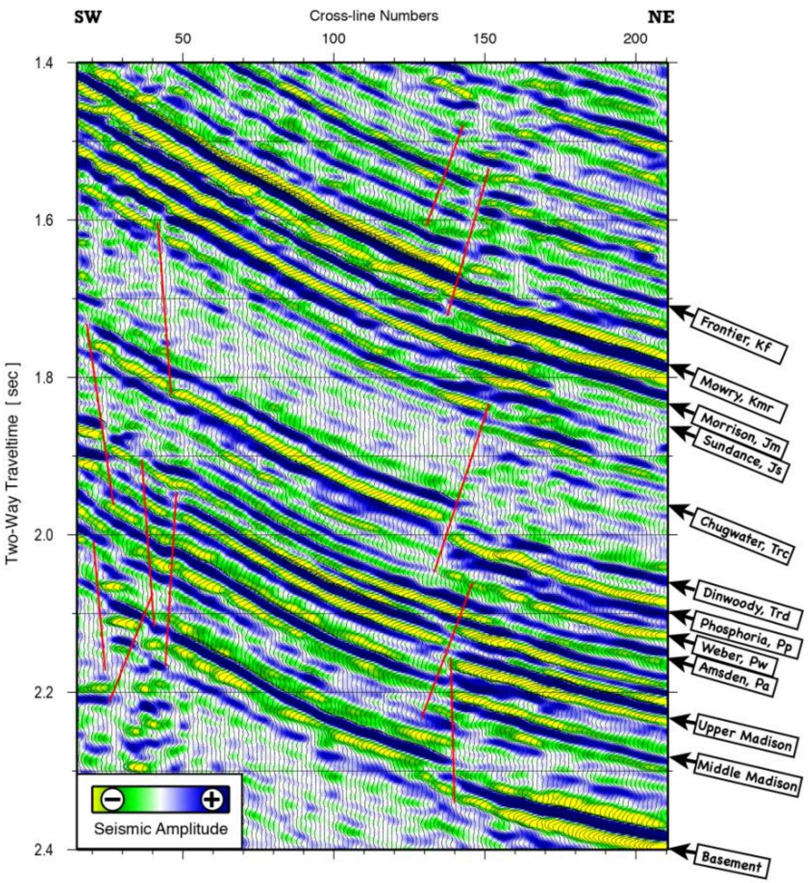
Outcrop Study of Joint and Fracture Systems in Cretaceous Sandstones: Study Site



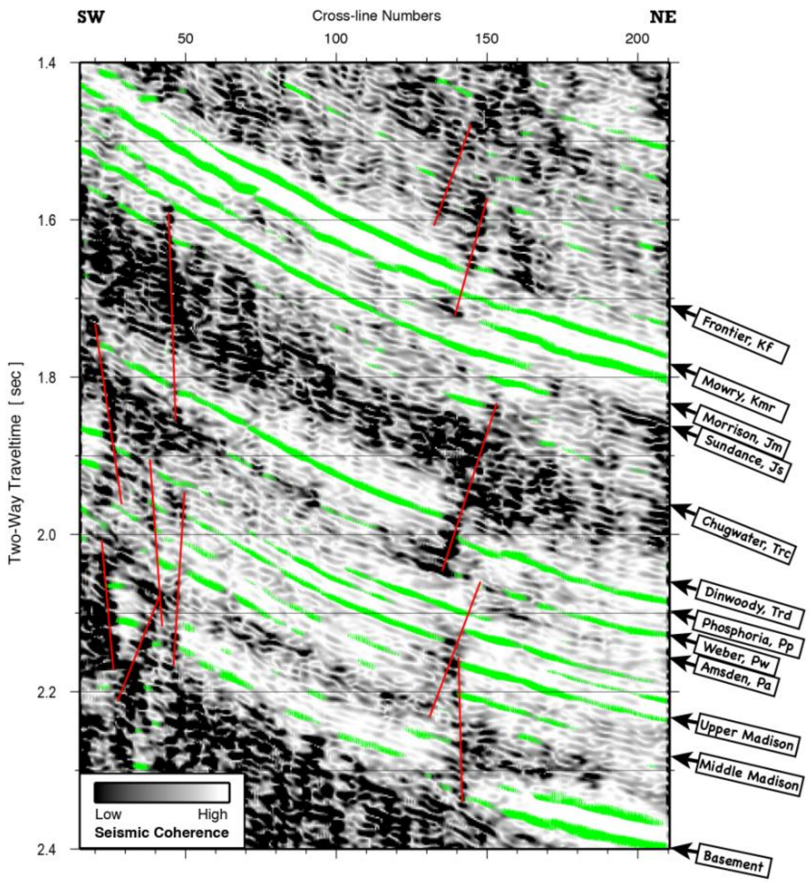
Dominant joint/fracture systems formed during the Laramide – related to flexure of sediments on the flank of the RSU

Seal Bypass System: Structural Deformation

Seismic Reflectivity: Interpreting Faults and Formations Tops



Amplitude Section



Coherency Section

Seal Bypass System: Structural Deformation

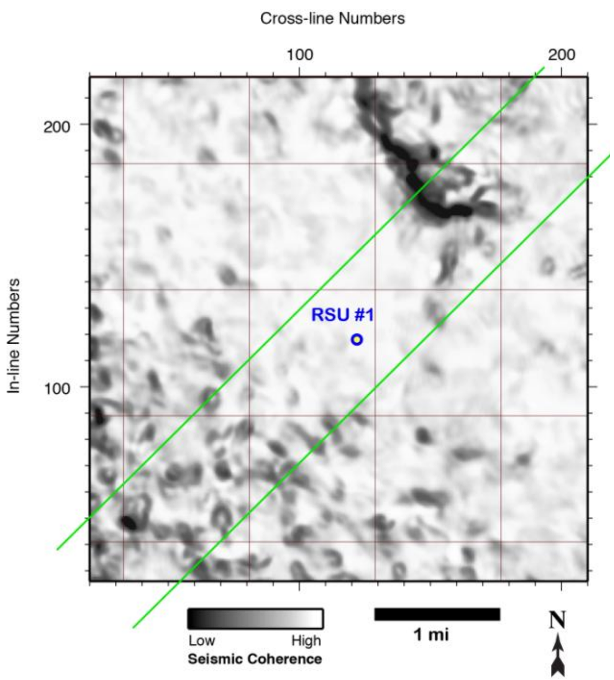
Summation:

- Dominant fracture, fold and joint patterns are orthogonal to strike/dip (horizon slices)
    - Laramide (~40Ma) and formed during regional flexural extension
- Up-dip Laramide reverse faults, minor folds (vertical slices)
- Major down-dip Quaternary extensional fault system
- Curvature, amplitude, and coherence

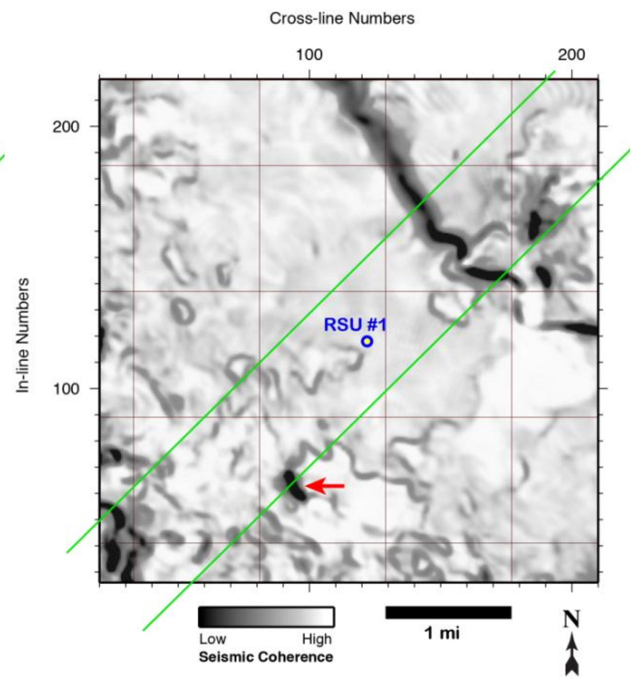
Seal Bypass System: Karstification

Coherency Analysis: Interpreting Anomalous (non-lateral) Features in Horizon Slices

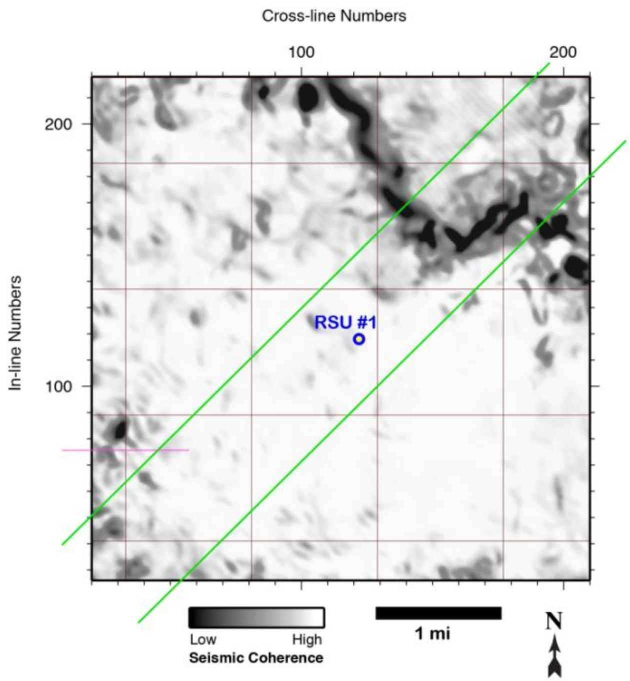
Triassic Seal



Permian Seal

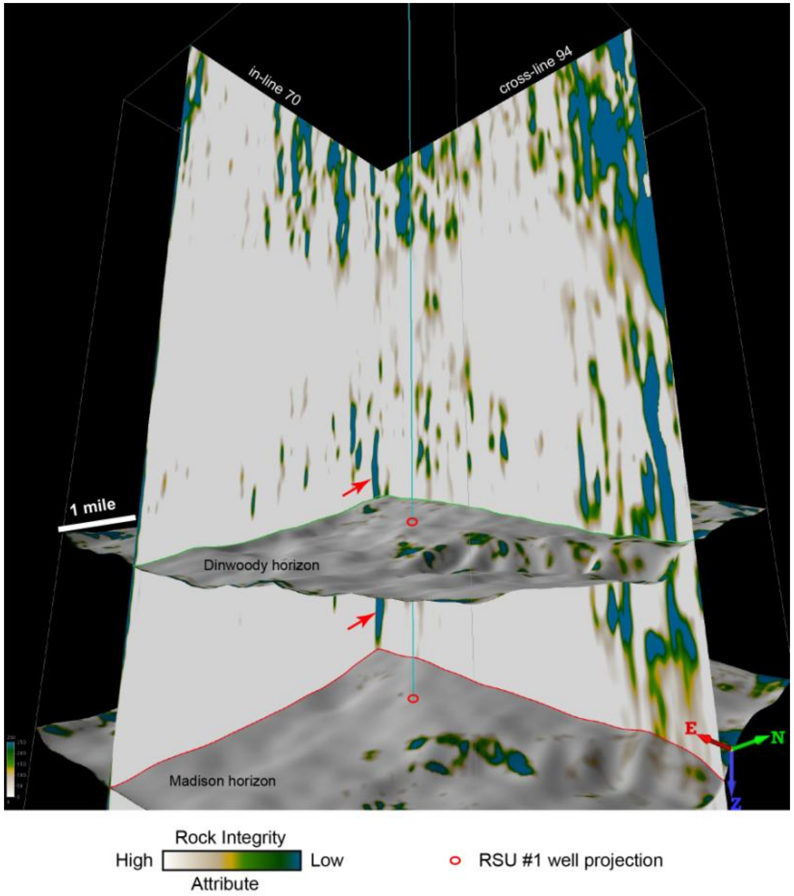


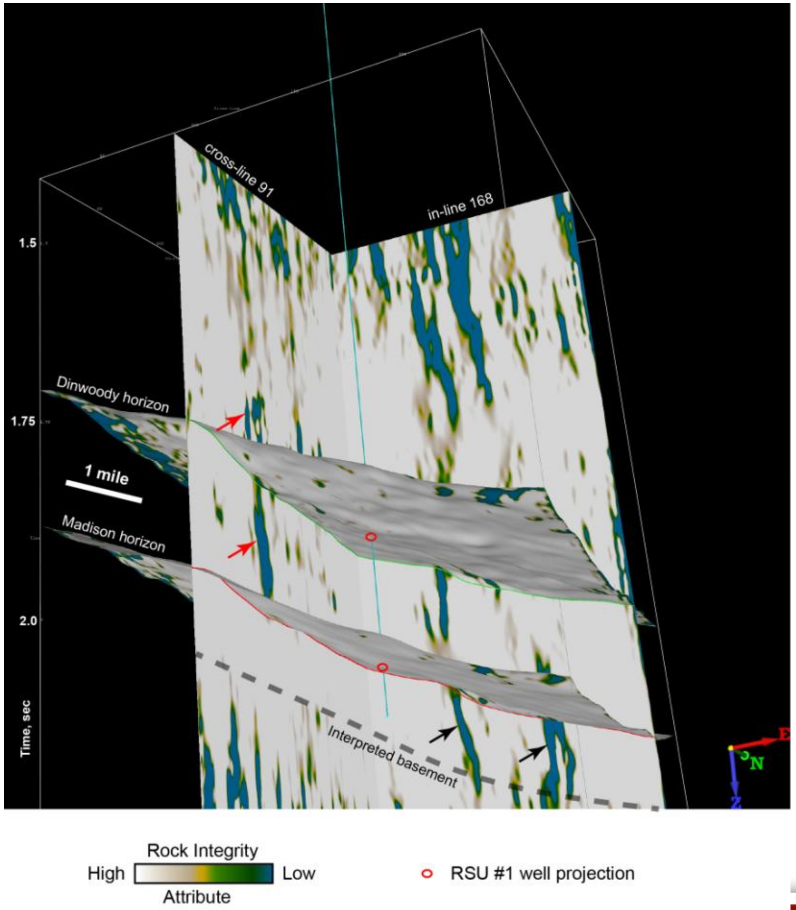
Mississippian Reservoir



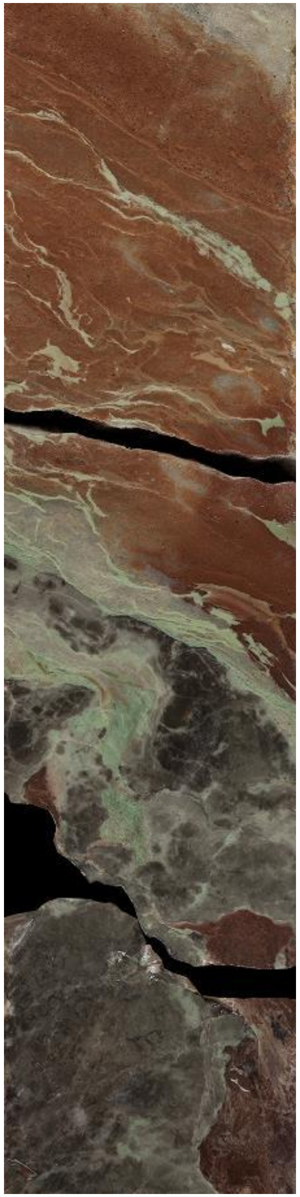
Seal Bypass System: Karstification

Coherency Analysis: Interpreting Anomalous (non-lateral) Features in Vertical Sections

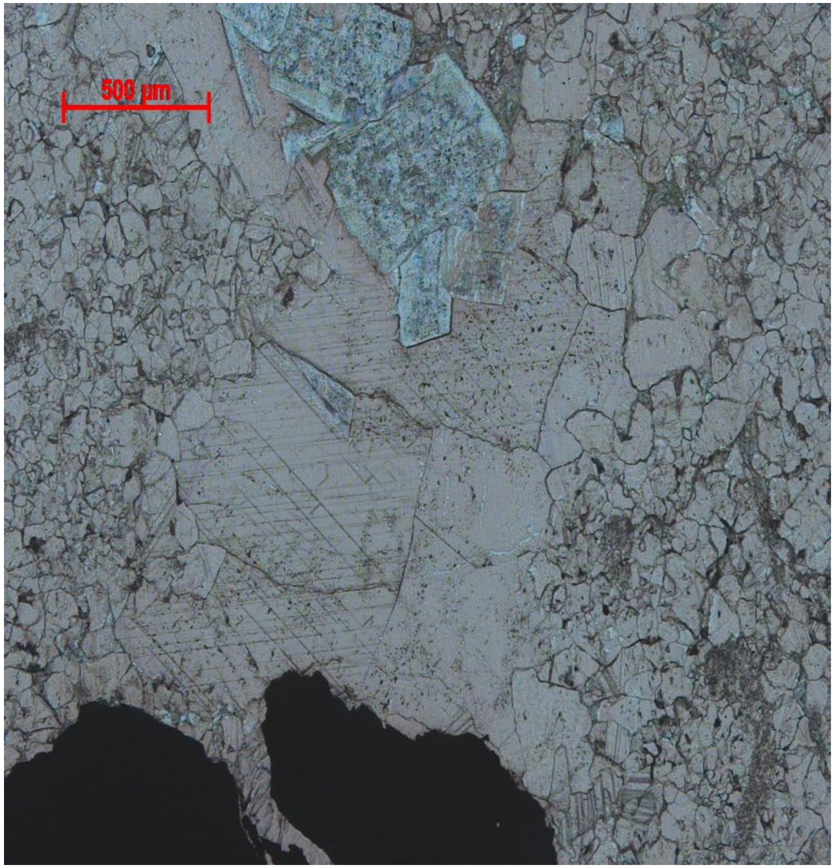




Seal Bypass System: Karstification



Karst Features



- Collapse breccia in core
- Recrystallization within brecciated zones

Seal Bypass System: Karstification

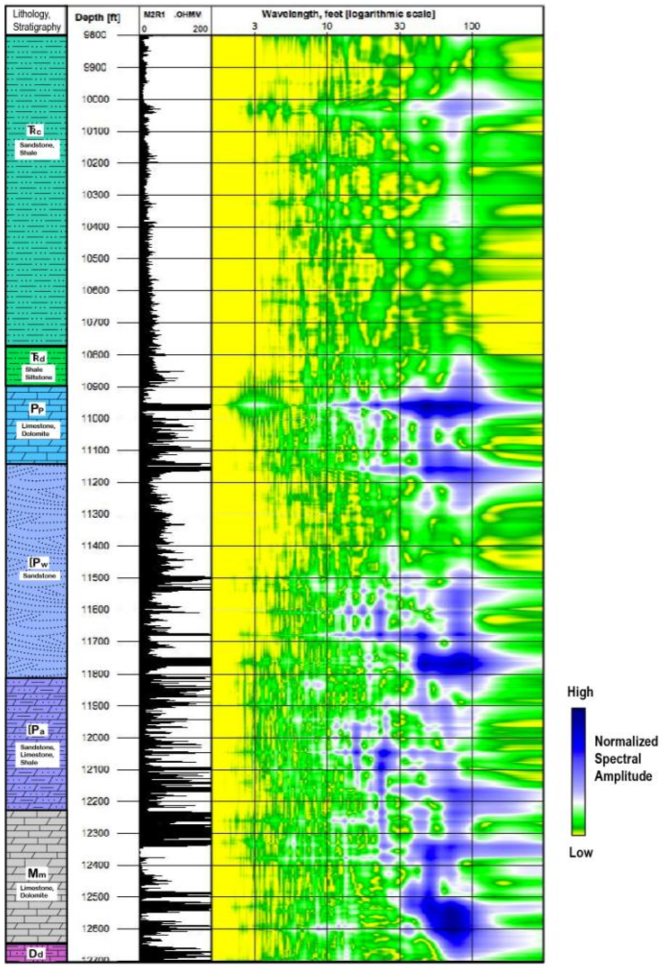
Summation:

- Observed as dispersed ellipsoids in horizon slices
- Rooted in the Madison Limestone and protrude through most of the Triassic seal
    - Triassic age/processes (>200 Ma)
- Associated with neomorphic calcite, TSR minerals, and secondary cementation
- Identified as karst collapse features
- Correlates with regional karst models

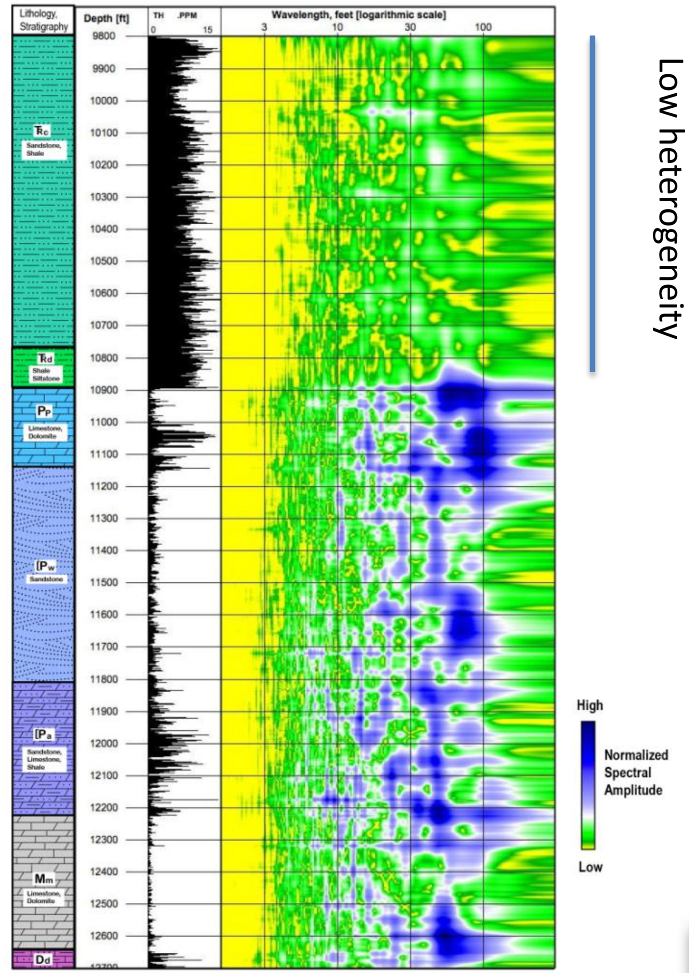
Seal Bypass System: Heterogeneity Analysis

Spectrogram Analysis: 1-D Well Log to 2-D Transformation for Lithological Heterogeneity

Resistivity



Thorium



Conclusions

Two distinct seal bypass systems

1. *Structural Deformation: dominant regional seal bypass system*
    - Response to Laramide flexural/compressional processes and Quaternary extension
    - Orthogonal joint/fracture systems and reverse faults and folding (regional)
    - Major Quaternary fault is down-dip form potential injection locality
    - Fluid injection could increase permeability in up-dip direction

2. *Karstification: dispersed seal bypass system*
    - Triassic in age
    - Associated with recrystallization/cementation
    - Karst collapse include pipes/chimneys

Seismic seal bypass interpretation has allowed us to further evaluate uncertainty at a potential CCUS site