Seismic Characterization of the San Juan Basin CarbonSAFE Site

Adewale Amosu[1], Dana Ulmer-Scholle[1,2], Luke Martin[2], William Ampomah[1], George El-Kaseeh[1]

1. Petroleum Recovery Research Center, New Mexico tech

2. New Mexico Bureau of Geology & Mineral Resources, New Mexico Tech

Summary

- Seismic characterization of the San Juan Basin CarbonSAFE site is implemented to complement geostatistical characterization using well log data.
- Structural interpretation generated 38 horizons spanning the top of the Precambrian to the Ojo Alamo Formation. The interpreted surfaces capture the slope variation and angle of the hogback monocline within the limits of the seismic volume.
- Faults interpreted include a low-angle thrust fault cutting through the Precambrian and lower units, stress release faults associated with the flexure of the Hogback monocline.
- Seismic inversion and neural network prediction results show a good match with volumes derived from geostatistical interpolation in the overall vertical trend patterns but with greater lateral resolution.

Introduction

- The San Juan Basin CarbonSAFE Phase III project is located in the northwest corner of New Mexico and southwestern corner of Colorado (Fig. 1). It has the capacity of storing ~7MMT/year of CO_2 generated at industrial facilities within the basin.
- Potential sequestration targets in the basin are the Jurassic Entrada and Bluff sandstone deposits, while the Brushy Basin Member, the Summerville Formation, and the Todilto Formation are the major confining zones (Fig. 2).
- An important feature in the San Juan basin is the Hogback monocline structure and understanding the deformation associated with it and its possible impact on plume migration

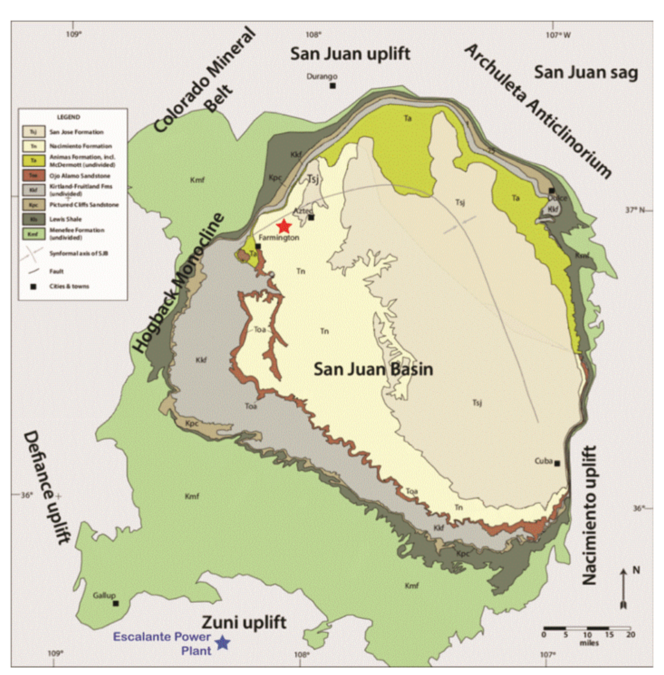

Figure 1. A geologic map of the San Juan Basin (modified from Pecha et al., 2018).

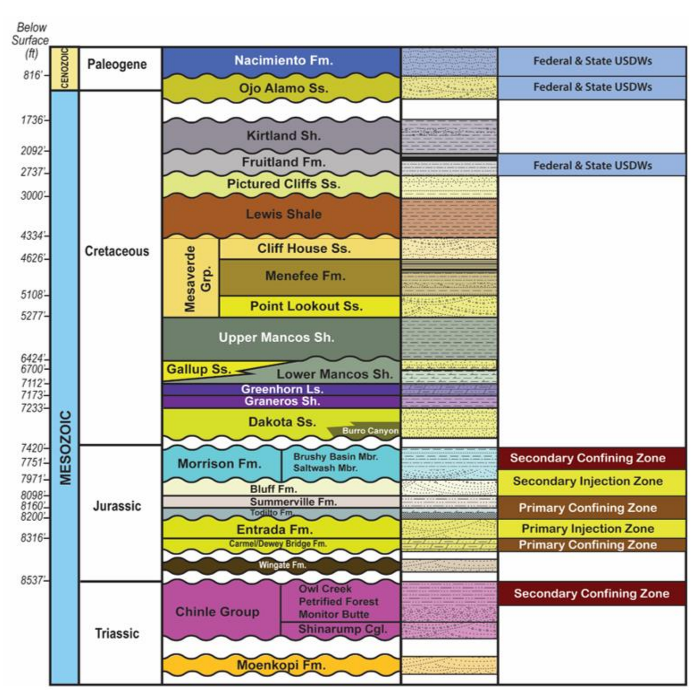

Figure 2: A detailed view of the stratigraphic section for the characterization well (not to scale).

Structural Interpretation

- Structural interpretation of seismic data is implemented to reconstruct the architecture of subsurface strata, illuminate the varying details of geologic structures (e.g., faults, folds, fracture networks), and understand their geometric and kinematic development.
- In all, 38 surfaces were generated spanning the Ojo Alamo to the Precambrian rocks. The seismic data reveals that most of the Pennsylvanian strata are folded. The interpreted surfaces capture the slope variation and angle of the hogback monocline within the limits of the seismic volume
- The data captures a low-angle thrust fault below the Hogback monocline, cutting through the Precambrian and lower units
- Stress release faults associated with the flexure of the Hogback monocline located above the low-angle thrust fault are identified

Structural Interpretation (continued)

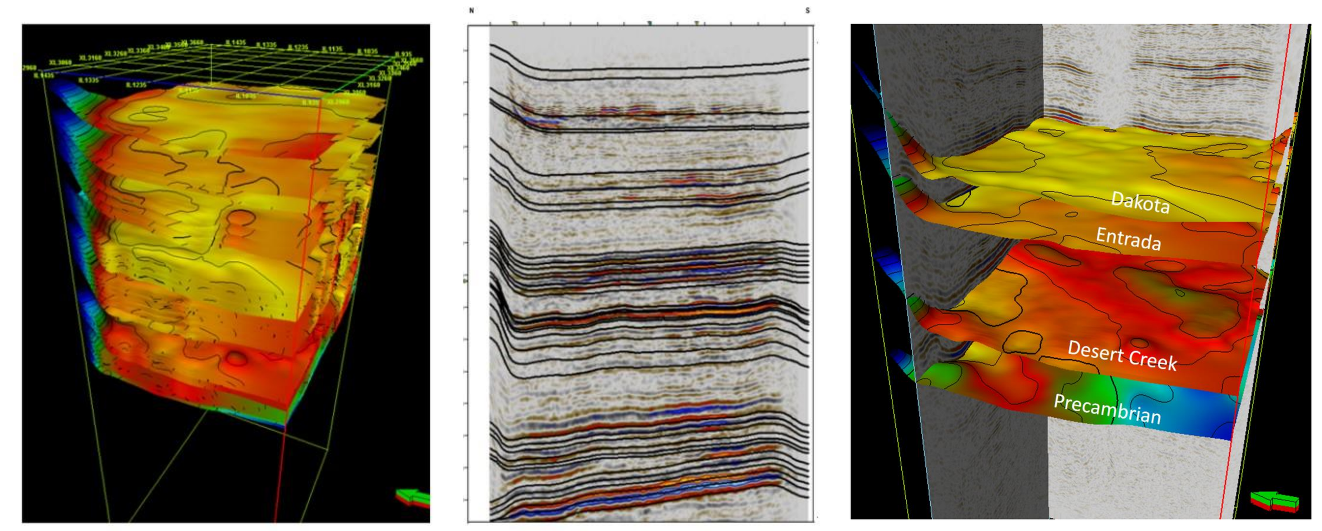

Figure 2. Extracted interpreted surfaces from the seismic data volume. Left: 3D surfaces spanning the Precambrian to the Ojo Alamo. Middle: Crossline 3115 with the interpreted surfaces outlined. Right: Some labeled interpreted surfaces as depth reference within the seismic volume. The Northwest corner captures the slope variation and flexure of the hogback monocline.

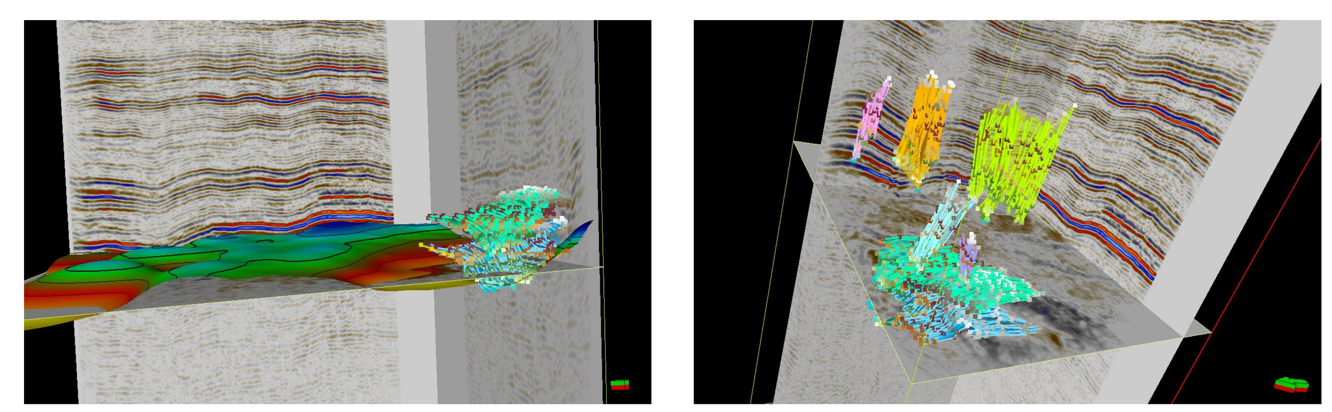

Figure 3. Left: Low angle thrust fault cutting the interpreted Precambrian surface and a time slice intersecting the surface at the northwest corner of the seismic volume. Right: Stress release faults associated with the flexure of the Hogback monocline located above the low-angle thrust fault. The stratigraphic well location is not affected by the faults.

Seismic Inversion

- Seismic inversion transforms seismic reflection data into a quantitative subsurface rock property and helps estimate underlying models of the physical characteristics of rocks and fluids from combined seismic and well-log data.
- Simultaneous inversion of pre-stack seismic data makes it possible to obtain several rock property parameters simultaneously (Acoustic Impedance, Vp/Vs, and density; Aki and Richards, 1980; Smith and Gidlow, 1987)
- Margrave et. al (2001) showed that the Aki and Richards approximation for the P-wave reflection coefficient (Rpp) can be inverted for the fluctuations of P-wave velocity, S-wave velocity, and density:

$$R_{pp}(x(\theta)) = C_\alpha(\theta)f_\alpha + C_\rho(\theta)f_\rho + C_\beta(\theta)f_\beta$$

In matrix format:

$$\begin{bmatrix} R_{pp}(x_1) \\ R_{pp}(x_2) \\ \vdots \\ R_{pp}(x_3) \end{bmatrix} = \begin{bmatrix} C_\alpha(\theta_1) & C_\rho(\theta_1) & C_\beta(\theta_1) \\ C_\alpha(\theta_2) & C_\rho(\theta_2) & C_\beta(\theta_2) \\ \vdots & \vdots & \vdots \\ C_\alpha(\theta_3) & C_\rho(\theta_3) & C_\beta(\theta_3) \end{bmatrix} \begin{bmatrix} f_\alpha \\ f_\rho \\ f_\beta \end{bmatrix}$$

where

θ Is the incidence angle; α, β, ρ are values of Vp, Vs, and density respectively

$\Delta\alpha, \Delta\beta, \Delta\rho$ are differences in Vp, Vs, and density

$f_\alpha = \frac{\Delta\alpha}{\alpha}, f_\beta = \frac{\Delta\beta}{\beta}, f_\rho = \frac{\Delta\rho}{\rho}$ are fluctuations of Vp, Vs, and density

$C_\alpha, C_\beta, C_\rho$ are coefficients that depend incidence angles and Vp, Vs, and density respectively, but not on the differences in the quantities

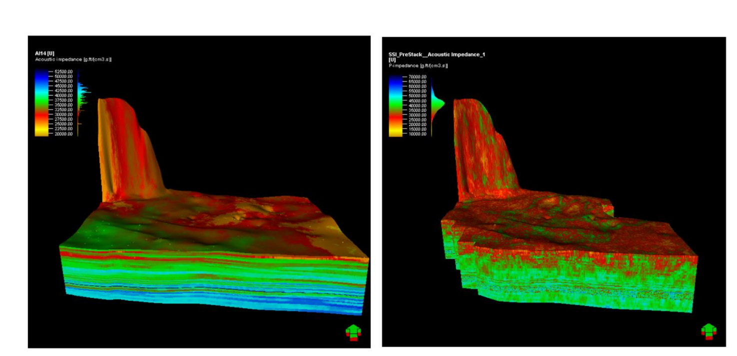

Figure 4. Acoustic impedance volume from geostatistical interpolation of well log data (left) and seismic inversion (right).

Seismic Inversion (continued)

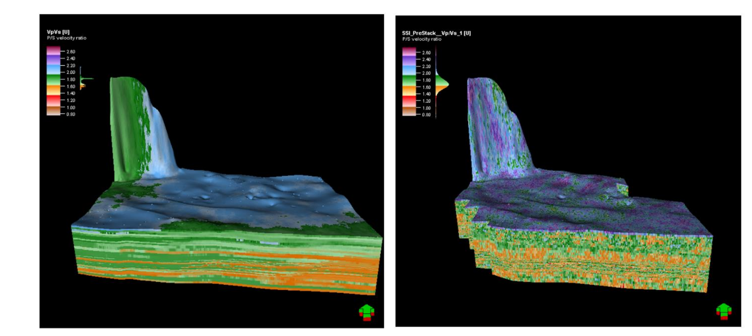

Figure 5. Vp/Vs volume from geostatistical interpolation of well log data (left) and seismic inversion (right).

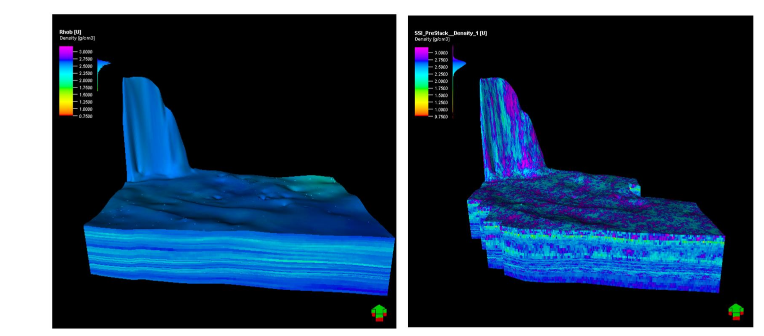

Figure 6. Density volume from geostatistical interpolation of well log data (left) and seismic inversion (right).

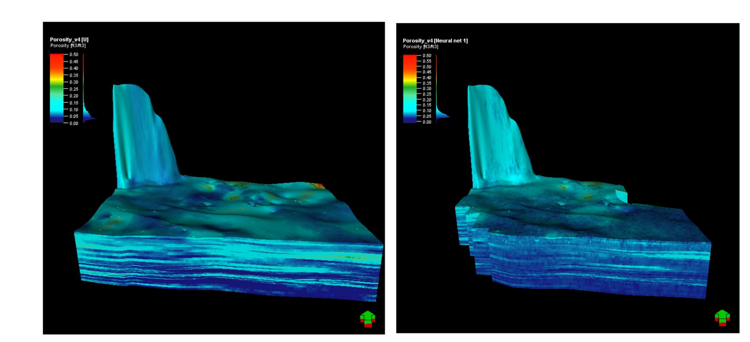

Figure 7. Porosity volume from geostatistical interpolation of well log data (left) and neural network application to seismic inversion results (right).

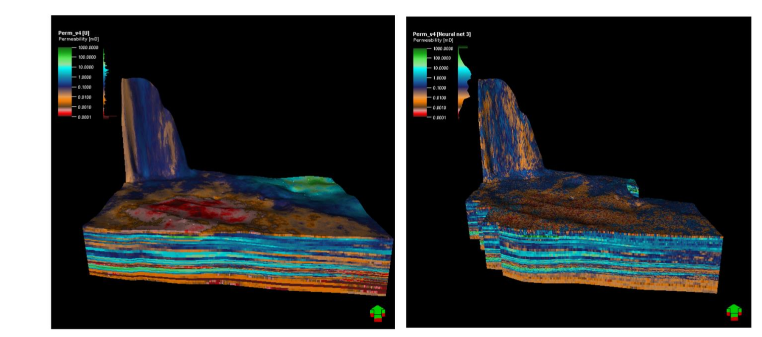

Figure 8. Permeability volume from geostatistical interpolation of well log data (left) and neural network application to seismic inversion results (right).

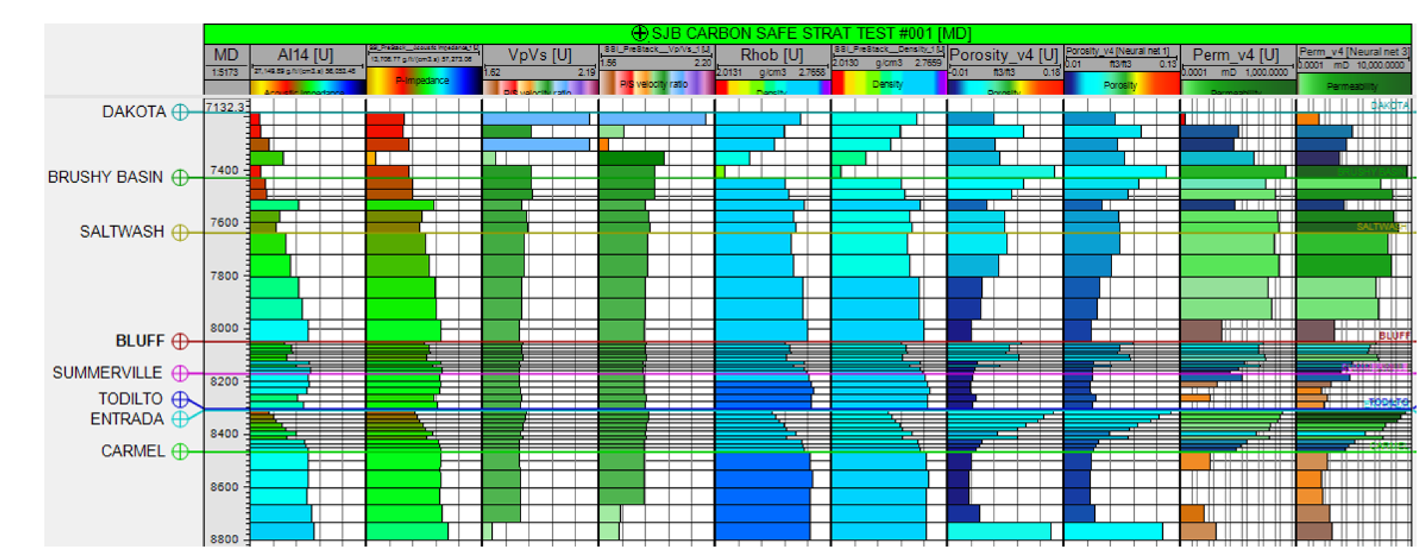

Figure 9. Comparison of properties derived from geostatistical interpolation with seismic inversion results at SJB CARBONSAFE TEST #001 well location. Pairs from left to right: Acoustic Impedance, Vp/Vs, Density, Porosity, and Permeability.

Conclusion

- Pre-stack seismic inversion results show a good match with volumes derived from geostatistical interpolation in the overall vertical trend patterns but with greater lateral resolution.
- Neural network predicted volumes of permeability and porosity show similar vertical trends to volumes from geostatistical interpolation, but with higher lateral resolution.
- The generated properties generally match with well log measurements at well locations.

References

- Margrave, G.F., Stewart, R.R. and Larsen, J.A., 2001. Joint PP and PS seismic inversion. The Leading Edge, 20(9), pp.1048-1052.
- Pecha, M.E., Gehrels, G.E., Karlstrom, K.E., Dickinson, W.R., Donahue, M.S., Gonzales, D.A. and Blum, M.D., 2018. Provenance of Cretaceous through Eocene strata of the Four Corners region: Insights from detrital zircons in the San Juan Basin, New Mexico and Colorado. Geosphere, *14*(2), pp.785-811.
- Richards, P.G. and Aki, K., 1980. Quantitative seismology: theory and methods (Vol. 859). San Francisco, CA: Freeman.
- Smith, G.C. and Gidlow, P.M., 1987. Weighted stacking for rock property estimation and detection of gas. Geophysical prospecting, 35(9), pp.993-1014.

Email: adewale.amosu@nmt.edu

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

San Juan Basin CarbonSAFE

NATIONAL ENERGY TECHNOLOGY LABORATORY