Site Characterization of the San Juan Basin CarbonSAFE Project Site Using 3D Seismic Imaging and Machine-Learning Fault Detection

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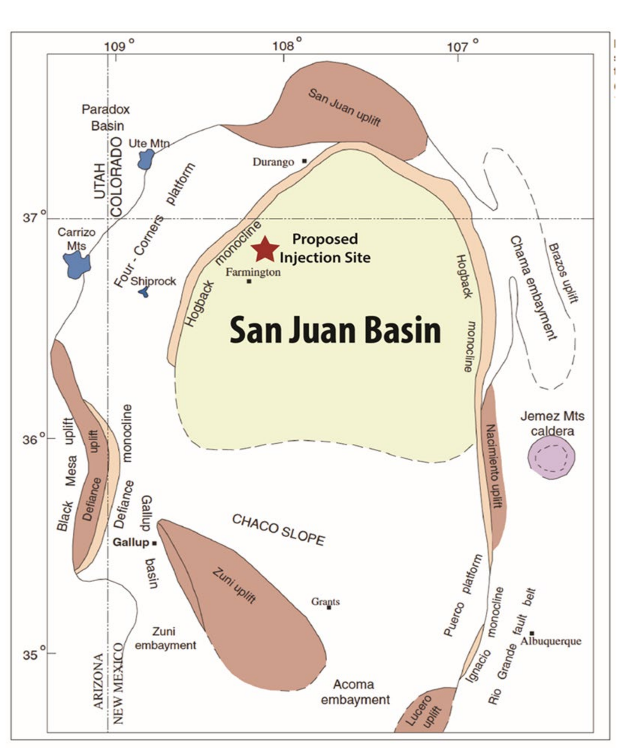
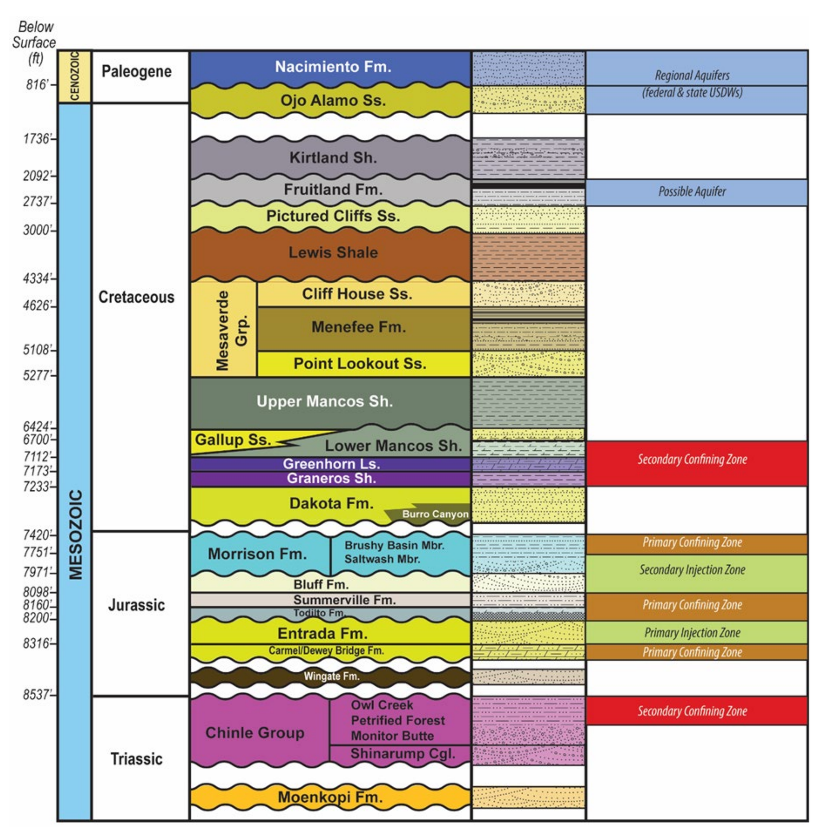
Introduction

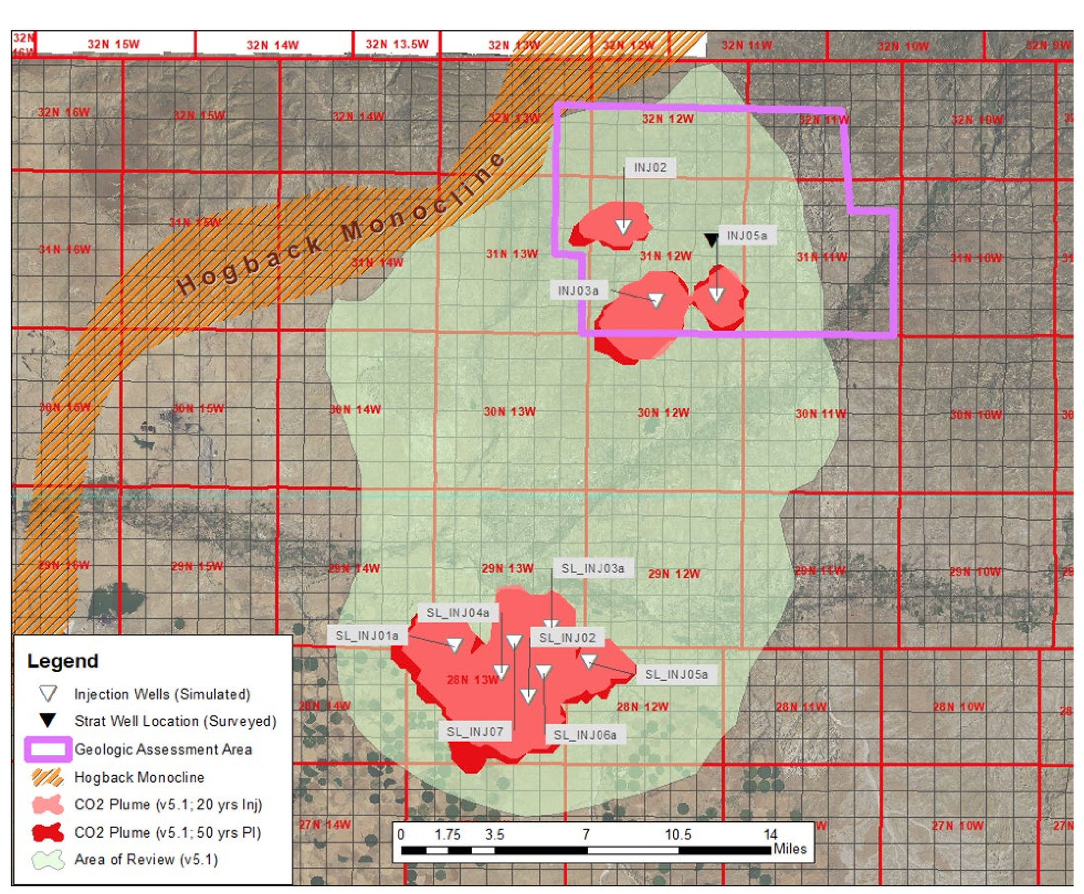
- Site characterization for geologic carbon storage (GCS) requires accurate and high-resolution 3D subsurface imaging.
- Faults could be primary potential CO_2 leakage pathways and induce seismicity.
- Fault detection on high-resolution 3D images is crucial for reliable site characterization and risk assessment for GCS.
- Machine learning fault detection is computationally efficient to detect faults on seismic migration images, including those invisible by human eyes.
- We perform first-arrival traveltime tomography, prestack depth migration velocity analysis, and prestack depth migration to obtain a high-resolution 3D image of the San Juan Basin CarbonSAFE project site.
- We delineate faults on the 3D seismic image using nested residual U-Net and find that there are no major faults around the planned CO_2 injection zone.

San Juan Basin CarbonSAFE Project

- The San Juan Basin CarbonSAFE Phase III project is performing GCS site characterization in the San Juan Basin in northwest New Mexico, USA.
- The project uses the available data and analysis results to prepare, submit, and obtain UIC Class VI permit from EPA.
- The project will inject CO_2 into Entrada Formation at ~ 2.5 km in depth.



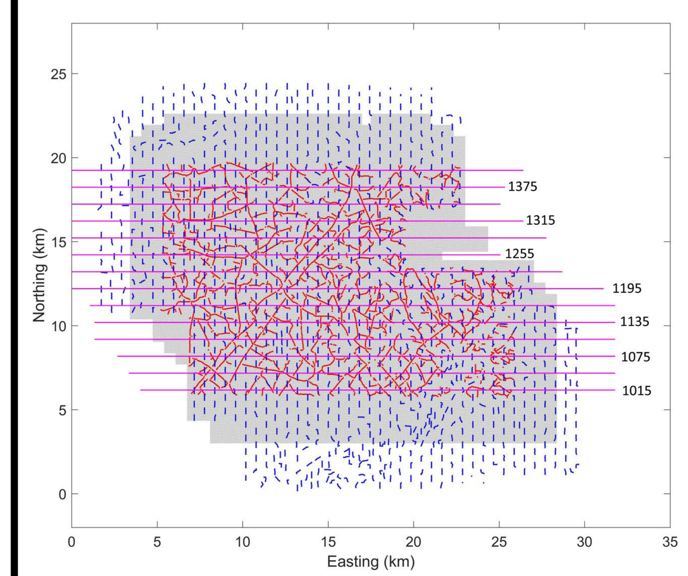




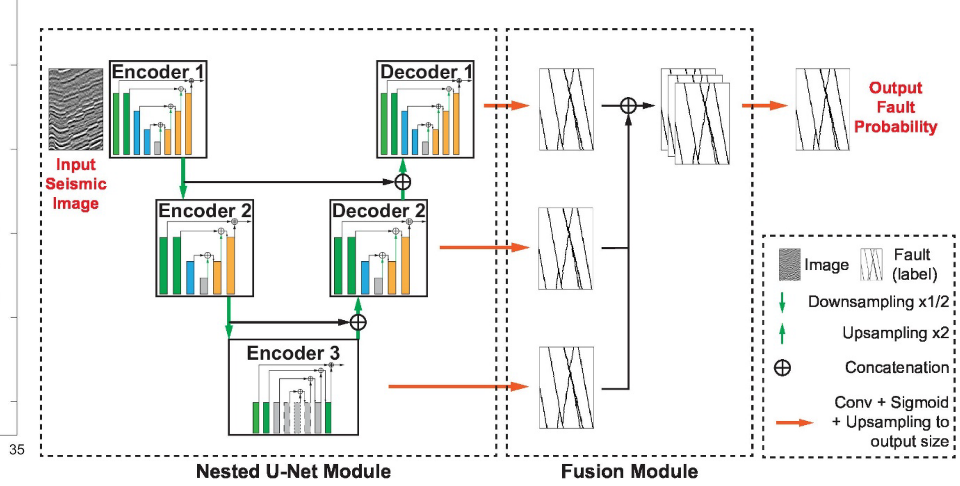
Legacy 3D Surface Seismic Data, CO_2 Plume, AoR Modeling

Workflow

- The project procured a legacy 3D surface seismic dataset acquired at the San Juan CarbonSAFE storage site in 1998.
- We update the 3D velocity model using prestack depth migration velocity analysis (MVA) with the ParadigmTM 22 Software Package.
- We perform 3D prestack depth migration to obtain subsurface structural image.
- We use anisotropic diffusing filtering to reduce image noise and improve the reliability of fault detection.
- We delineate faults on the 3D migration image using nested residual U-Net (Gao, Huang, Zheng, 2022).

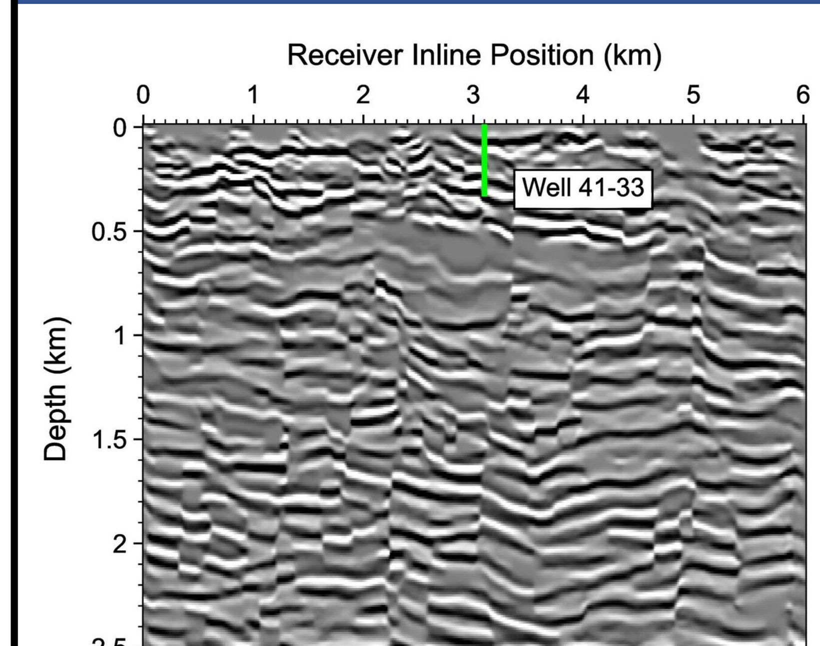


Source and Receiver Distributions

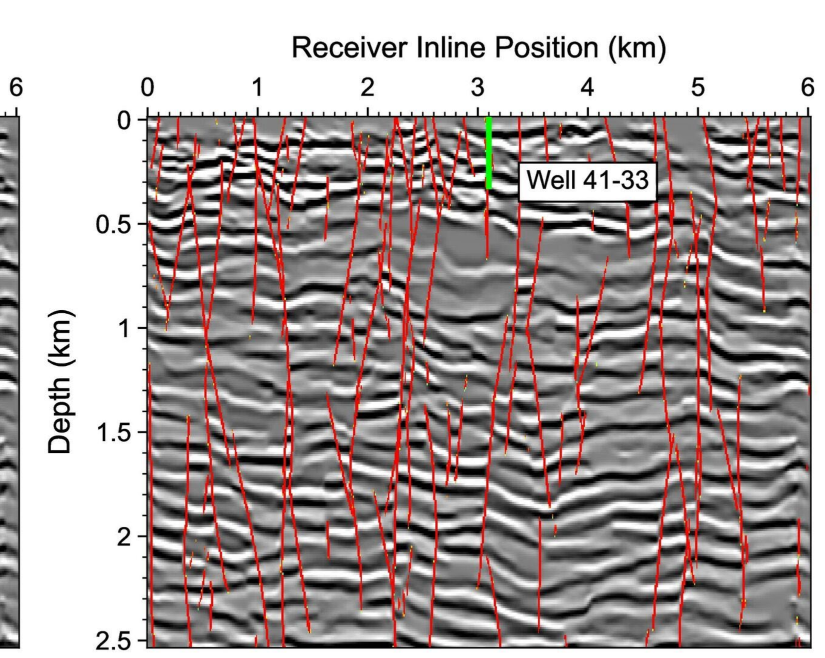


Nested Residual U-Net (NRU) Fault Detection

Example of ML Fault Detection on Seismic Image

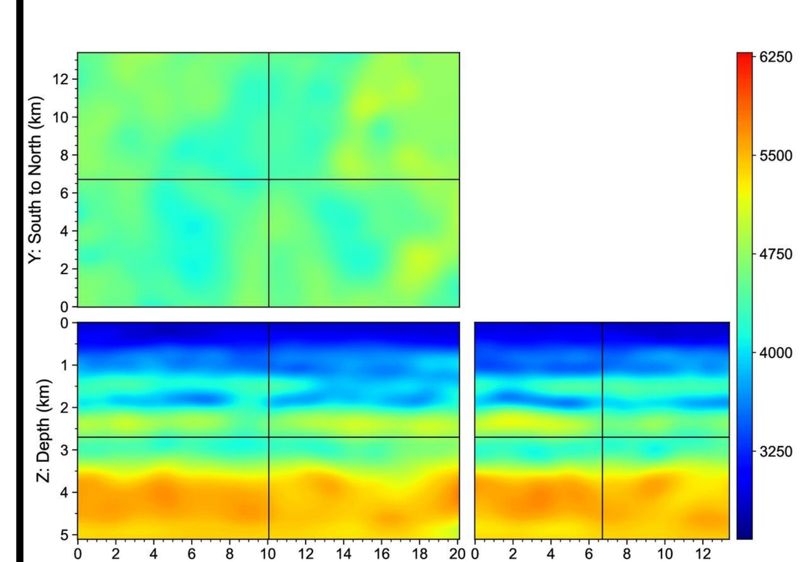


Migration Image
from Soda Lake Geothermal Field

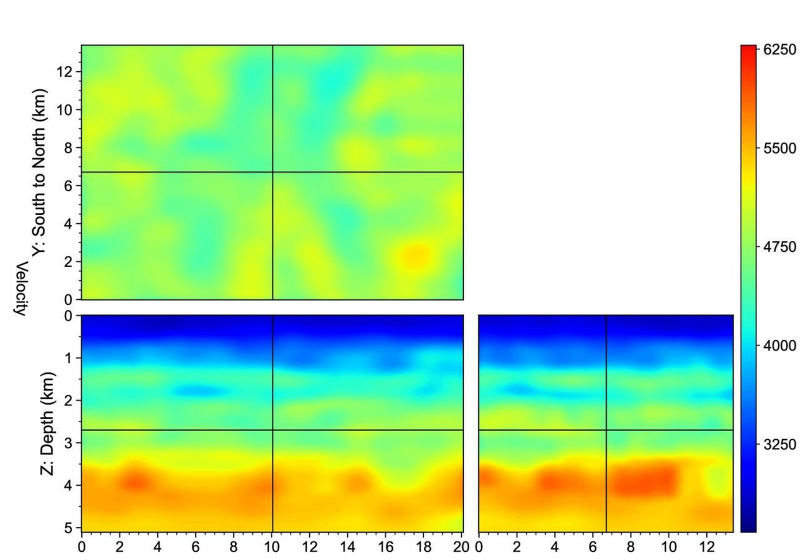


ML Fault Detection

Building 3D Velocity Model

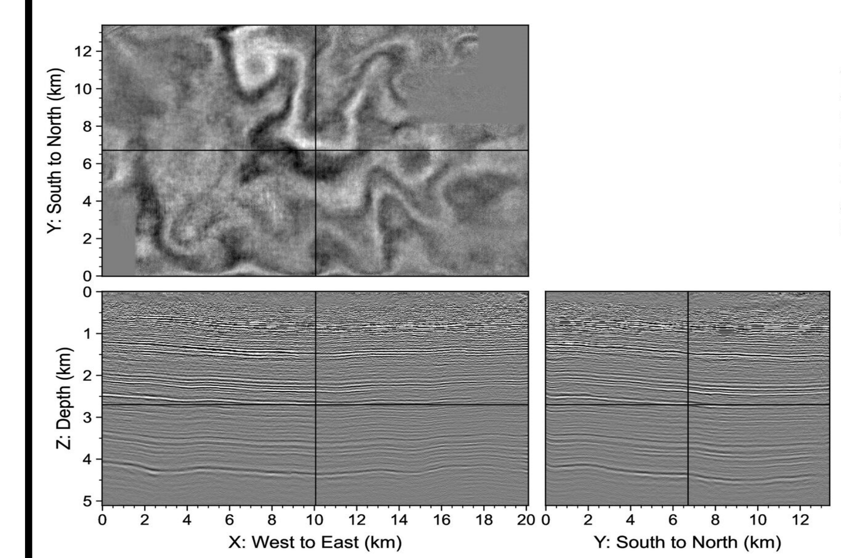


Initial 3D Velocity Model

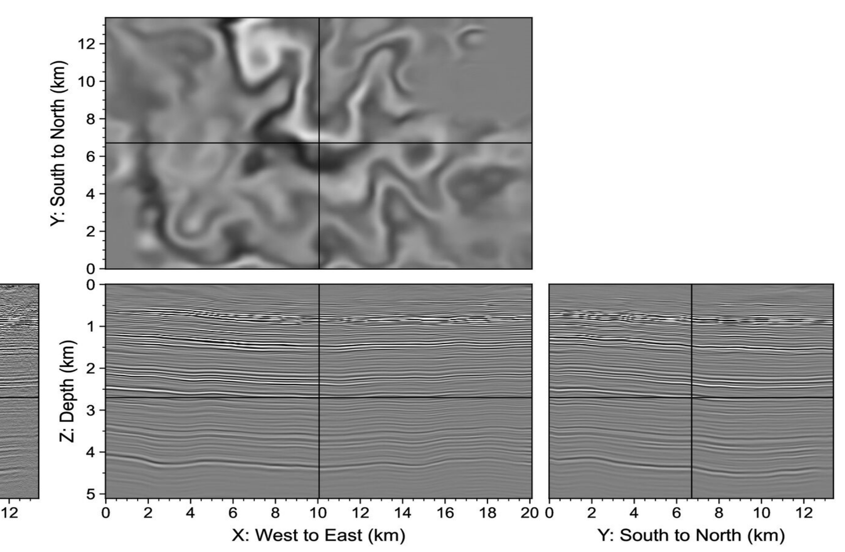


MVA-Updated 3D Velocity Model

3D Prestack Depth Migration

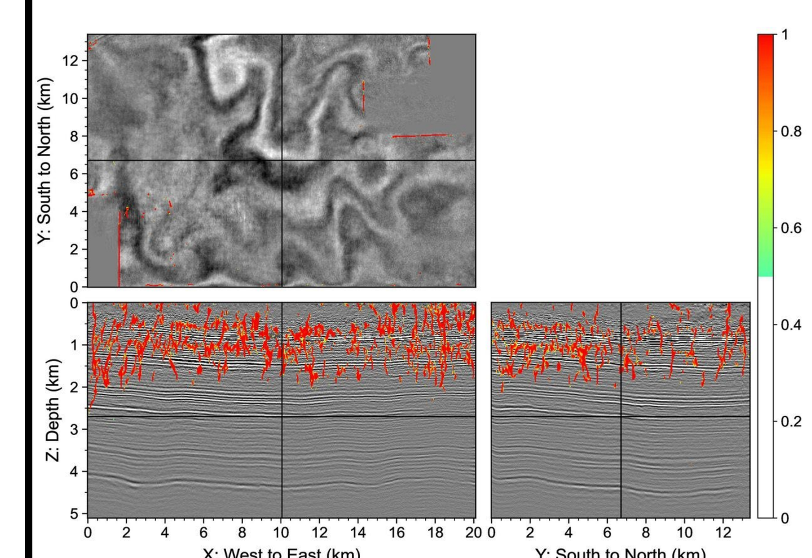


PSDM 3D Migration Image

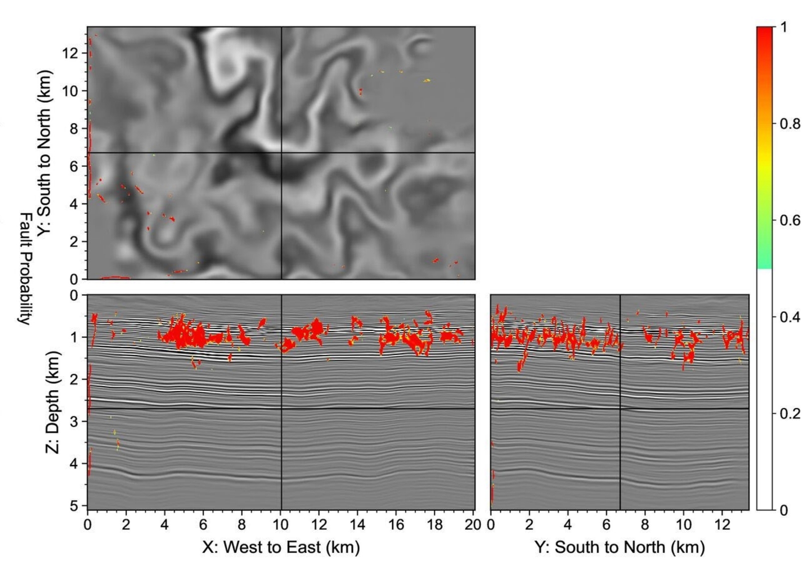


Denoised 3D Migration Image

ML Fault Detection on 3D Seismic Images



ML Fault Detection



ML Fault Detection

Conclusions

- We have performed 3D migration velocity analysis and prestack depth migration of the 3D surface seismic data acquired at the San Juan Basin CarbonSAFE project site.
- We have performed machine-learning fault detection on the denoised 3D migration image.
- We found that there are no major faults around the primary CO_2 injection zone, the Entrada formation at ~ 2.5 km depth, and that there are no major basement faults either.
- Our results provide valuable information for site characterization and risk assessment at the San Juan Basin CarbonSAFE project site.

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