Geophysical Modeling and Interpretation of 3D Seismic Data from Farnsworth Unit, TX

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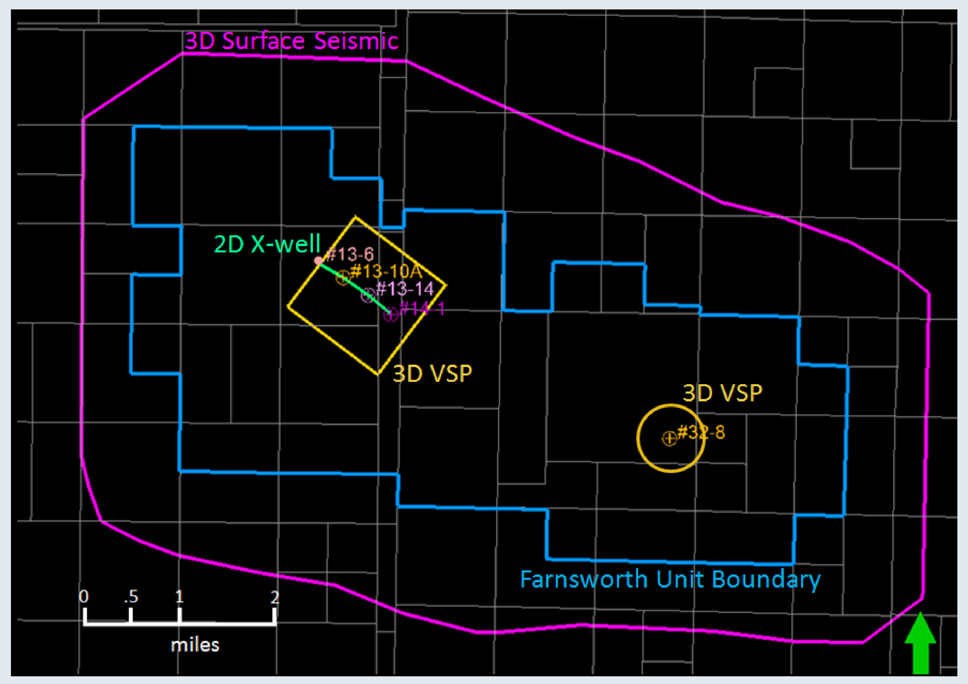
Southwest Partnership CO_2 Sequestration

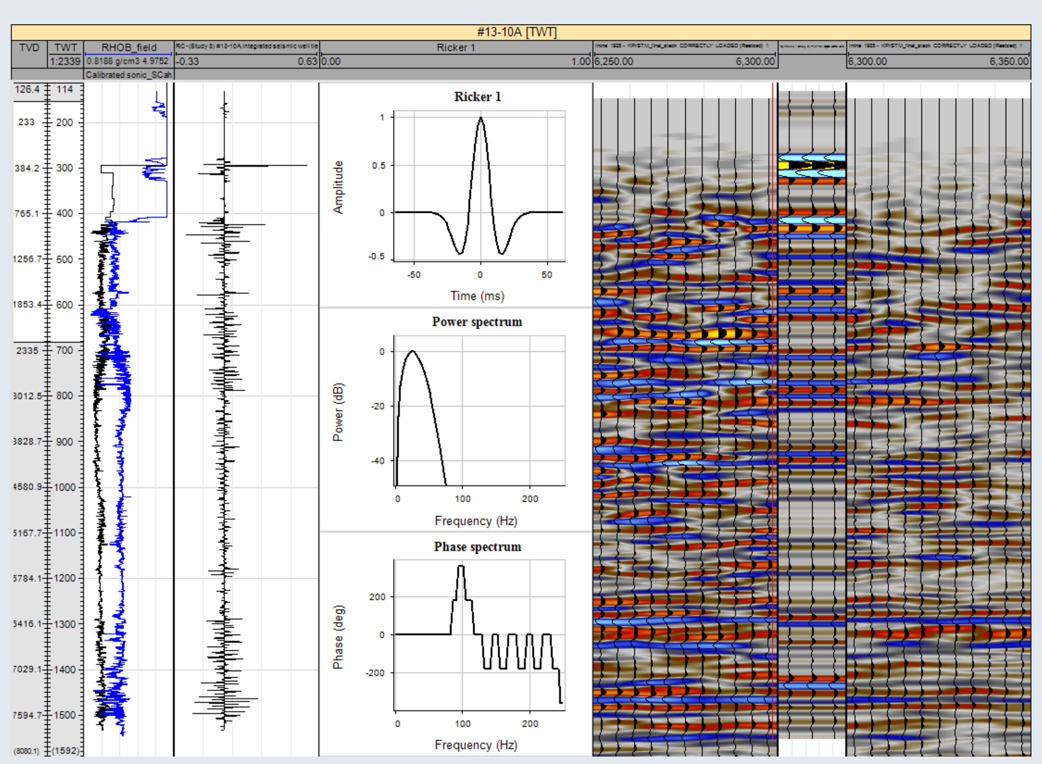
The Farnsworth Unit, located in the western Anadarko Basin in Ochiltree County, TX, is the site of a CO_2 enhanced oil recovery (EOR) project and the location of the Phase III large-scale carbon capture, utilization, and storage (CCUS) demonstration project conducted by the Southwest Regional Partnership on Carbon Sequestration (SWP). Funding for this project is provided by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) under Award No. DE-FC26-05NT42591. Additional support has been provided by site operator Chaparral Energy, L.L.C. and Schlumberger Carbon Services.

The SWP's primary objective is to effectively store 1,000,000 metric tons of anthropogenic CO_2 within the Morrow B sandstone reservoir with 99% storage permanence. The successful storage of CO_2 requires stratigraphic and structural characterization. The interpretations provided the architectural framework for a comprehensive geologic model .

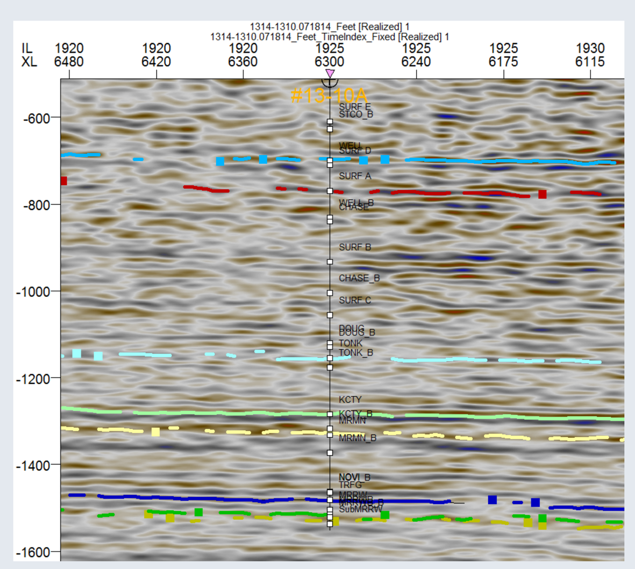


The primary seismic dataset was a 42 mi^2 3D reflection surface seismic survey (pink) that encompasses FWU (blue). Three 3D vertical seismic profiles (VSP) were acquired; two in the west side (yellow square), and one on the east side (yellow circle). 2D crosswell tomography (green) spans across four wells intersecting the western VSP, and between two wells in the eastern VSP survey.

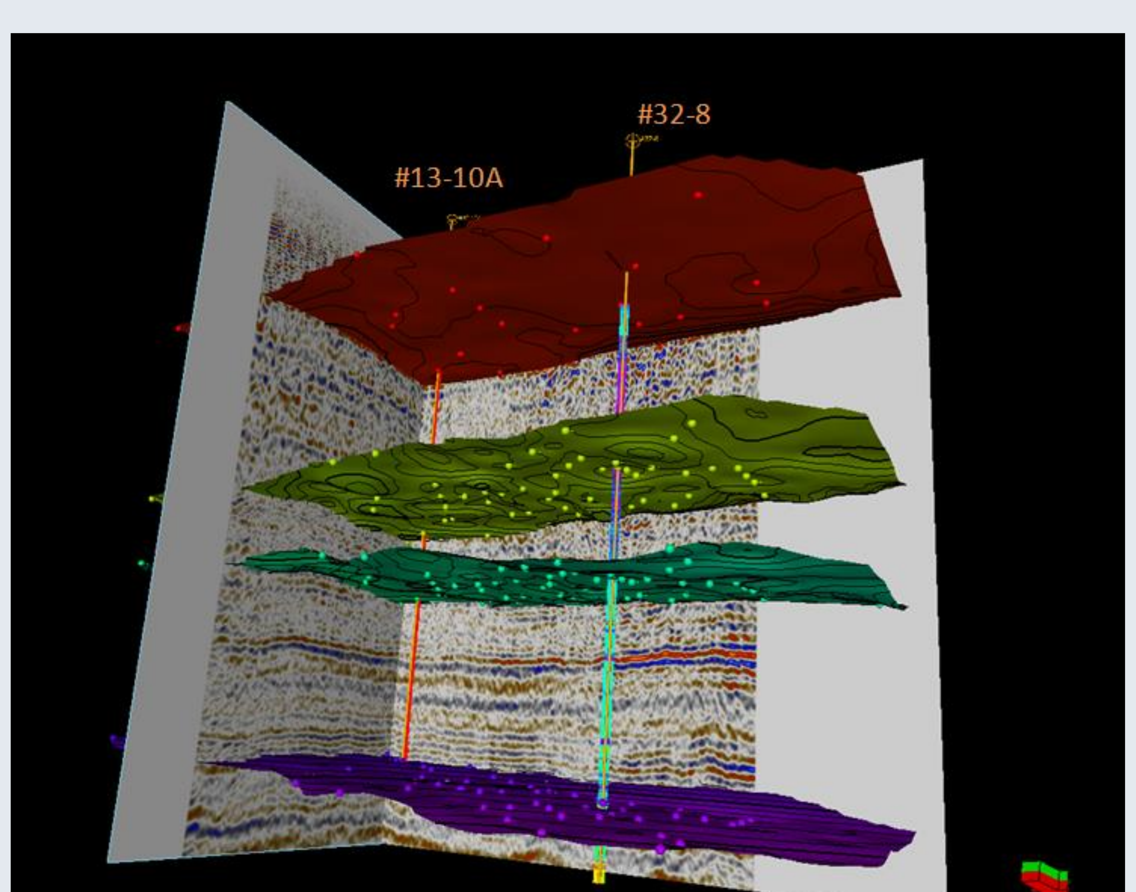
Formation top picks were the basis for the stratigraphic interpretation. This was achieved with a well tie to seismic data. Using the time-depth relationship generated by the well tie and the 3D horizon picks, a velocity model was constructed to convert time-domain seismic data to the depth-domain. It is useful to have depth-domain seismic data to correlate to other depth-domain datasets, such as wireline and core.



Above is the #13-10A seismic well tie in which a synthetic seismogram was generated by convolving a Ricker wavelet with a reflection coefficient log, which was computed from sonic and density logs. The synthetic events are then matched to seismic events.

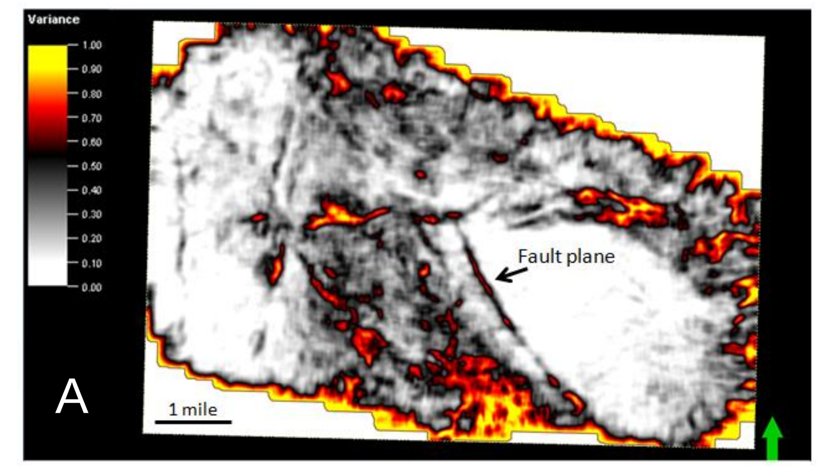


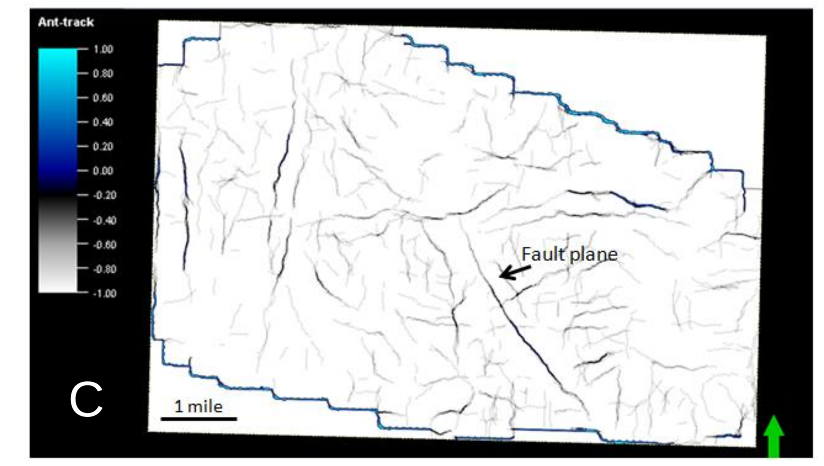
The #13-10A well is displayed with formation tops (white squares) in a seismic cross-section above. Horizons were picked on reflections corresponding to the lithology changes recorded in wire-line logs

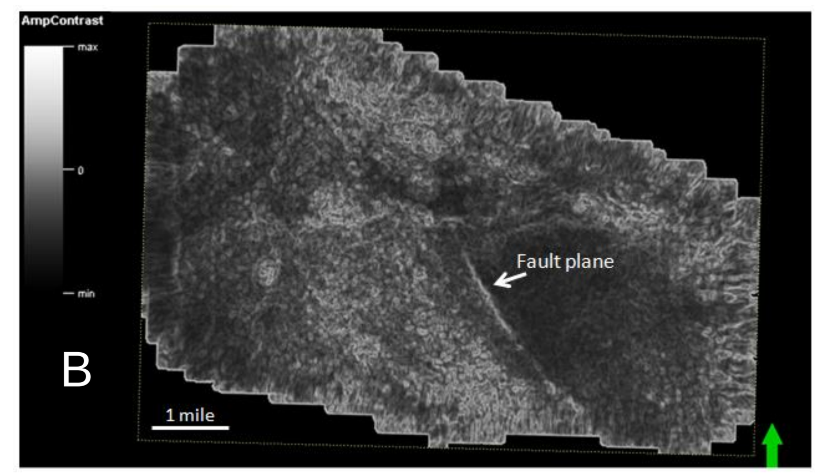


To the left the velocity model output displays depth-converted surfaces and seismic cross-sections. Each brightly-colored point is a well top from a well within the FWU. Each depth-converted surface intersects the well top points, indicating there is a good fit between the time and depth-domain datasets, and the correct geometry of the data has been preserved across domains.

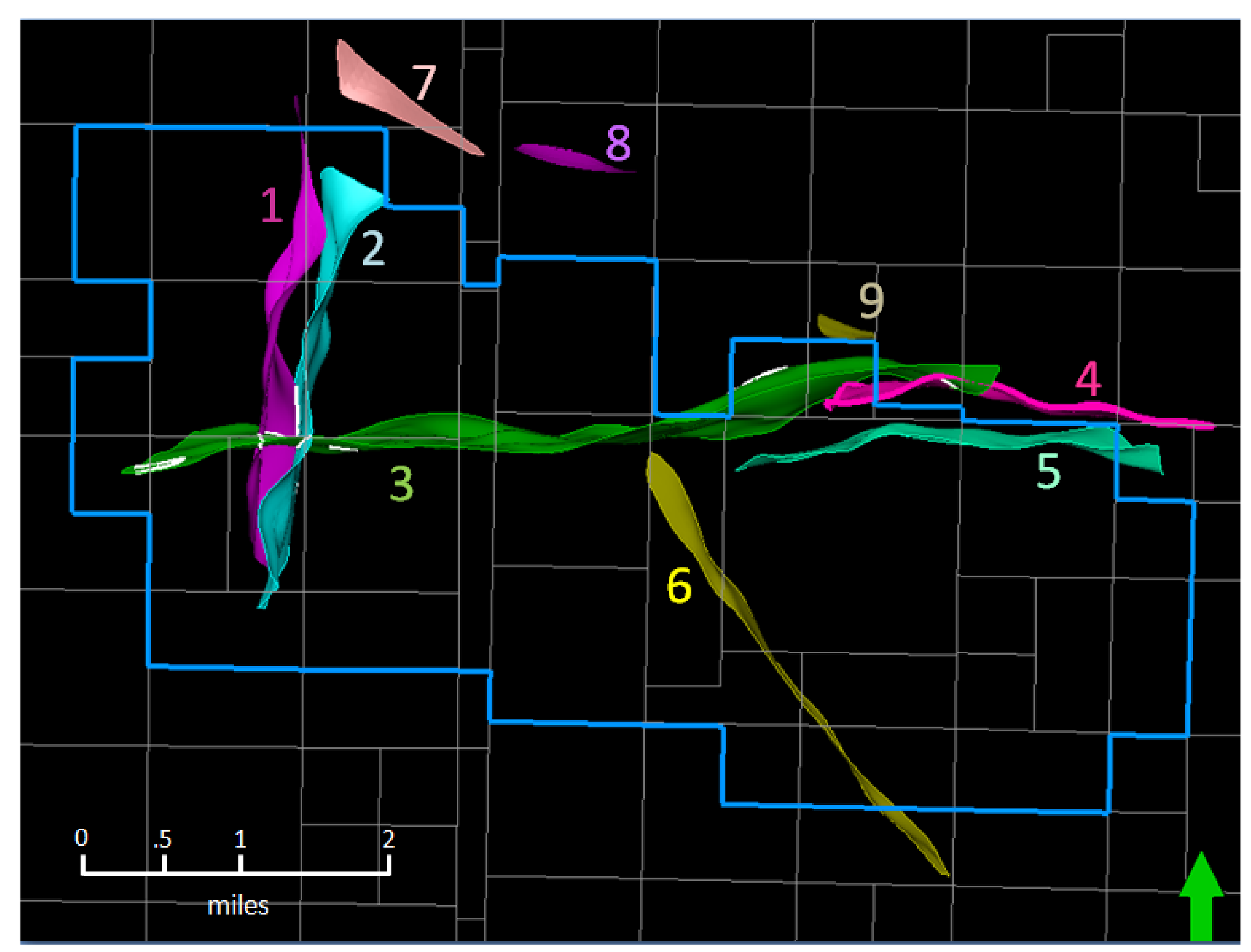
The existence of pre-existing faults in a reservoir indicate that consideration of induced seismicity and caprock formation integrity is warranted. In FWU, nine faults were interpreted from the 3D surface seismic data and extracted attributes. Variance, amplitude contrast, and ant-track volumes were extracted from the 3D seismic data to visually enhance fault planes within the seismic cube by visually and numerically enhancing fault planes. All but one intersect both reservoir and caprock but none has a surface expression or even penetrates all the caprock units.







The variance dataset (A) is an edge enhancement method that estimates the localized variance in the seismic signal. The amplitude contrast dataset (B) is also an edge enhancement attribute that analyzes derivatives in all three dimensions. The ant-track dataset (C) is an automated fault extraction attribute applied to the variance and amplitude contrast datasets.



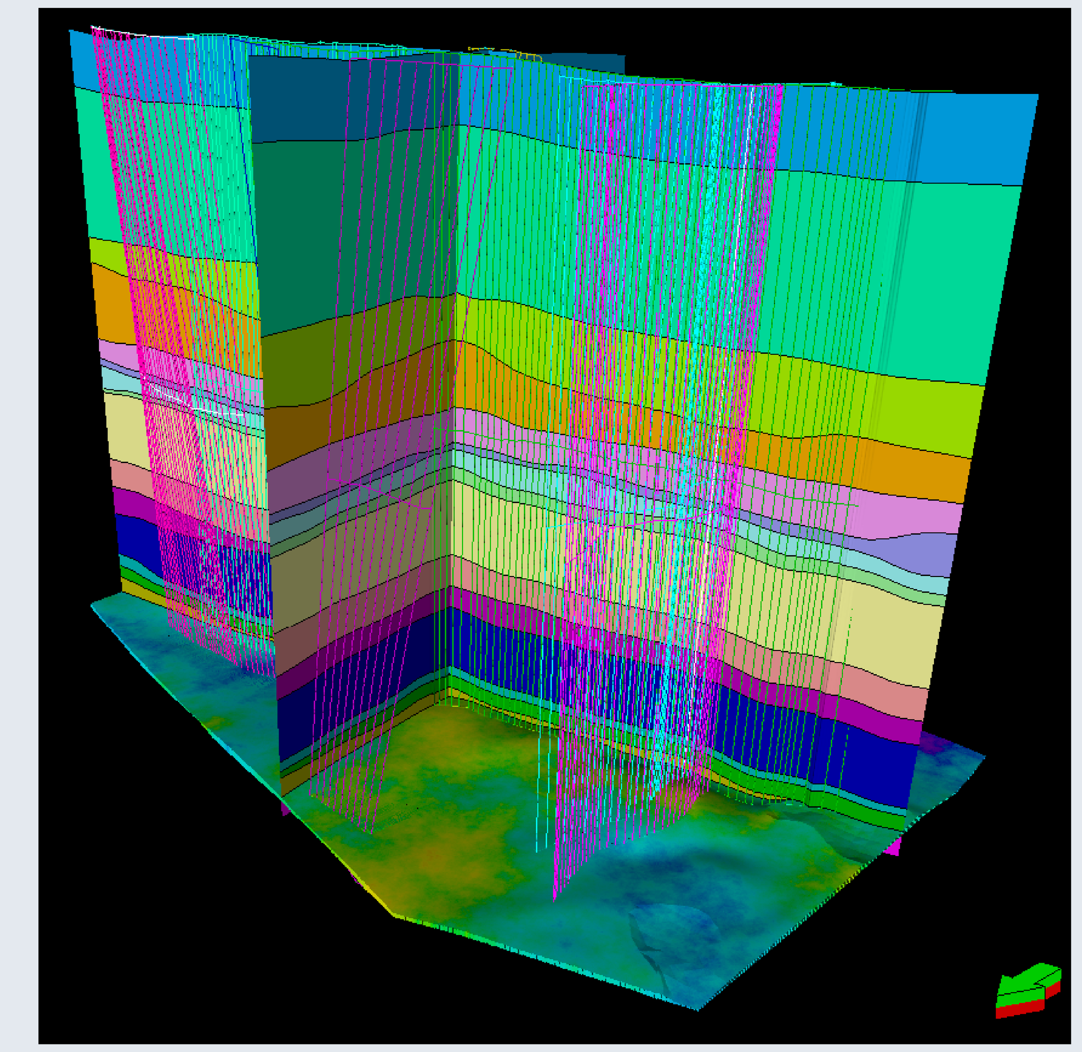
Nine subvertical faults shown in the figure above were picked from the ant-track dataset. Faults 1-5 constitute a sinistral wrench fault system, similar in orientation to the Wichita megashear that bounds the southern Anadarko Basin. Fault 3 is the principal displacement zone. Faults 4 and 5 are the bounding faults of a graben at a releasing bend in the PDZ. Faults 1 and 2 are probably conjugate strike-slip faults in a pure shear regime. They typically form in convergent stress regimes, such as the Anadarko's Pennsylvanian crustal shortening event.

Seismically resolvable faults also have implications for creating seal bypass systems, through which fluid could migrate outside the reservoir. The shale gouge ratio (SGR) was calculated for each fault. All SGRs exceed 25-30%, which indicated the faults would act as barriers to fluid flow rather than conduits.

Fault	Throw (ft)	SGR (%)
1	68	89
2	89	68
3	123	49
4	208	29
5	103	59
7	83	73
8	143	42
9	79	76

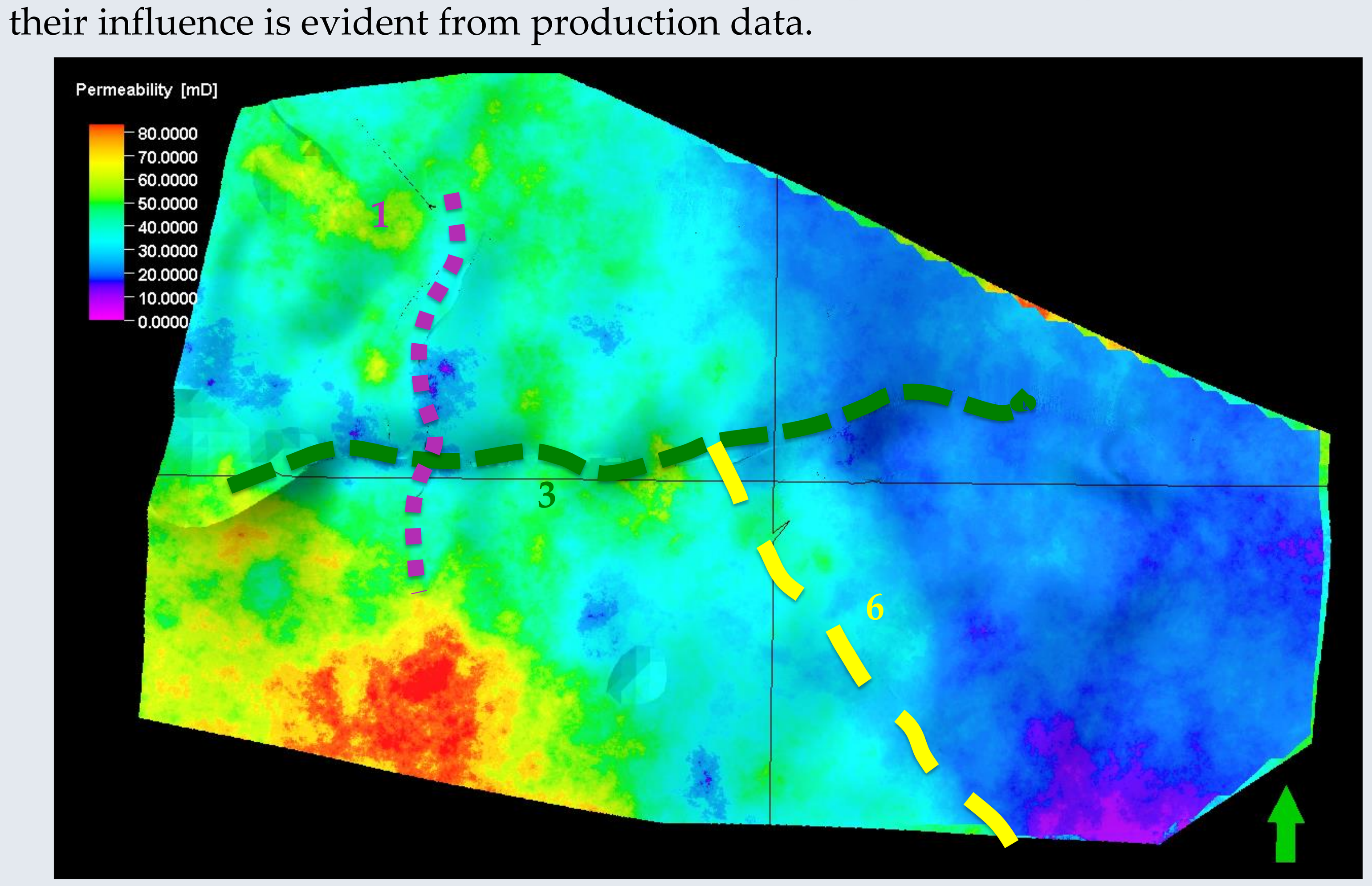
The Morrow B sand reservoir was found to always be juxtaposed on low permeability lithology.

The architecture of the FWU contains several features that could affect oil production, fluid migration through the reservoir, and have implications for the successful long-term storage of CO_2. Characterizing the reservoir and caprock system using the 3D surface seismic survey provided additional details to be included into a fine-scale geologic model.

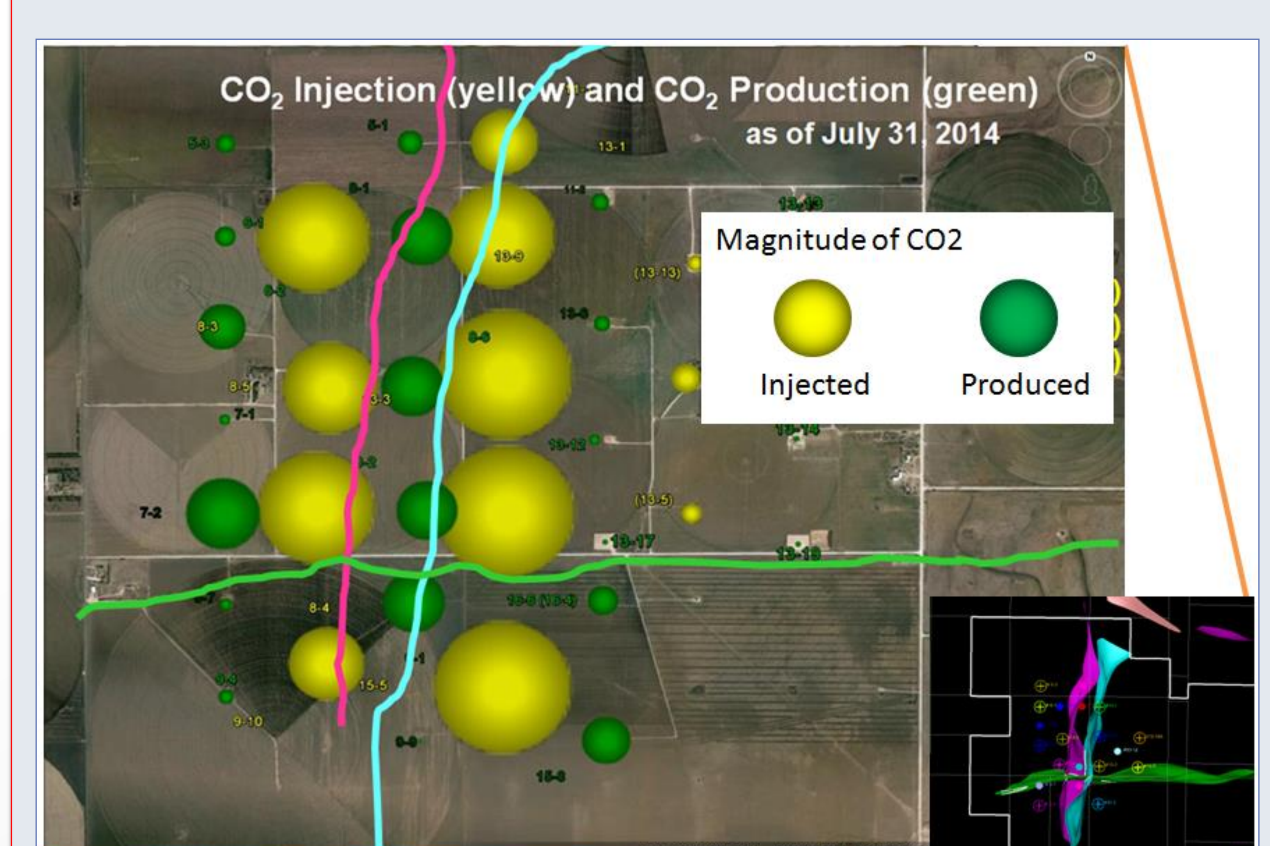


The image to the left looks southeast at intersections of the 3D geomodel. The i and j intersections display stratigraphic structure from horizon interpretations. The horizontal layer is the Morrow B reservoir populated with porosity data. The vertical fence post planes cutting through the Morrow B reservoir are the fault model.

The faults and associated structures affect the properties in the geologic model, and their influence is evident from production data.



When fault planes are incorporated into the geologic model, the resulting permeability property model above shows that the faults probably affect fluid flow. Low permeability values near the intersections of Faults 1-3 and near Fault 6 suggest the fault planes would inhibit flow across the reservoir.



CO_2 production and injection data also suggest that the fault planes are barriers to fluid flow. It was observed that while large amounts of CO_2 are injected at the injection wells, some nearby production wells produce little CO_2. This may be an indication that the fault planes are affecting sweep efficiency.