Geomechanical characterization of the Arbuckle-Basement system, Payne Co, OK

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Objectives

- To characterize subsurface properties of the Arbuckle-Basement system and overlying formations in north-central Oklahoma in an integrated manner using state-of-the-art geoscientific and engineering data and technologies
- To create 3-D numerical models of the subsurface geology that depict the spatial distribution of rock types and petrophysical properties.
- To perform fluid-flow and stress simulations to understand subsurface dynamics that would shed light on the triggers and controls of induced seismicity.

Data available

Post stack seismic volume (cropped above the Arbuckle formation) converted to depth with earthquake event locations.

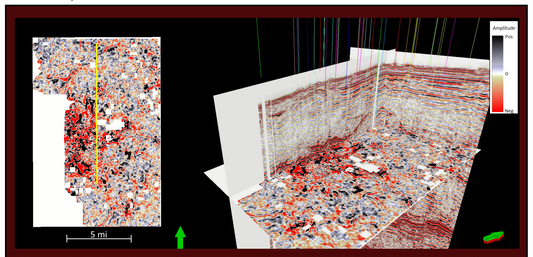

Figure 1. Seismic amplitude time slice at 11000 ft displayed with two vertical cross sections. All wells that fall within the seismic region are shown with different colors. Most do not penetrate basement.

Seismic horizons and velocity models for the cropped out portion of the seismic.

29 wells with well logs digitized from raster images. Well tops provided by the OGS.

Seismic interpretation

In order to perform a proper seismic interpretation, a Structure-Oriented-Filter and phase shift were applied to the seismic volume, as displayed by Figure 2.

A suite of different seismic attributes were computed to characterize the coupled system on a regional level (Figure 3).

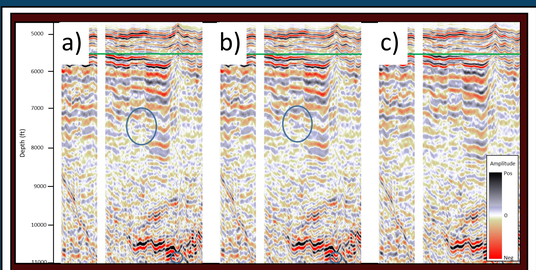

Figure 2. Vertical cross section of a) original seismic amplitude, b) after two iterations of Structure-Oriented-Filtering and c) after -114° phase shift.

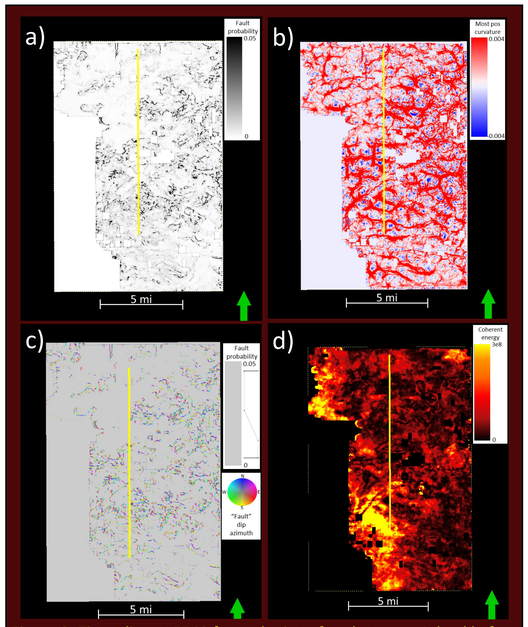

Figure 3. Time slice at 5740 ft. on the interface between Arbuckle formation and acoustic basement through a) Directional Laplacian of a Gaussian (dLoG) coherence, b) K1 most positive curvature, c) dLoG co-rendered with "fault" dip azimuth and d) coherent energy. Note that the deformation at this level is better illuminated by curvature. This improvement may be due to geology or to limitations in the seismic imaging.

As observed in Figure 3, most structures on the interface of the Arbuckle formation and the acoustic basement are poorly illuminated by coherence-based attributes. The strike-slip nature of most faults in the basement exhibit little to no vertical displacement . We hypothesize that some of these strike slip faults and pop-up structures were generated by pre-Ordovician uplift of the basement. We created a fault map for the survey using a multi-attribute display, as can be seen on Figure 4.

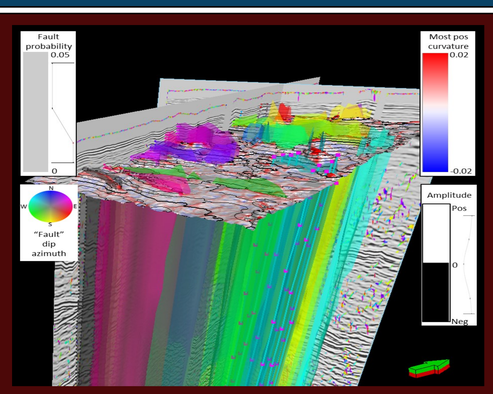

Figure 4. Fault map for the seismic region. Faults are colored the same if they belong to the same pop-up structure. We plotted dLoG against a monochrome gray color bar, and seismic amplitude as a bi-modal color bar. Opacity bars are displayed next to the color bar when appropriate. The top of the basement is displayed as a surface through the curvature attribute.

Geologic model

To build the stratigraphic network for the geologic model, we first digitized a suite of well logs for 29 wells, interpreting formation tops.

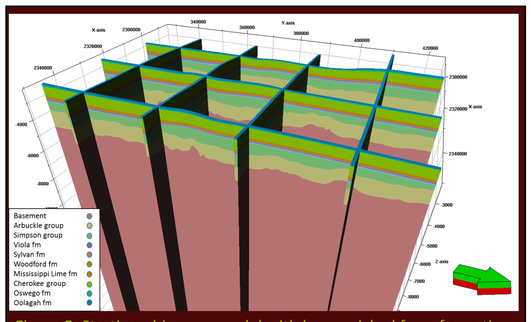

Figure 5. Stratigraphic zone model with layers picked from formation tops.

With the stratigraphic network from Figure 6 we created a bulk density and porosity model for the whole section covering the seismic and above. Porosity in basement is set to zero. Faults from seismic were input into the model and used to interpret areas of higher fracture density. Porosity values up to 6% are directly proximal to fault surfaces.

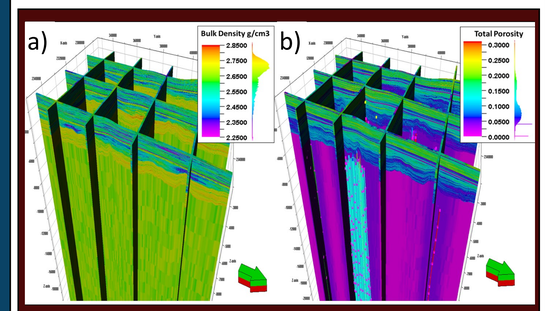

Figure 6. a) Bulk density model and b) porosity model , both constructed from the stratigraphic model on Figure 5.

Engineering Data Analytics

Performing a flow regime identification, we were able to estimate ambient reservoir pressure. Then we looked for signatures of fractures or plugging using Hall integrals. By plotting peak injection rates, among others, we intend to correlate with seismicity in Oklahoma.

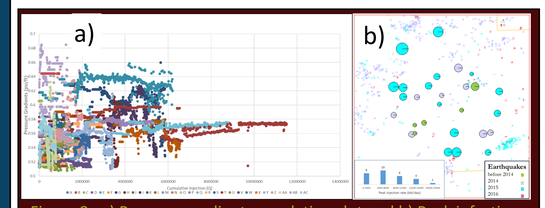

Figure 8. a) Pressure gradient cumulative plot and b) Peak infection rate for all wells within the survey. Small dots represent earthquake events within seismic survey area

Future work

- Generate a Geomechanical stress model based on estimates of Young's modulus and Poison's ratio within and below the Arbuckle.
- Numerically model waste water flow within and below the reservoir to predict areas of effective strain.

For questions or suggestions:

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