A workflow to quantify the relationship between structural seismic attributes and waste water injection parameters in Payne County, Oklahoma

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1. Geologic background

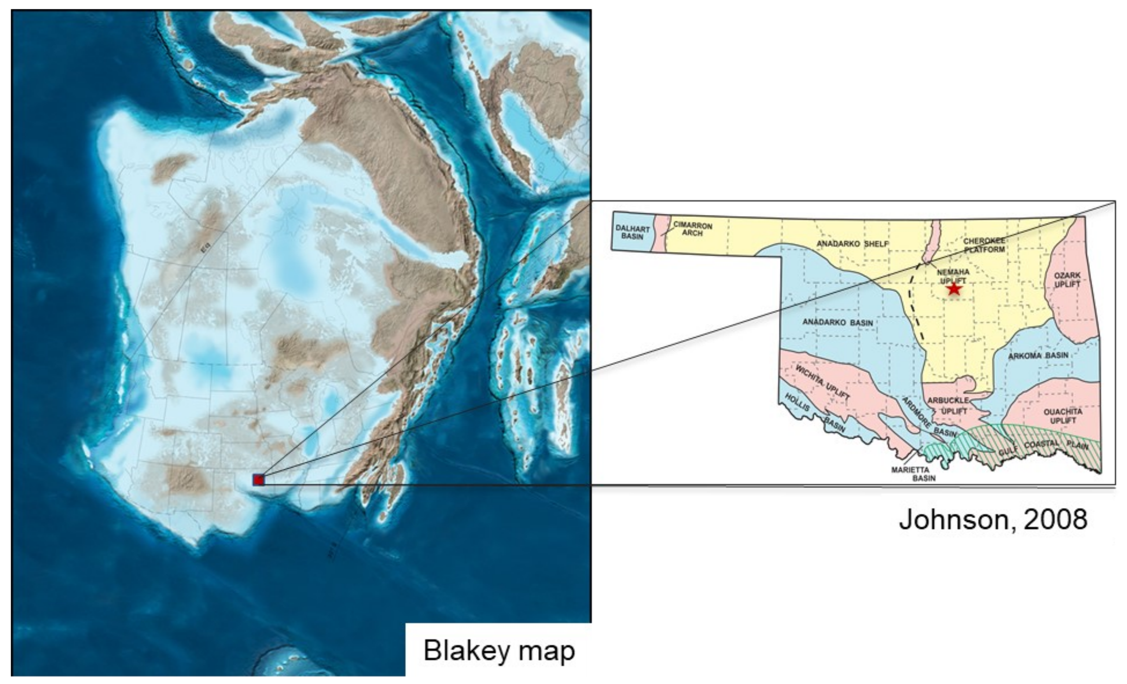

Figure 1. Paleo-topographic map of North America during Paleozoic times. Red square denotes approximate location of survey during these times. Red star denotes location of survey within Oklahoma, in the Anadarko Shelf, as can be observed from the map of geological provinces of Oklahoma (Johnson, 2008).

2. Data available

- A modern, pre-stack time-migrated wide-azimuth seismic survey shot in 2014, covering 240 mi^2 (Figure 2)
- For investment purposes, we cannot show data in the overlying Woodford, Mississippi Lime, and Red Fork reservoirs
- 11 wastewater disposal well with injection volumes and rates
- Pressures at the surface.

3. Methodology

Seismic attributes

- 24 seismic attributes were computed to both perform a basic seismic interpretation of basement faults and to quantify relationship with waste water injection parameters. (Figure 3).
- 3 Fault recognized that penetrate both the basement and Arbuckle Group tops.

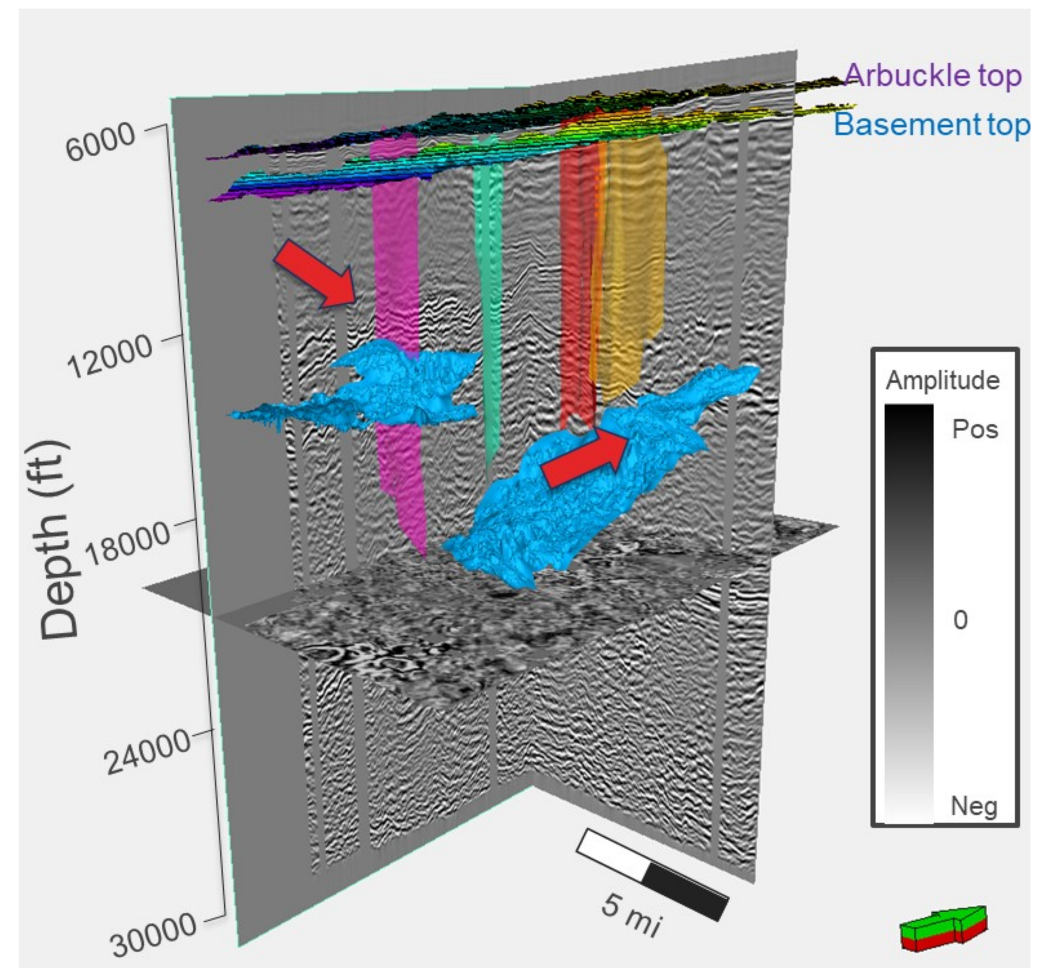

Figure 2. Chair display of seismic amplitude of dataset. Both the Arbuckle Group and Basement top are displayed on the top. Red arrows point at amplitude anomalies recognized in the basement thought to be caused by magmatic intrusions. Colored polygons represent interpreted faults in basement.

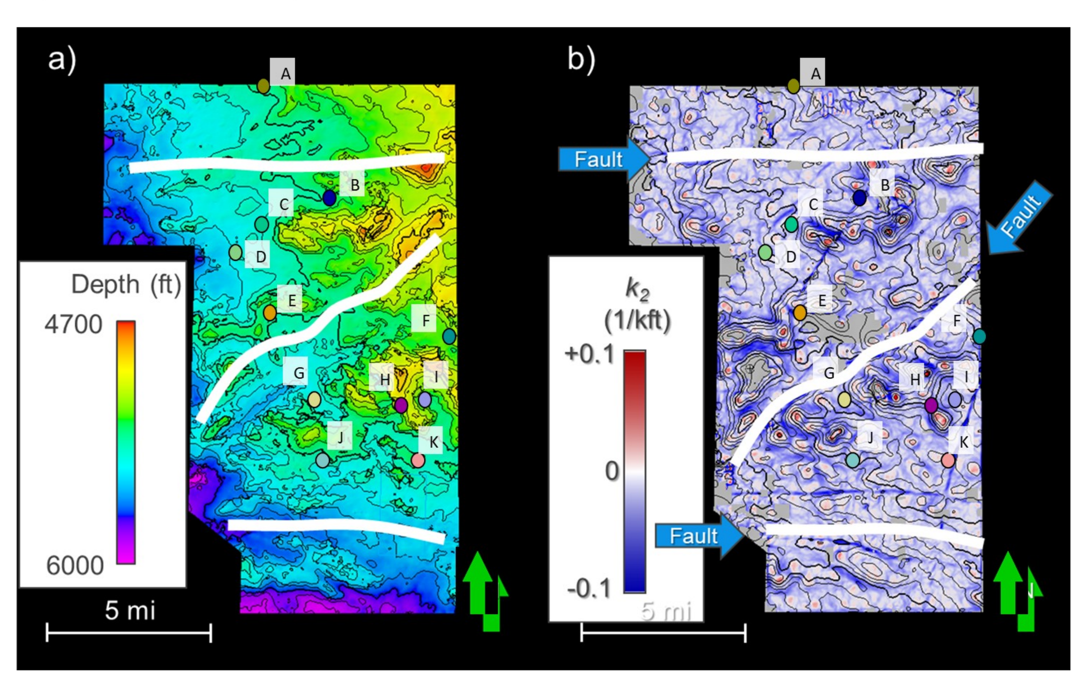

Figure 3. a) Depth map of Basement top b) most negative curvature. Three faults that cut across through basement and Arbuckle top were recognized. Wells highlighted in colors with corresponding letters for identification.

- Computed azimuthally limited fault density volumes using AASPI program azimuthal-fault density.
- Determined a statistically representative seismic attribute value for each well using AASPI program cigar-probe. (Figure 4).
- Generated pseudo seismic attribute well logs for each seismic attribute, where depth values corre-

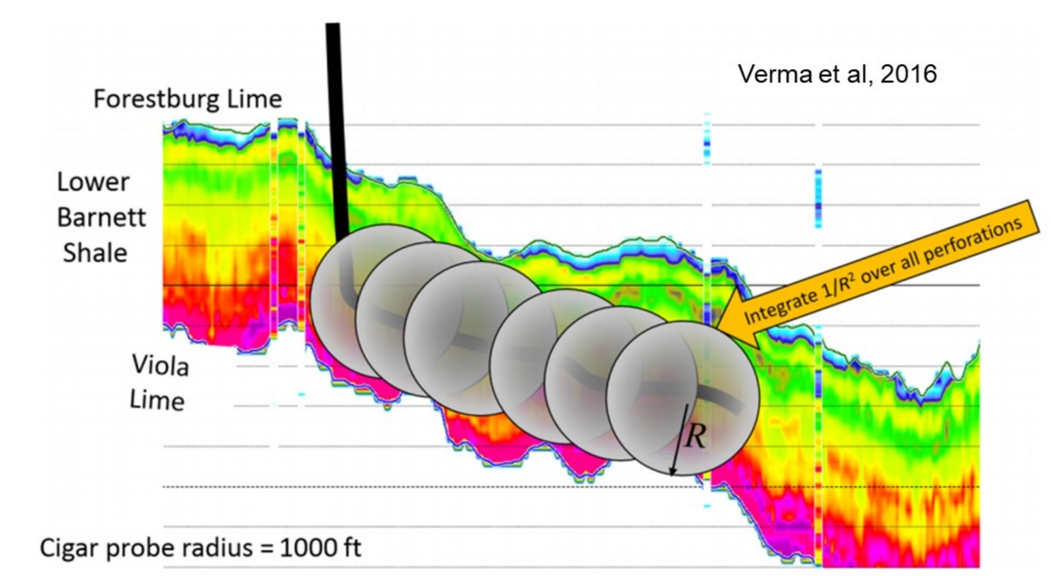

Figure 4. Illustration of cigar probe workflow. The flow (production) at each perforation can be approximated by the impulse response of Green's function $1/R^2$. We assume all the sections are perforated, and each point on the well is producing equally. Integration of all the points along the wellbore path to obtain the weighted average property is needed to correlate attribute values with the production (After Verma et al, 2016).

- Performed multi linear attribute regression using "Emerge" tool of the Geoview software to generate an equation capable of predicting the initial reservoir pressure at any location of the survey.
- Performed blind tests for each well to validate results.

4. Results and key observations

Table 1 summarizes the results of the multi linear attribute regression. Some of the key observations that can be drawn from this:

Leave-one-out cross validation	Predicted value	Actual value	Error (%)	N of attributes	Correlation
Well A	2624	2700	2.8	4	0.61
Well B	2617	2630	0.5	3	0.87
Well C	3178	2740	-16.0	4	0.84
Wel D	2687	2750	2.3	5	0.99
Well E	2630	2750	4.4	4	0.68
Well F	2719	2450	-11.0	5	0.8
Well G	2627	2630	0.1	3	0.73
Well H	2489	2285	-8.9	5	0.95
Well I	2698	2545	-6.0	6	0.99
Well J	2683	2600	-3.2	4	0.8
Well K	2668	2525	-5.7	5	0.99

- Number of samples: Too small to be statistically significant. However, large enough to present a workflow applicable in other regions.
- Examining tests with the smallest error shows

  excluding well G the seismic attributes used for prediction: seismic amplitude, k1 curvature and fault probability

  excluding well B the seismic attributes used for prediction: GLCM energy, k1 curvature and -60° azimuthal fault density.

Because of the predominance of structural seismic attributes, there seems to be some structure control on the initial reservoir pressure

High correlations: both single and multi attribute regressions indicate a proportionality between some seismic attributes and initial reservoir pressure. However, single attribute regression yielded unacceptably low R^2 values.

5. Acknowledgements

We would like to thank Schlumberger for the Petrel licenses used for displaying purposes. CGG Veritas for the Geoview licenses to perform the multi linear regression and the company owner of the dataset for allowing us to use it for research purposes.

6. References

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