Correlation of fluid flow from injection wells to fault proximity and orientation

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Introduction

Water disposal type II wells have been extensively correlated with induced seismicity in places like California, Texas and the Arbuckle-Basement system in Oklahoma. Although the latter is currently covered in n-thousand water disposal wells, it is only the north-central part of Oklahoma that experiences a recent increase in seismicity.

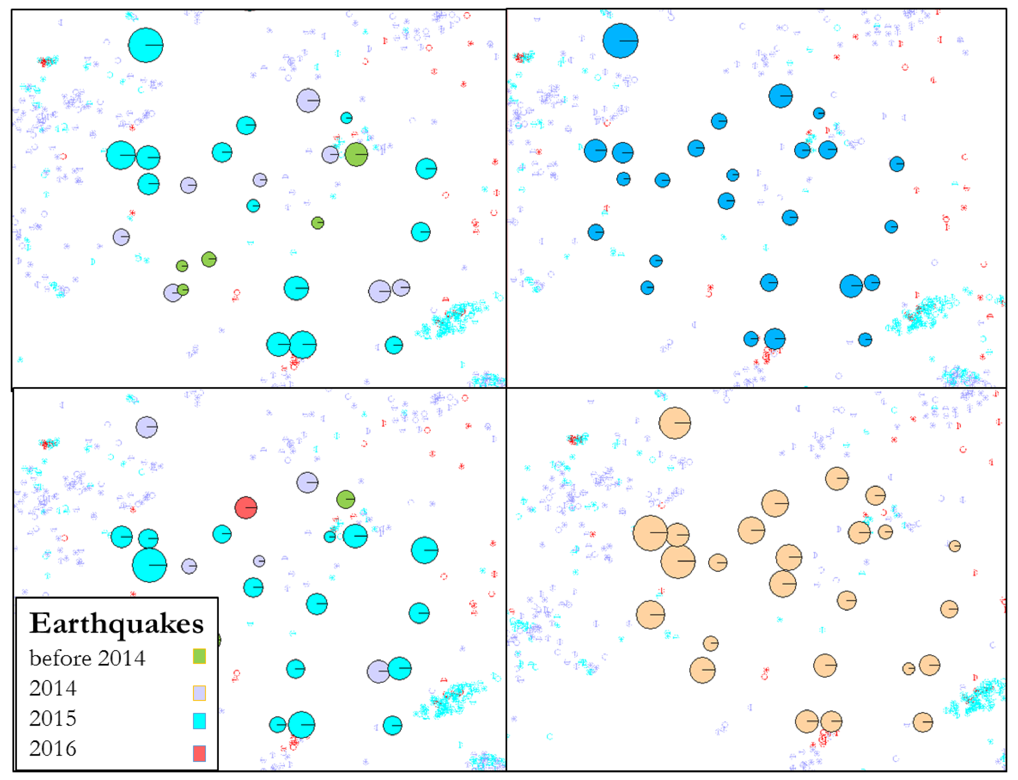

Figure 1. a) Peak injection rate, b) cumulative injected volume, c) Peak wellhead pressures and d) ambient reservoir pressures for available wells within Payne County, Oklahoma. Small dots are the earthquake events colored by the year in which they occurred.

Several initiatives have been started in order to understand the mechanisms that trigger these seismic events. Figure 1 shows different parameters calculated in the area of study in order to correlate with the seismic events.

Guo et al (2010) presented a workflow to quantitatively correlate production through fluid flow to negative curvatures anomalies. The data set for such analysis corresponded to a seismic volume from the Mississippi Lime in Kansas. The hypothesis was that open natural fractures or fractures opened through hydraulic activity act as dominant fluid conduits in the reservoir.

Figure 2 shows the result of their prediction of fracture "fluid flow" from different azimuths.

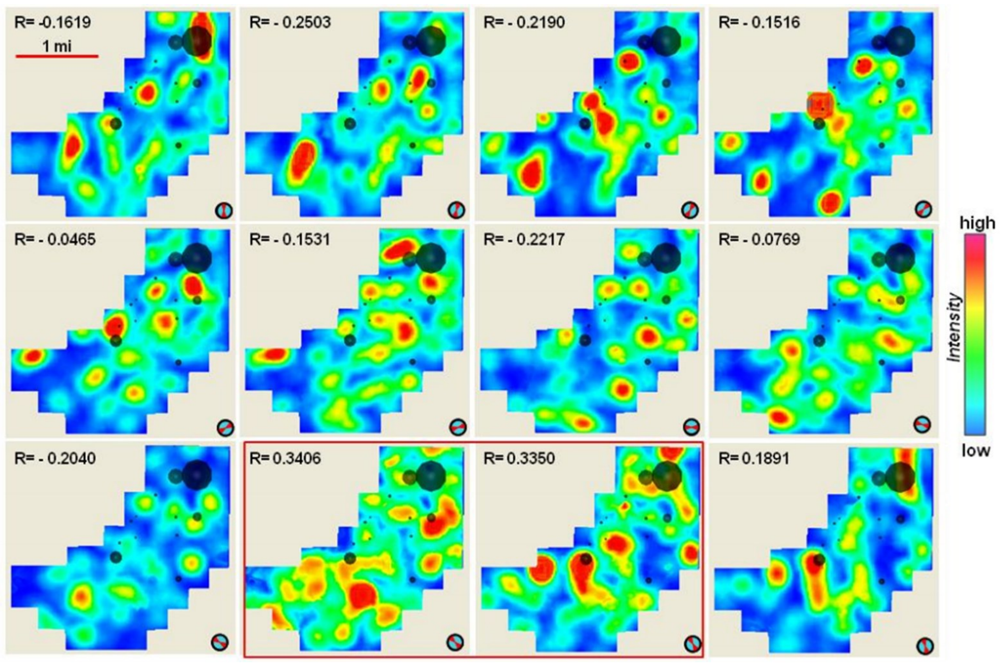

Figure 2. 5 year water production against hypothesized fracture fluid flow computed from K_2 curvature and its strike. The strongest positive correlation at –45° suggests that NW-SE-trending fractures are open. Bubble size represents relative water production (from Guo et al, 2010).

Following the steps of Guo et al (2010), we apply a similar workflow to a data set from Payne County, Oklahoma, in order to correlate fluid flow to water disposal activity in the Arbuckle Group-Basement system. Water disposal activity in the Arbuckle Group in Oklahoma has been linked to triggered seismicity events.

Azimuthal fault density

The basic assumption is that the reservoir has a constant, finite permeability κ that becomes extremely large in open fractures. In order to detect potentially fracture portions of the reservoir, we implement a seismic amplitude sensitive to such features, along its azimuthal information. Guo et al (2010) used K_2 most negative curvature and its strike. With a new application, we implement the azimuthal fault density attribute using fault probability and "fault" dip azimuth as input for the computation. We compute a set of 12 azimuthal volumes which we display in Figure 3. Higher correlation values imply a bigger density of faults for that azimuthal orientation.

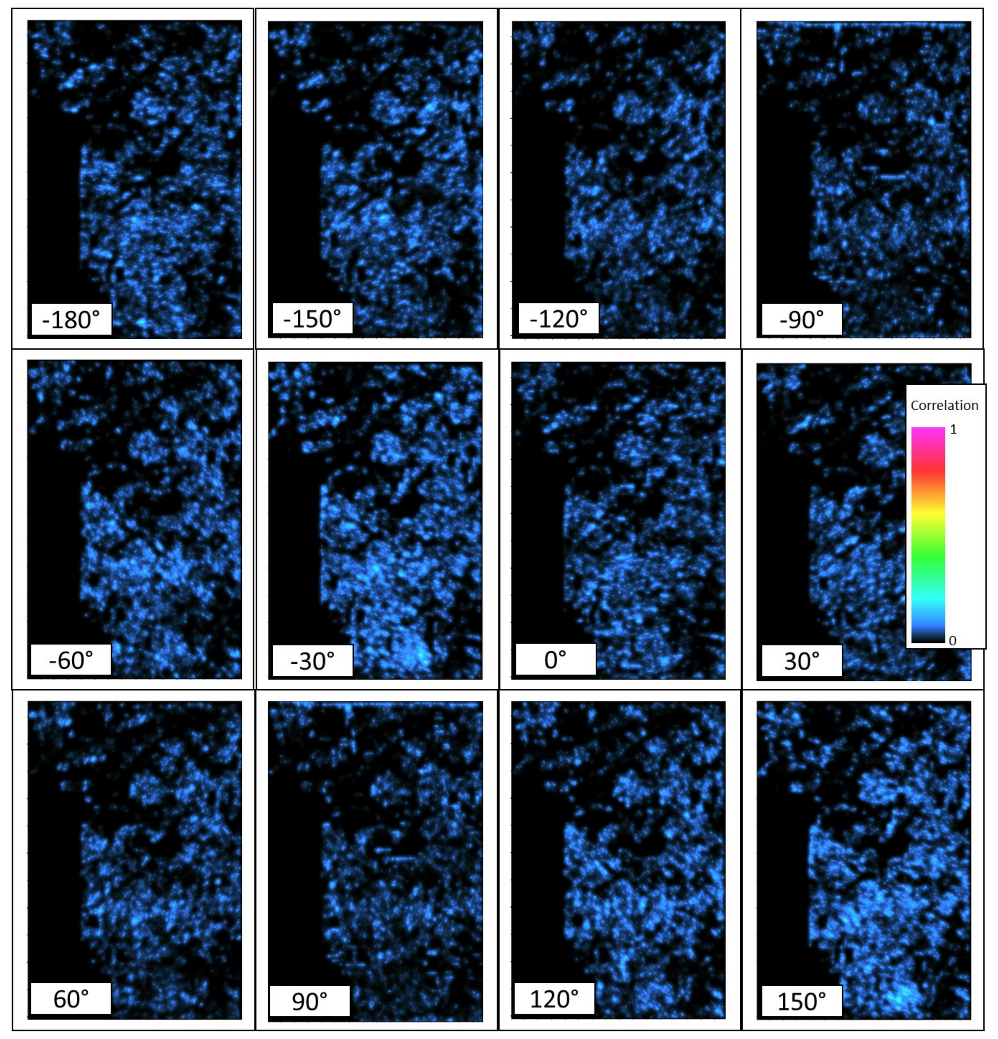

Figure 3. Time slice at 5740 ft through the Azimuthal fault density attribute computed along 12 azimuths. We used fault probability and "fault" dip azimuth attributes as input. Note that the major correlation of fault density is for the –30° azimuth and 150°, which are the same in essence.

The dominant fault density orientation corresponds to –30° and 150°, both belonging to the same strike direction. In the face of this, we selected the –30° azimuthal volume for the following analysis.

Figure 4 displays faults orientation through a fault probability and curvature attributes. We recognize two major fault trends: one with SW-NE orientation and another one oblique to the first. Both orientations are highlighted with orange arrows on Figure 4a.

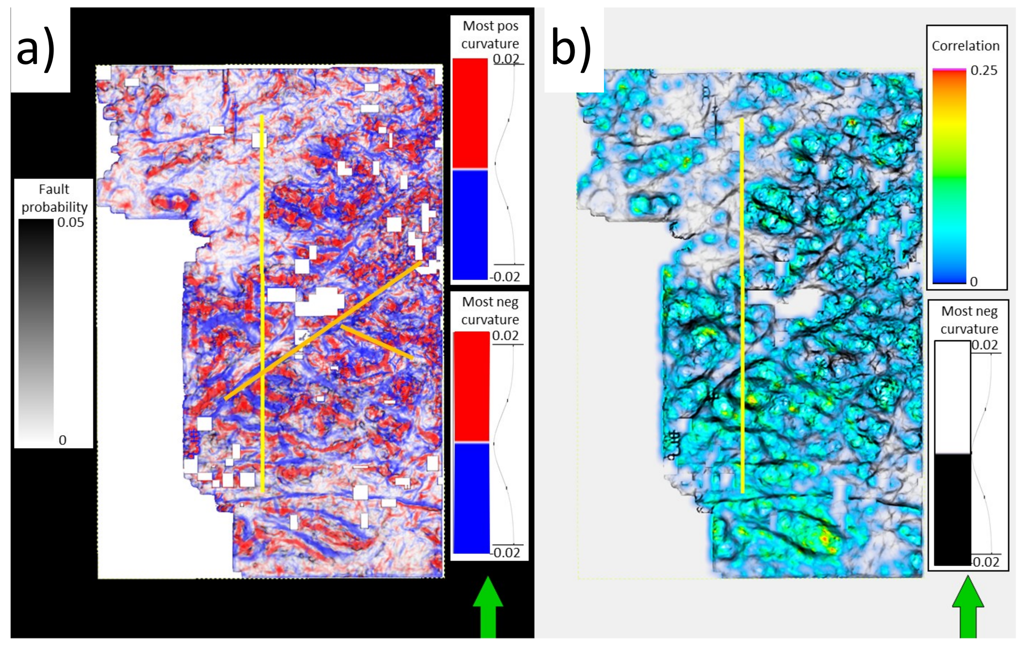

Figure 4. Time slice at 5740 ft. through a) fault probability co-rendered with K_1 most positive and K_2 most negative curvature and b) azimuthal fault density oriented at –30° co-rendered with K_2 most negative curvature against a bi-modal black and white color bar. Note two major trends of faulting: one SW-NE and another oblique to it, as denoted by the orange lines on a).

Most negative curvature anomalies are also associated with high correlation of azimuthal fault density, as we would expect given the relationship between curvature anomalies and fracture zones. However, this represents an interesting fact since both attributes are computed from different inputs.

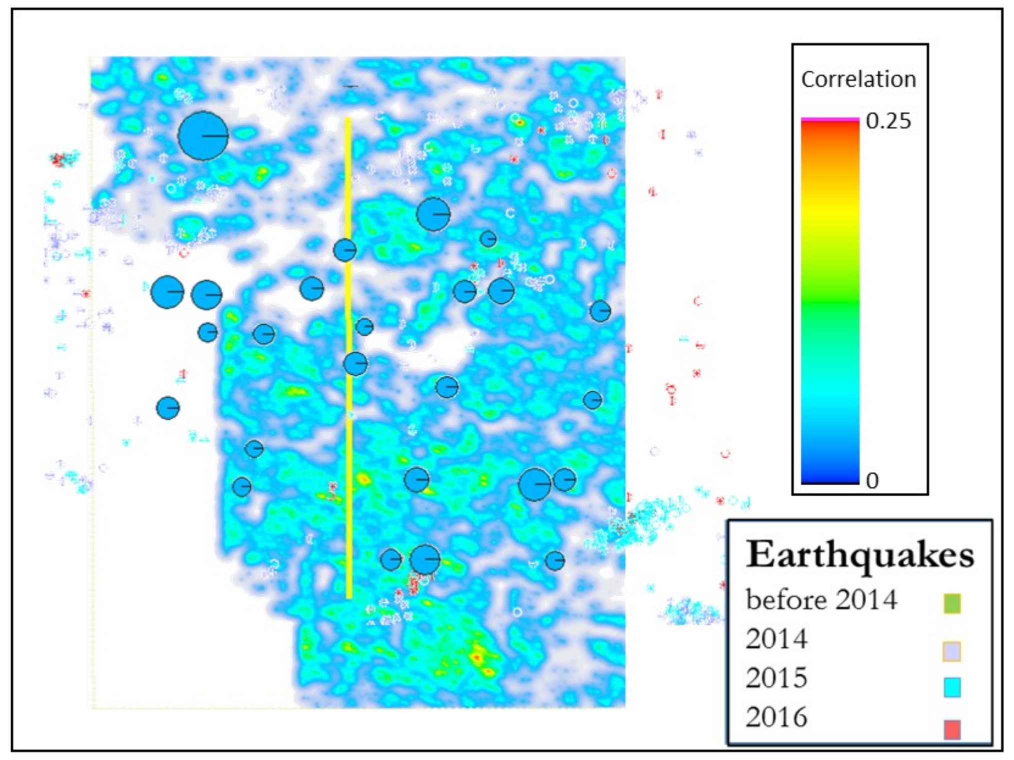

Figure 5. Time slice at 5740 ft. through azimuthal fault density on top of map of cumulative injection volumes of water for wells within the seismic survey area. Bigger circles correspond to higher cumulative water disposal volumes. Small dots represent earthquake events color coded by the year in which they happened.

We display the cumulative volume of water disposed on the wells that fall within the seismic survey area on Figure 5. No visual correlation can be implied between both images at the moment

Future work

- Identify any potential dependence between azimuthal attributes and water disposal activity
- Quantitatively correlate azimuthal faults density attribute with water injection volumes.

Acknowledgements

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