2.3 Injection and Seismicity

Use all the wells within 20 km radius.

Figure a1: Injection rate peaked in 2012 and 2013. Seismicity peaked in 2015, followed by a few months of quiescence, renewed again with accelerating foreshocks. Two periods: T1 - before May 2016. T2 - Q, Seismic quiescence period T2 - N, Nucleation period for mainshock (foreshock activities)

Figure a2: Total injection volume is 7.7 e7 barrels, equivalent to 1.267 m3. Maximum seismic moment is 5.6e17 Nm, factor of 4.67e10 injection volume, slightly larger than the typical shear modulus of 3e10, but on the same order of magnitude. During T2-Q, the increase of seismic moment paused, but followed by rapid increase of EQ.

The foreshock sequence likely represents extended nucleation process of the mainshock.

Part 3: The Fairview (M5) sequence in western Oklahoma

Figure a3: Evidence for injection related triggering process.

Space-time evolution Fairview Sequence

Conclusions:

(1) Large earthquakes tend to occur in regions with lower b-value and the edges of seismic zone.
(2) The M5.8 Pawnee earthquake is triggered as a result of injection, earthquake-to-earthquake triggering, and aseismic slip.
(3) The seismic moment of the Pawnee earthquake is slightly larger than the expected moment from GdV, but on the same order of magnitude.
(4) The M5 Fairview sequence shows evidence of diffusive migration, but also shows evidence of triggering from small earthquake clustering.
(5) The Fairview sequence continues to migrate to the south, continuing seismic hazard.
(6) Need to consider full spectrum of triggering process for induced seismicity.