Exploring the Evolution and Source Properties of Injection-Induced Seismicity in Northern Oklahoma Using a Large-N Seismic Array

Kilian B. Kemna¹, Alexander Wickham-Piotrowski², Andrés F. Peña-Castro³, Elizabeth S. Cochran⁴, and Rebecca M. Harrington¹

¹Ruhr University Bochum, Institute of Geology, Mineralogy, and Geophysics, Germany
²Environnement, Géoresources et Ingénierie du Développement Durable, École Nationale Supérieure, Bordeaux, France
³McGill University, Department of Earth and Planetary Sciences, Montréal, Canada
⁴Earthquake Science Center, U.S. Geological Survey, Pasadena, CA, USA

The LArge-n Seismic Survey in Oklahoma (LASSO) array recorded local seismicity in 2016 in a region of active saltwater disposal. The month-long deployment of 1,833 vertical-component nodes had a nominal station spacing of 400 m and covered a 25 by 32 km² area. We estimate local event magnitudes and focal mechanisms of the induced seismicity using the vertical component waveforms from a catalog of 1375 earthquakes. Here we use the developed catalog to investigate the spatio-temporal evolution of seismicity and the source properties of the induced events.

The catalog is complete to a local magnitude of ~0.9, with a b-value of ~1.1. Focal mechanisms, which we determined using the HASH method, show a mix of strike-slip and normal faulting. The majority of the events are located at 1.5 – 5.0 km depth, where injection depths range from 0.1 – 2.0 km, and the basement contact is located at 1.5 – 2.5 km. Analysis of the coefficient of variation of interevent times suggests that the time evolution of seismicity is close to Poissonian, with minimal temporal clustering. We observe spatial clustering, with larger (M > 2) events occurring within dense clusters near the footprint of the array.

The dense station coverage of the array permits the exploration of variations in corner frequency and resulting stress drop estimates as a function of azimuth, i.e. radiation pattern. We calculate stress drops for the local catalog within 5 km of the array footprint from individual spectral and spectral ratio corner frequency values. Single spectra corner frequency estimates for events within the array footprint on individual nodes show evidence of variation related to radiation pattern, and vary as much as 100% from the mean for an individual event. Stress drop estimates from spectral ratio corner frequency estimations range between 10 – 100 MPa, show self-similar scaling, and fall within the typical range observed for intraplate (tectonic) earthquakes. Both single spectra and spectral ratio corner frequency estimates show a significant sample bias in the corner frequency estimation by using less than ~10 stations, and highlight the importance of azimuthal coverage for the stability of spectral estimates.