Focal Mechanism and Stress Drop Estimates of the 2018/11/30 Mₗ 4.5, Injection-induced Earthquake Sequence near Dawson Creek, British Columbia, Canada

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Introduction

• Globally, fluid injection operations for permeability enhancement and wastewater disposal correlate with increased seismicity [e.g., Keranen & Weinigarten, 2018].
• Several potentially hydraulic fracturing induced earthquakes have been detected in northeastern British Columbia (e.g., Fig. 1)
• We use data from 15 broadband stations to study source properties of the 2018/11/30 Mₗ 4.5 induced earthquake near Dawson Creek, northeast British Columbia.
• We aim to determine the orientations of the seismogenic faults and source properties such as stress drop values of the sequence.

Methods

Moment Tensor Inversion:
• We use a probabilistic moment tensor inversion tool, *Grond* [Heinmann et al., 2018], to compute focal mechanism solutions (FMSs) of the mainshock, one foreshock, and three aftershocks.
• *Fomato*, a Green’s Function (GF) database management tool, is used to manage GF pre-calculated with [Becis code; Wang, 1999; Heinmann et al., 2017].
• Waveforms of both P & S waves as well as envelopes are fit in time and frequency domain simultaneously to determine optimum solutions.

Spectral Analysis:
• We follow the approach of Onwuemeka et al. [2018] to estimate seismic moment, corner frequency, and stress drop of 7 events with individual spectra and 2 events (the two largest Mₗ 3+ aftershocks) using the spectral ratio methods [Hartzell, 1978].
• Empirical Green's functions (eGFs) selected on 1) similarity in the difference between S-phase and P-phase arrival times (≤ 1 s); 2) hypocentral separation (≤ 3km); and 3) cross-correlation (cc) values (≥ 0.7).
• We fit station-averaged stacked spectral ratios weighted by the cc value.

Results

Focal Mechanism Solutions

Figure 2. Example waveform fitting for the 2018/11/30 Mₗ 4.5 event in (a) time domain for P-wave (Z-component); (b) time domain for S-wave (T-component). Text to the left of each subplot in (a) & (b) represent network, station, and component; station-epicenter distance; azimuth; solution weight factor; and relative residual. (c) Global misfit. (d) Full moment tensor solution.

Figure 3. Map view showing focal mechanism solutions (FMSs) of the mainshock, one foreshock, and three aftershocks. Blue arrows indicate the reported maximum horizontal principal stress. Bottom-left inset shows rose diagram of P-axis trend of all FMSs.

Figure 4. (a & b) Raw waveforms of an event pair. (c) Spectra of windowed event-pair signal and noise for one station. (d) Spectral ratios for the event pair color-coded by station. eGF_M₀, eGF_Mₗ 4.5, and rms are the estimated corner frequency and magnitude of the main event and eGF, and normalized root-mean-square error between the weighted-mean representative spectral ratio, and best-fit model, respectively.

Figure 5. (a) Corner frequency versus seismic moment. (b) Stress drop versus seismic moment. Main shock stress drop was calculated using only single spectra, due to a lack of a smaller event with similar waveforms.

Stress drop between ~1 and 10 MPa

P-axes follow the trend of the regional maximum horizontal principal stress

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References