Rupture Characteristics of Hydraulic Fracture Induced Seismicity

Schatzalp Induced Seismicity Workshop
March 12, 2015

T. Urbancic
G. Viegas Fernandes
& A. Baig
Motivation

Understanding the rupture processes could help explain induced seismicity generation processes

– Fault behaviour
  • Perturbations in the local stress field
  • Degree of surface roughness, asperities and barriers to slip
  • Frictional stress of the rock and resulting rupture velocity
  • Influence of fluids and proppant

– Goal – to derive a picture of the types of faulting processes
  • We examine seismicity recorded over a wide frequency range associated with stimulations in Horn River formation NE BC.
    – Rupture characteristics
    – Scaling behavior
The Horn River Basin is a natural gas bearing shale in northeastern British Columbia, Canada.

Reservoir depth: 2500 m
Seismicity

• ~820 events with $0 < M < 2.9$ and hypocentre distance from 2550 to 10000 m.
• ~30,000 events with $M < 0$ within 1km of injection zones
Waveforms

Example of waveforms from a M1 deep event recorded at borehole and near-surface geophone sensors.

near-surface sensors – 4.5 Hz geophones

borehole sensors – 15 Hz geophones
Signal Comparison

**Window 430 ms**
- **Frequency (Hz)**: fc = 140 Hz, Q = 90, Mw = 0.8
- **Distance to source**: ~1000 m

**Window 500 ms**
- **Frequency (Hz)**: fc = 10 Hz, Q = 30, Mw = 1.7
- **Distance to source**: ~4200 m
Stress Release Estimates

- Less than M0 cluster borehole data
- Greater than M0 cluster near-surface data

Graphs showing stress drop (Pa) and radius (m) with markers for borehole and near-surface data.
Rupture Characteristics

Rupture velocities:
- M>0; ~0.5Vs to ~0.8Vs
- M<0; ~0.3Vs to ~0.5Vs

Deeper formation events

Transition from reservoir to below reservoir events correlate with increasing seismic efficiency – transition from induced to triggered events?
Observed Scaling Behavior

Corner frequency (Hz)

Seismic moment (Nm)

Source radius (m)

Moment magnitude

SD 0.0001 MPa
SD 0.001 MPa
SD 0.01 MPa
SD 0.1 MPa
SD 1 MPa
SD 10 MPa
Generally, smaller stress drops are observed for hydraulic fracture stimulations over observed scale sizes.
Hydraulic Fracturing Process

- Generally... Shear-tensile failures with low radiated energy, dynamic stress and seismic efficiency, consistent with slow rupture velocities
  - Increased seismic efficiencies with growth out-of-zone
- Events are overshoot (slip weakening), with fluids lubricating fractures and resulting in a decrease in resisting friction
- Deeper larger events (M>0) tend to have faster rupture velocities and are more efficient in radiating energy
- Stress drop relationships consistent with natural earthquakes
  \[ \Delta \sigma_d > \Delta \sigma \text{ and } \Delta \sigma_{\text{RMS}}, \Delta \sigma \sim \Delta \sigma_{\text{RMS}} \]
  For induced seismic events, stress drops scale similarly, however, are generally lower than natural earthquakes
- Suggests the impact of HF events not as pervasive as natural earthquakes
WE'RE GOING TO START FRACKING UNDER OUR BIGGEST COMPETITOR'S HEADQUARTERS.

MY PLAN IS TO POLLUTE THEIR WATER AND GENERATE EARTH-QUAKE TO DESTROY THEIR CAMPUS.

THE PROJECT CODE NAME IS "FRACKING AWESOME."

CATCHY