

Ground Motions and Source Properties of Natural Vs Induced Earthquakes

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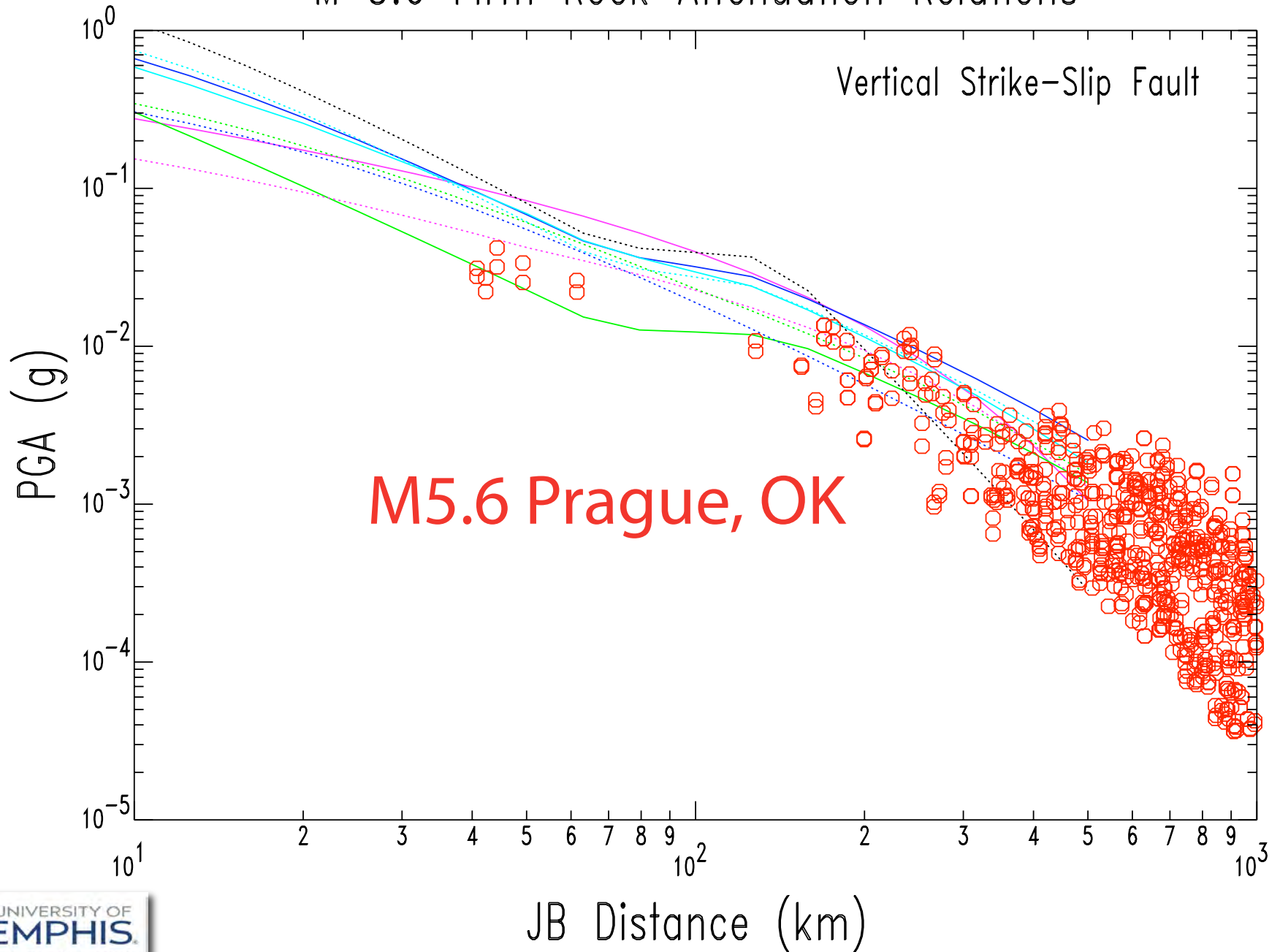
Outline

- Decay with Distance and Crustal Attenuation
- Brune Stress Parameter Estimates
- Earthquake dependent systematic variations (event terms)

Crustal Attenuation

- Earthquake wave attenuation is proportional to the inverse of Seismic Quality factor (Q).
- Q is frequency dependent
 - $Q(f) = Q_0 f^n$
- Gulf Coast Q is different from Mid-Continent Q
 - Gulf Coast Q_0 (1 Hz Q) is 250 to 300
 - Mid Continent Q_0 is 500 to 600

M 5.6 Firm Rock Attenuation Relations



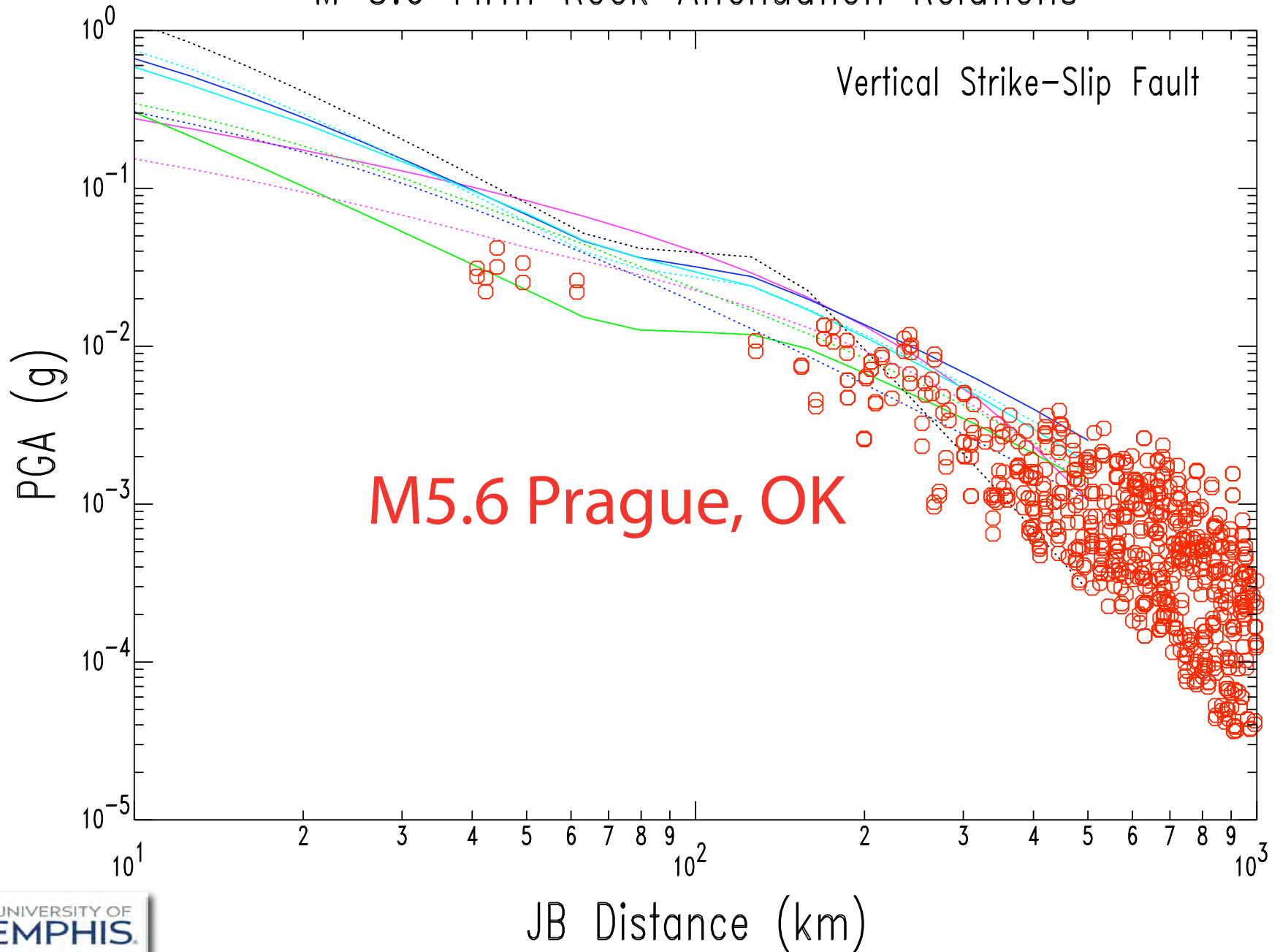
Regional Q Trends

- Earthquakes in Oklahoma and Arkansas are near the Q transition from Mid-Continent to Gulf Coast Q
 - Earthquake wave paths to the North show Mid-Continent Q values
 - Earthquake wave paths to the South show Gulf Coast Q values
- Earthquake wave paths in Texas show Gulf Coast Q values

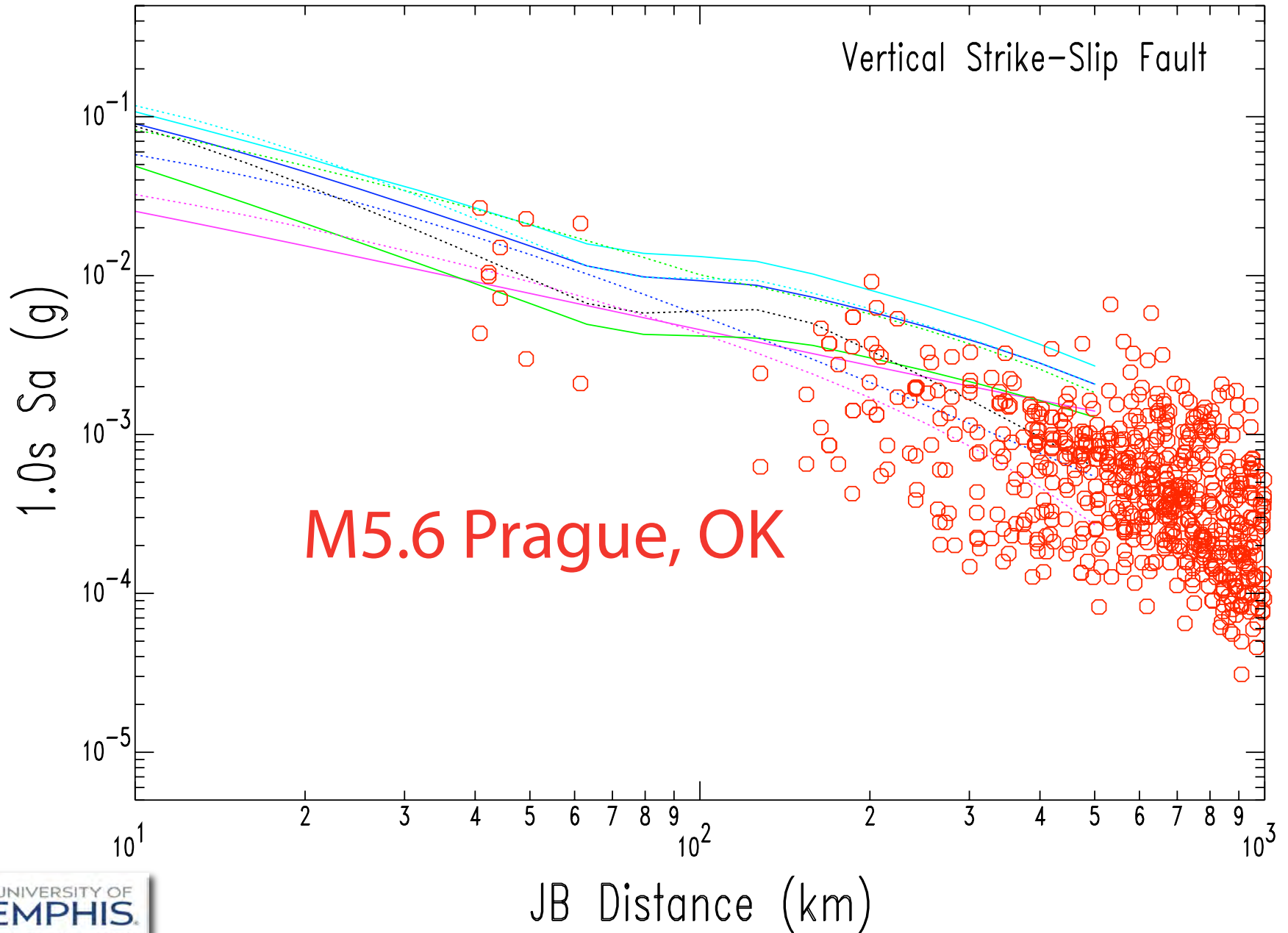
Brune Stress Parameter

- Brune stress parameter is a measure of the high-frequency energy content relative to the low-frequency energy level.
- For a given earthquake magnitude, a higher stress parameter implies larger high-frequency amplitudes and hence potentially greater damage.
- There is a suggestion that shallow earthquakes (< 5 km hypocenters) tend to have lower stress parameters than deeper earthquakes.

M 5.6 Firm Rock Attenuation Relations



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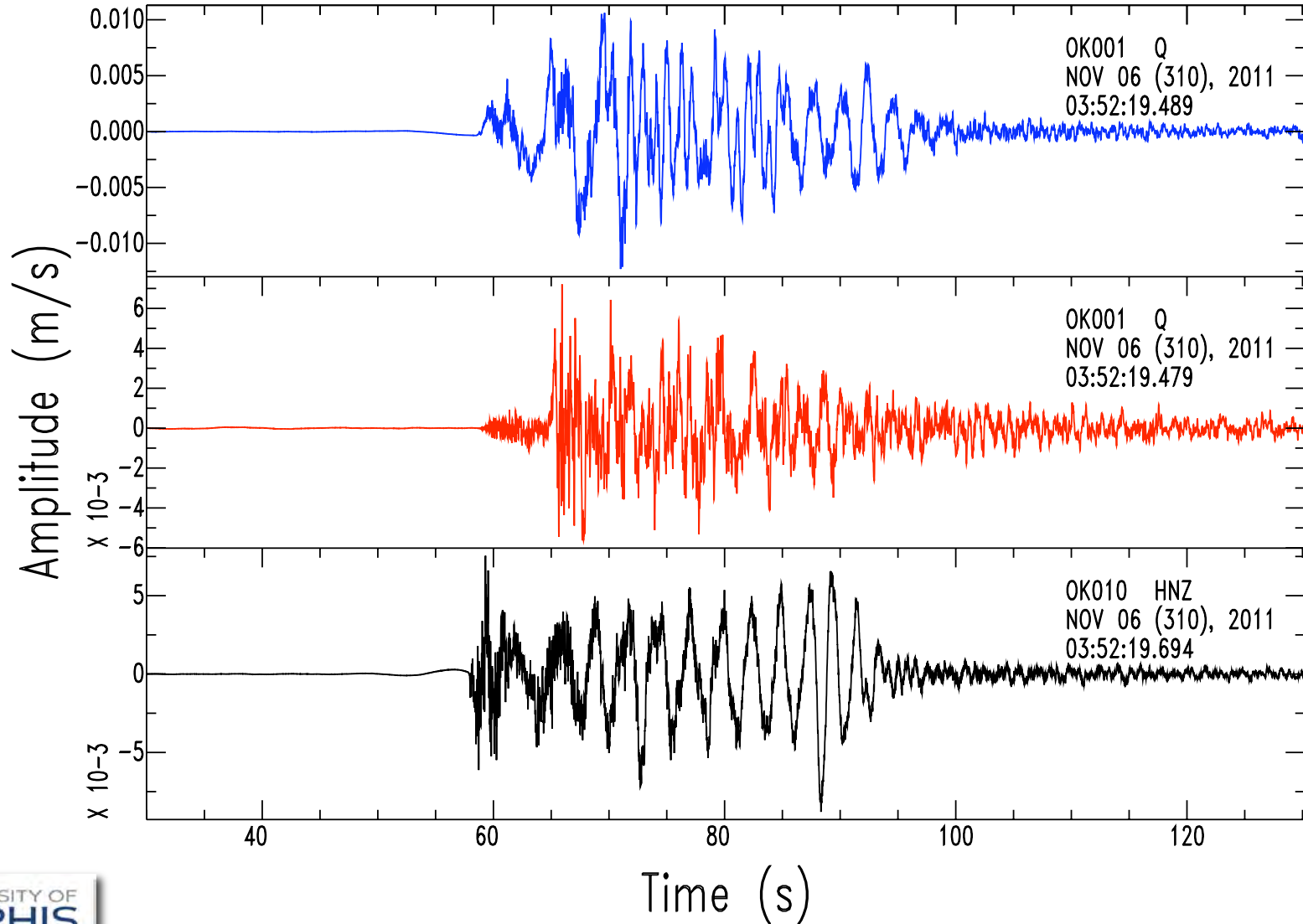


Potentially Induced Earthquake (PIE)

Brune Stress Parameters

- Published average for ENA earthquakes is 14 MPa
- Limited Number of Initial Estimates:
 - M4.4 2010-10-15 Guy AR -> 8 MPa
 - M4.2 2010-11-20 Guy AR -> 8 MPa
 - M4.7 2011-02-28 Greenbrier AR -> 8 MPa
 - M4.3 2010-10-13 Slaughterville OK -> 10 MPa
 - M5.6 2011-11-06 Prague OK -> 10 MPa
 - M4.6 2011-10-30 Comal TX -> ~5 MPa
 - M4.3 2012-05-17 Timpson Tx -> ~5 MPa ?
 - M3.7 2011-12-31 Youngstown OH -> ~ 5 MPa
- M4.8 2014-11-12 Conway Springs KS -> ~5 MPa

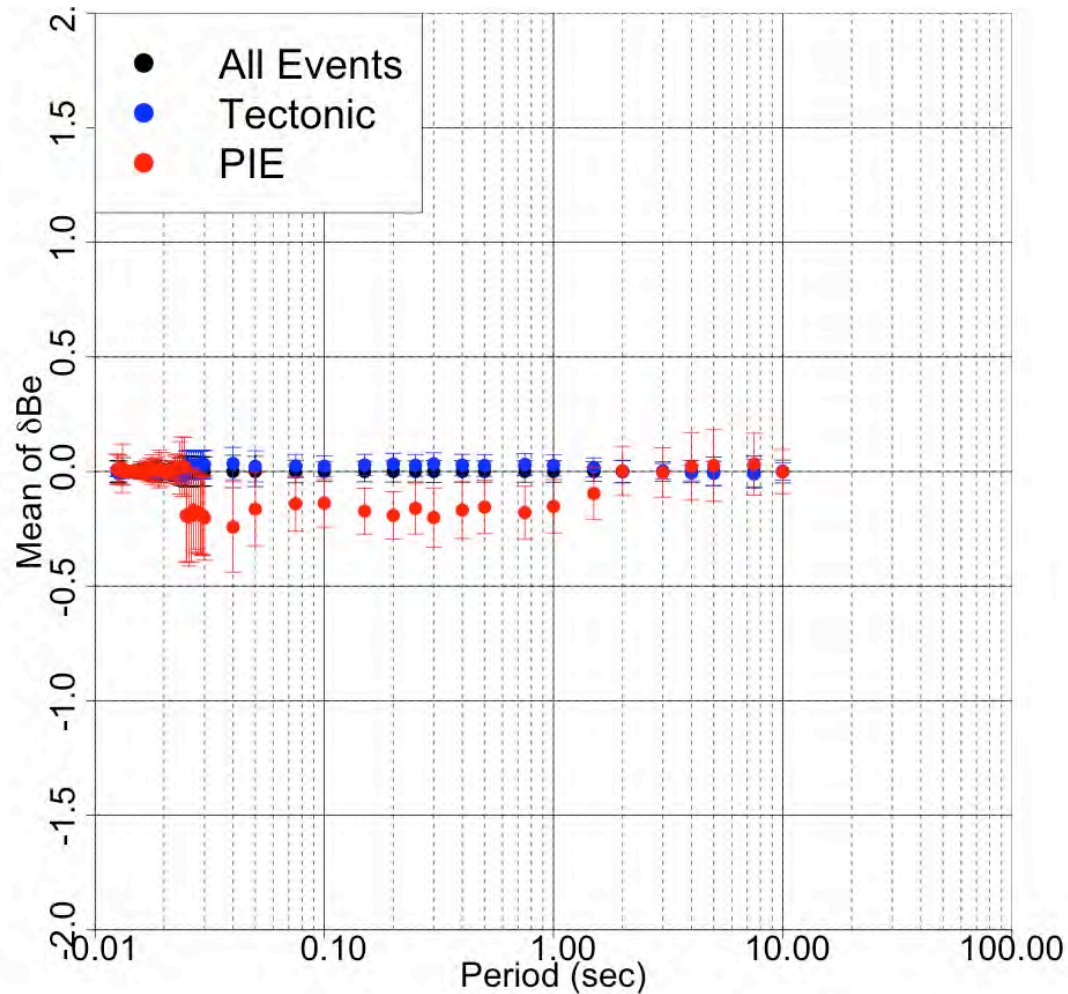
M5.6 OK010 Waveform



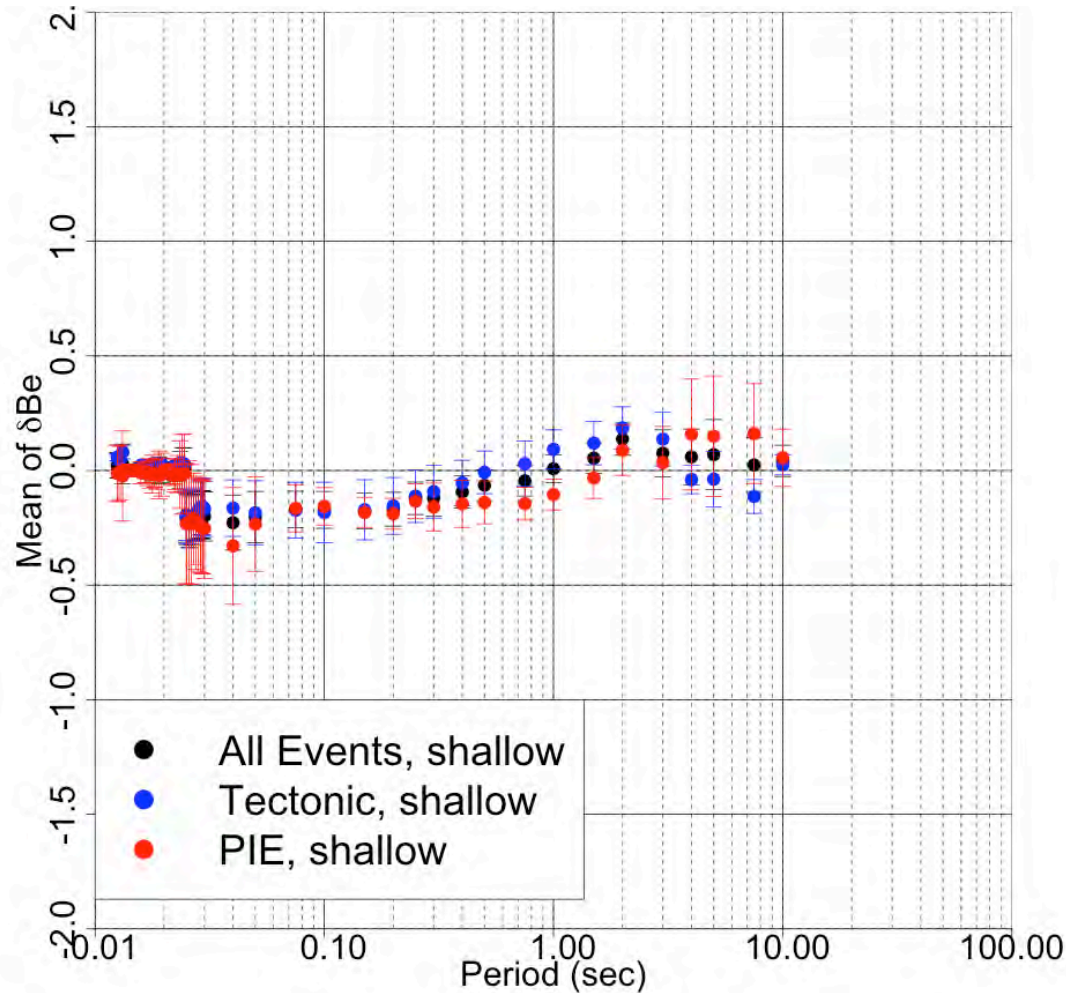
Event Term Analysis

- Event Terms show systematic variations among earthquakes
- Preliminary results by Justin Hollenback for NGA East project at PEER Center
 - All earthquakes outside Gulf Coast
 - Shallow earthquakes outside Gulf Coast

Updated Model: Event-Terms



Updated Model: Shallow Event-Terms



Summary

- Observed ground motions from Arkansas, Oklahoma, and Texas earthquakes can be affected by higher regional attenuation in the Gulf Coast.
- Potentially Induced Earthquakes tend to have below average Brune Stress parameters in the range of 5 to 10 MPa.
- Potentially Induced Earthquakes tend to be shallow with event terms similar to shallow tectonic earthquakes and have about 20–30% lower short-period ground motions than average.