

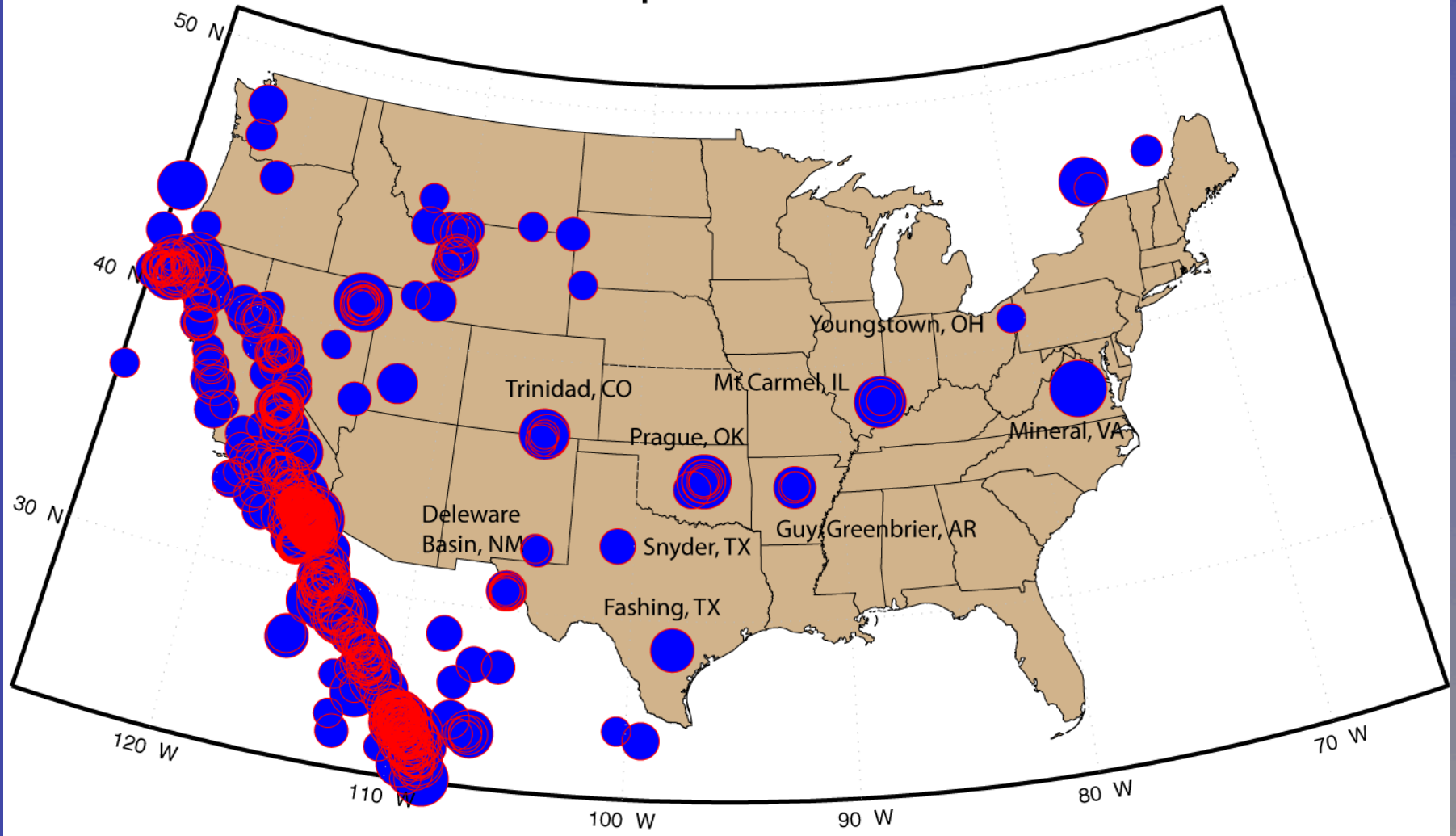
# Significant (Induced?) Earthquakes in the Central and Eastern US Since 2008

Justin L Rubinstein  
William L Ellsworth  
Art McGarr



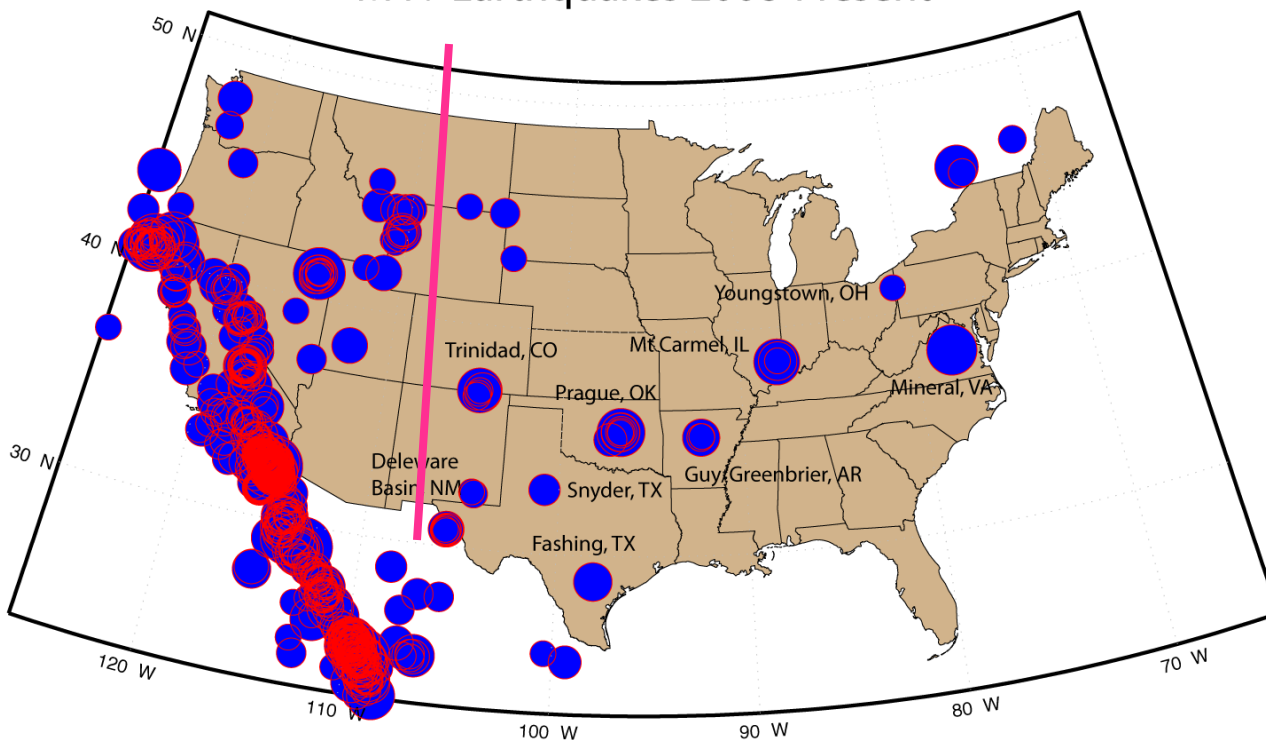
# 683 M4+ EQs 2008– Present

## M4+ Earthquakes 2008-Present



# M4+ Earthquakes in CEUS

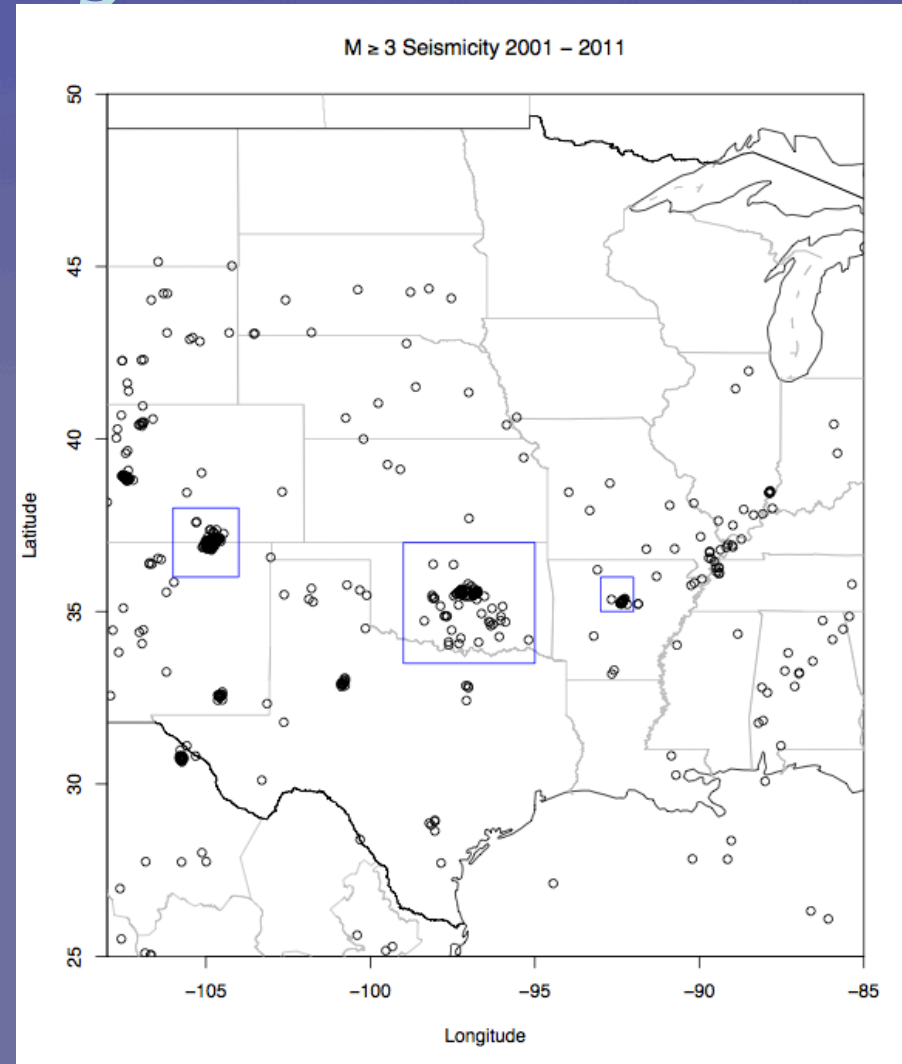
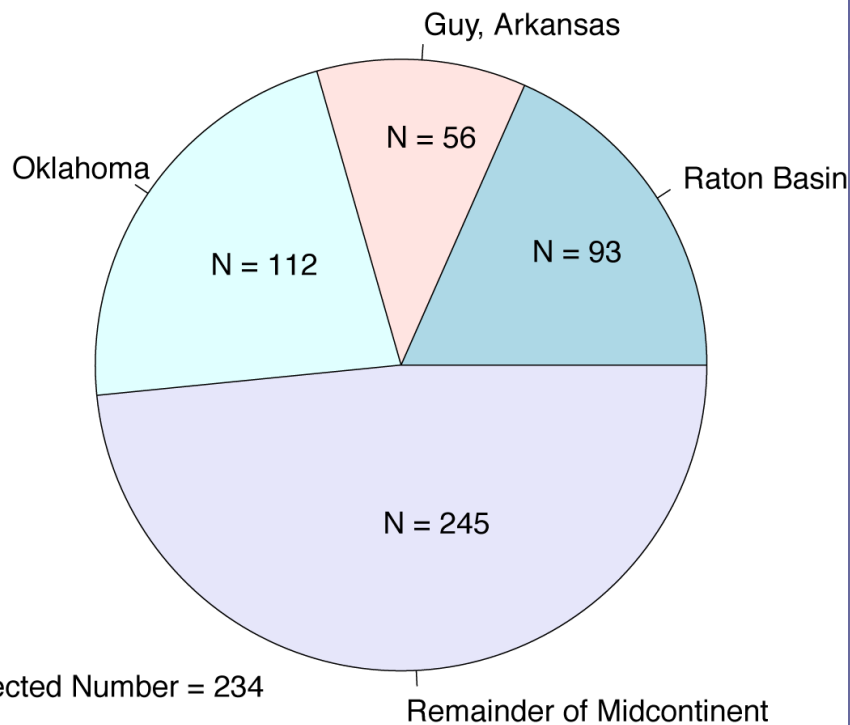
M4+ Earthquakes 2008-Present



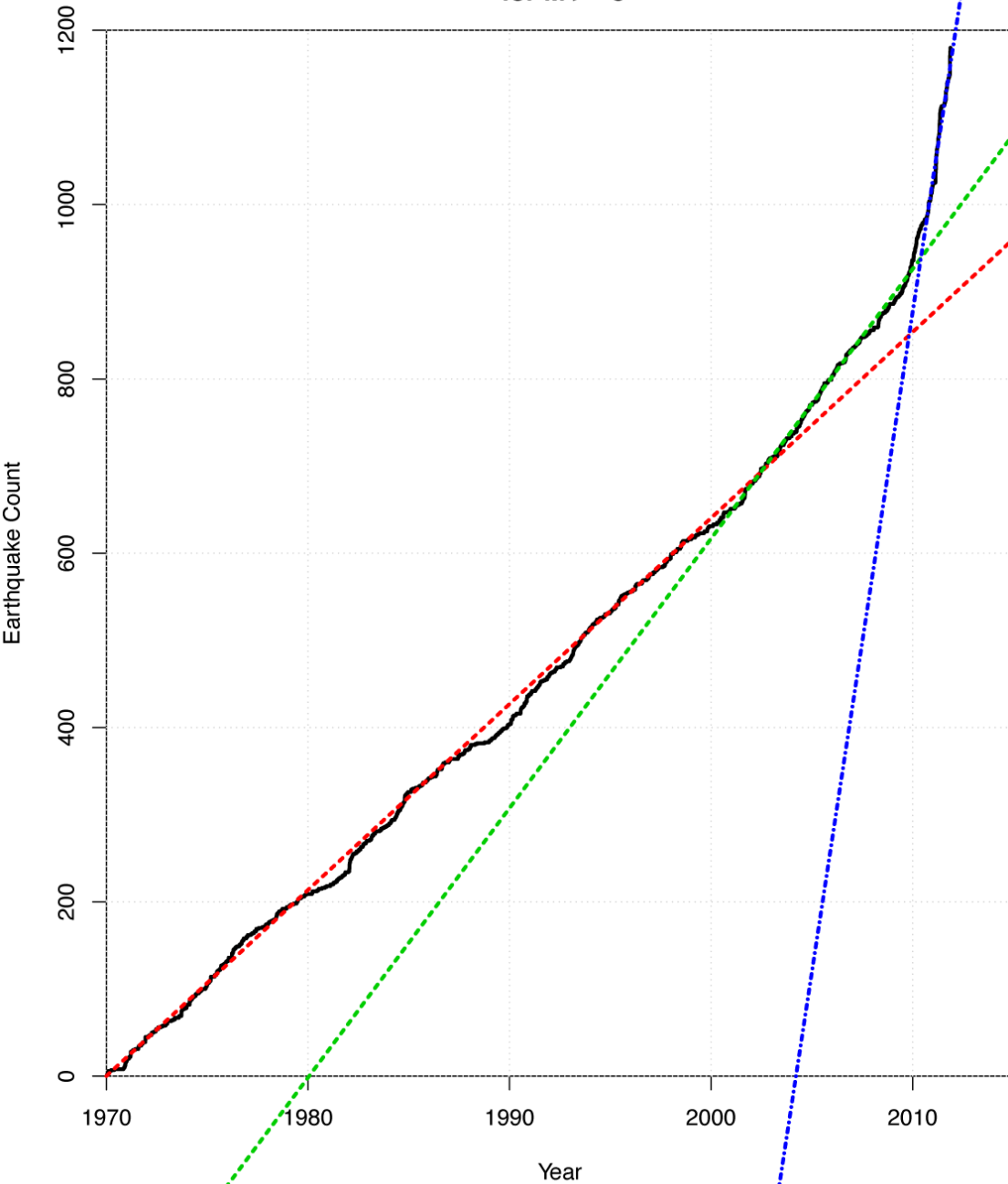
- 39 in CEUS
- 13 Tectonic
- 8 Induced
- 18 Potentially Induced
- 5  $M \geq 5$

# Seismicity Rate Doubled 2001–2011 – This Appears to Come from 3 regions

506  $M \geq 3$  Earthquakes in the Midcontinent 2001 – 2011



Cumulative Number of Earthquakes  
for  $M \geq 3$



# Cumulative CEUS EQs

Observed

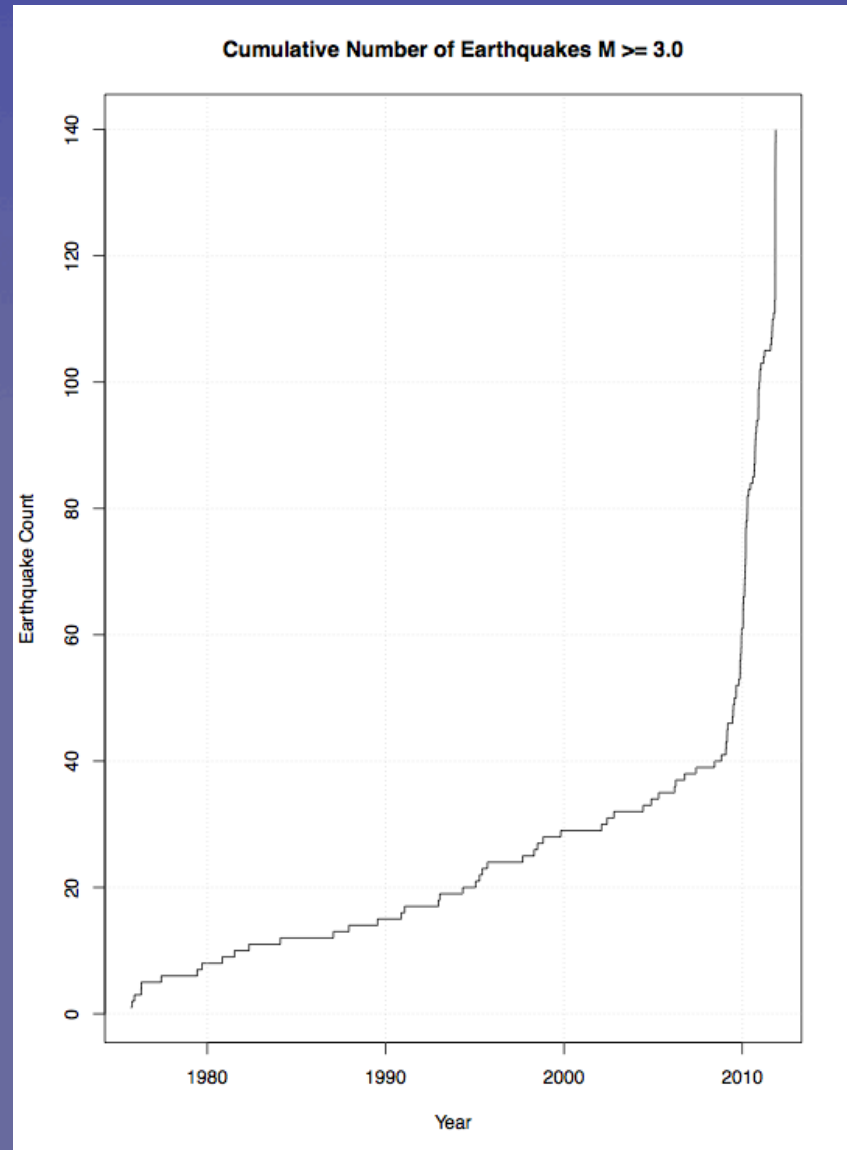
Linear Fit

2001-2009 Fit

2009-present  
Fit

# Oklahoma

- The largest earthquake in Oklahoma prior to the November earthquake was M 5.2.
- Recorded history is less than 200 years.
- Between 1960 and 2008 only 1 to 2 M>3 earthquakes occurred per year.
- Since 2009, there have been over 100 M 3+ earthquakes.
- Does the increase in activity reflect a natural or man-made cause?
- Was the November M 5.6 earthquake natural or triggered?
- Could a larger earthquake occur?





# Induced Earthquakes on the Rise?

## Recent Earthquakes in the CEUS

Trinidad, CO 8/22/2011 Mw 5.3

Mineral, VA 8/23/2011 Mw 5.8

Snyder, TX 9/11/2011 Mw 4.4

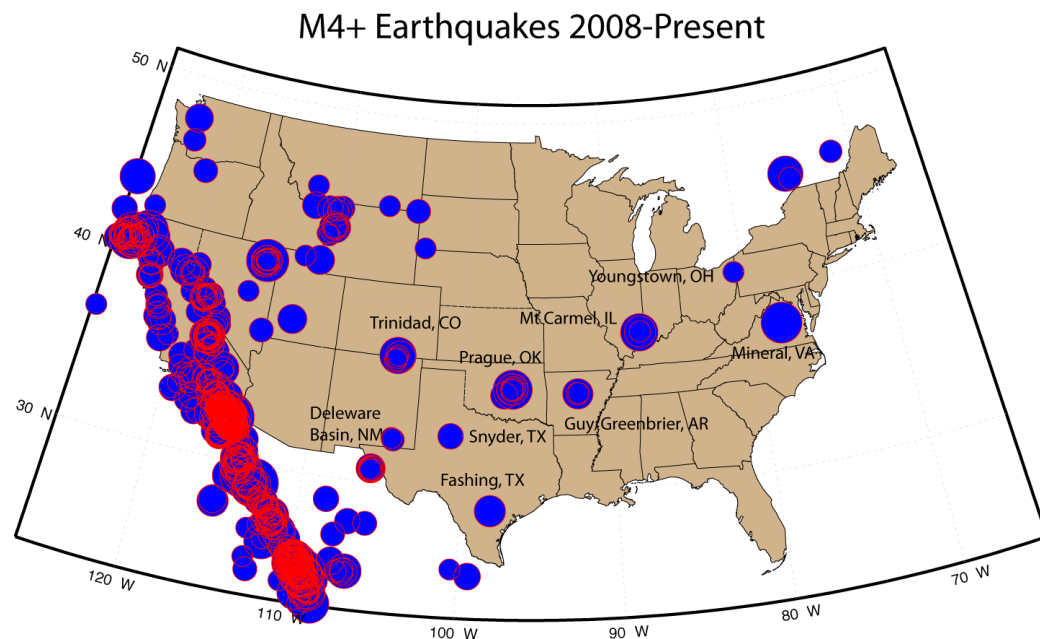
Fashing, TX 10/20/2011 Mw 4.8

Prague, OK 11/06/2011 Mw 5.6

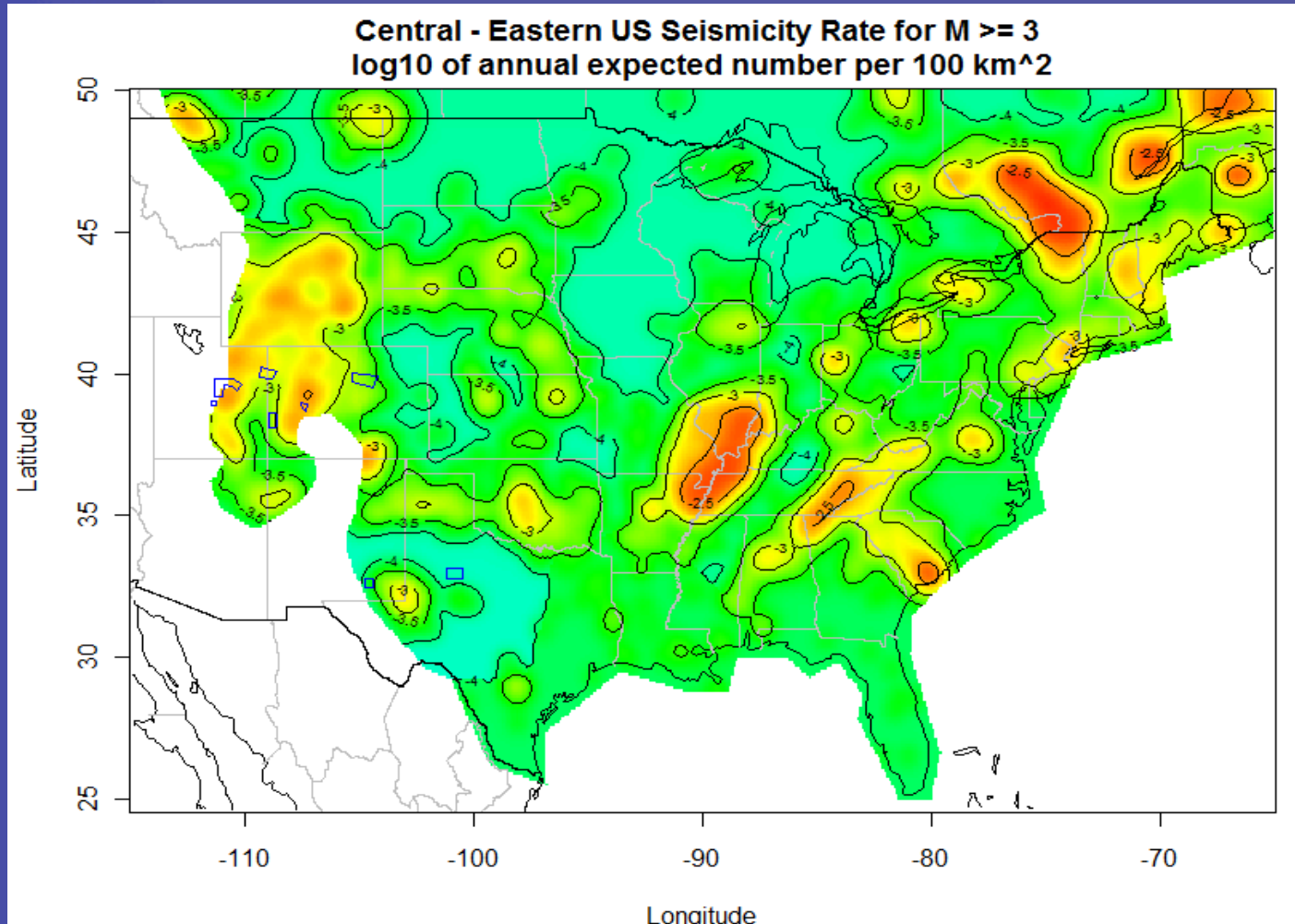
Ardmore, SD 11/14/2011 Mw 4.0

Youngstown, OH 12/31/2011 Mw 4.0

- Increasing demand for cleaner energy means more activities requiring injection of fluids at depth.
  - EGS (Enhanced Geothermal Systems)
  - Waste liquid disposal
  - Geothermal production
  - Tight shale gas exploitation (disposing of “fracking” fluids)
  - Coal-bed methane production
  - Carbon dioxide sequestration
- Earthquakes caused by these operations are becoming more widespread.
- Induced Earthquakes Have Exceeded 6.5



# Background Seismicity & Designated Induced Seismicity Regions



Induced Earthquakes are Presently Removed from the Hazard Maps