Seismic Hazard and Class 2 UIC Disposal Wells

Presentation to Workshop on CUES Sources

February 22, 2012

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Horton, S., Disposal of Hydrofracking-Waste Fluid by Injection into Subsurface Aquifers Triggers Earthquake Swarm in Central Arkansas with Potential for Damaging Earthquake, *Seismological Research Letters* **83**, 250-260, 2012.

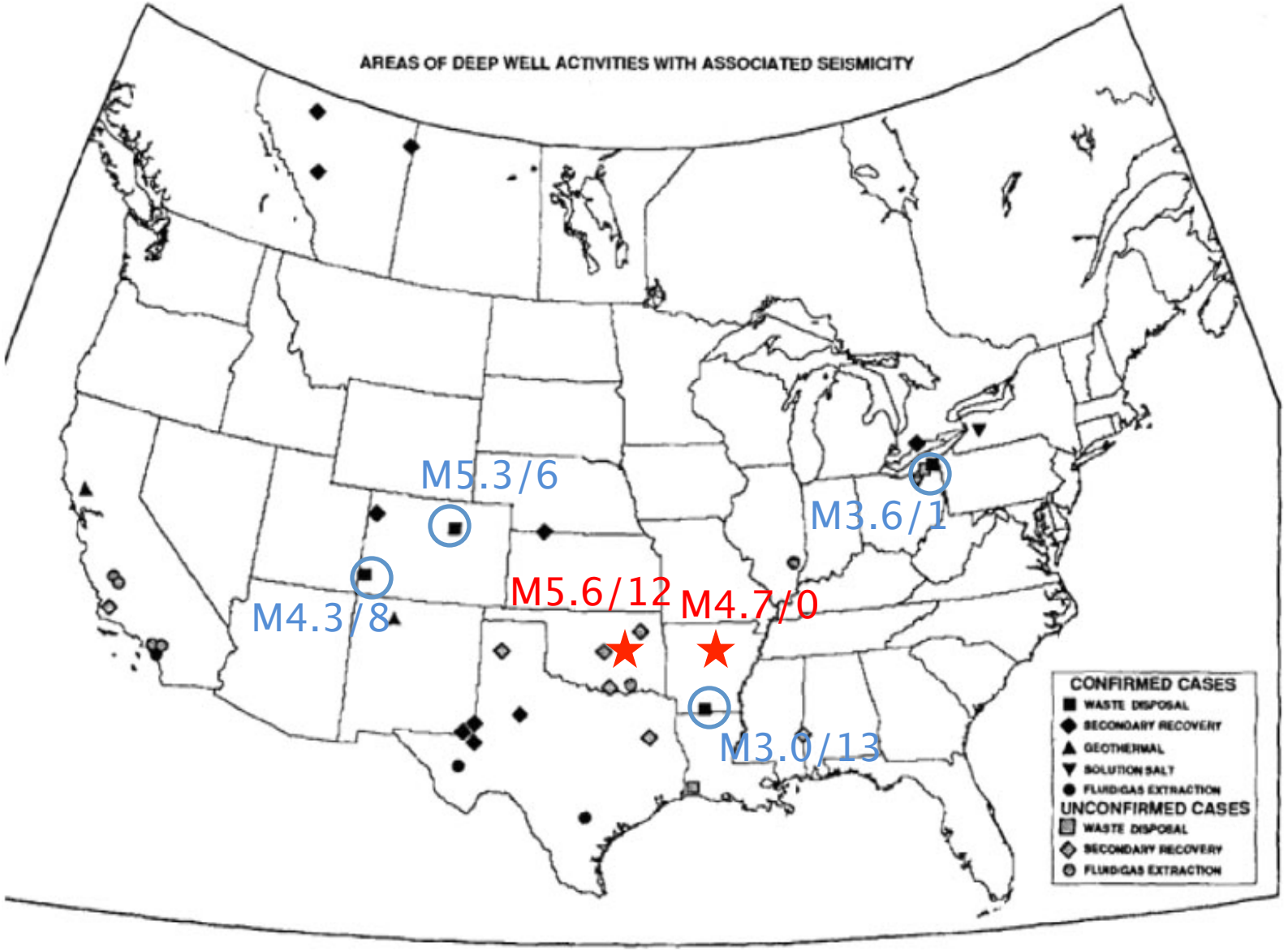
Contributors:

AGS: Scott Ausbrooks, Susan Horvath, Jerry Clark, and Mike Hanley

CERI: M. Withers, H. Withers, J. Bollwerk, C. McGoldrick, D. Steiner, and K. Tucker.

USGS: NEIC locations and notification; two seismic stations

Nicholson and Wesson, 1992,
Triggered Earthquakes and Deep Well Activities



Triggered earthquakes: Fault is critically stressed prior to injection of fluids

Mechanism: In the presence of pore fluids, the condition for slip on a fault is

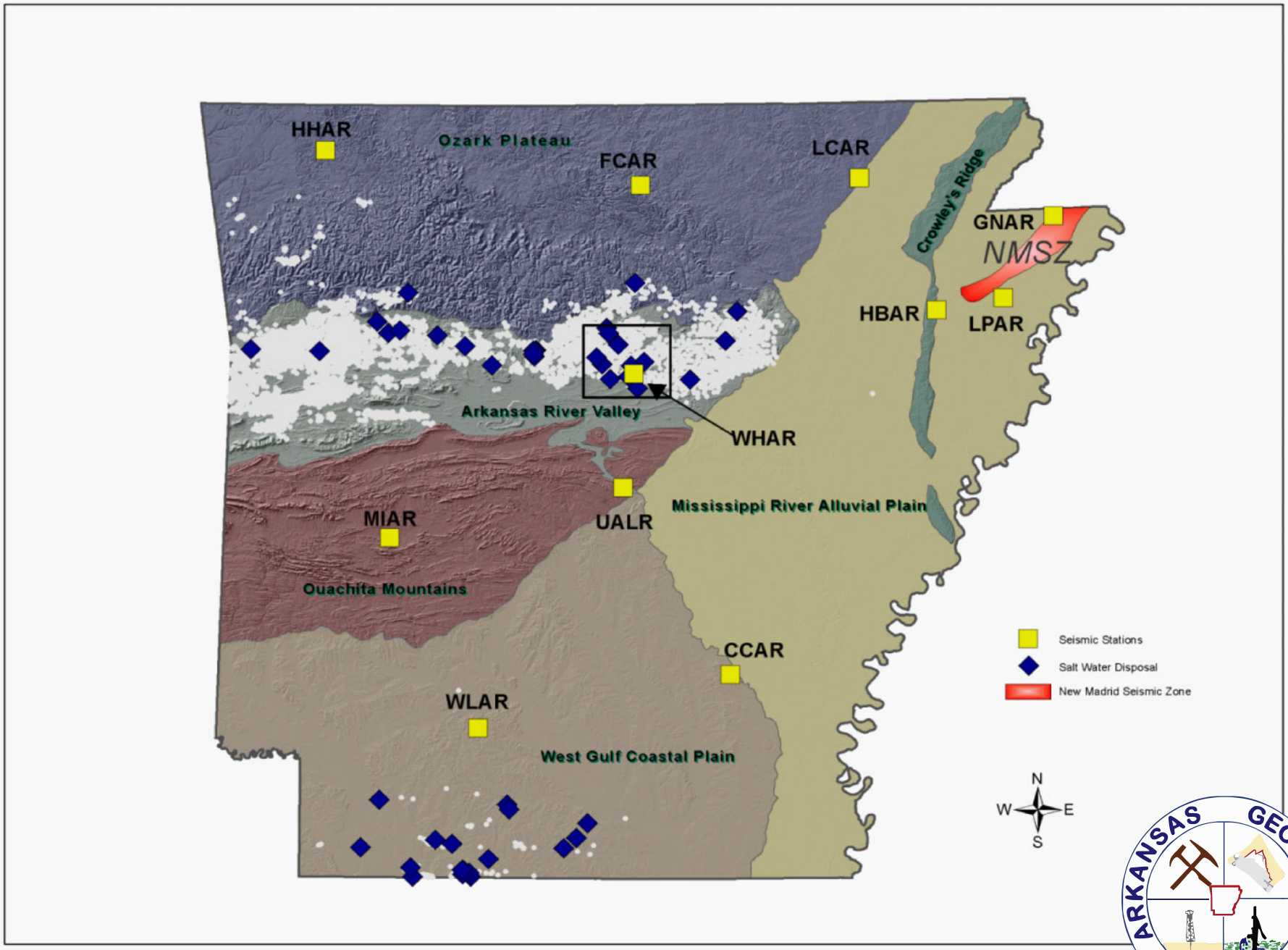
$$|\sigma_s| = S_0 + \mu(\sigma_n - P)$$

where σ_s is the shear stress, S_0 is the cohesion of the surface, μ is the coefficient of friction, σ_n is the normal stress, and P is pore pressure.

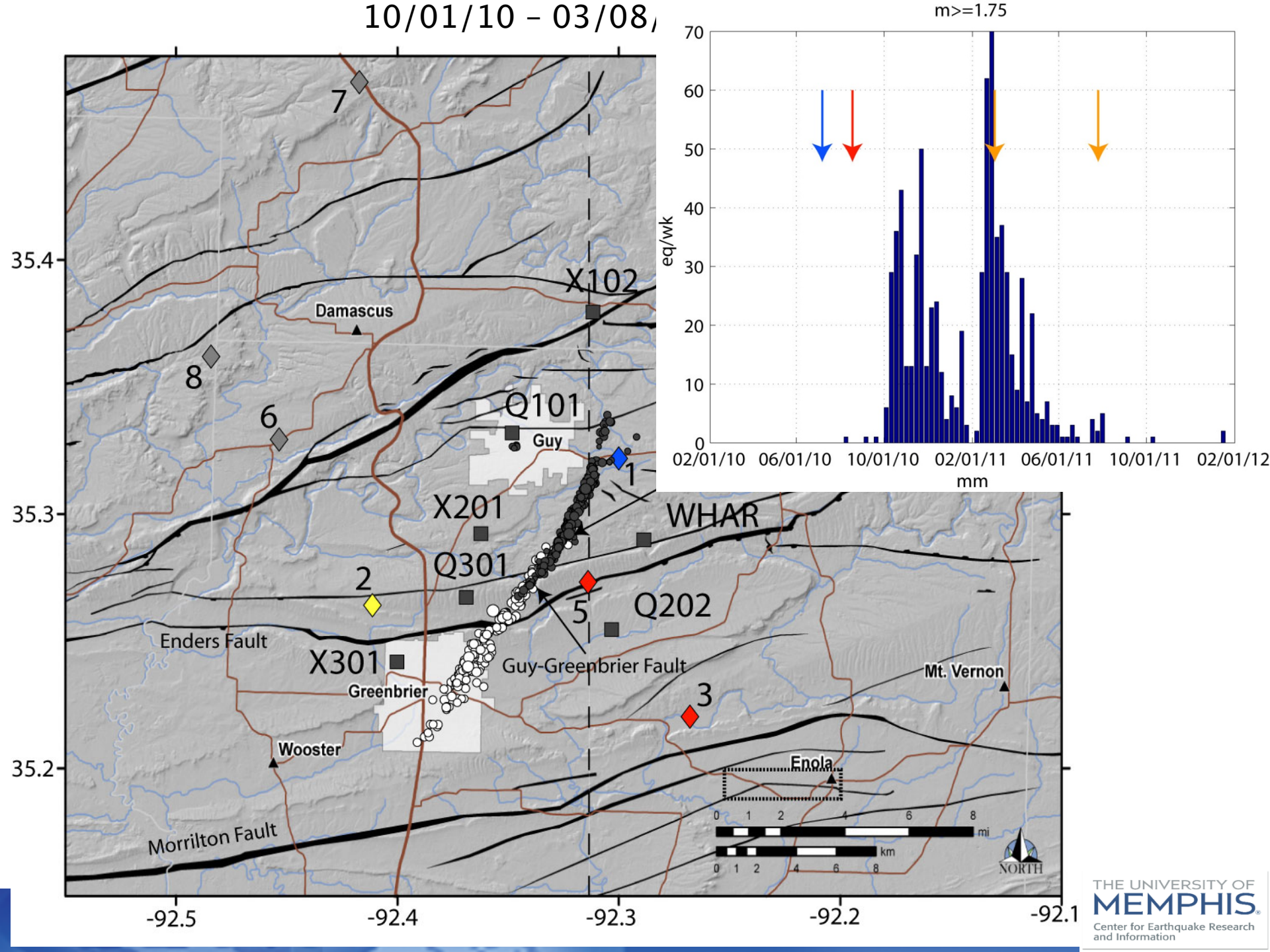
Requirements:

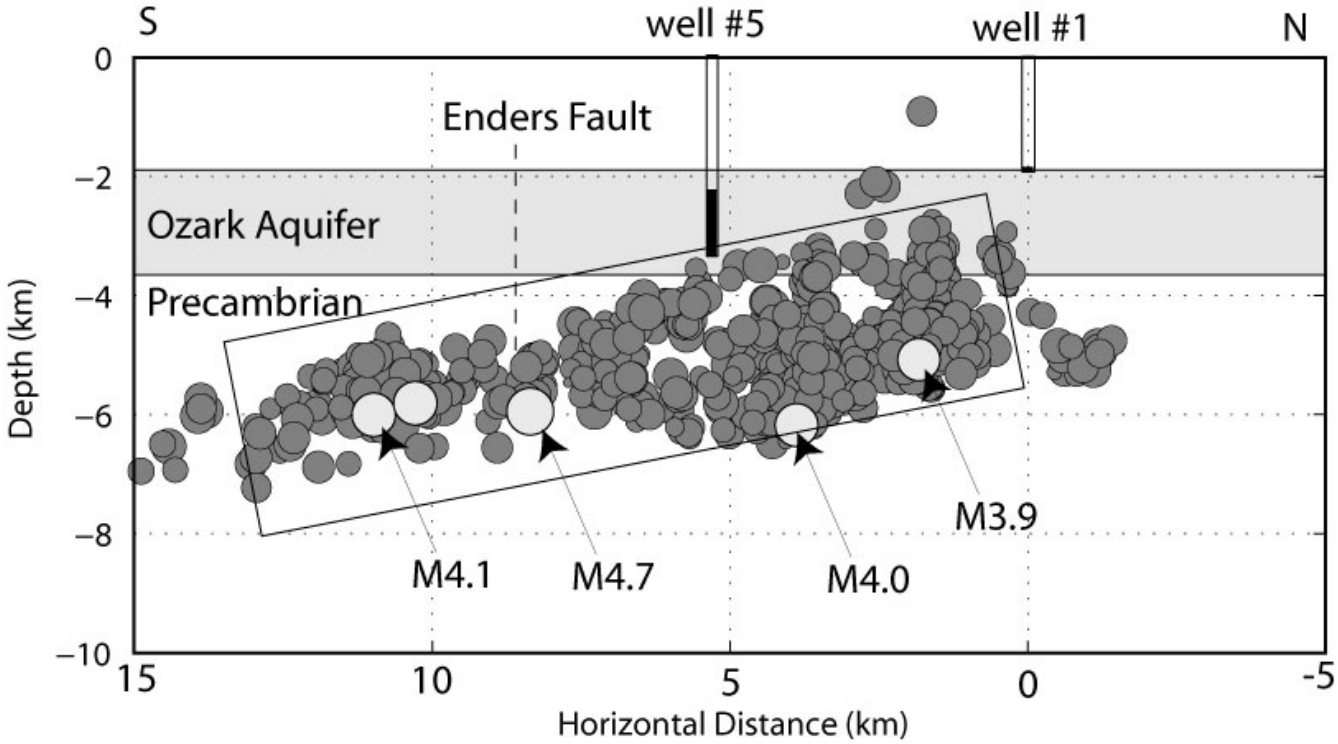
Fluid Injection wells within range of the fault ($r < 10$-20km)

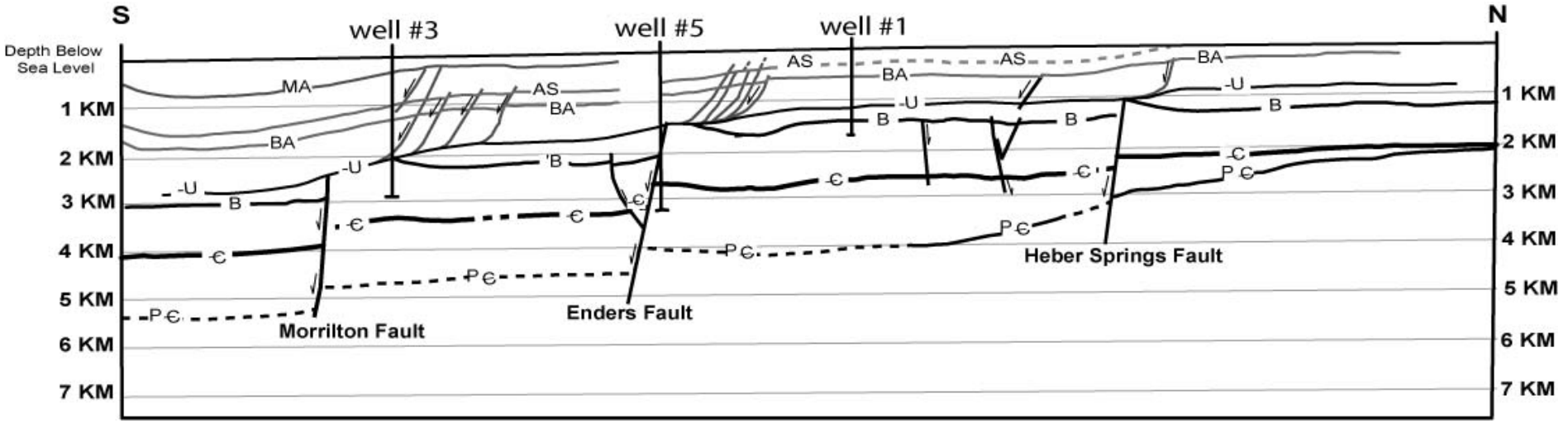
Hydraulic connectivity between UIC well injection depths and earthquakes


HHAR
Ozark Plateau
FCAR
LCAR
Crowley's Ridge
GNAR
NMSZ
HBAR
LPAR
Arkansas River Valley
WHAR
Mississippi River Alluvial Plain
MIAR
UALR
Ouachita Mountains
CCAR
WLAR
West Gulf Coastal Plain
Seismic Stations
Salt Water Disposal
New Madrid Seismic Zone
N
W
E
S
ARKANSAS GEOLOGICAL SURVEY

10/01/10 – 03/08/

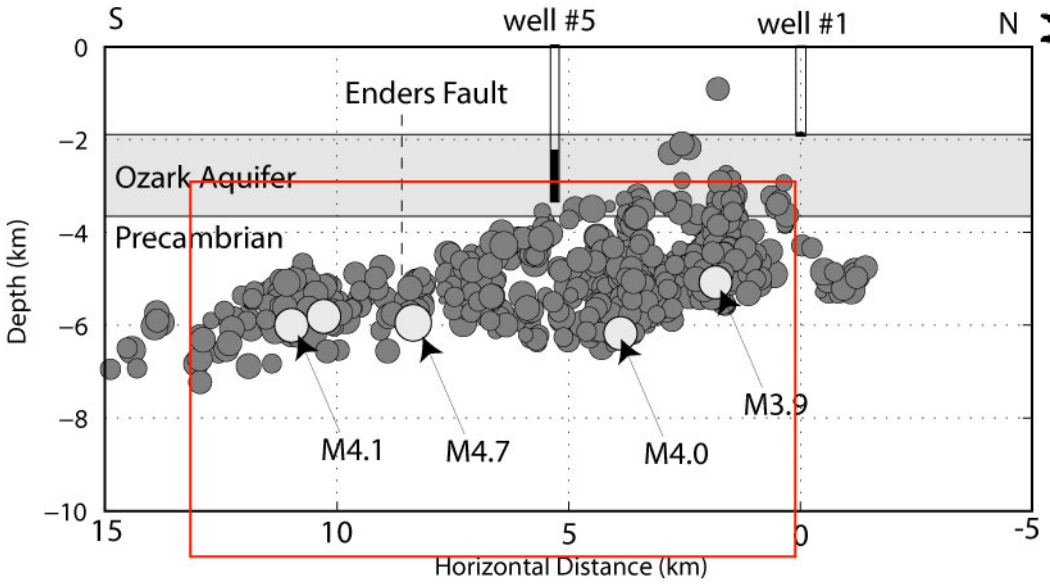

m>=1.75
eq/wk
mm
02/01/10
06/01/10
10/01/10
02/01/11
06/01/11
10/01/11
02/01/12
35.4
35.3
35.2
-92.5
-92.4
-92.3
-92.2
-92.1
X102
Damascus
Q101
Guy
X201
WHAR
Q301
Q202
X301
Greenbrier
Guy-Greenbrier Fault
Enders Fault
Morrilton Fault
Wooster
Mt. Vernon
Enola
1
2
3
5
6
7
8
mi
km
NORTH

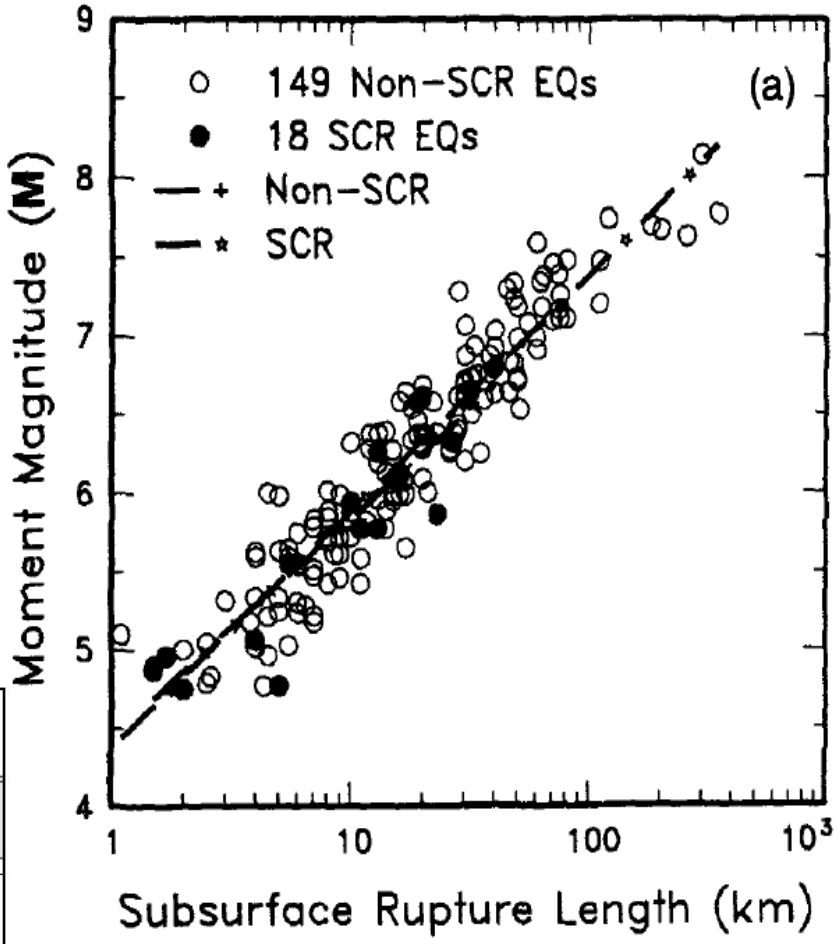

S
well #5
well #1
N
Enders Fault
Ozark Aquifer
Precambrian
Depth (km)
0
−2
−4
−6
−8
−10
M4.1
M4.7
M4.0
M3.9
15
10
5
0
-5
Horizontal Distance (km)

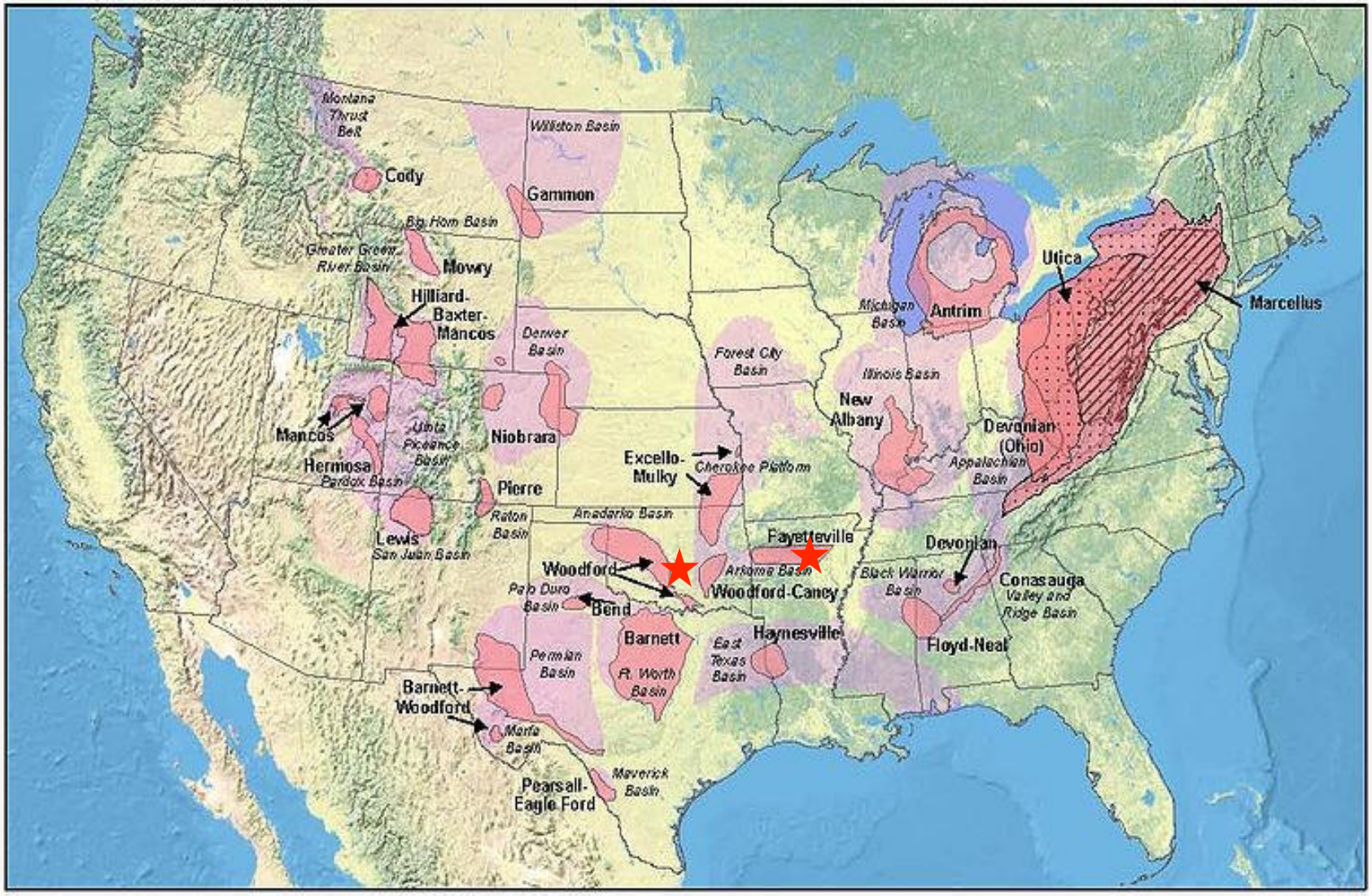

S
N
well #3
well #5
well #1
Depth Below Sea Level
1 KM
2 KM
3 KM
4 KM
5 KM
6 KM
7 KM
MA
BA
AS
-U
B
-C
P C
Morrilton Fault
Enders Fault
Heber Springs Fault

Wells and Coppersmith (1994)
M=3.98 + 1.02log(area)
M(41)=5.6

M=4.33+1.49log(RLD)
M(13)=6.0







United States Shale Gas Plays

www.eia.doe.gov
Energy Information Administration
Office of Oil and Gas

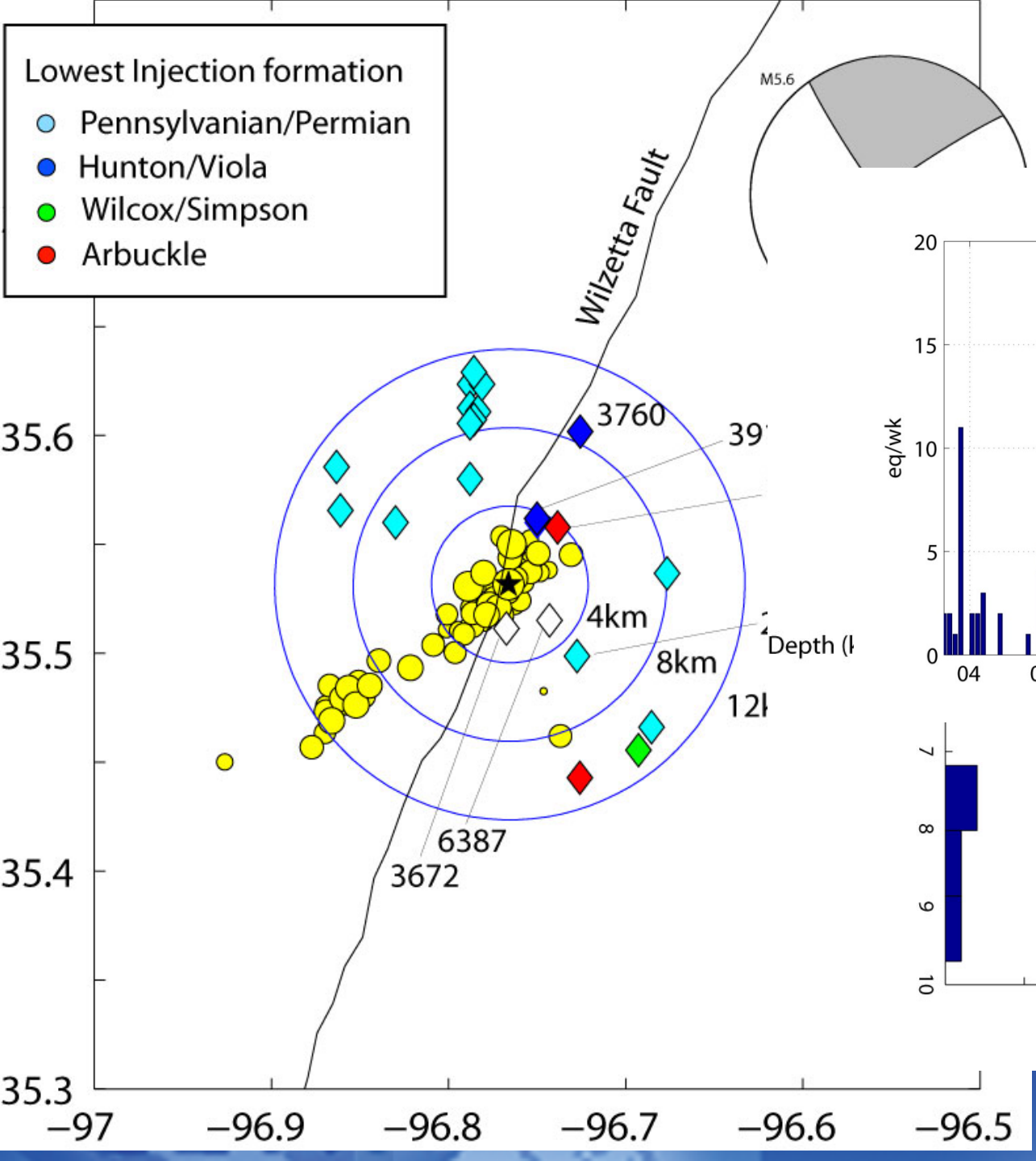
Shale Gas Plays
Basins

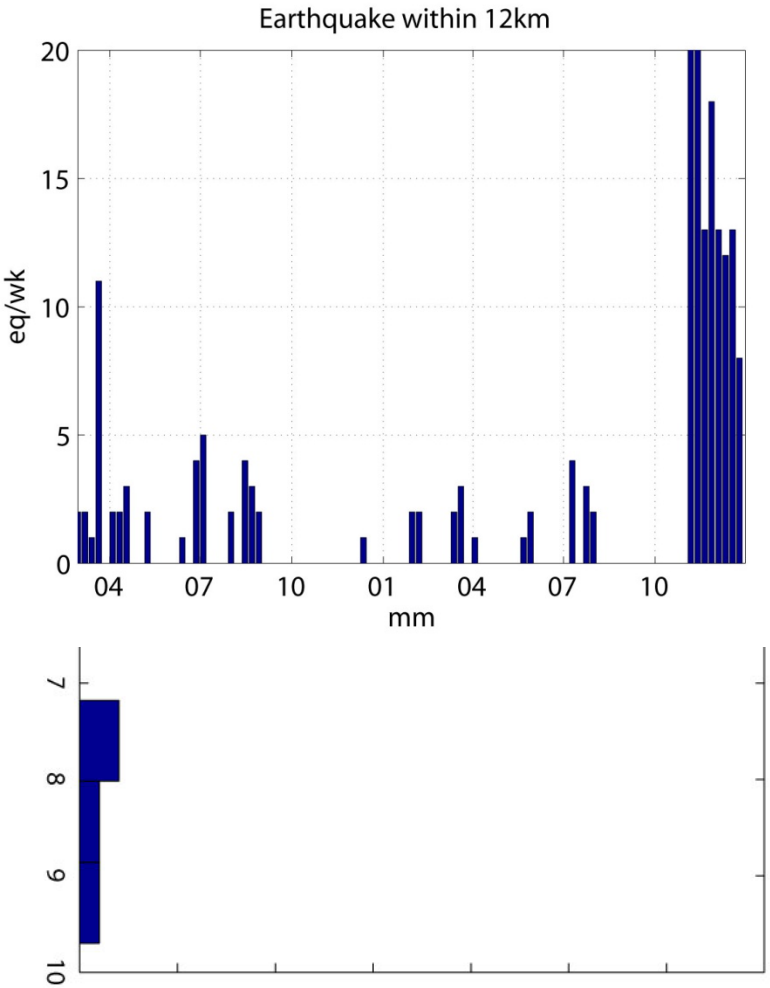
Stacked Appalachian Plays
Marcellus
Utica
Devonian (OH shale)

November 2008
Miles
0 150 300 600

N

Oklahoma Earthquake
November 5, 2011
M5.6





Observations:

The fault presents a seismic hazard independent of the injection wells. Not every fault is capable of a M6.0 earthquake.

Injecting fluids compresses the time scale for earthquake occurrence on the fault.

The maximum possible size of triggered earthquake changes with time, Generally increasing as the pressure front migrates to include more of the critically stressed fault area.

This suggests a reasonable seismic hazard management strategy Is to monitor earthquake activity and reduce (or stop) the injection rate/pressure when seismic activity warrants.

It should be some one's job to monitor seismic activity around these wells.