Unregulated Earthquakes

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Recent events

Oklahoma

50% increase in seismicity since Fall 2014 seismicity rate higher than California modeling points to large-volume injectors

Kansas

Oklahoma quakes invade southern Kansas

Ohio

small earthquakes triggered during fracking fracking halted; new regulations implemented

Colorado

series of earthquakes north of Denver injection halted

NRC induced seismicity study completed

EPA analysis and recommendations... still not released
High rate of earthquakes in the midcontinent since 2001

Ellsworth, 2012
How well does the national hazard map forecast 2009-2013 seismicity?

- How many earthquakes were expected to occur in 2009 – 2013?

- How many earthquakes did occur?

- How likely was it that the differences were by chance?
Excess earthquakes, 2009-2013

Content is preliminary and should not be considered a final USGS product.

Llenos, 2014
Earthquakes for the week of May 30 – June 5, 2014

What is Happening Now

Magnitude $\geq 2.5$

Exponential growth

Event Rate (Magnitude $\geq 3$)

Log Rate

Year

Ellsworth, 2014
2014 to date

P(M ≥ 5½) = 0.23 to 0.53 in the next 12 months

Compared with the 1970-2008 expectation of
P(M ≥ 5½) = 0.003

Ellsworth, 2014
Record Number of Oklahoma Tremors Raises Possibility of Damaging Earthquakes

Updated USGS-Oklahoma Geological Survey Joint Statement on Oklahoma Earthquakes
Originally Released: 10/22/2013 1:07:59 PM; Updated May 2, 2014

The rate of earthquakes in Oklahoma has increased remarkably since October 2013 -- by about 50 percent -- significantly increasing the chance for a damaging magnitude 5.5 or greater quake in central Oklahoma.

View map of Oklahoma seismicity.
View animation of Oklahoma Seismicity.

A new U.S. Geological Survey and Oklahoma Geological Survey analysis found that 145 earthquakes of magnitude 3.0 or greater occurred in Oklahoma from January 2014 (through May 2; see accompanying graphic). The previous annual record, set in 2013, was 109 earthquakes, while the long-term average earthquake rate, from 1978 to 2008, was just two magnitude 3.0 or larger earthquakes per year. Important to people living in central and north-central Oklahoma is that the likelihood of future, damaging earthquakes has increased as a result of the increased number of small and moderate shocks.
Earthquakes close to, and widely felt in, Oklahoma City

- Mw3.8 - 10:01 PM Local Monday November 4, 2013
- M3.2 - 2:32 AM Local Tuesday November 5, 2013
Oklahoma Earthquakes November 5, 2013 (UTC) recorded at station TUL1 (~160km from epicenters)

$M_w 3.8$; 10:01 PM local; 546 DYFI responses up to Intensity V.

$M_b lg 3.2$
Earthquakes are clustered in a region of high fluid redistribution in central Oklahoma.

High water production well

High-volume disposal well

Earthquake

after Keranen et al, 2014
Central Oklahoma “Jones” Swarm 2009-2011

After Keranen et al., 2014
Proposed triggering at 30km or more from high-volume injection wells

Gradient of hydraulic head

- Earthquake

High-volume disposal well

*These are four of the top six wells by injection rate in the state*
COLUMBUS, Ohio (AP) — Geologists in Ohio have for the first time linked earthquakes in a geologic formation deep under the Appalachians to hydraulic fracturing, leading the state to issue new permit conditions Friday in certain areas that are among the nation's strictest.
Ten seismic events were detected by the OhioSeis network from October 2-9, 2013, near active three fracking wells in Harrison Co., Ohio.

Magnitudes were in the range of 2.0-3.0, large enough to be felt locally. Waveform matching found 298 events, as far back in time as Sept 8. During this same time, hydraulic fracturing was conducted at the three wells.

An additional 190 earthquakes were observed between Oct. 2 and Dec. 13, 2013. Using data from an array installed later by ODNR, a cluster of 30 seismic events were located directly below the three fracking wells. These define a fault plane.

ODNR halted the fracking operation. Under Ohio's new permit conditions, all new drilling sites within 3 miles of a known fault or seismic activity of 2.0 magnitude or higher will be conditioned on the installation of sensitive seismic-monitoring equipment.

Friberg (2014) concluded that the fracking operation triggered a preexisting fault.

These are the largest known fracking-induced earthquakes in the U.S. (larger events have occurred in the Horn River Basin).
Colorado

Magnitude 3.2 earthquake occurred on May 31, 2014
Greeley, Colorado

Correlation with injection rate at well C4A
Greeley, Colorado

Many small events, largest M 1.5

M 2.6 earthquake. Well shut-in

M 3.2 felt earthquake

Station GRES starts

Sheehan, 2014
Think Locally, Act Globally

2011 Prague, Oklahoma Earthquake

$M_w$ 5.7

No fatalities; a few injuries; moderate economic damage

Think Locally, Act Globally

2011 Prague, Oklahoma Earthquake
$M_w 5.7$
No fatalities; a few injuries; moderate economic damage

1986 San Salvador Earthquake
$M_w 5.7$
1500 fatalities; 10,000 injuries; 100,000 homeless
Think Locally, Act Globally

Figure 1. Map of basins with assessed shale oil and shale gas formations, as of May 2013

Legend
- Assessed basins with resource estimate
- Assessed basins without resource estimate

Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.
WELCOME TO OKLAHOMA
Home of the QUAKENADO
11/07/2011