Worldwide Seismic Activity and Recent Oklahoma Earthquakes

July 23rd, 2014

Oklahoma seismic activity uptick in last 5 years is not unprecedented. During the 50’s another active earthquake period occurred in Oklahoma but was poorly measured as compared to today. From a global perspective both earthquake prone periods in Oklahoma history were each coincident with 50% of the largest Worldwide quakes over 8.8 Richter Scale from 1900 to 2014. Oklahoma activity may be related to these large quakes despite being away from actual plate boundaries. Earthquake locations in Oklahoma are inversely related to horizontal drilling, stimulation and/or salt water disposal. Unusual earthquake activity is also observed during the last 5 years in Virginia, South Carolina, Alaska, Mexico and the Gulf of California in areas where no oil and gas activity is present.
2008 U.S. Event Hazards Rating Map

“Before this all started…”

In the lower 48:

46 states have documented earthquakes 96%

32 states have magnitude greater than 5 66%

8 States have magnitude greater than 4 16%
U.S. Tectonic Map with historic Earthquake events

- Pacific Plate
- Cocos Plate
- North American Plate
- Caribbean Plate

- **San Francisco CA Quake**
  - March 18 1906
  - 7.8 Magnitude
  - 3000 fatalities

- **New Madrid 1811 swarm started**
  - December 16 1811
  - Swarm lasted 5 years with 4 major earthquakes over 7, with two max 7.7
  - Several fatalities

- **Cape Ann Massachusetts**
  - November 18 1755
  - Intensity "8"
  - 100 chimneys fell and 1500 homes destroyed

- **Giles County Virginia**
  - May 31 1897
  - Magnitude 5.9

- **Charleston SC**
  - Sept 1st 1886
  - 6 month swarm of 10 major earthquakes with max 7.3 Mag
  - 60 Fatalities

- **Senora Mexico Quake**
  - May 3 1887
  - 7.6 Magnitude
  - 42 fatalities

- **Valentine Texas**
  - August 16 1931
  - 5.8 Magnitude
  - Largest quake ever in Texas

- **San Francisco CA**
  - Quake
  - March 18 1906
  - 7.8 Magnitude

- **Massena New York**
  - September 5 1944
  - Magnitude 5.8

- **Valentine Texas**
  - August 16 1931
  - 5.8 Magnitude
  - Largest quake ever in Texas

- **El Reno Oklahoma**
  - March 9 1952
  - 5.5 Magnitude

- **Massena New York**
  - September 5 1944
  - Magnitude 5.8

- **Giles County Virginia**
  - May 31 1897
  - Magnitude 5.9

*Source: Geologic Data Systems*
Oklahoma detection of earthquakes has evolved. What is “unprecedented” is our ability to detect earthquakes now as compared to before 1961.

*Source: OGS/USGS, 2014*
Oklahoma Earthquakes

- **1882 - 2008**
- **2009 - 2014**
- **Monitoring Station (15 OGS & 3 USGS as of 2014)**

**Source: OGS, USGS, GDS, September 2014**

- 55 total stations in late 2014
- 27 additional mobile/temp USGS stations in use within North-Central Oklahoma (exact locations not available)
- Installing 10 new Seismographs fall 2014
In 2009 the NSF EarthScope U.S. Array program deployed stations at 70-km spacing across Oklahoma.
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In 2011 the NSF EarthScope U.S. Array program deployed stations at 70-km spacing across Oklahoma.
USGS: Are Earthquakes Really on the Increase?

• In 1931, there were about 350 stations operating in the world

• Today, more than 8,000 stations are in place and data now comes in rapidly via electronic mail, internet and satellite

• The NEIC (National Earthquake Information Center) now locates about 20,000 earthquakes each year (or 50 per day).

• According to long-term records (since about 1900), we expect about 17 major earthquakes (7.0 - 7.9) and one great earthquake (8.0 or above) in any given year.

*Source: http://earthquake.usgs.gov/learn/topics/increase_in_earthquakes.php
Prior to 1961 there were no seismic stations in Oklahoma. The closest was in St. Louis 600 Miles away.
“Due to low station density and low instrument magnifications only a very few earthquakes were located instrumentally less than magnitude 4 until the 1960’s”

“The deployment of 10 stations starting in 1961 coincided with a dramatic increase in the number of instrumentally located earthquakes”

*Modern day very different!
Seismometers in the permanent monitor grid in most of the central and eastern continental U.S. are spaced up to 200 miles apart. With this spacing, the system is capable of measuring events down to approximately M3.0 or M3.5
Some areas this may extend down to a M2.5.

* Revised Instrumental Hypocenters and Correlation of Earthquake locations and tectonics in the central United States
By David Gordon

**Quote from USGS website 2014
<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Description</th>
<th>Mercalli intensity</th>
<th>Average earthquake effects</th>
<th>Average frequency of occurrence (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 2.0</td>
<td>Micro</td>
<td>I</td>
<td>Microearthquakes, not felt, or felt rarely by sensitive people. Recorded by seismographs.[15]</td>
<td>Continual/several million per year</td>
</tr>
<tr>
<td>2.0–2.9</td>
<td></td>
<td>I to II</td>
<td>Felt slightly by some people. No damage to buildings.</td>
<td>Over one million per year</td>
</tr>
<tr>
<td>3.0–3.9</td>
<td>Minor</td>
<td>II to IV</td>
<td>Often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable.</td>
<td>Over 100,000 per year</td>
</tr>
<tr>
<td>4.0–4.9</td>
<td>Light</td>
<td>IV to VI</td>
<td>Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves or be knocked over.</td>
<td>10,000 to 15,000 per year</td>
</tr>
<tr>
<td>5.0–5.9</td>
<td>Moderate</td>
<td>VI to VIII</td>
<td>Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt by everyone. Casualties range from none to a few.</td>
<td>1,000 to 1,500 per year</td>
</tr>
<tr>
<td>6.0–6.9</td>
<td>Strong</td>
<td>VII to X</td>
<td>Damage to a moderate number of well-built structures in populated areas. Earthquake-resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas;</td>
<td>100 to 150 per year</td>
</tr>
<tr>
<td>7.0–7.9</td>
<td>Major</td>
<td>VIII or greater[16]</td>
<td>Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across great distances with major damage mostly limited to 250 km from epicenter. Death toll ranges from none to 250,000.</td>
<td>10 to 20 per year</td>
</tr>
<tr>
<td>8.0–8.9</td>
<td>Great</td>
<td></td>
<td>Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake-resistant buildings. Damaging in large areas. Felt in extremely large regions. Death toll ranges from 1,000 to 1 million.</td>
<td>One per year</td>
</tr>
</tbody>
</table>

Magnitude 4 is light slight felt outside no to minimal damage some objects may fall off shelves
### Oklahoma Earthquakes from 1/1/2009 to 9/9/14

The figure shows the number of earthquakes in Oklahoma from 1/1/2009 to 9/9/14, categorized by magnitude on the Richter scale. The distribution is as follows:

- **0 to 1.9**: 25 quakes
- **2 to 2.4**: 237 quakes
- **2.5 to 2.9**: 1,056 quakes
- **3 to 3.4**: 501 quakes
- **3.5 to 3.9**: 93 quakes
- **4 to 4.4**: 16 quakes
- **4.5 to 4.9**: 3 quakes
- **5 to 5.4**: 1 quake
- **5.5 to 5.9**: 1 quake

### World Earthquakes

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Average Annualy</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 and higher</td>
<td>1</td>
</tr>
<tr>
<td>7 - 7.9</td>
<td>15</td>
</tr>
<tr>
<td>6 - 6.9</td>
<td>134</td>
</tr>
<tr>
<td>5 - 5.9</td>
<td>1319</td>
</tr>
<tr>
<td>4 - 4.9</td>
<td>13,000</td>
</tr>
<tr>
<td>3 - 3.9</td>
<td>130,000</td>
</tr>
<tr>
<td>2 - 2.9</td>
<td>1,300,000</td>
</tr>
</tbody>
</table>

Source: USGS Earthquake database June 25th 2014

### How Much Bigger... Calculator

Input Magnitude 1: 4
Input Magnitude 2: 2.5

Magnitude Difference: 1.5

A magnitude 4 earthquake is 31.622 times bigger than a magnitude 2.5 earthquake on a seismogram, but is 177.827 times stronger (energy release).
Earthquake Energy

Magnitude 4 to 4.9 is still considered “light” and “slight felt outside” Generally causes none to minimal damage with “some objects may fall off shelves”

1, 2 and 3 magnitudes are obviously less significant

Note: M2 Earthquake has 1000 times less energy released than an M4!

*Sources: USGS, 2014*
Oklahoma Earthquakes from 1/1/2009 to 6/25/2014

*Sources: USGS & OGS, 2014*
### Oklahoma Geologic survey

<table>
<thead>
<tr>
<th>Year</th>
<th>0-1.9</th>
<th>2.0-2.4</th>
<th>2.5-2.9</th>
<th>3.0-3.4</th>
<th>3.5-3.9</th>
<th>4.0-4.4</th>
<th>4.5-4.9</th>
<th>5.0-5.4</th>
<th>5.5-5.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>1</td>
<td>15</td>
<td>12</td>
<td>15</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>611</td>
<td>320</td>
<td>91</td>
<td>28</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>742</td>
<td>488</td>
<td>168</td>
<td>49</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>575</td>
<td>278</td>
<td>84</td>
<td>34</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>1764</td>
<td>718</td>
<td>252</td>
<td>88</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>1002</td>
<td>1311</td>
<td>751</td>
<td>273</td>
<td>52</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total:** 4695

### USGS

<table>
<thead>
<tr>
<th>Year</th>
<th>0-1.9</th>
<th>2.0-2.4</th>
<th>2.5-2.9</th>
<th>3.0-3.4</th>
<th>3.5-3.9</th>
<th>4.0-4.4</th>
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<th>5.5-5.9</th>
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<tr>
<td>2009</td>
<td>1</td>
<td>16</td>
<td>13</td>
<td>16</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2010</td>
<td>6</td>
<td>37</td>
<td>101</td>
<td>35</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>13</td>
<td>87</td>
<td>48</td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>12</td>
<td>49</td>
<td>32</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>11</td>
<td>59</td>
<td>145</td>
<td>82</td>
<td>16</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>3</td>
<td>100</td>
<td>661</td>
<td>288</td>
<td>52</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total:** 1932

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**Quakes by year**

Oklahoma & South Kansas

January 1st 2009 to September 9th 2014
Gutenburgh-Richter Plot Oklahoma earthquakes
Determine “location threshold” value from 1/1/2009 to 6/25/2014 recorded by USGS (red) OGS (green)
Slope 1.2
Oklahoma Large Earthquakes: Past and Present

Prague, Oklahoma
5.6 event on November 7th 2011

El Reno, Oklahoma
5.5 event on April 9th 1952

Limited detection by people and damage only and no internet to collect data


**Graphic representation as per textual information contained in the Earthquake Information Bulletin, Volume 8, Number 2, March - April 1976, by Carl A. von Hake

**Expanded Felt Intensity (von Hake)
El Reno Quake – Wells Prior to April 1952

M5.5, April 9th

Sources: USGS, 2014
EL Reno  Ok has long history of quakes

- 27 reported “felt” quakes in 1908, 1910, 1918(4), 1929, 1933, 1952 (16), 1953(3)

**September 1918**

“Objects were thrown from shelves”

”It cracked the bank building in Union City”

**December 27, 1929**

“at least one chimney fell “

“clocks stopped, objects moved, and some reports indicated the walls and floors seemed to sway.”

“ In several cities, people rushed from their homes in alarm. “

“It sounded as though an automobile had crashed into our house””

“ I thought my furnace has exploded”!
Newspaper reports from El Reno 1952

• “Windows and water pipes were broken in many areas”

• “Bomb burst feared”

• “An El Reno infant narrowly escaped death when a brick chimney crashed into the room where he slept”

• “It almost shook me out of bed, it sounded like something blew up in the basement”

• One women reported ”a man is under my bed” she said she “awoke and saw the bed move and wanted police to investigate!”
El Reno 1952/1953 continued

• “buildings swayed for 23 minutes”

• “Oklahoma City’s Lynn Groom was knocked down while trying to get out of bathtub and required stitches”

• “Mrs Deshaw was cut and bruised by falling plaster in her home”

• “Dr. Hamm was dumped out of his chair in Norman by the shocks”

• “Oklahoma City Policeman said the quake nearly shook the phone right out of his hand”

• “A two foot neon sign was jarred loose and fell to the pavement”
On February 16, 1956, a shock at Edmond broke windows and cracked plaster. It was also felt strongly at Guthrie, Oklahoma City, and Pawnee.

*Source: OGS, USGS September 2014; Abridged from Earthquake Information Bulletin, Volume 8, Number 2, March - April 1976, by Carl A. von Hake*
Earthquakes not in same areas as Horizontal Oil and Gas activity!

“These earthquakes had absolutely nothing to do with hydraulic fracturing, we can say that with confidence.”

Austin Holland, Oklahoma Geological Survey research seismologist

Source: September 2014 OGS, DI Desktop, & GDS

**Source:** Shaking up state
By Bailey Elise McBride
Associated Press, May 2014
Quakes in Oklahoma are moving north!

Jan 1st 2009 to June 9th 2013 quakes in OK

June 9th 2013 to June 9th 2014 quakes in OK

June 9th 2014 to September 9th 2014 quakes in OK

initial 3½ years

15 to 3 months ago

Last three months
Velocity Model

An initial 1D velocity model (figure 2) was developed by digitizing and averaging compressional sonic logs for the 22 closest wells to the Wilzetta Fault to constrain the shallowest ~2 km of the crust (figure). Deeper velocities were constrained by analyzing surface wave dispersion curves (Robert Herman, personal communication, 2012).

Figure 2: Left: Velocity models and sonic logs from the Wilzetta Fault area down to 2 km deep, the top of crystalline basement (Luza and Lawson, 1981).

Right: Velocity models down to 15 km.

Blue: final 1D model used in Keranen et al (2013).
Red: gradient-based starting model used in this study (input for NonLinLoc).
Green: discrete-layer starting model used in this study (input for HypoDD2.1b and FMTomo).
Black: Smoothed sonic logs.
Grey: Average station elevation.

The locations here are significantly deeper than those reported in Keranen (2013).

Separation of the Earthquake Tomography Inverse Problem to Refine Hypocenter Locations and Tomographic Models: A Case Study from Central Oklahoma

Toth, C.R.¹, Chen, C.¹, Holland, A.A²

¹ University of Oklahoma, Norman; ² Oklahoma Geological Survey

From Keranen et al 2014
Claims that “over 20% of the quakes are in the sedimentary column”

From Toth, Chen Holland 2014
“in the 100 quakes near the Prague event only approximately 7.5% were in the sedimentary column less than 2 KM”
Central Oklahoma Quake events 3 or greater from OGS database 2009 to July 2014

View looking southeast
Datum = ground level

Quakes 3D plotted as compared to depth to magnetic basement by Earthfield Technology Project Elephant Merge
**data accuracy +/-10% of total depth
2x vertical exaggeration
Median depth of quakes in Northern Oklahoma and Logan County

- Choctaw 6.8 KM 4.2 Miles 22,176 feet
- Arcadia 5.6 KM 3.5 Miles 18,480 feet
- Waterloo 5.0 KM 3.1 Miles 16,380 feet
- Liberty 5.0 KM 3.1 Miles 16,380 feet
- Langston 5.0 Km 3.1 Miles 16,380 feet
- Marshall 4.6 KM 2.85 Miles 15,048 feet

**Average** 17,477 feet

Source OGS OF1 2014 Town hall Meeting Edmond
Worldwide Quakes

Worldwide $\geq 8^*$

Earthquake Magnitude

Felt quakes prior to 1961

Detection by people

Oklahoma $\geq 3.5^{**}$ 1961 to present

Modern Detection

30 felt Earthquakes 1950 - 1961

20 Earthquakes $> 4.0$ USGS

Sources:
- USGS, 2014
- OGS, 2014

*Source: OGS, 2014
Worldwide Earthquakes Larger than M8.8

**M9.2 Southern Alaska**
3-27-1964

**M9.0 east coast of Kamchatka Peninsula, Russia**
11-4-1952

**M9.0 east coast of Honshu, Japan**
3-11-2011

**M9.1 west coast of northern Sumatra**
12-25-2004

**M8.8 offshore Bio-Bio, Chile**
2-27-2010

**M9.5 Araucania, Chile**
5-22-1960

**M8.6 Tibet, China**
8-15-1950

*Sources: USGS, 2014*
Summary of Large World Quakes

• Since 1900 there have been 6 Earthquakes magnitude 8.8 or greater.

• 3 happened after 2004

• 3 happened between 1952 and 1964

• The 9.1 Indonesian event in 2004 sped up the rotation of the earth by 3 microseconds (Nature, Dec 30 2004).

• The 2011 magnitude 9 event offshore Japan shifted the planet on its axis by nearly 4 inches and shortened the day by 1.8 milliseconds (Nasa Earth 3/14/2011)

• Both Earthquakes resulted in widespread Tsunami damage.
World Earthquakes 1980 – June 2014

*Source: USGS, June 2014*
North, South, & Central America’s Earthquakes
1980 to 2013

*Source: USGS, 2014*
North & Central America Earthquakes
1980 – June 2014

*Source: USGS, June 2014*
California
1990 - Present

*Sources: USGS, June 2014*
Subduction Area of Southern Mexico
1970 - present

*Source: USGS, June 2014
Gulf of California
1990 - present

*Source: USGS, June 2014
Gulf of California (GOC) & South Mexico Subduction Area

*Source: USGS, June 2014
Gulf of California: Quake History count and Maximum Magnitude by decade

USGS GOC ≥6*
USGS large-earthquake catalog (Mw6+)

<table>
<thead>
<tr>
<th>Decade</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900's</td>
<td>7.2</td>
</tr>
<tr>
<td>1910's</td>
<td>7.1</td>
</tr>
<tr>
<td>1920's</td>
<td>6.6</td>
</tr>
<tr>
<td>1930's</td>
<td>6.6</td>
</tr>
<tr>
<td>1940's</td>
<td>6.7</td>
</tr>
<tr>
<td>1950's</td>
<td>7.1</td>
</tr>
<tr>
<td>1960's</td>
<td>7.0</td>
</tr>
<tr>
<td>1970's</td>
<td>6.6</td>
</tr>
<tr>
<td>1980's</td>
<td>6.6</td>
</tr>
<tr>
<td>1990's</td>
<td>6.5</td>
</tr>
<tr>
<td>2000's</td>
<td>6.9</td>
</tr>
<tr>
<td>2004-2014</td>
<td>7.2</td>
</tr>
</tbody>
</table>

*Sources: USGS, 2014; Latitude 22.0° to 32.6°N, Longitude -105.2° to -117.3°W
More evidence of seismicity in the 50’s!

“Shake Rattle and Roll “
Bill Haley and the Comets 1954

“Whole Lotta’ Shakin’ Going On”
Jerry Lee Lewis 1957

“All Shook Up”
Elvis Presley 1957
The Rest of the Story!
North America Map by Lat/Long Quadrant

Data trend from 1980 - 2013

*Source: USGS, 2014
Historical Earthquake Count

*Source: USGS, 2014*
This is not Oklahoma! It is Mexico!

Mexico Interior Historical Earthquake Count

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Naica, Mexico</th>
<th>Monterrey, Mexico</th>
<th>Chihuahua, Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3.5</td>
<td>Green</td>
<td>Orange</td>
<td>Black</td>
</tr>
</tbody>
</table>

*Source: USGS, 2014*
North America Key Earthquake Activity

*Source: Geologic Data Systems, USGS July 2014

M5.2 on June 28, 2014!
Intra-plate Earthquake Activity on the Rise

**Naica/Oklahoma Activity Comparison**

<table>
<thead>
<tr>
<th></th>
<th>&gt;4.0</th>
<th>&gt;4.5</th>
<th>&gt;5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naica, MX: Last 8 mos</td>
<td>49</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Oklahoma since 2009</td>
<td>19</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

**United States** *(M ≥3.5)*

<table>
<thead>
<tr>
<th></th>
<th>OK &amp; KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1994 - Apr 2004</td>
<td>6</td>
</tr>
<tr>
<td>May 2004 - Jul 2014</td>
<td>105</td>
</tr>
</tbody>
</table>

**Mexico** *(M ≥3.5)*

<table>
<thead>
<tr>
<th></th>
<th>Naica</th>
<th>Chihuahua</th>
<th>Monterrey</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1994 - Apr 2004</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>May 2004 - Jul 2014</td>
<td>52</td>
<td>14</td>
<td>15</td>
<td>81</td>
</tr>
</tbody>
</table>

*Source: USGS, 2014*
Gutenberg-Richter plot for Northern Mexico determines the “Location Threshold 1900 to August 21st 2014
Oklahoma vs Naica, Mexico
Since May 2013

*Source: USGS updated September 9th 2014
Virginia Quake
August 23rd, 2011

5.8 Richter

“This may be the largest earthquake to strike the central and eastern United States since the M=5.8 earthquake near Cornwall and Massena, N.Y., in 1944”


U.S. Geological Survey “Did You Feel It?” data from the M = 5.8 Virginia earthquake (green) and from one of similar magnitude and depth in California (red) illustrate how earthquakes are felt over much larger areas in the eastern United States than those west of the Rocky Mountains.

Damage to buildings such as the Washington National Cathedral in Washington, D.C., 135 kilometers northeast of the central Virginia epicenter,

Source: VOLUME 93 NUMBER 33, 14 AUGUST 2012, PAGES 317–324, EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION
Be careful of false information on the Internet

The animals are supposedly evacuating themselves in anticipation of an eruption at the Yellowstone National Park, which sits on a huge volcanic system.

Curiosity was further fueled by the recent magnitude 4.8 earthquake last month, the largest at the park in 30 years.

But the warning turned out to be a hoax!

Yellowstone released the explanation that it’s not unusual for wildlife to leave the park during the winter to seek food.

The Bison featured in the video are actually running into the park—that is, “towards” the volcano.

Don’t Get “Buffaloed!”*

*As per Urban dictionary definition
Summary

• Oklahoma seismic activity uptick in last 5 years is not unprecedented, what is unprecedented is our ability to measure them

• During the 50’s and early 60’s a similar active earthquake period occurred in Oklahoma but “under-reported” as compared to today

• Both earthquake prone periods in Oklahoma history were each coincident with 50% of the largest Worldwide quakes over 8.8 Richter Scale during 1900-2014

• Oklahoma activity is likely related to these large quakes despite being away from actual plate boundaries (normally “protected areas”)

• Earthquake locations in Oklahoma are inversely related (statistically) to horizontal drilling, fracking and/or salt water disposal

• Synchronous earthquake activity /swarms have occurred in Virginia, South Carolina, Arizona, NW Alaska and neighboring Mexico where no oil and gas activity is present
QUESTIONS
or
COMMENTS
(Misc Slides)