



DANA MURPHY
COMMISSIONER
OKLAHOMA CORPORATION COMMISSION

NARUC 128TH ANNUAL MEETING COMMITTEE ON ELECTRICITY

November 14, 2016

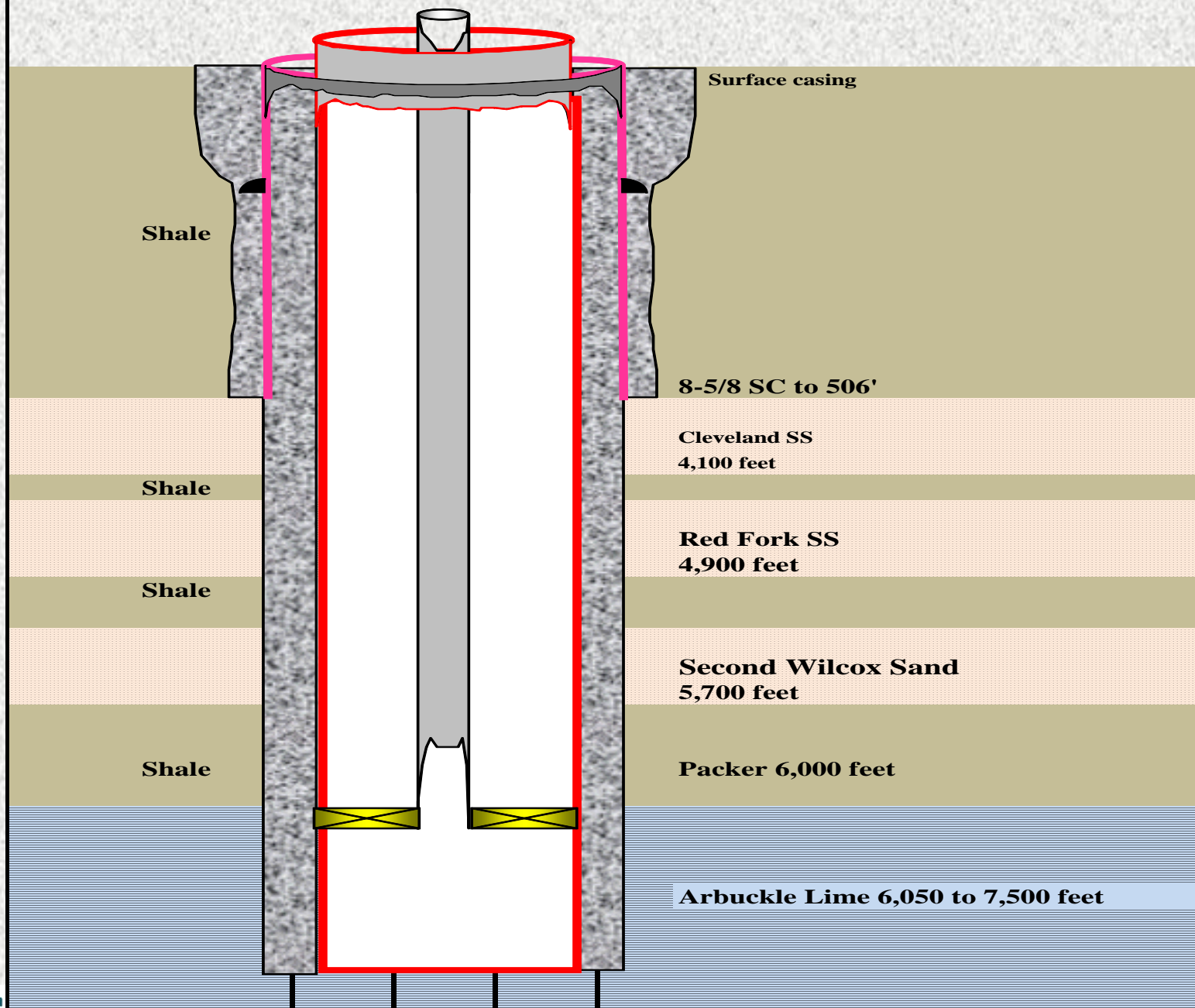
Earthquake Impacts from Waste Water Injection from Oil and Gas Production



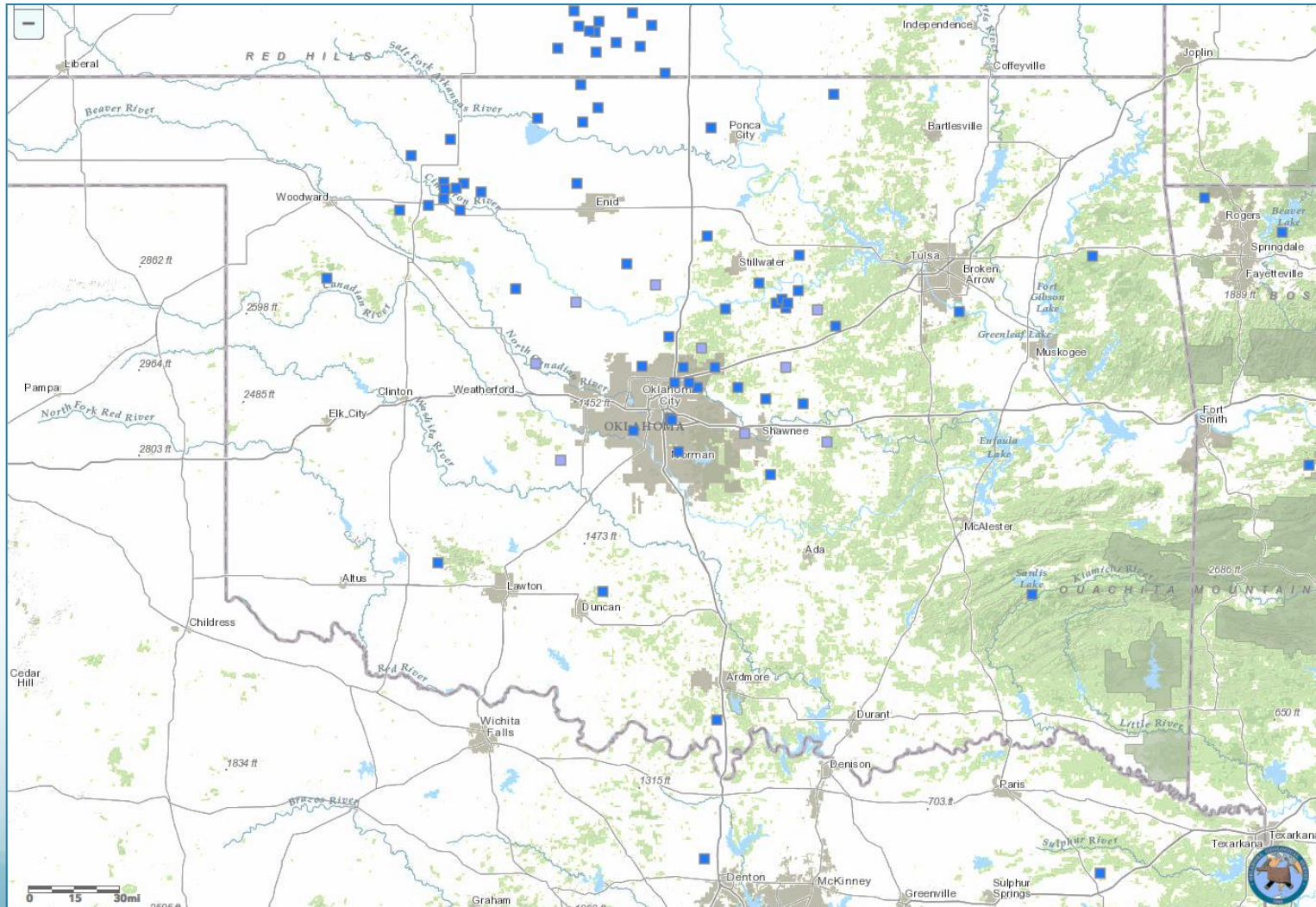
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System/Series/ Stage		Conodont Zones/ Subzones		Southern Oklahoma	Ouachitas	Ozarks		
Ordovician	Cincinnatian	Gamachian	<i>Aphelognathus shufeldti</i>	Viola Group	Keel Formation	Polk Creek Shale	Oolitic unit	
		Richmondian	<i>Aphelognathus divergens</i> <i>A. grandis</i>		Sylvan Shale		Cason Shale	
		Maysvillian	<i>Cordylus robustus</i> <i>O. vellicuspis</i>		Welling Fm.			
		Edenian	<i>Belodina confluens</i>		Viola Springs Fm.		Fernvale Ls.	
	Mohawkian	Chatfieldian	<i>Plectro tenuis</i> <i>Phragmodus undatus</i>	Simpson Group	Viola Springs Fm.	Bigfork Chert	Kimmswick Limestone	
		Turinian	<i>Belodina compressa</i> <i>Erismodus quadridactylus</i> <i>Plectodina aculeata</i>		Corbin Ranch Fm.		Plattin Fm.	
			<i>Amorhognathus bukenensis</i>		Bromide Formation		Joachim Dolomite	
			<i>Pygodus serra</i>		Tulip Creek Fm.		Womble Shale	Dutchtown Fm.
	Whiterockian	Chazyan	<i>Cahabagnathus sweeti</i> <i>Cahabagnathus friendsvillensis</i>	McLish Formation	St. Peter Ss.			
		No Laurentian stages	<i>Phragmodus polonicus</i> <i>Histiodela halodentata</i> <i>H. alpinosa</i>	Oil Creek Fm.	Blakely Sandstone	Everton Fm.		
			<i>Tripodus laevis</i>	Joins Fm.				
			Rangerian	<i>Reutterodus andinus</i>		West Spring Creek Formation	Powell Dolomite	
	Ibexian	Cassinian	<i>Oepikodus communis</i>	Arbuckle Group	Kindblade Formation	Mazam Shale	Southville Fm. Cotter Dolomite	
		Jeffersonian	<i>Acodus deltatus</i> - <i>Oneotodus costatus</i>		Cool Creek Fm.		Jefferson City Dolomite	
		Stairsian	<i>Macerodus diana</i>		McKenzie Hill Fm.		Roubidoux Fm.	
		Skullrockian	Low Diversity Interval		Signal Mountain Formation		Collier Shale	Gasconade Dolomite
			<i>Rossodus manitouensis</i>					Eminence Dolomite
			<i>Cordylodus angulatus</i> <i>Cordylodus angustirostris</i> <i>Cordylodus inebriatus</i> <i>Cordylodus intermedius</i> <i>Cordylodus proavus</i>					
	<i>Eoconodontus</i> <i>Proconodontus muelleri</i> <i>P. posterocostatus</i> <i>P. tenuiserratus</i>		Fort Sill Limestone	Potosi Dolomite				
Cambrian (part)	Millardian	Sunwaptan	Timbered Hills Gp.	Honey Creek Limestone	7	Elvins Group		
		Reagan Sandstone						
	Steptoean							
	Marjuman					Bonnetterre Fm. Lamotte Ss.		

Multizone Well Bore Schematic



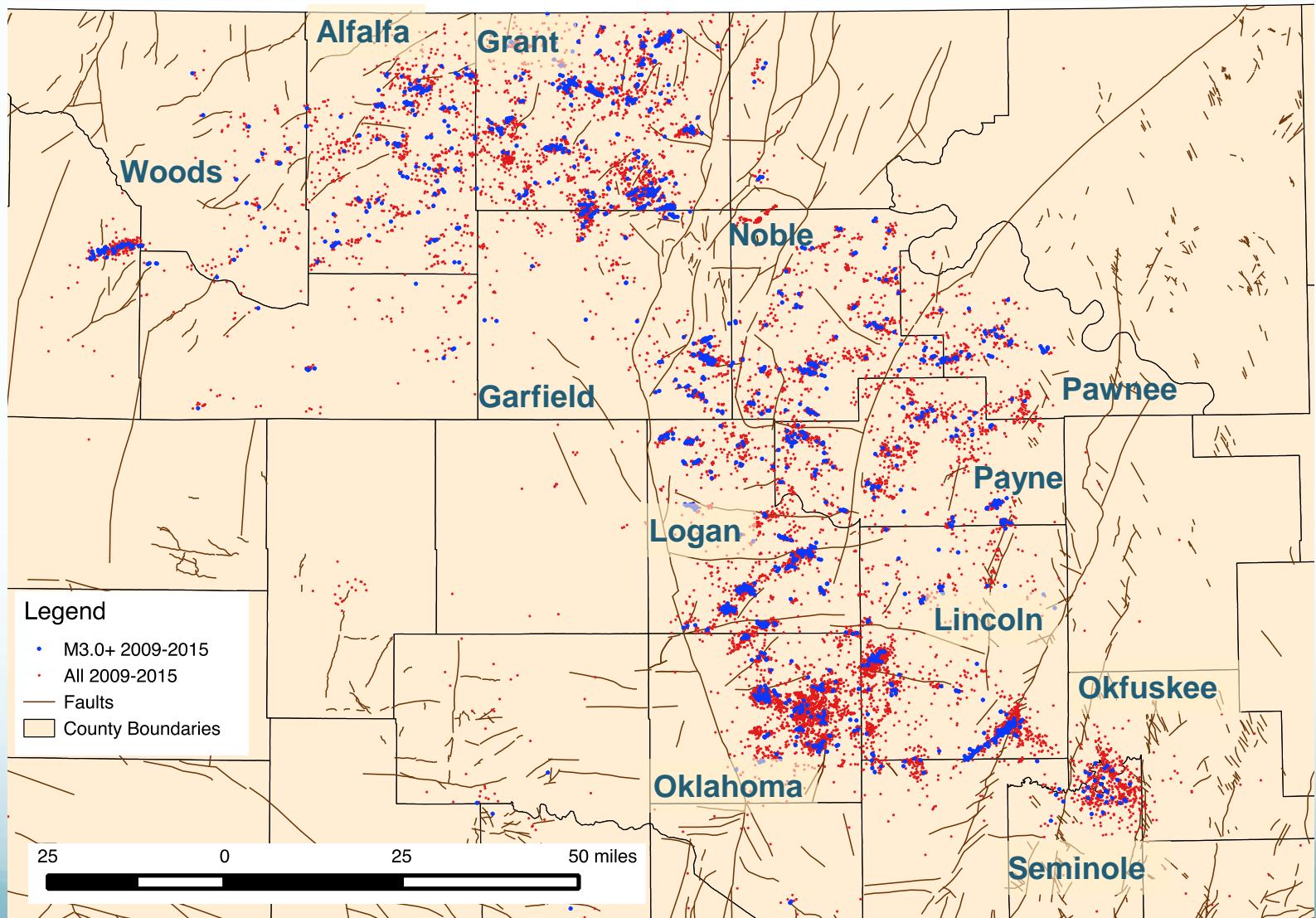
OGS Uses about 40 Stations to Locate Oklahoma Earthquakes



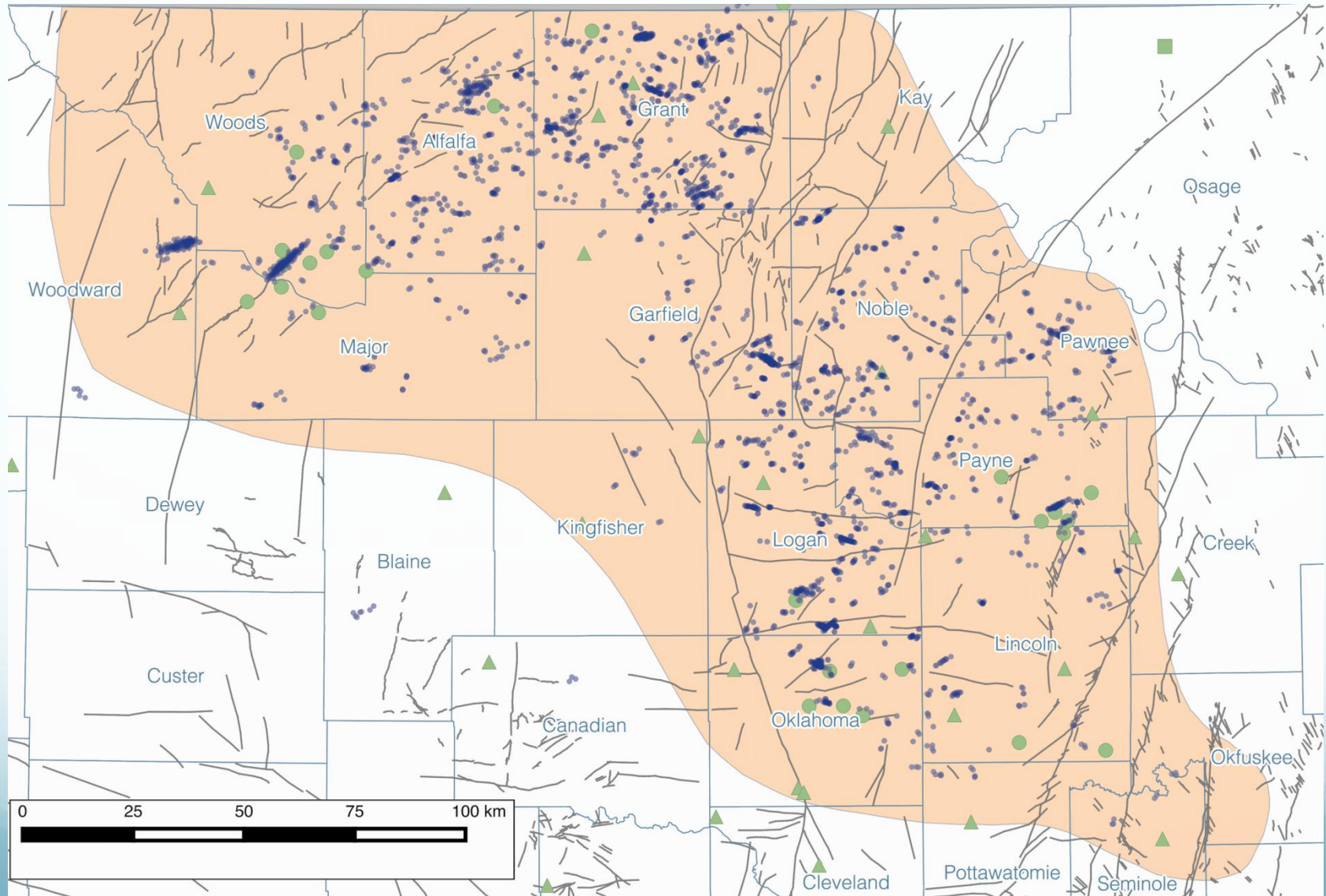
Measuring an Earthquake

- ✗ Magnitude - a scaled estimate of energy released as seismic waves, proportional to rupture area
- ✗ Magnitude measured multiple ways (M_L , m_b , M_w , M_o , M_s)
 - ✗ Magnitude estimates rarely the same between different methods
 - ✗ All magnitude measures are uncertain
 - ✗ Magnitude scales logarithmic (+1 unit of magnitude = ~10 times shaking & ~32 times the energy release)
- ✗ Earthquake Intensity is a qualitative estimate (using Modified Mercalli scale ranging from I-XII)

Earthquakes 2009-2015



Earthquakes 2015-2016



Human Activity Can Induce Earthquakes

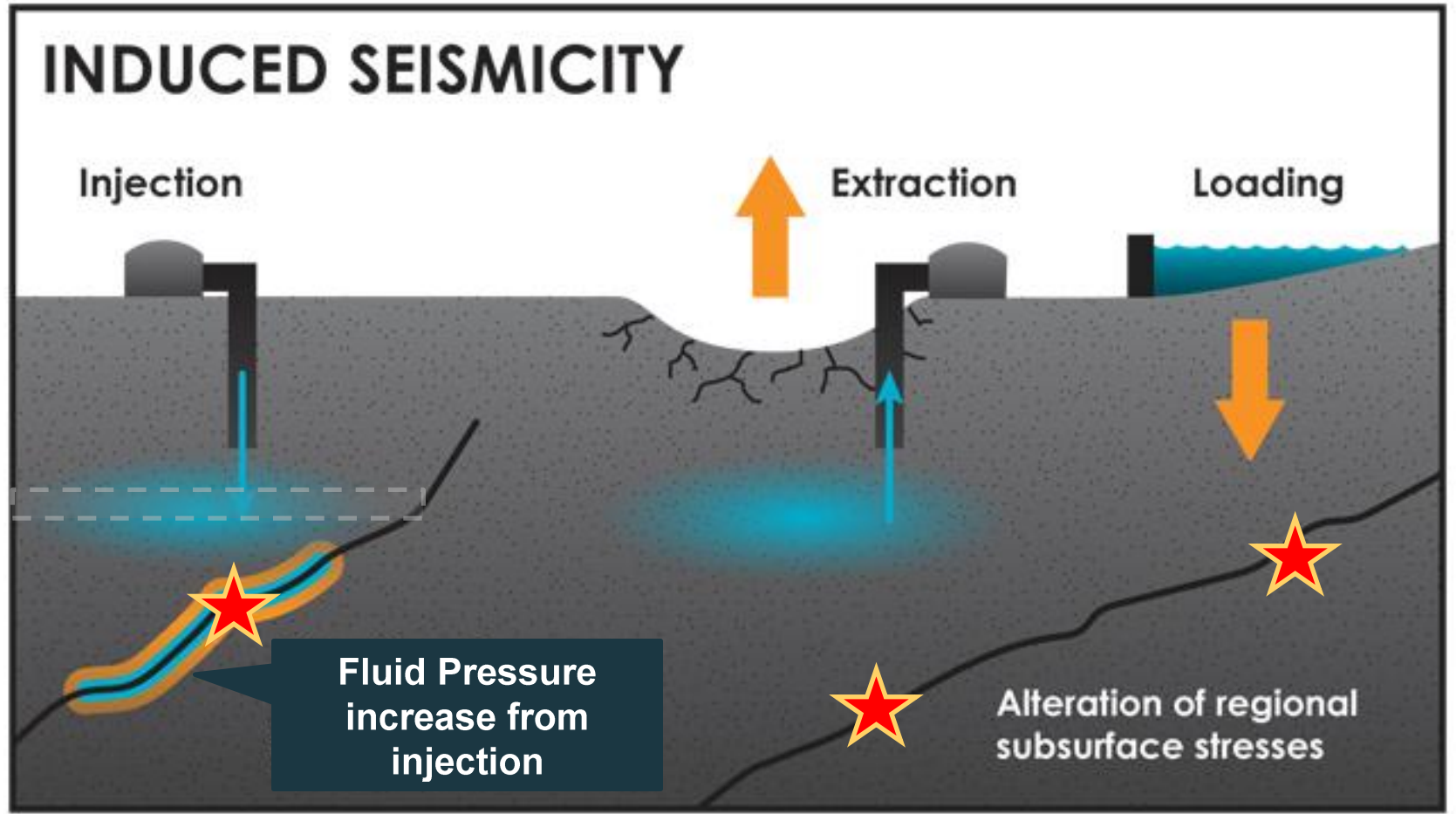
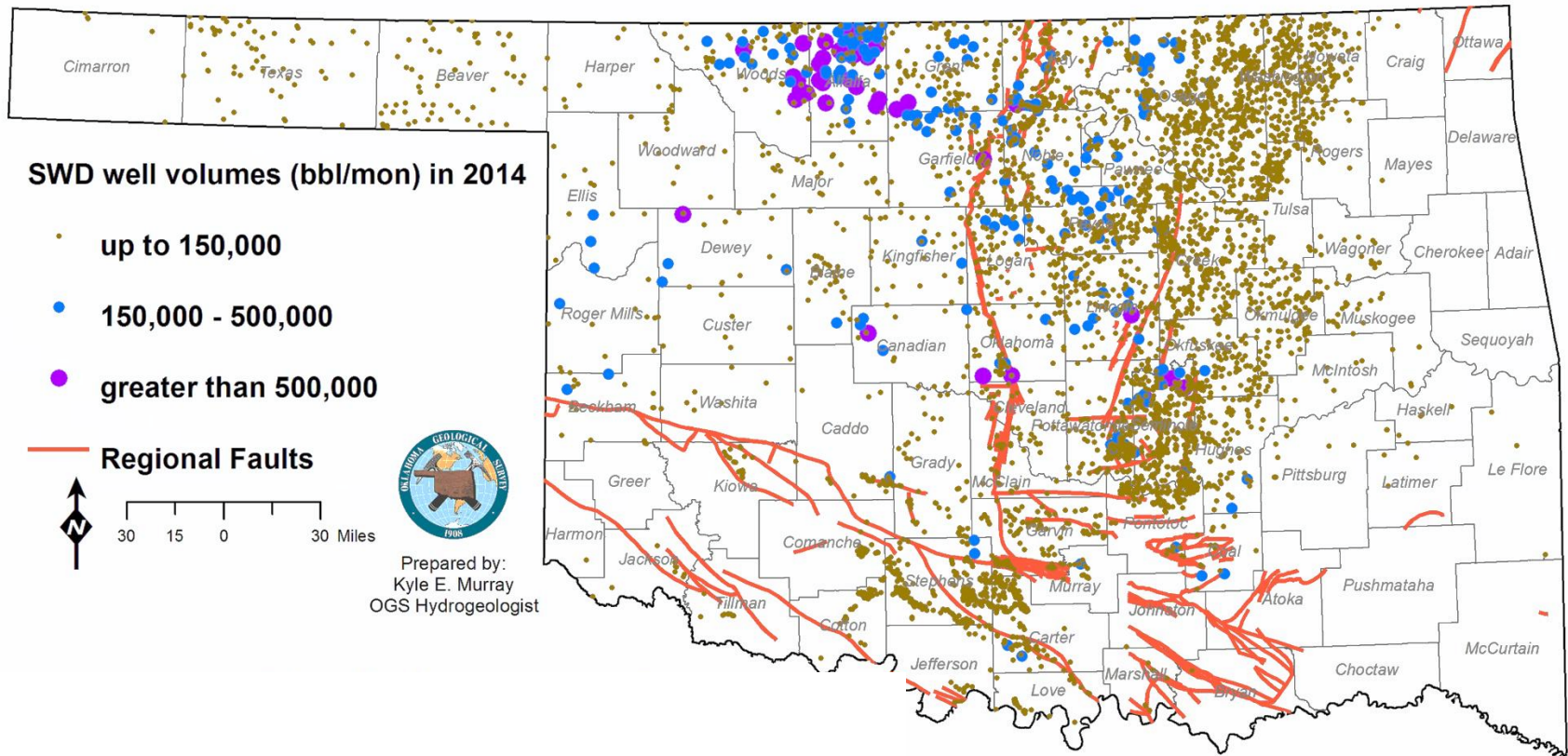


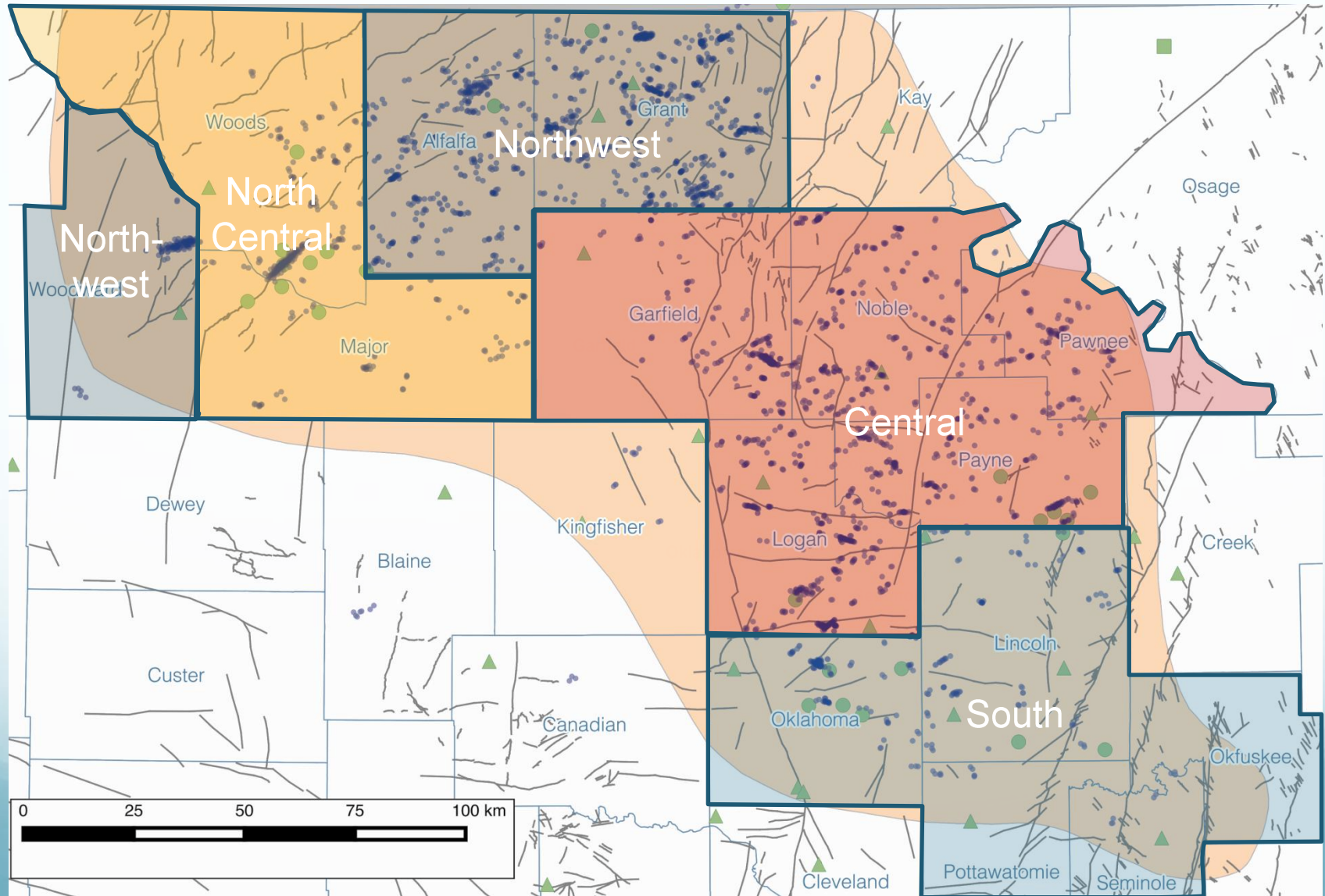
Figure modified from: <http://www.earthmagazine.org/article/ground-shaking-research-how-humans-trigger-earthquakes>

Underground Injection Control (UIC) Class II Injection Salt Water Disposal (SWD) Wells

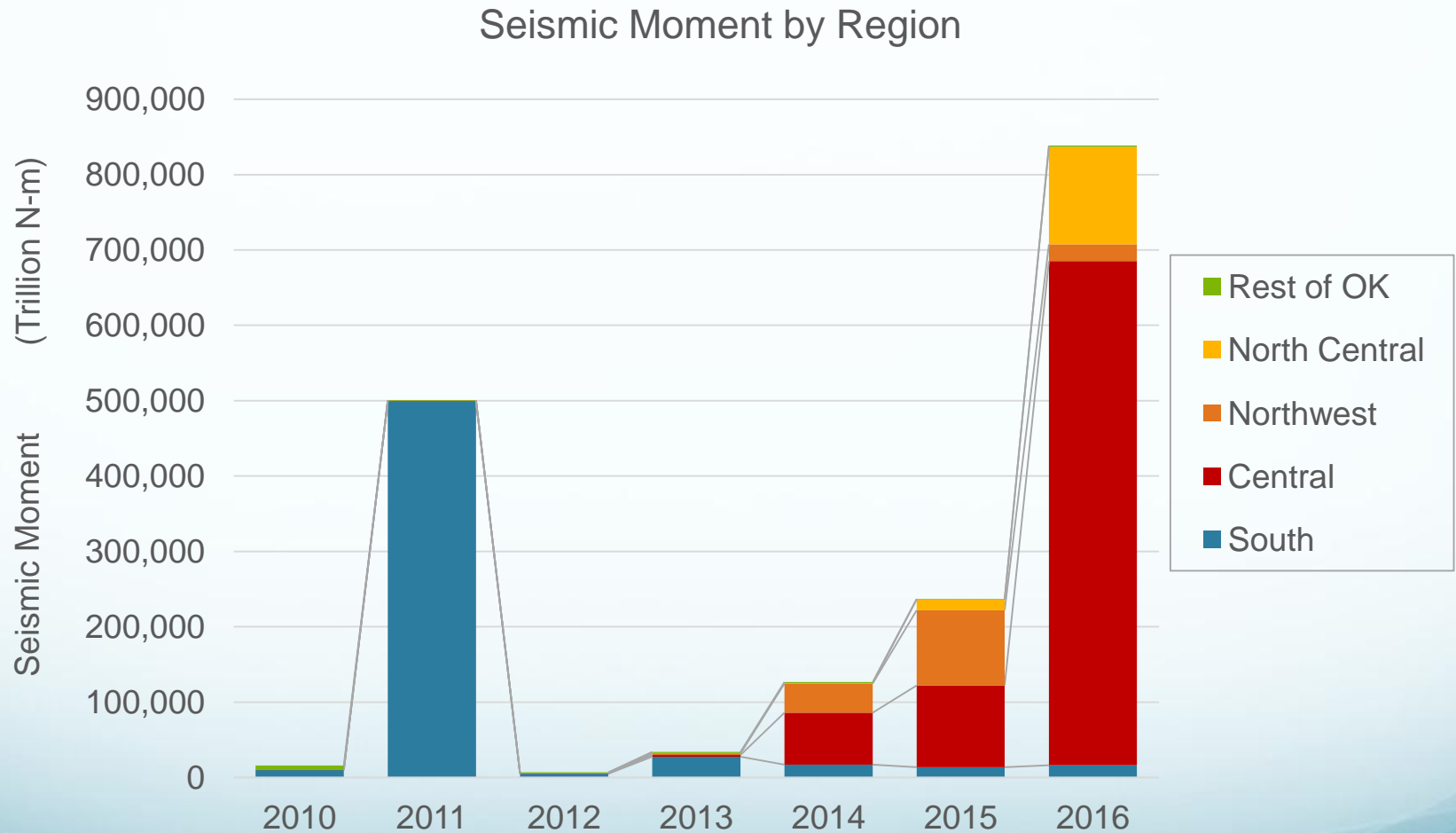


Murray 2014, OGS OF5-2015

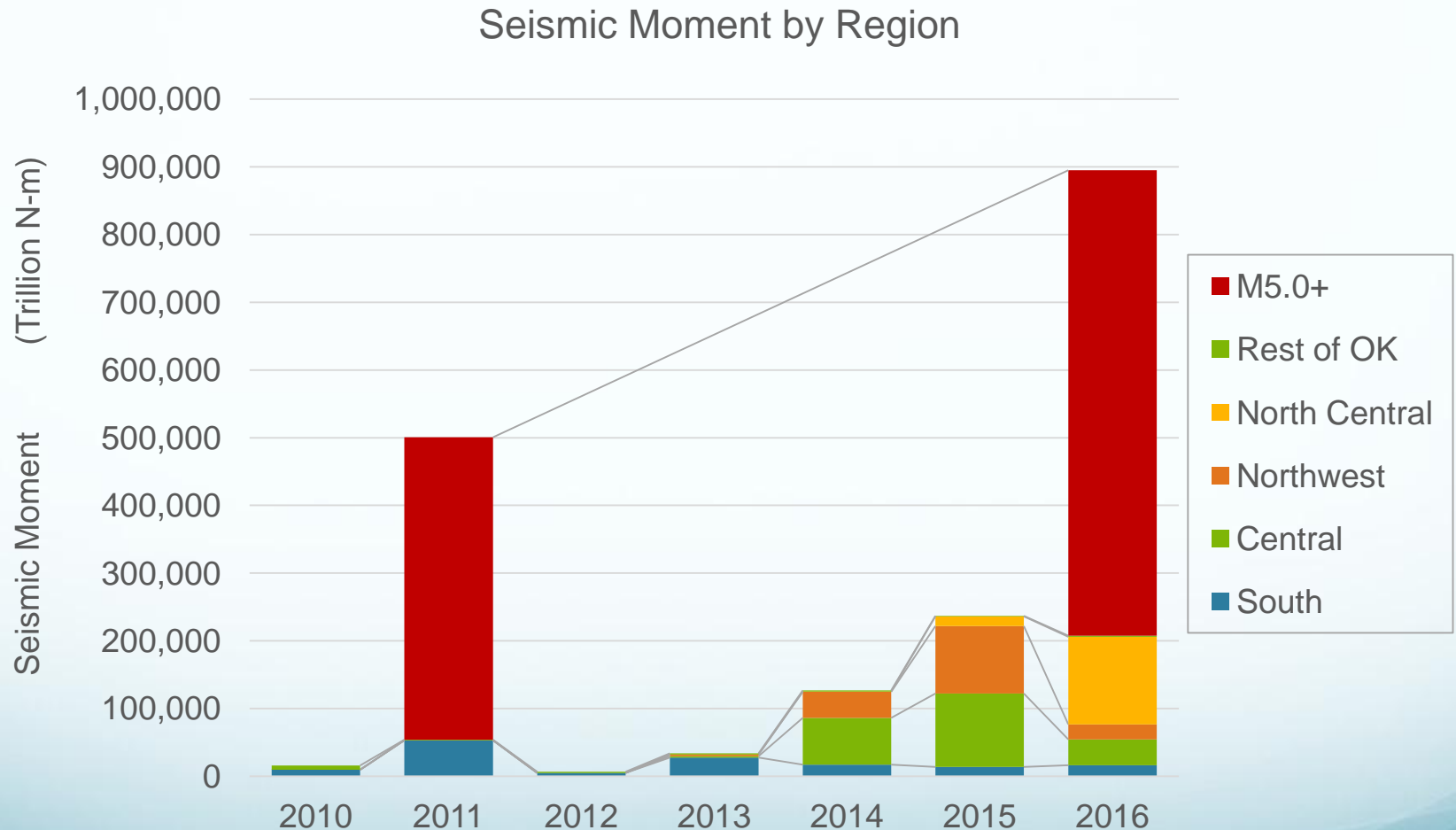
Simplified Regional Grouping



Seismic Activity Shifts Regionally Through Time

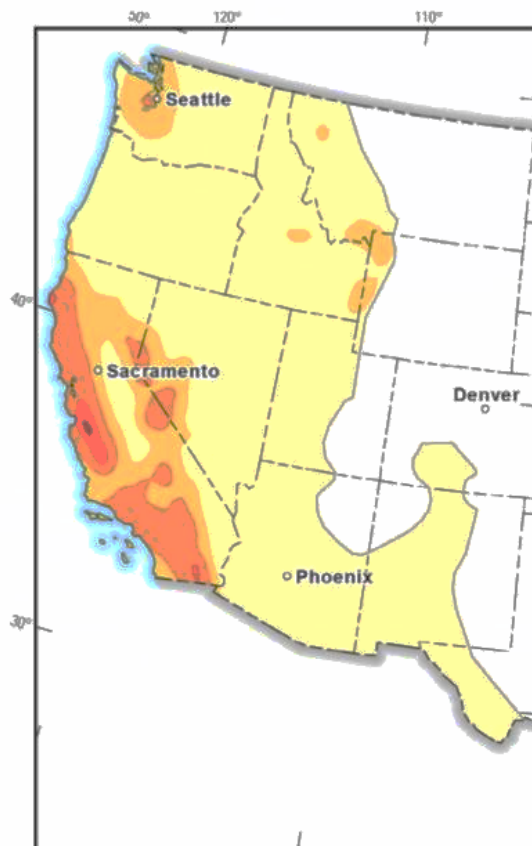


Three Large Quakes Dominate Energy Release

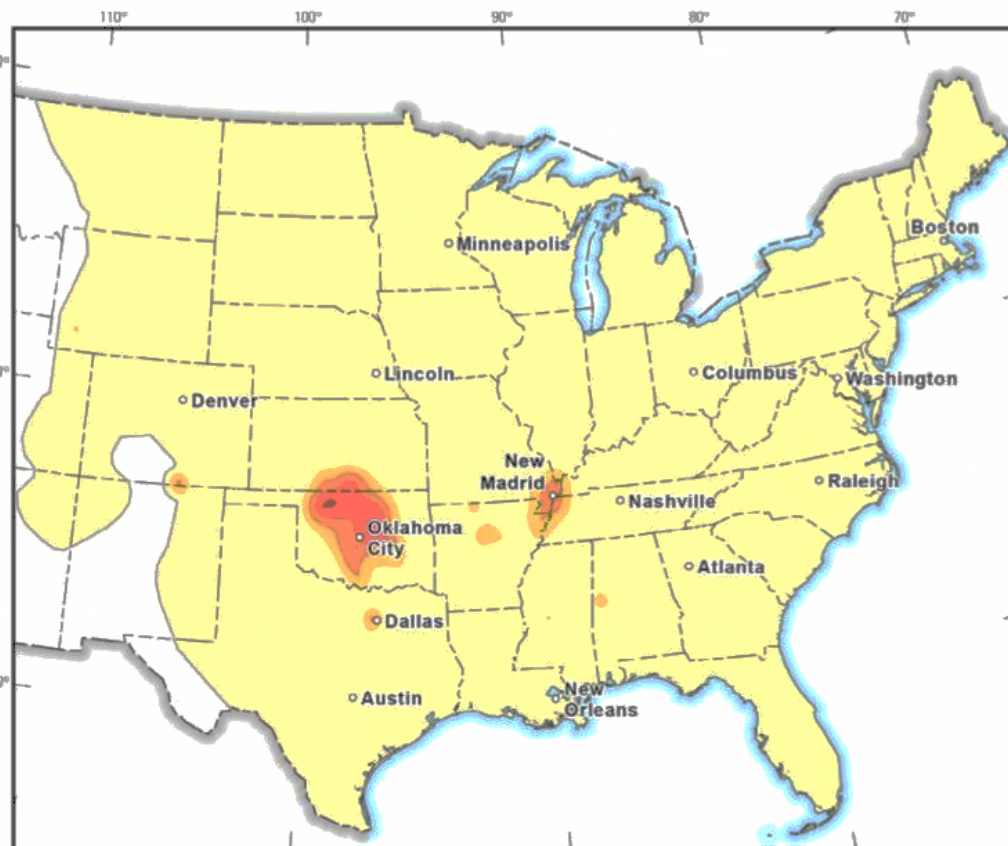


Comparison of Damage Probabilities

Damage defined as forecasted ground motions of MMI VI or greater ($\geq 0.12g$)

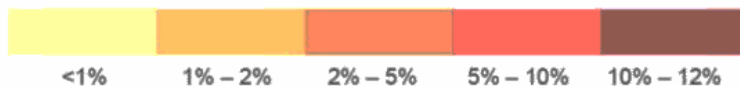


Based on results from the 2014
National Seismic Hazard Model



Based on results from this study

Chance of damage from an earthquake in 2016



Source: <https://pubs.er.usgs.gov/publication/ofr20161035>

11/14/2016

Summary: Induced Seismicity in Oklahoma

- ✗ No documented case of induced seismicity comes close to the current earthquake rates or the area over which the earthquakes are occurring in Oklahoma
- ✗ The OGS considers it very likely that the majority of recent earthquakes, particularly those in central and north-central Oklahoma, are triggered by the injection of produced water in SWD wells.
- ✗ Hydraulic fracturing flowback water only contributes a small amount to the SWD apparently responsible for the observed rate of earthquakes
- ✗ The drop in earthquake frequency over the past year likely results from decreases in injection in the Area of Interest driven both by oil price and by Corporation Commission actions

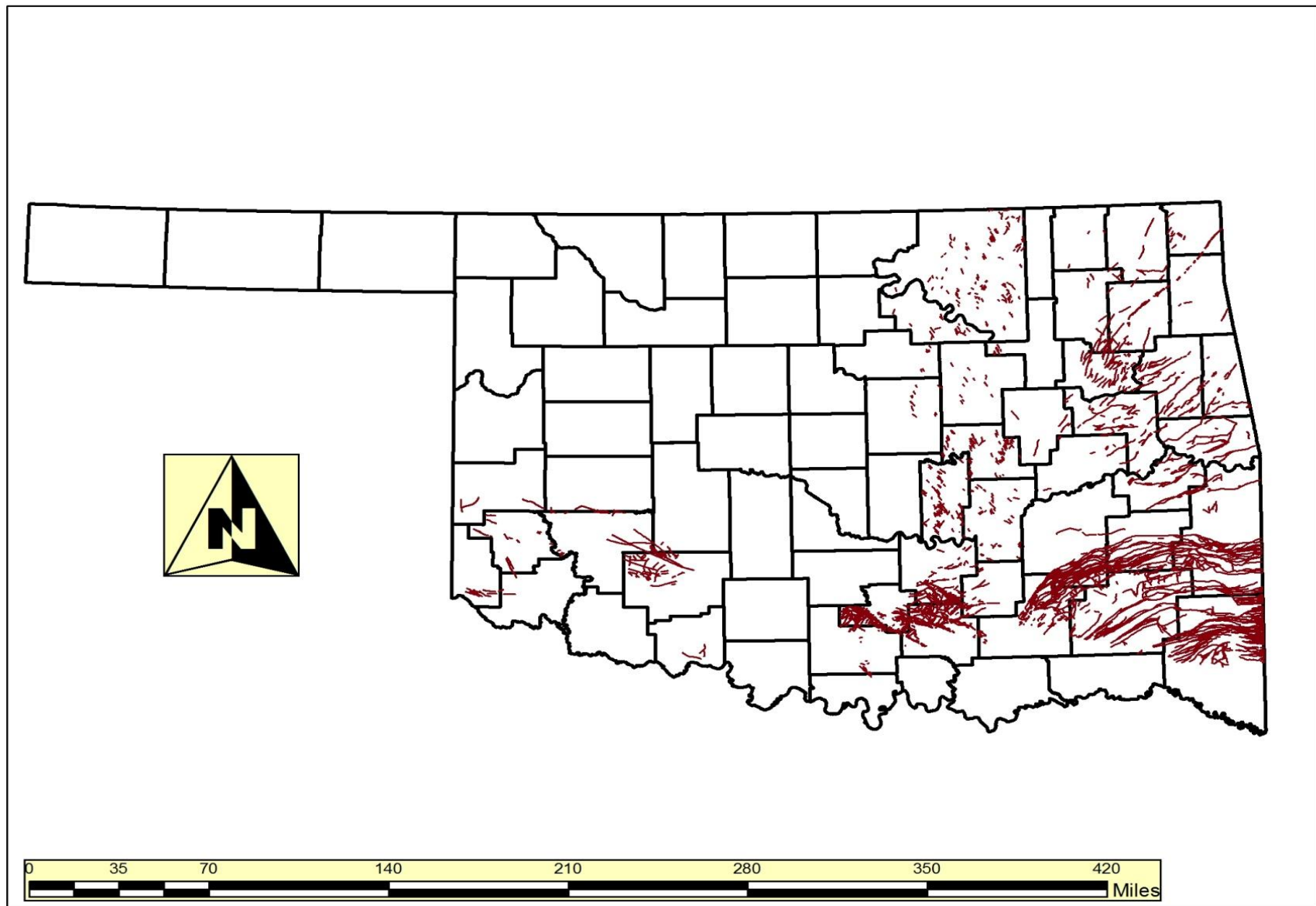
SEISMICITY ISSUES – ACTIONS

- Oil and Gas Division continues to address “basement” issues
- Broad agreement among researchers that injecting into the basement carries high potential risk of seismicity
- **March/July of 2015** plans apply to about **560** Arbuckle disposal wells (plug backs)
- **August 2015** – 38% volume reduction within the “**Logan County Trend Area**”
- **October 2015** plan for **Cushing Area** (shut-in and volume reductions)
- **November 2015** plan for **Medford Area** (volume reductions)
- **November 2015 and January 2016** plans for **Fairview Area** (shut-in and volume reductions)

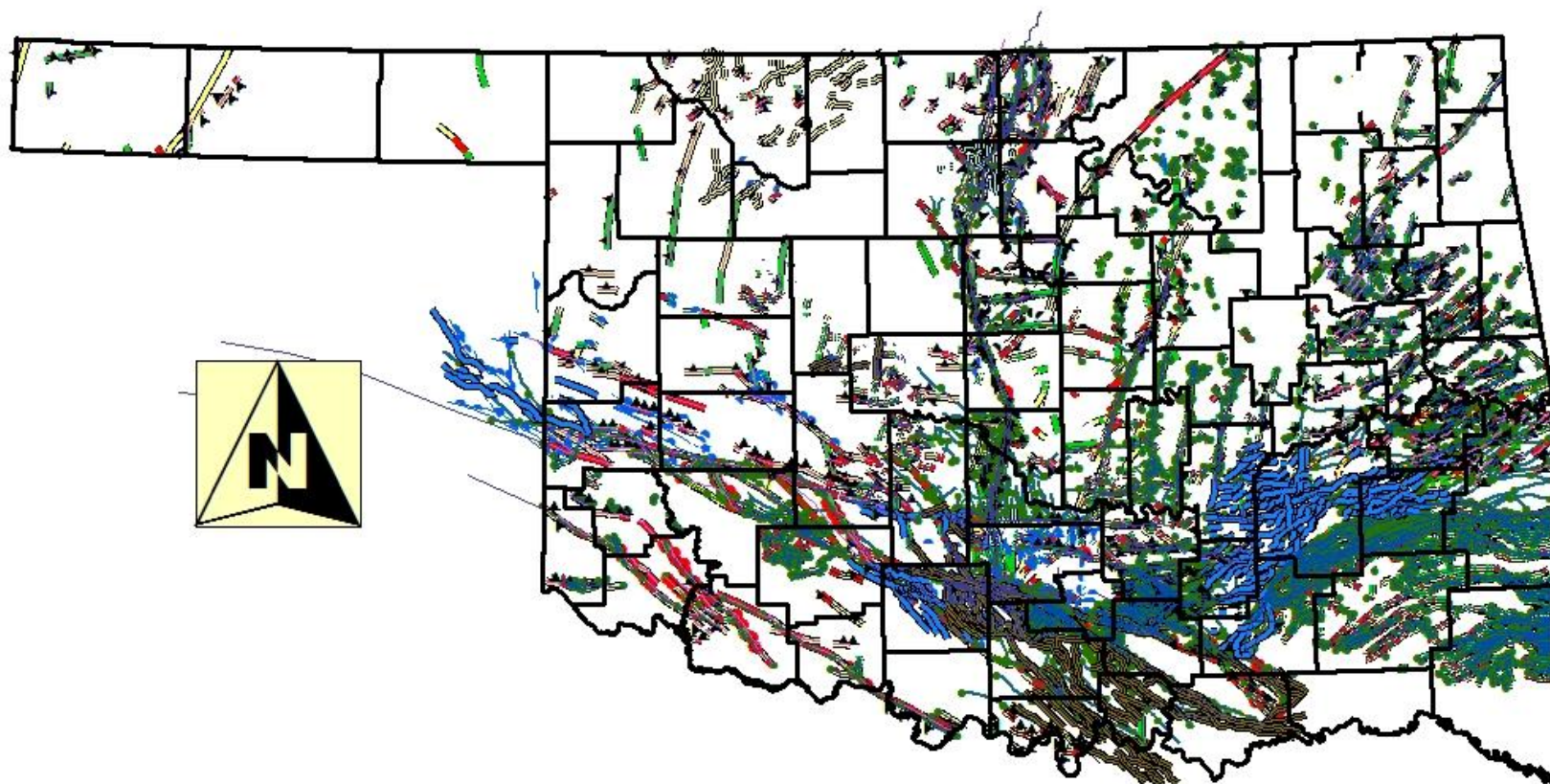
SEISMICITY ISSUES – ACTIONS (cont.)

- **December 2015** plan for **Bryon/Cherokee and Medford Areas** (shut-in and volume reductions)
- **January 2016** plan for **Edmond Area** (volume reductions)
- **February 2016** plan for **Western Oklahoma** (volume reductions)
- **March 2016** plan for **Central Oklahoma** (volume reductions)
- **August 2016** – plan for **Luther/Wellston Area** (shut-in and volume reductions)
- **September 2016** plan for **Pawnee Area** (shut-in)
- **September 2016** (updated) plan for **Pawnee Area** (shut-in and volume reductions)

2013 FAULT MAP



Fault Data Available after 04/01/2015

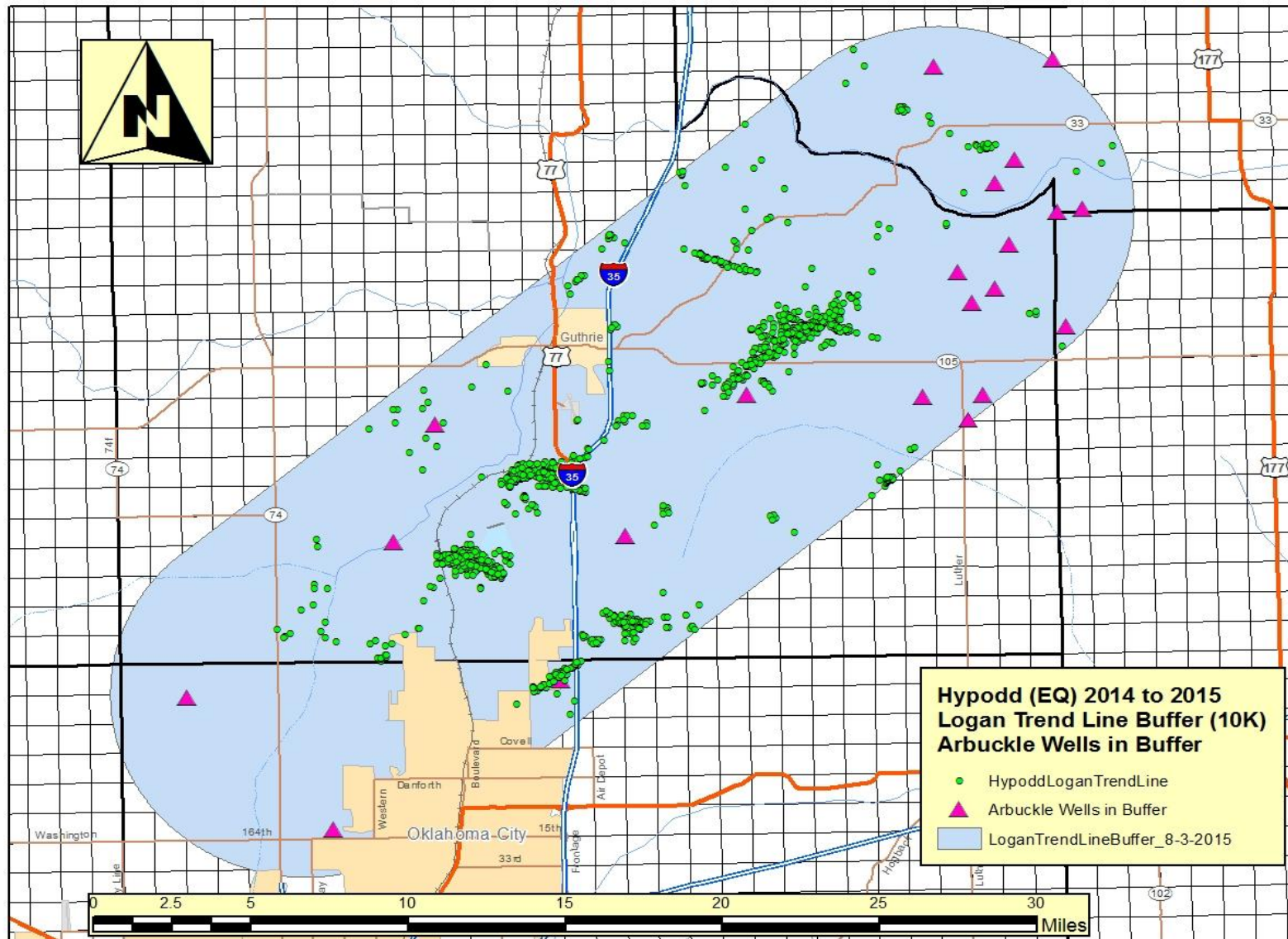


Date: 2/17/2016

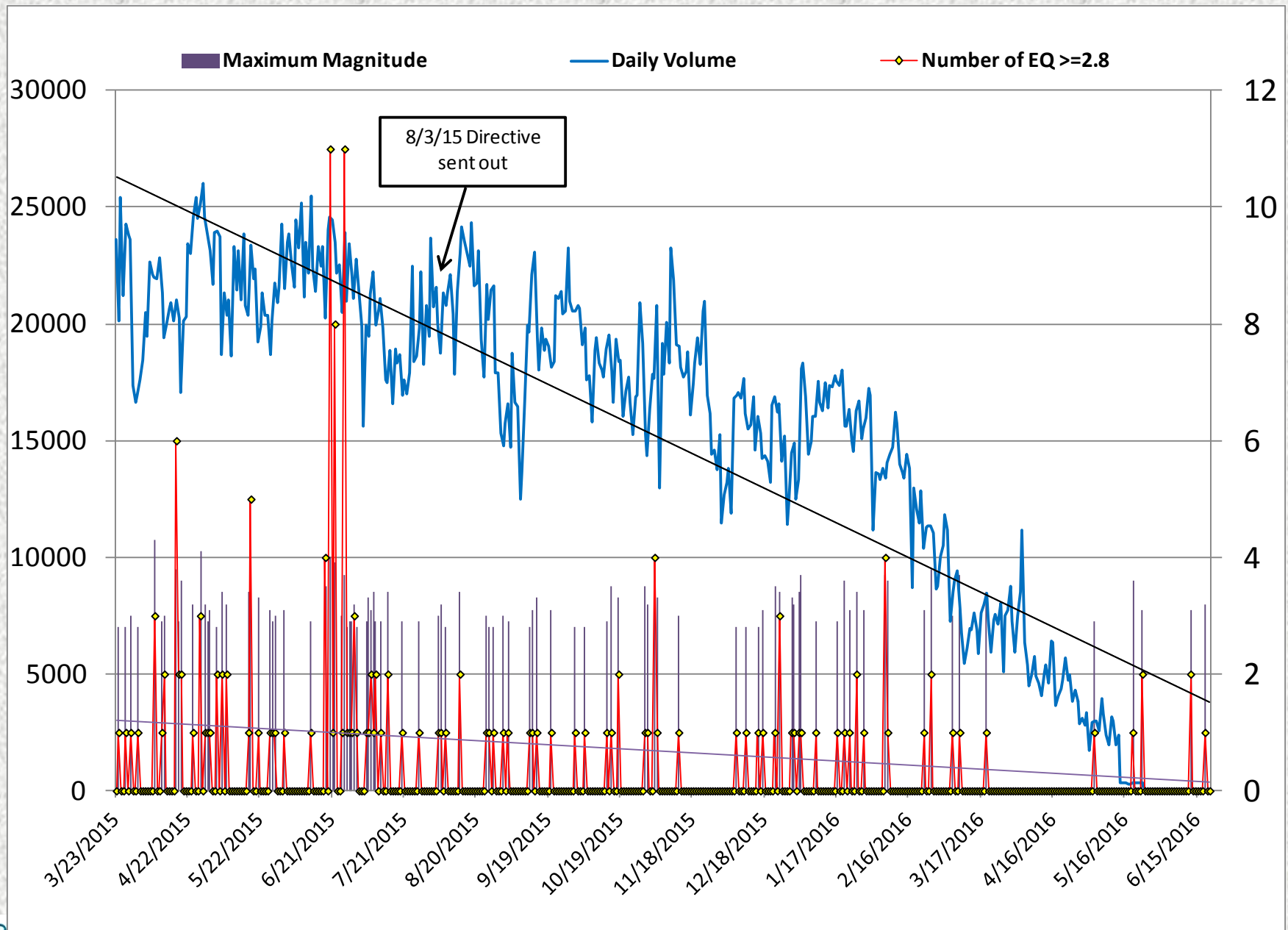
UIC Program

- In Oklahoma there are:
 - 4,391 Disposal Wells
 - 6,890 EOR Wells
- Of the 4,391 disposal wells there are **1045 wells** that are authorized for disposal into the Arbuckle formation.

SEISMICITY ISSUES –LOGAN COUNTY TREND AREA



(Update 6/22/16)



11/14/2016

Cushing 3,6,10 mile
EQ Last 30 Days 10/16/15

past30days_10/16/2015
prefmag

- 0.200000 - 1.000000
- 1.000001 - 2.000000
- 2.000001 - 3.000000
- 3.000001 - 3.500000
- 3.500001 - 3.999999
- 4.000000 - 4.500000

Arbuckle Well SA OIL 9-18-2015

● well other values

Current St

- Decreased injection by half
- Injecting +1000 per day
- Never injected Permit expired
- No Action
- Not Drilled
- Not an Arbuckle Well
- Not in Arbuckle
- Not in Granite
- Not in granite
- Not injecting
- Not volume reporting - preparing documentation
- Plugging Procedure Approved
- Plugging Procedure will be sent
- Plugging procedure approved
- Plugged Back
- Plugged Back-Terminated
- Plugged Back-Shut-in
- Plugged back
- Shut-in
- Shut-in 1-25-2015
- Shut-in 1/25/15: Preparing plugback documentation
- Volume Reporting - preparing documentation
- Volume Reporting-inaction
- Volume reporting

- Cushing 3 mile Buffer
- Cushing 6 mile Buffer
- Cushing 10 mile Buffer

LEIGH 8-19N-03E 1 SWD

T19N R3E

T19N R4E

T19N R5E

T19N R6E

CROCKETT-1-D

Yale

WILLIAMS 1-33

UNDA 1 SWD

CALDWELL-LIONEL HARRIS 1

HANNAH JO A 10 SWD

HC RYAN 15-18N-6E 1SWD

JOYCE 1-5 SWD

5-19N-3E 1 SWD

N-3E 1SWD KING 2

Wheeler 11-1

11-1

ORE 1-18SWD

3E

MURLIN SWD 1-27

3E 1SWD

STOCKTON 1-27SWD

3E 1SWD

LOWE 1-16 SWD

T17N R3E

T17N R4E

T17N R5E

T17N R6E

T17N R7E

T17N R8E

T17N R9E

T17N R10E

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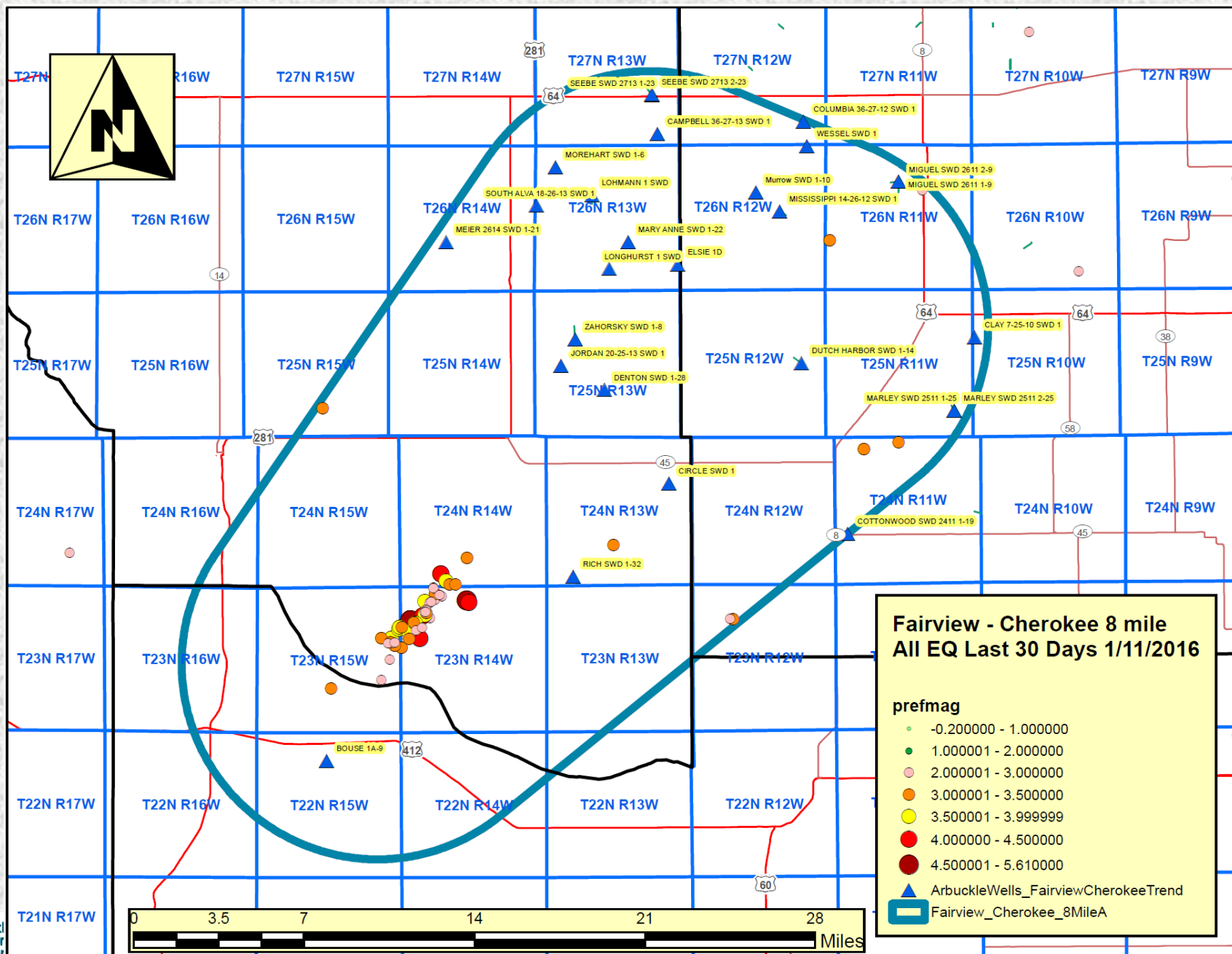
T17N R225E

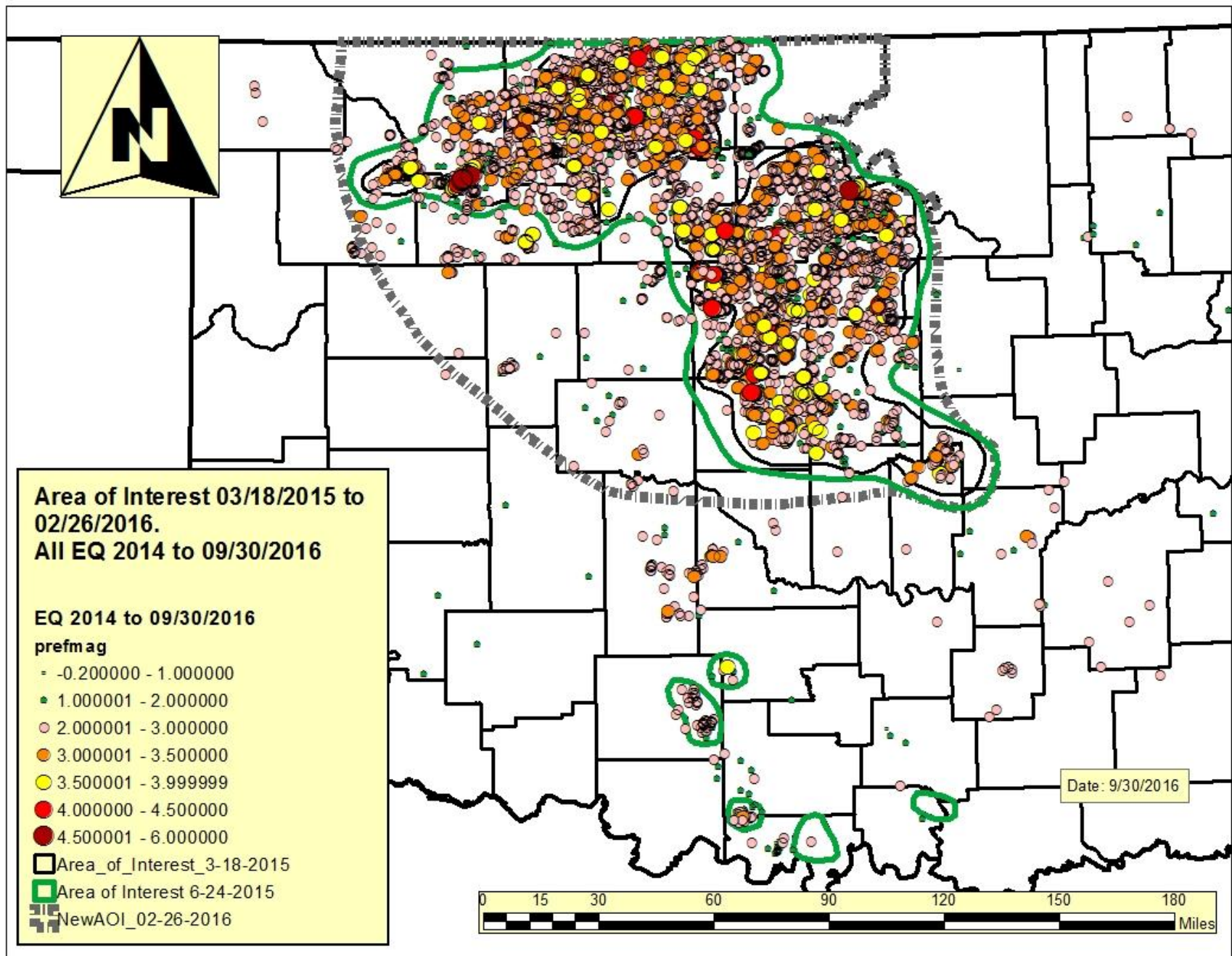
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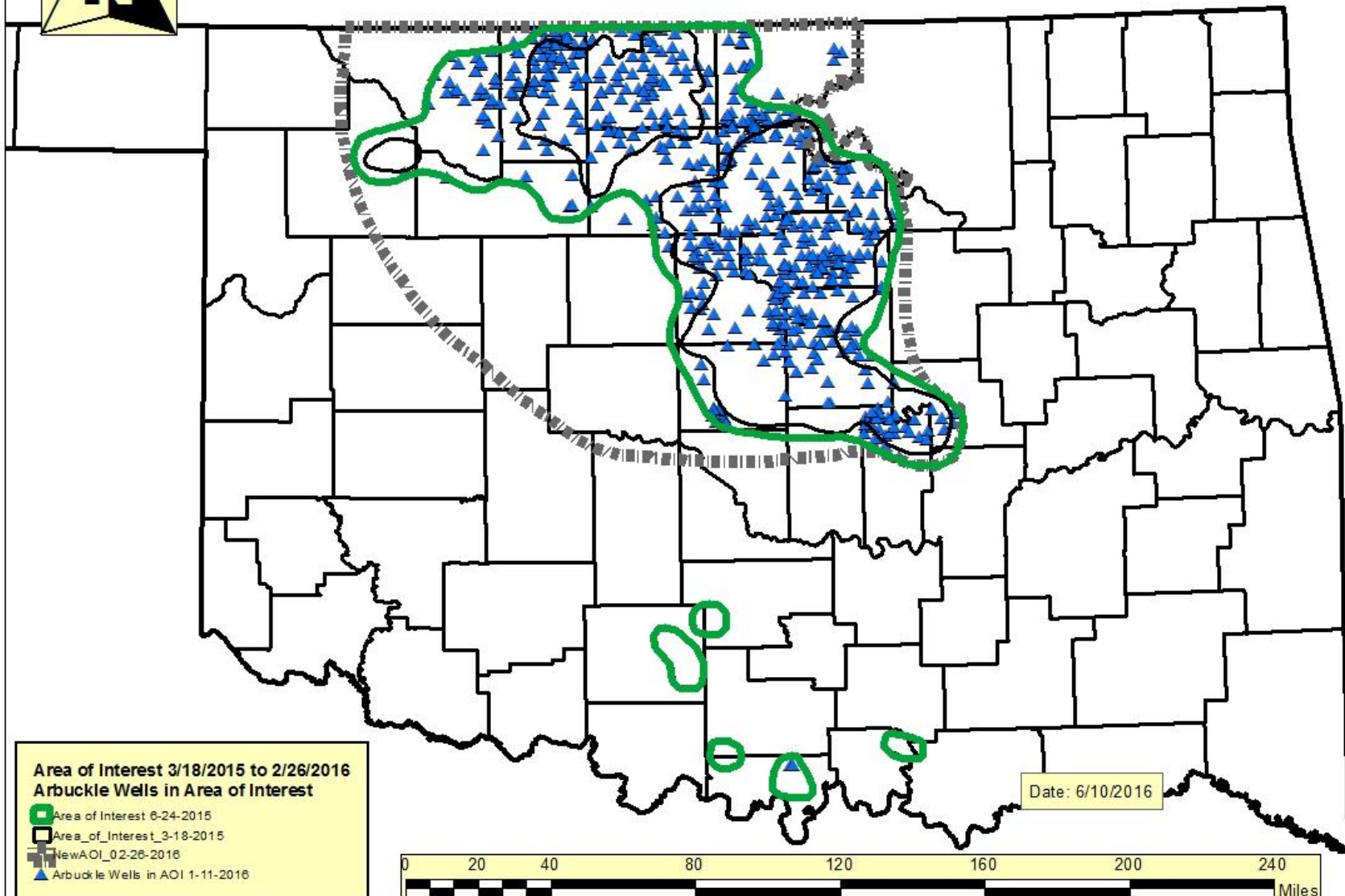
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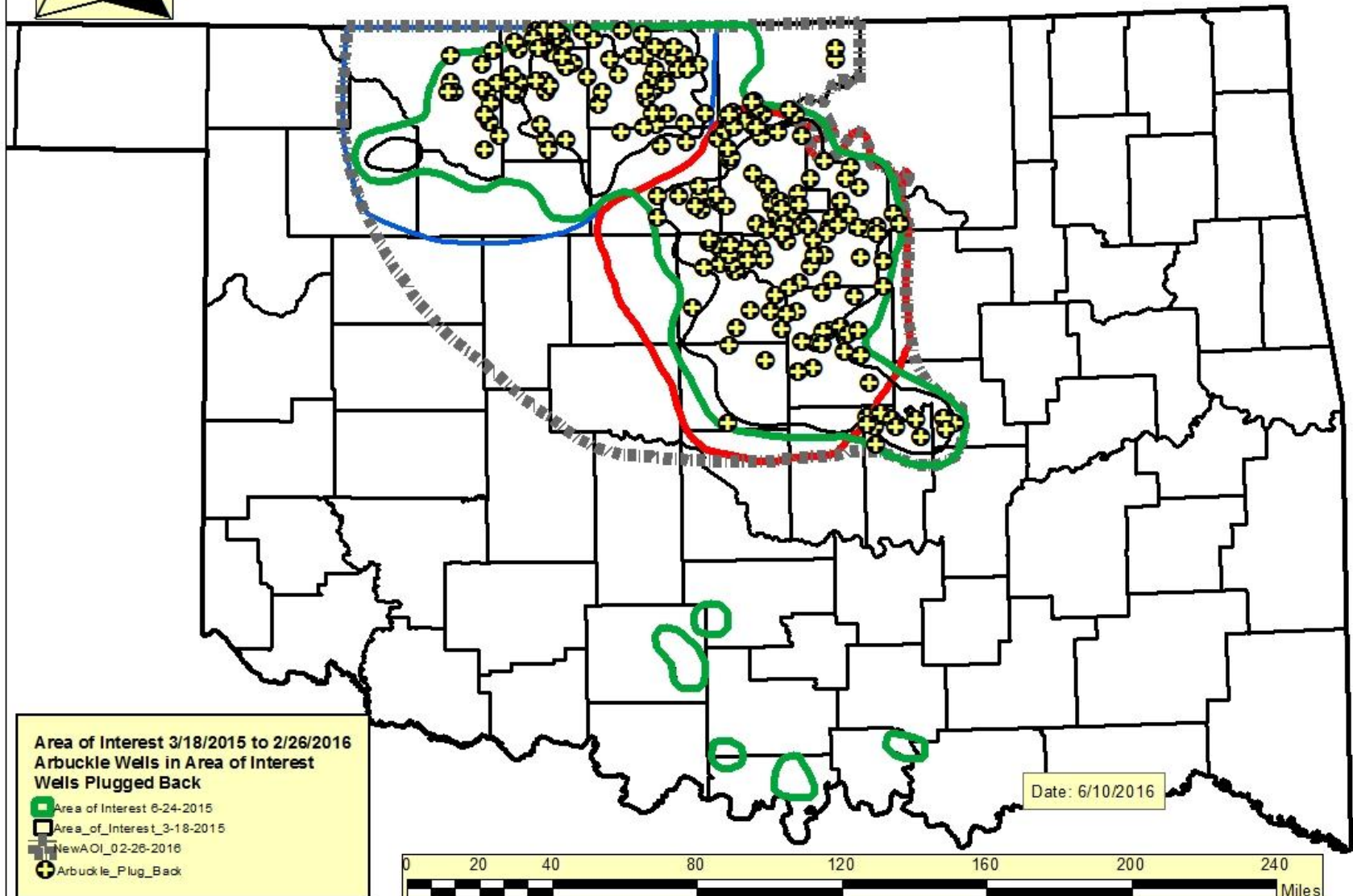
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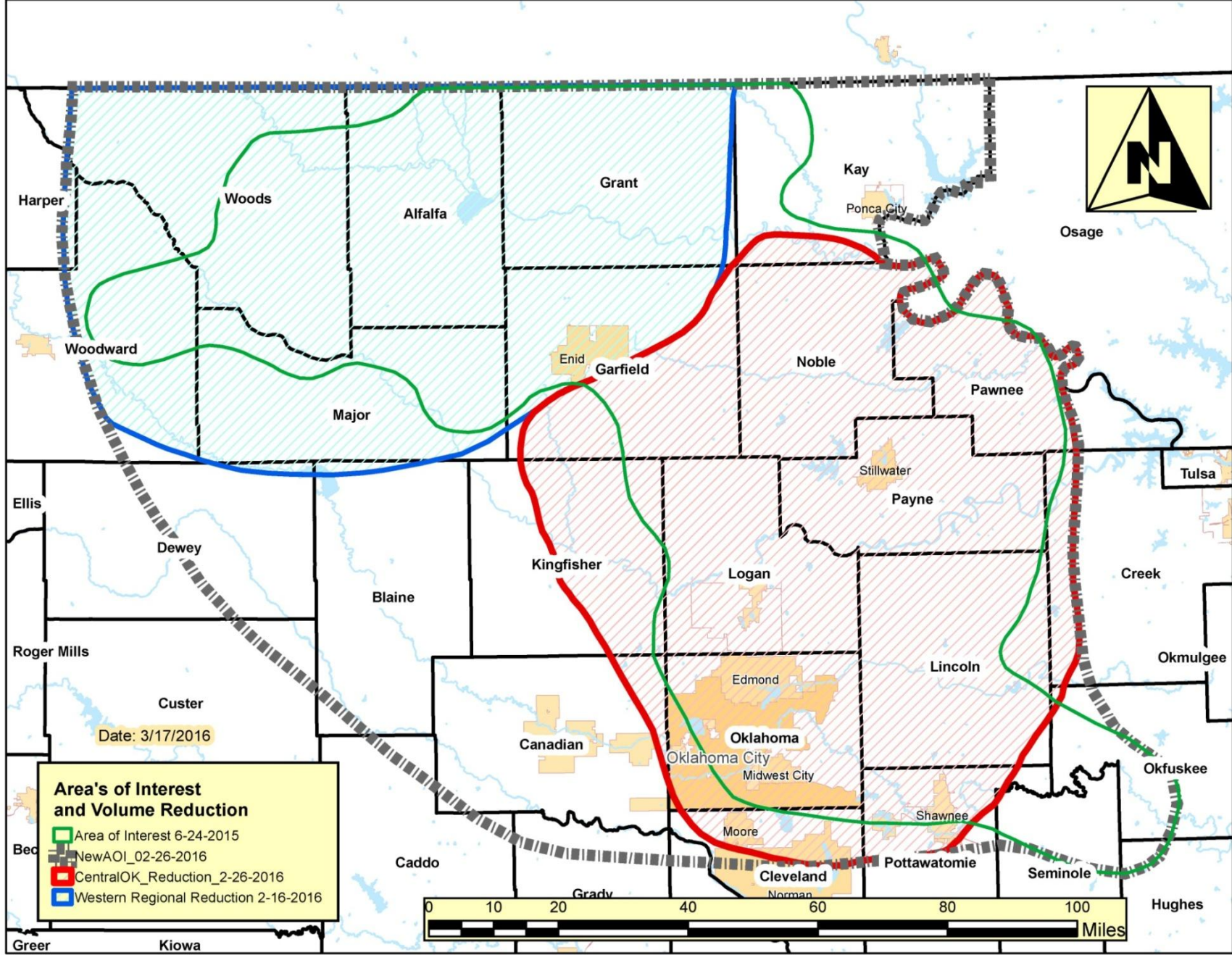
FAIRVIEW TREND AREA

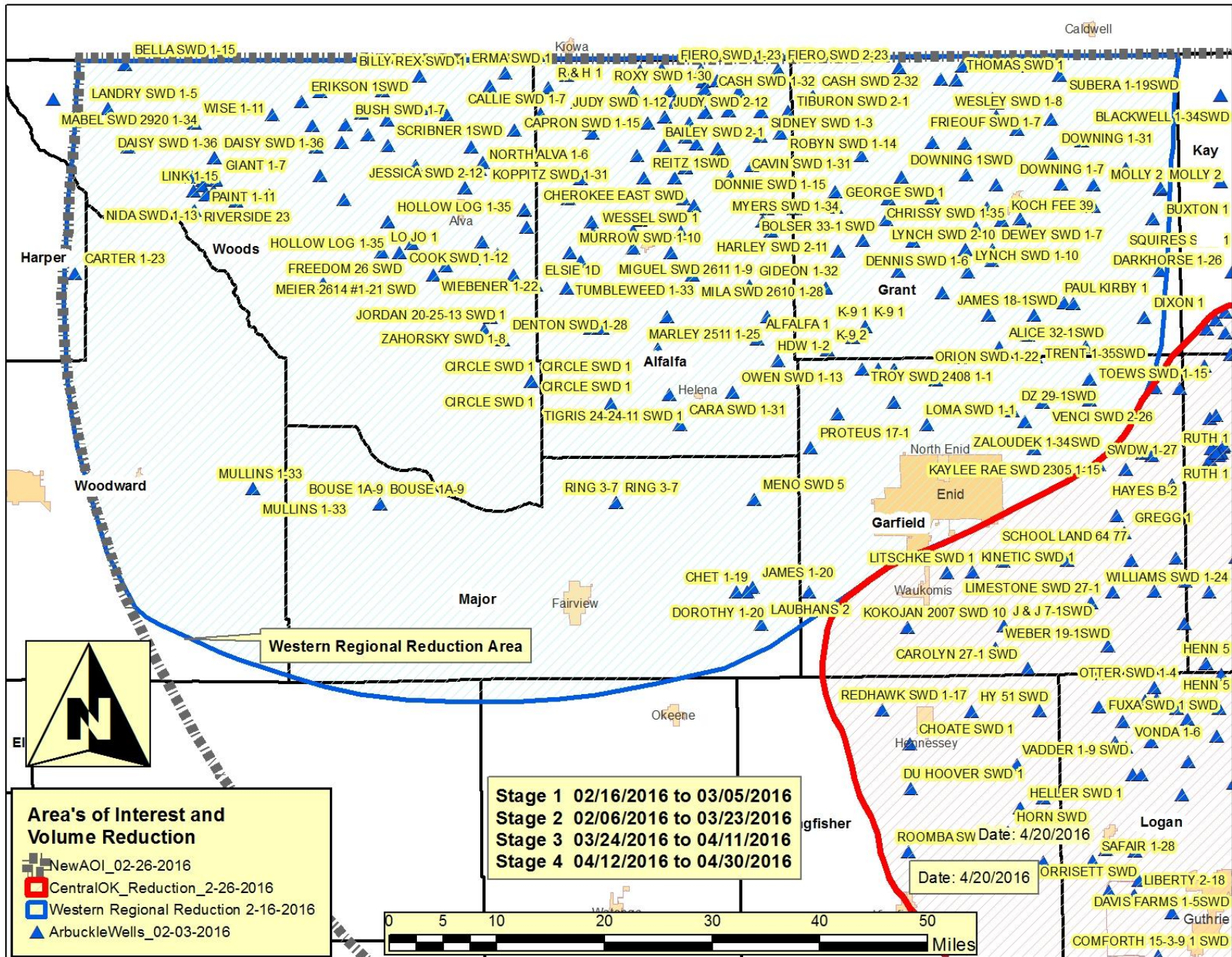


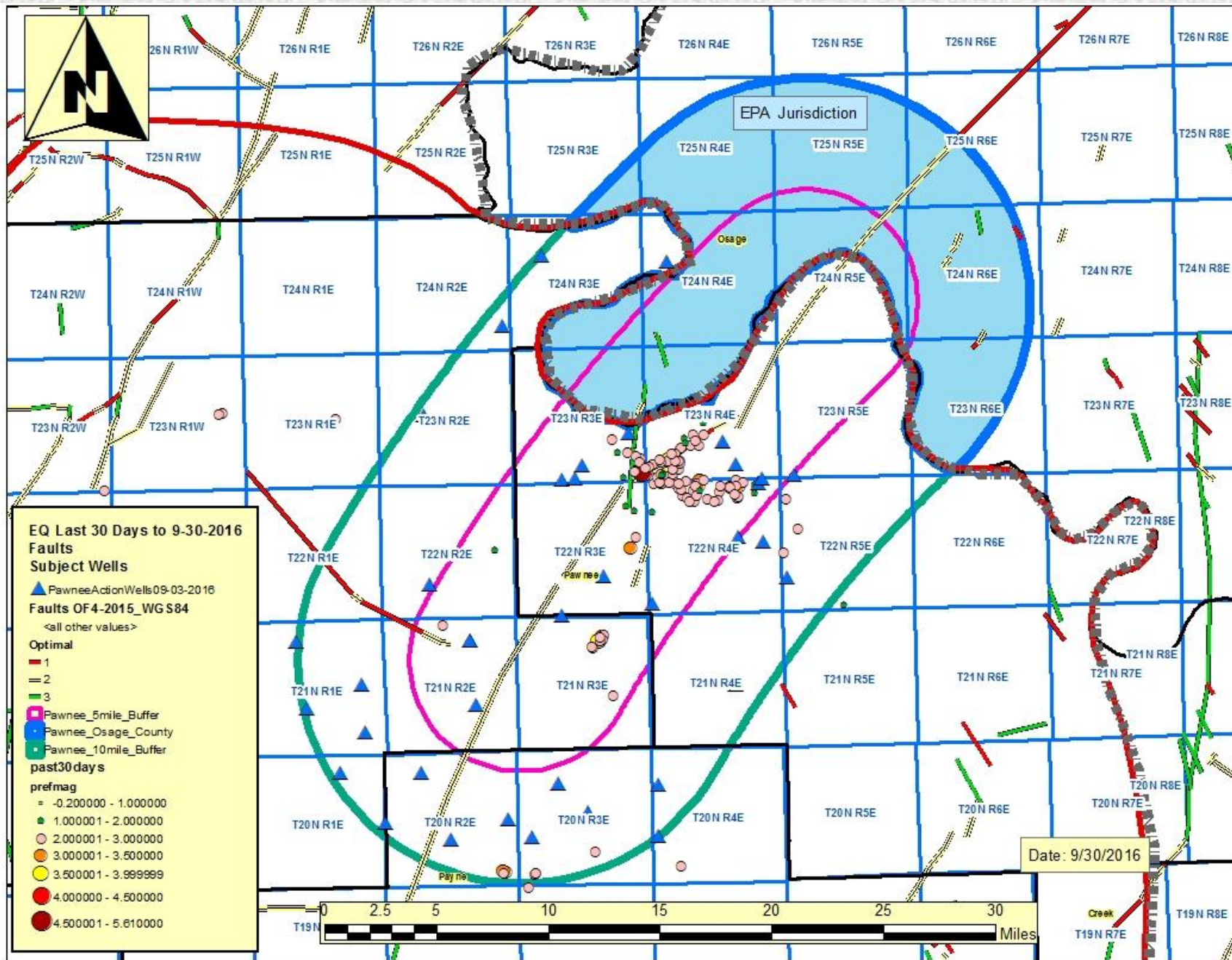


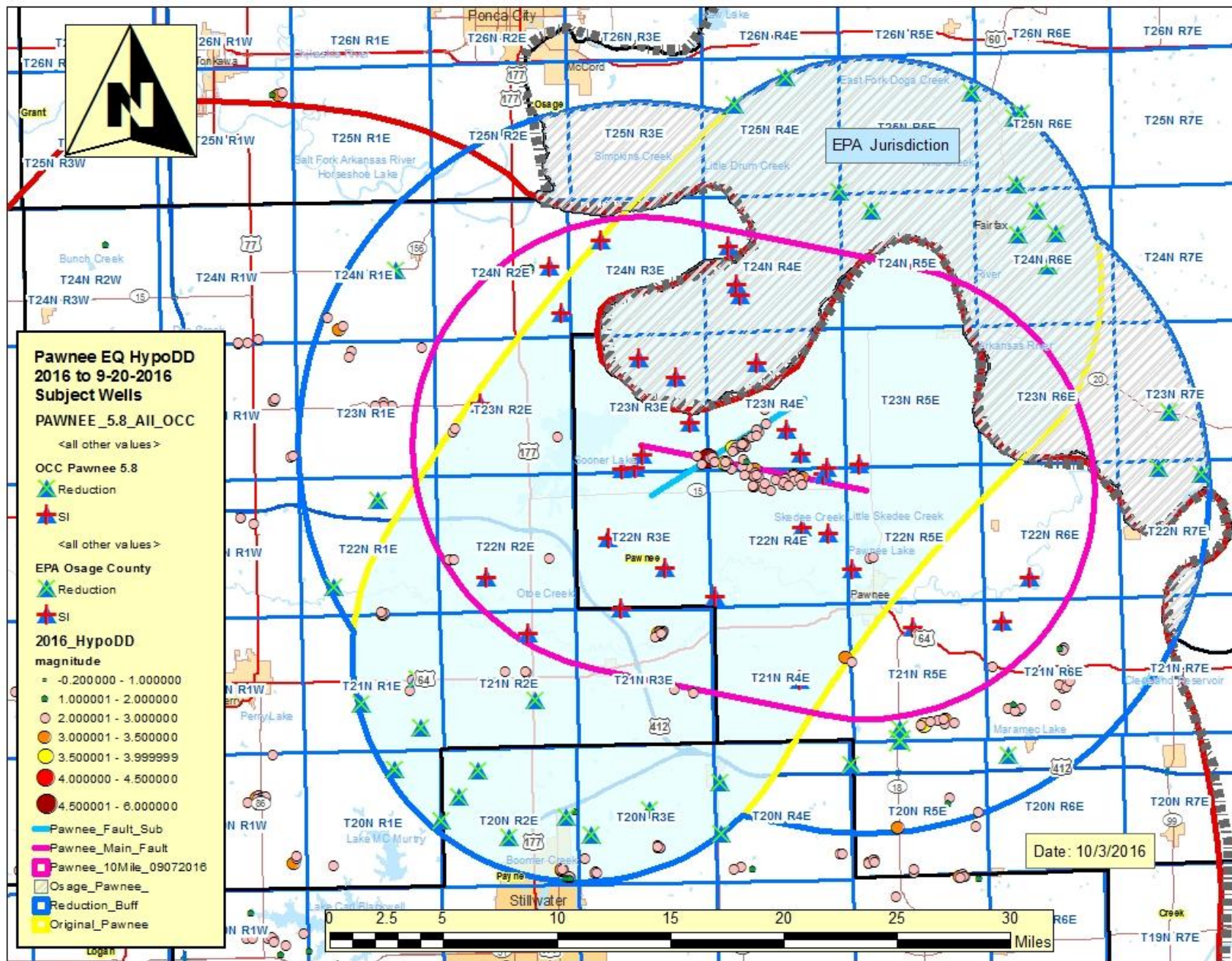








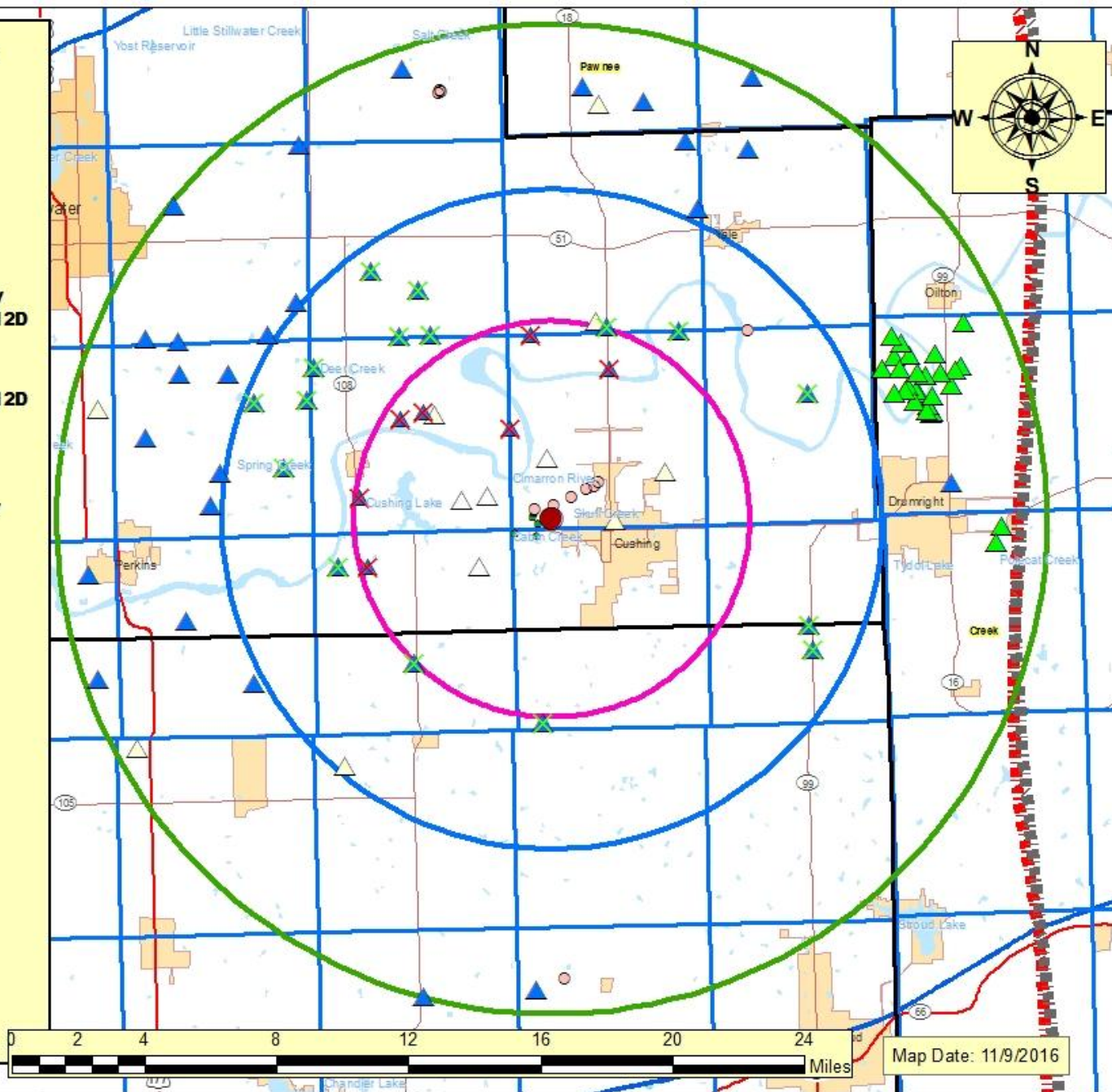




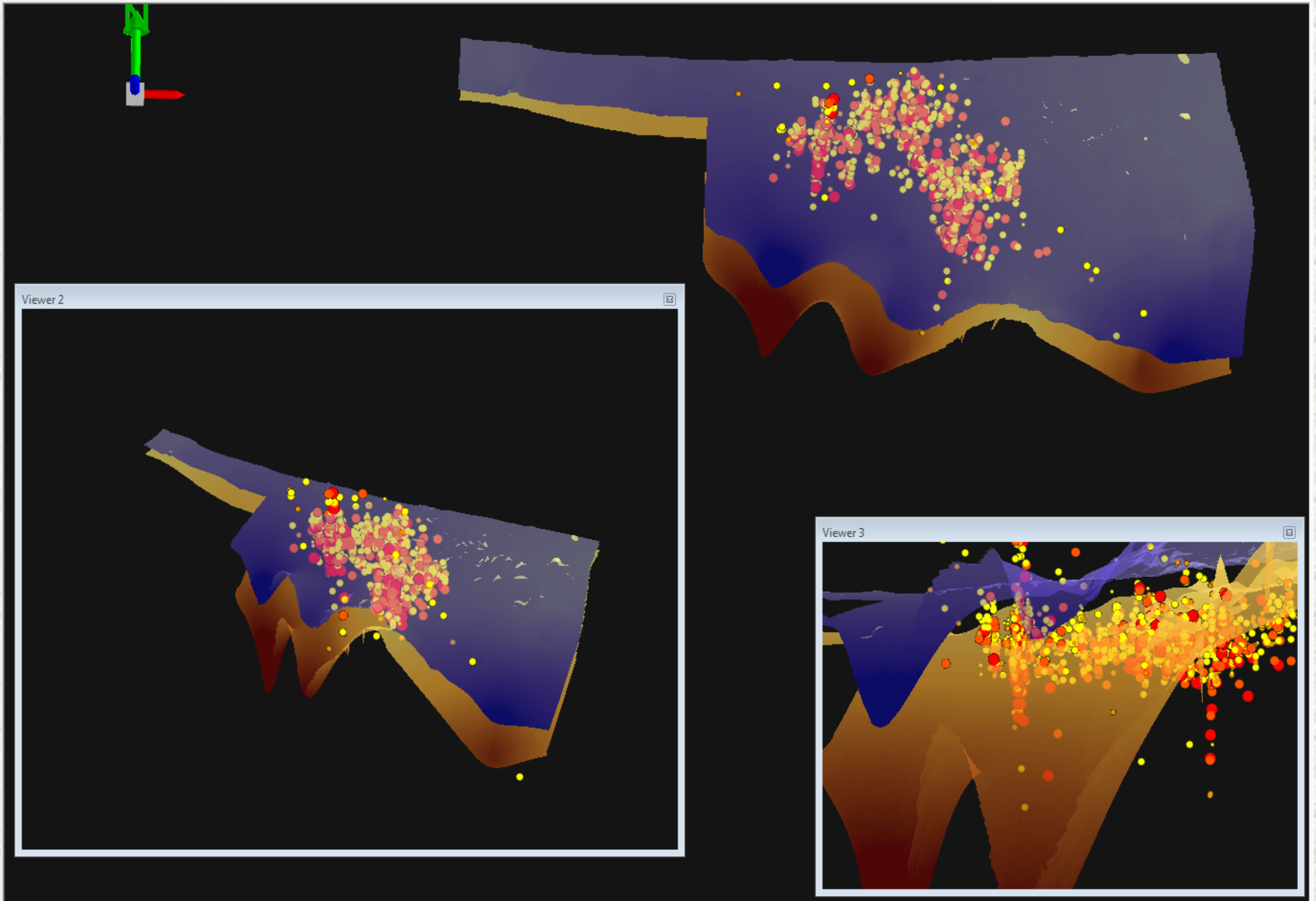
Cushing Area Revised
MW 5.0 06 Nov. 2016
EQ Last 7 days

- ◆
- ✕ **Reduce from last 30 day average reported to 1012D**
- ▲ **Limited to last 30-day average reported to 1012D**
- △ **Prev. Arbuckle No New**
- △ **Previous Shutin No New**
- ◆ <all other values>
- Action**
- ▲ ERF

- 20161106_8mile
- 20161106_10mile
- 20161106_15mile
- past7days
- premag
- 0.200000 - 1.000000
- 1.000001 - 2.000000
- 2.000001 - 3.000000
- 3.000001 - 3.500000
- 3.500001 - 3.999999
- 4.000000 - 4.500000
- 4.500001 - 6.000000
- NewAO_02-26-2016
- CentralOK_Reduction_2-26-2016

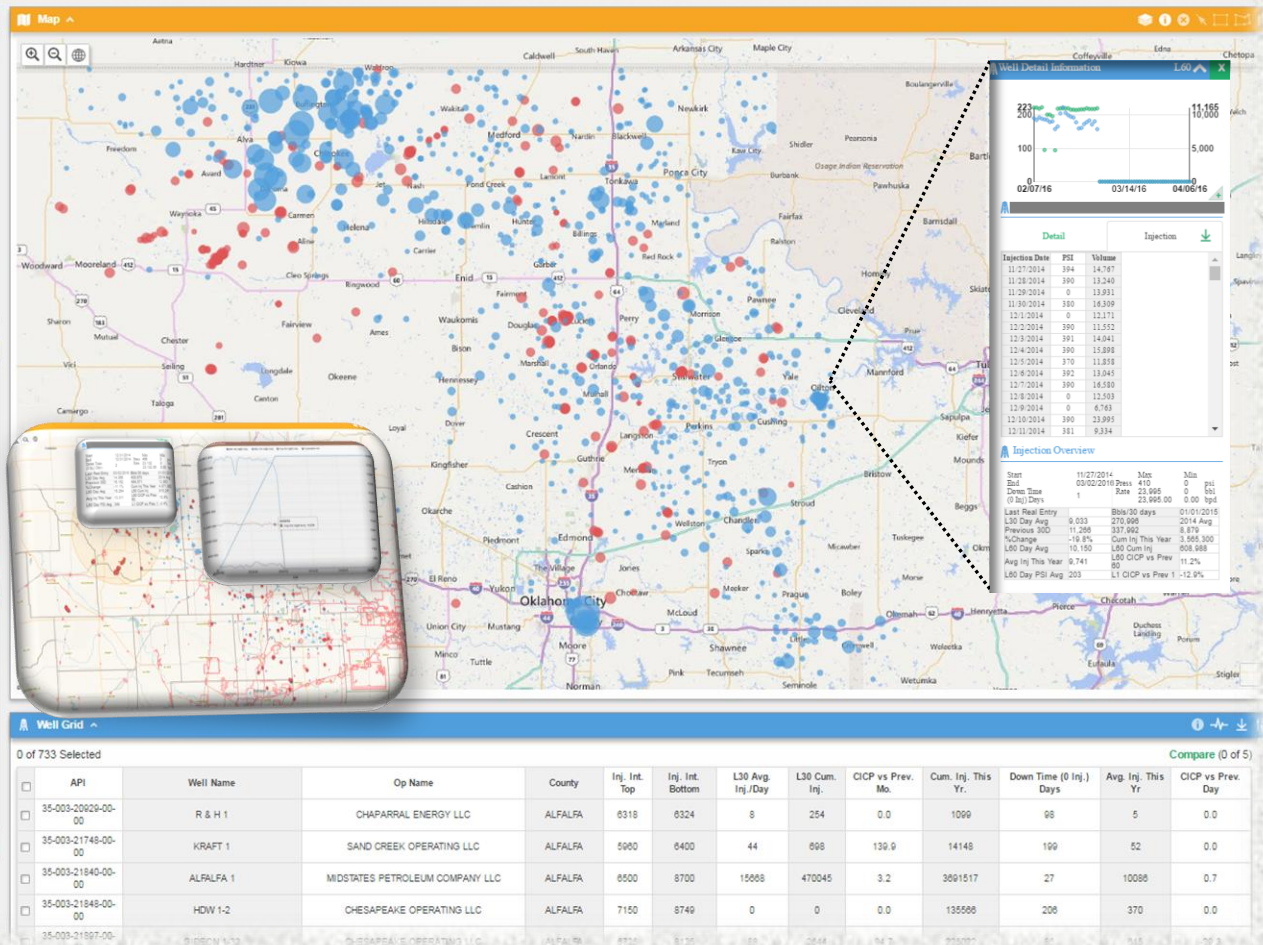
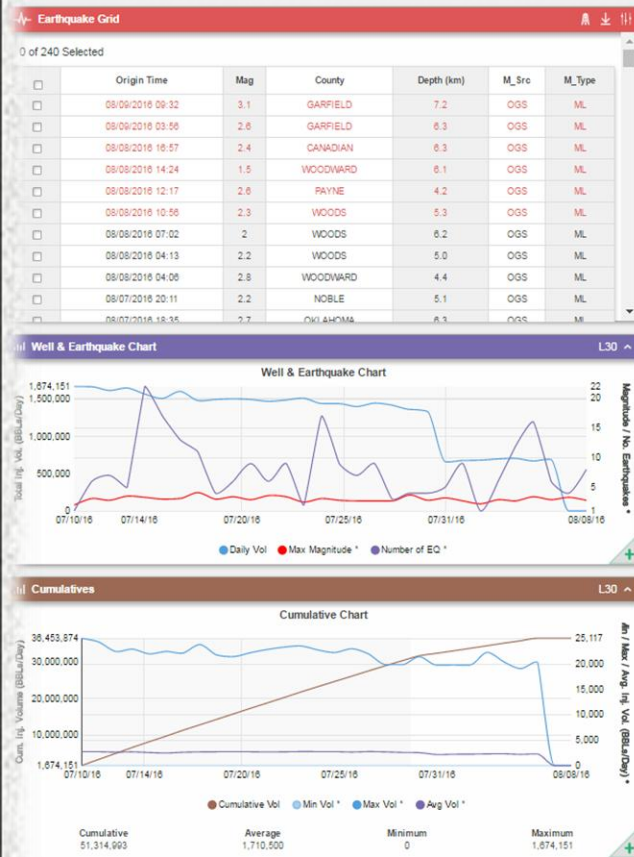


Map Date: 11/9/2016



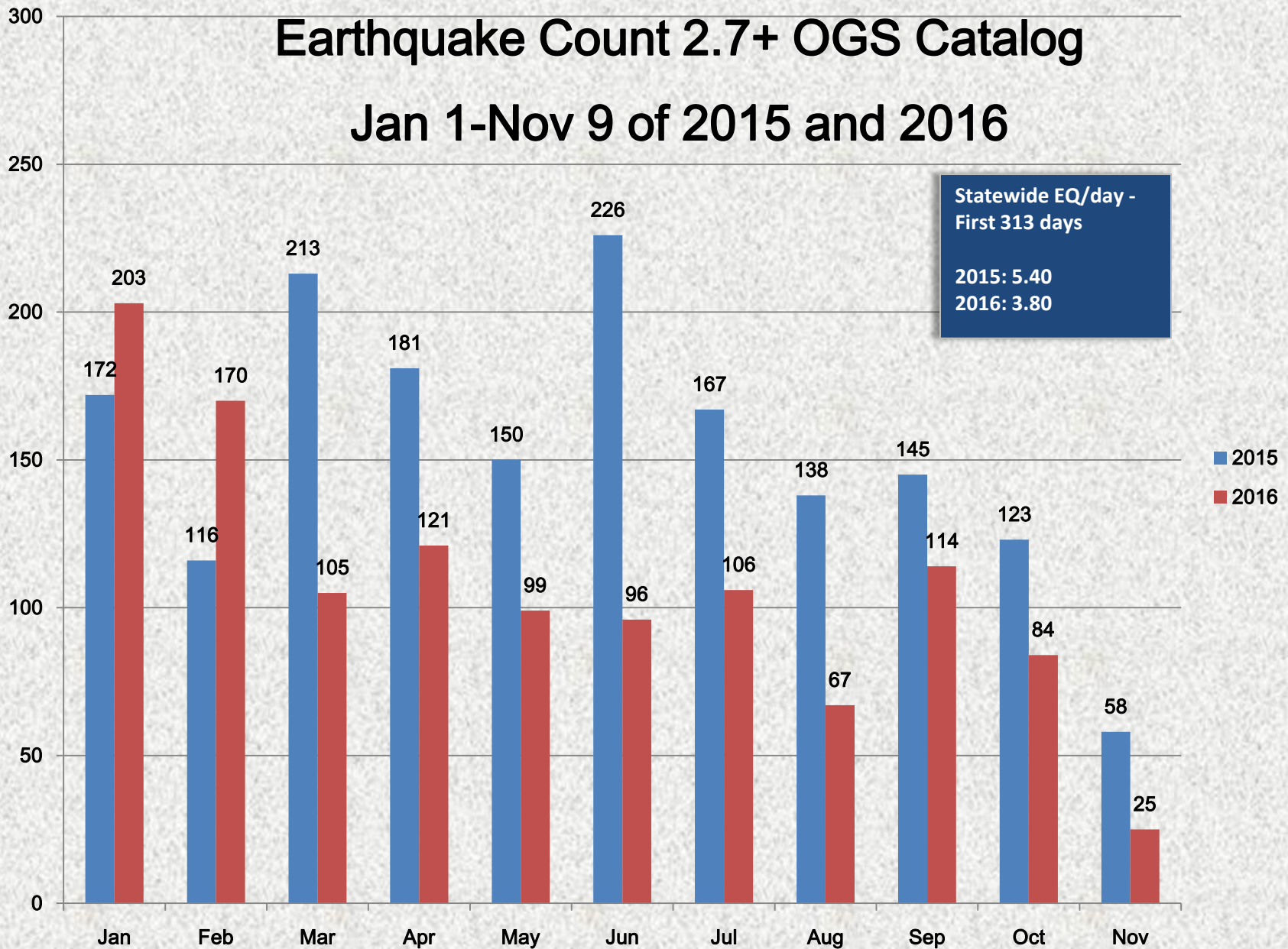
OCC WELL & SEISMIC MONITORING (O.W.S.M.)

OCC Well and Seismic Monitoring (O.W.S.M.)



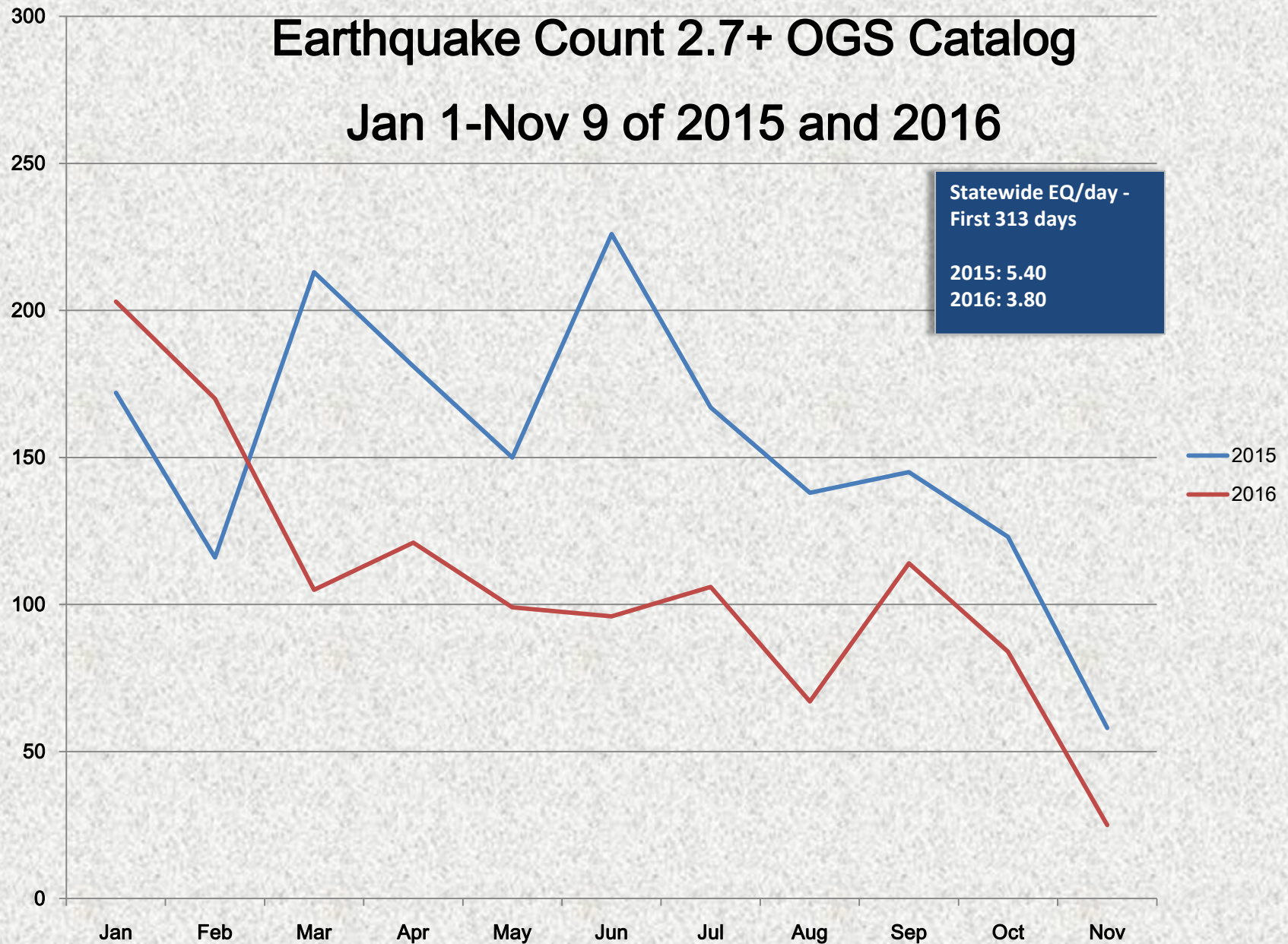
Earthquake Count 2.7+ OGS Catalog

Jan 1-Nov 9 of 2015 and 2016



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