Relationships between Geologic Zones, Produced Water, Saltwater Management, and Seismicity in Oklahoma*

Kyle E. Murray[1]

Search and Discovery Article #80519 (2016)**
Posted March 14, 2016

*Adapted from oral presentation given at AAPG-SPE Joint Forum, Reality-Based Reservoir Development: New Teams, Techniques, Technologies, Oklahoma City, Oklahoma, September 23, 2015

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Abstract

Management of produced fluids has become an important issue in Oklahoma because large volumes of saltwater are co-produced with oil and gas, and subsequently disposed into saltwater disposal (SWD) wells. Statewide (excluding Osage County) SWD volumes ranged from 800 to more than 1266 MMbbl from 2009–2014, and steadily increased at rates that mimic petroleum production from the Mississippian and Woodford zones. Much of the increase in production has occurred in central and north-central Oklahoma because of development in the Cherokee Platform and Anadarko Shelf geologic provinces. The Arbuckle Group is the main disposal zone in these geologic provinces for a number of reasons including that it is highly permeable, has a capacity to accept waste fluids, underlies the producing zones, but yet is sufficiently shallow to make completion of a SWD wells relatively inexpensive. Research indicates that earthquakes can be triggered by fluid injection near strike-slip faults that are oriented in the same manner as regional stresses, especially when high-volume SWDs are completed in basal sedimentary strata (such as the Arbuckle). Because of the confluence of these desirable conditions and confounding challenges, it is critical to investigate the physical and chemical properties of geologic materials that store and produce fluids, and to understand how regional geologic conditions affect fluid production and injection. Water and energy resources are important to the state and the nation, so best management practices must be developed to minimize co-produced water volumes and to handle the co-produced saltwater while minimizing deleterious effects

References Cited

Boyd, D.T., 2008, Stratigraphic Guide to Oklahoma Oil and Gas Reservoirs: Oklahoma Geological Survey Stratigraphic Guide, SP 2008-1.

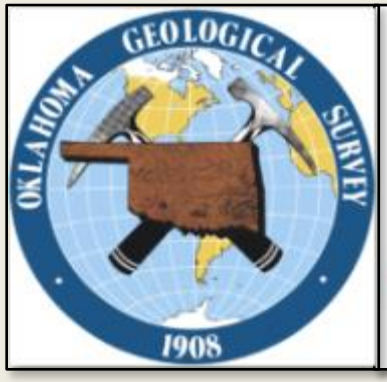
Murray, K.E., 2015, Class II Saltwater Disposal for 2009-2014 at the Annual-, State-, and County- Scales by Geologic Zones of Completion, Oklahoma: Oklahoma Geological Survey Open File Report (OF5-2015), Norman, OK, 18 p.

Murray, K.E., 2014, Class II Underground Injection Control Well Data for 2010-2013 by Geologic Zones of Completion, Oklahoma: Oklahoma Geological Survey Open File Report (OF1-2014), Norman, OK, 32 p.

Murray, K.E., 2013, State-Scale Perspective on Water Use and Production Associated with Oil and Gas Operations, Oklahoma, U.S.: Environmental Science & Technology, v. 47, p. 4918-4925.

Murray, K.E., and A.A. Holland, 2014, Inventory of Class II Underground Injection Control Volumes in the Midcontinent: Shale Shaker, v. 65/2, p. 98-106.

Northcutt, R.A., and J.A. Campbell, 1995, Geologic Provinces of Oklahoma, Oklahoma Geological Survey Open file Report OF 5-95, Map Scale: 1:750,000.



Kyle E. Murray, PhD, Hydrogeologist

Presents:

Relationships between Geologic Zones, Produced Water, Saltwater Management, and Seismicity in Oklahoma

Reality-Based Reservoir Development
AAPG Workshop

Oklahoma City, OK
September 23, 2015

Water and Energy Related Publications

Environmental Science & Technology

Article

pubs.acs.org/est

State-Scale Perspective on Water Use and Production Associated with Oil and Gas Operations, Oklahoma, U.S.

Kyle E. Murray*

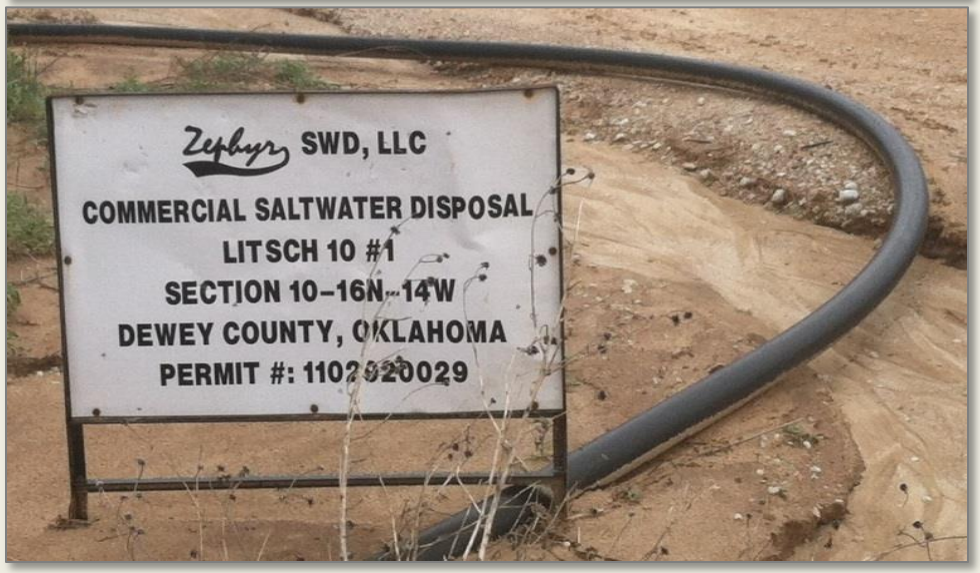
Oklahoma Geological Survey, The University of Oklahoma, 100 East Boyd Street Norman, Oklahoma 73019-0628, United States

Resource Management

Shale Shaker

By Kyle E. Murray, Oklahoma Geological Survey | kyle.murray@ou.edu; Austin A. Holland, Oklahoma Geological Survey | austin.holland@ou.edu

Inventory of Class II Underground Injection Control Volumes in the Midcontinent



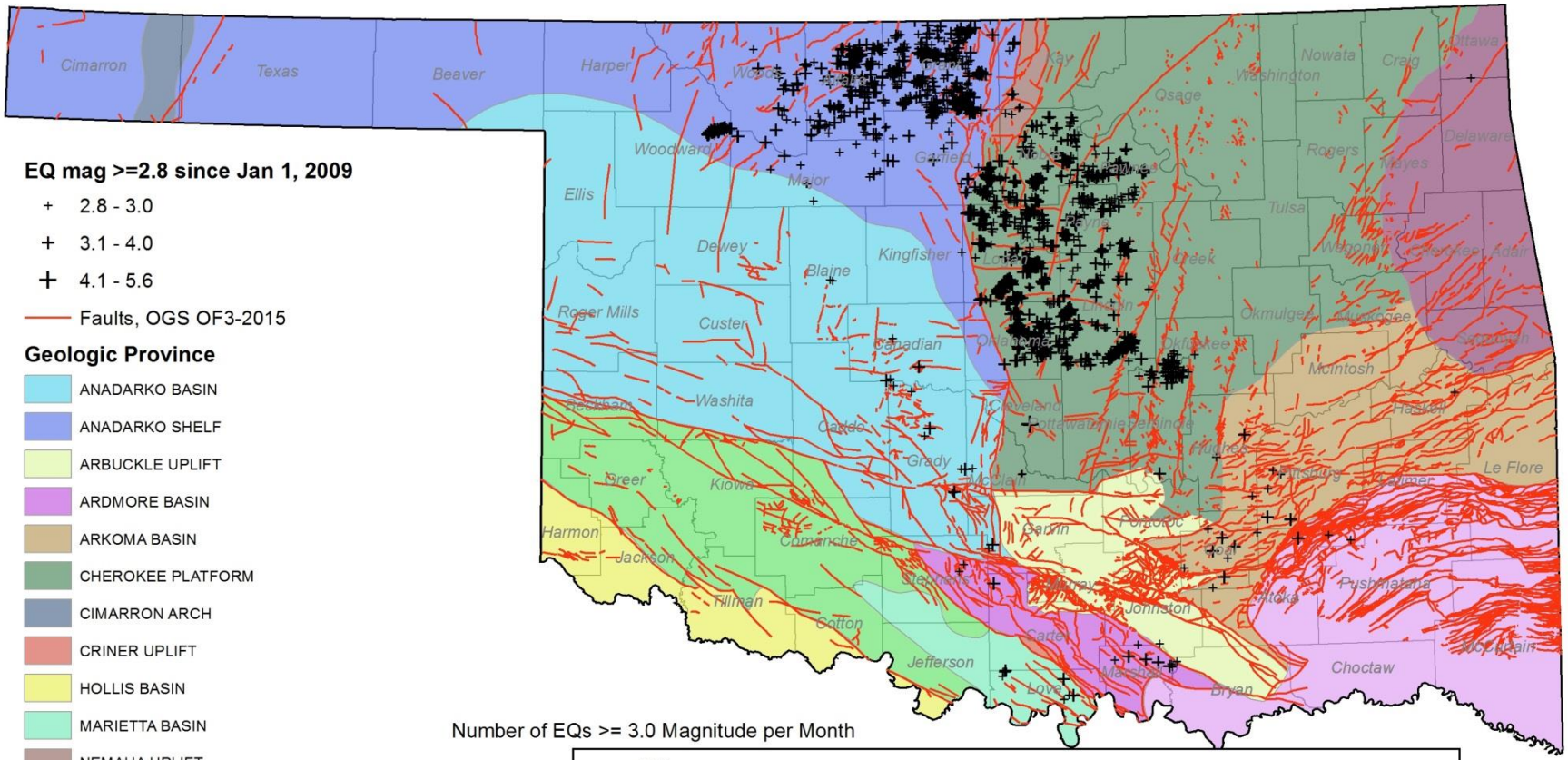
Class II Underground Injection Control Well Data for 2010–2013 by Geologic Zones of Completion, Oklahoma

Open-File Report (OF1-2014)

Kyle E. Murray

Oklahoma Geological Survey
University of Oklahoma
100 East Boyd Street
Norman, OK 73019

Map of Earthquakes Mag >=2.8 since Jan 1, 2009



EQ mag >=2.8 since Jan 1, 2009

- \+ 2.8 - 3.0
- \+ 3.1 - 4.0
- \+ 4.1 - 5.6
- Faults, OGS OF3-2015

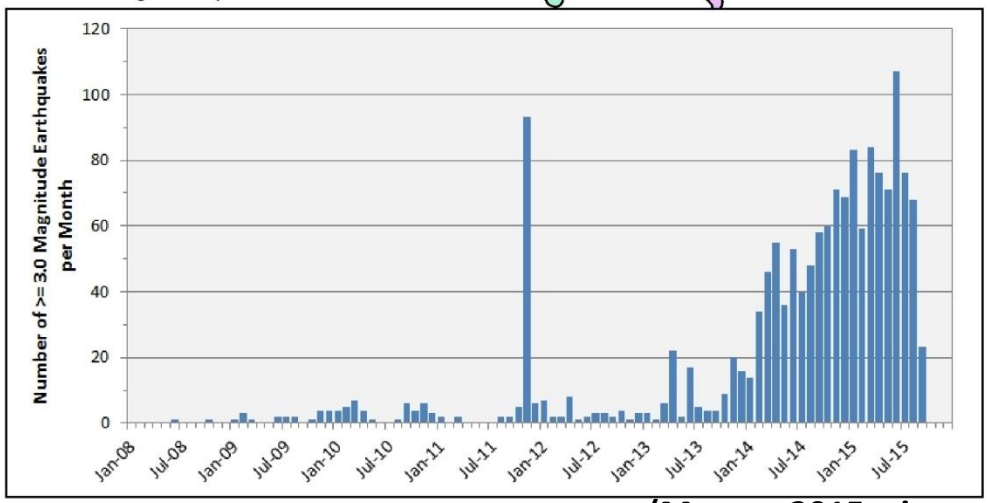
Geologic Province

- ANADARKO BASIN
- ANADARKO SHELF
- ARBUCKLE UPLIFT
- ARDMORE BASIN
- ARKOMA BASIN
- CHEROKEE PLATFORM
- CIMARRON ARCH
- CRINER UPLIFT
- HOLLIS BASIN
- MARIETTA BASIN
- NEMAHA UPLIFT
- OUACHITA MOUNTAINS UPLIFT
- OZARK UPLIFT
- WICHITA UPLIFT
- County

Prepared by:
Kyle E. Murray
OGS Hydrogeologist

30 15 0 30 Miles

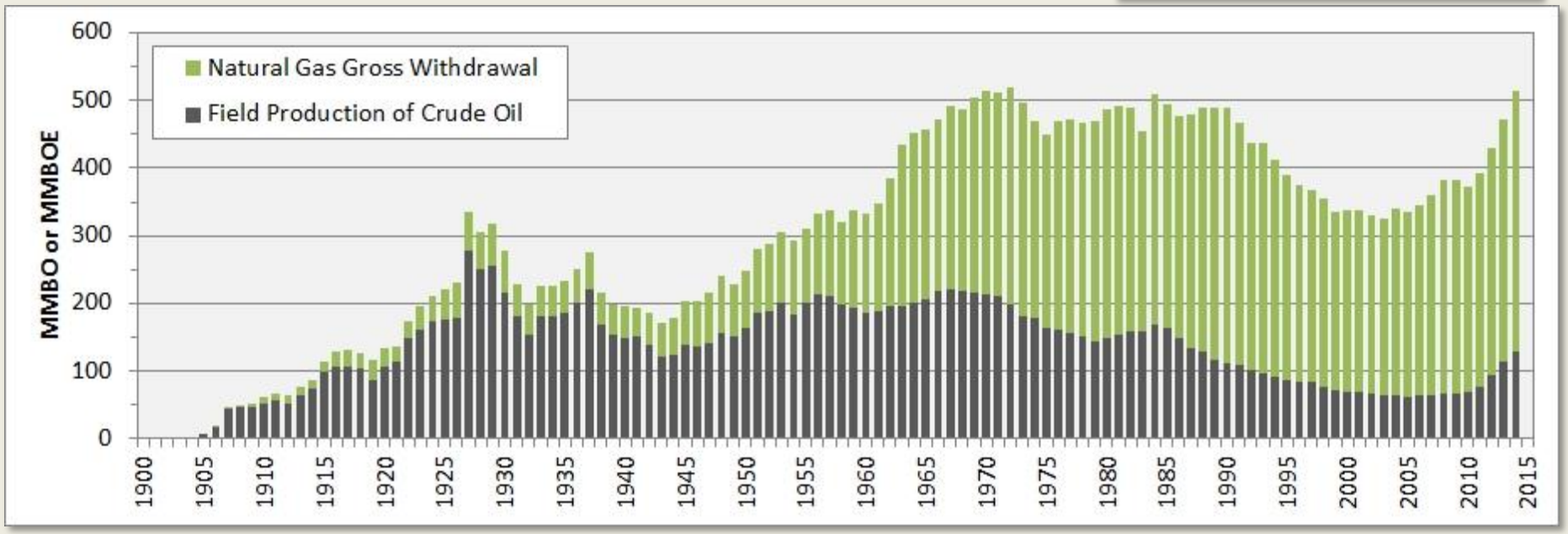
Number of EQs >= 3.0 Magnitude per Month



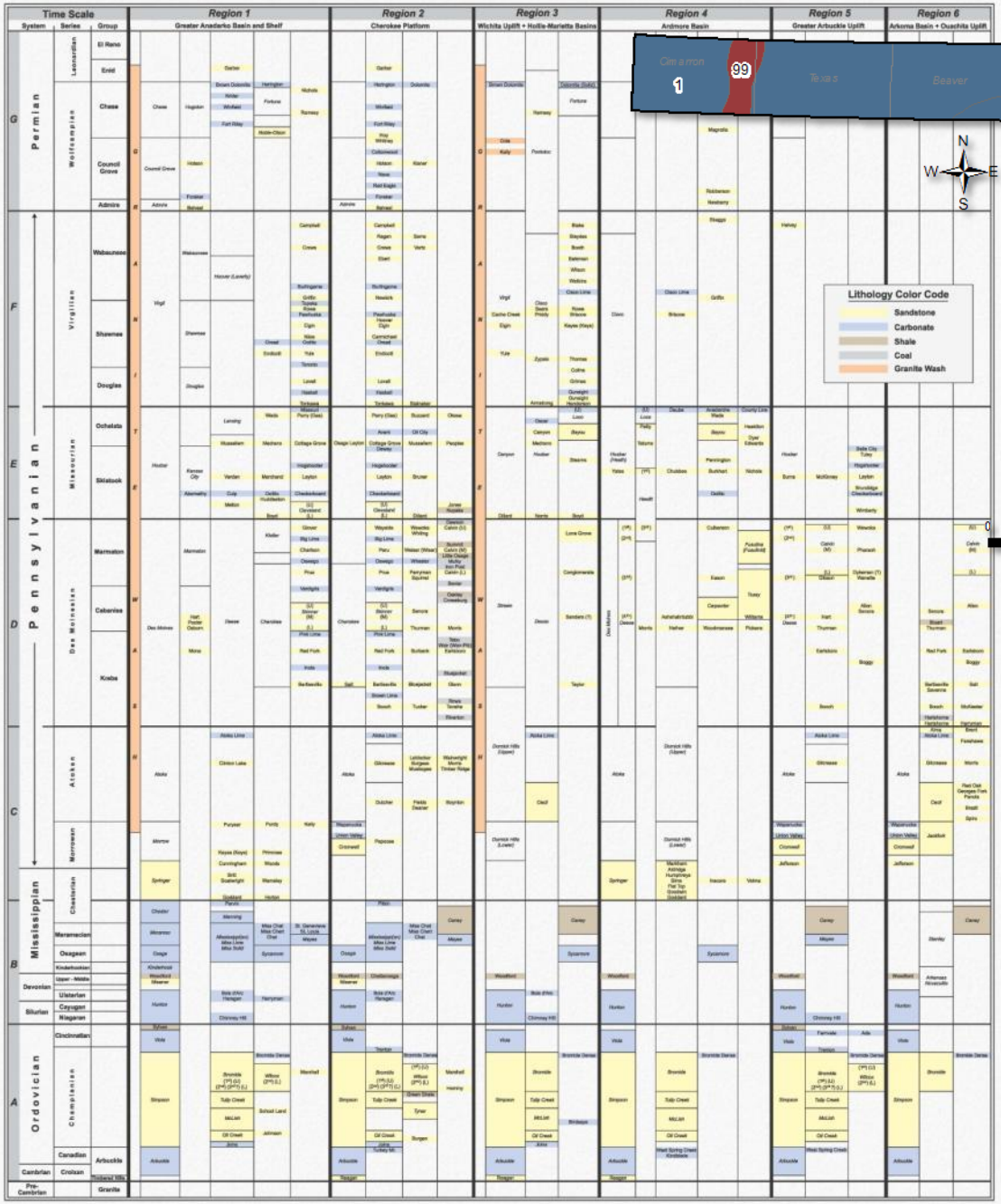
(Murray, 2015 – in preparation)

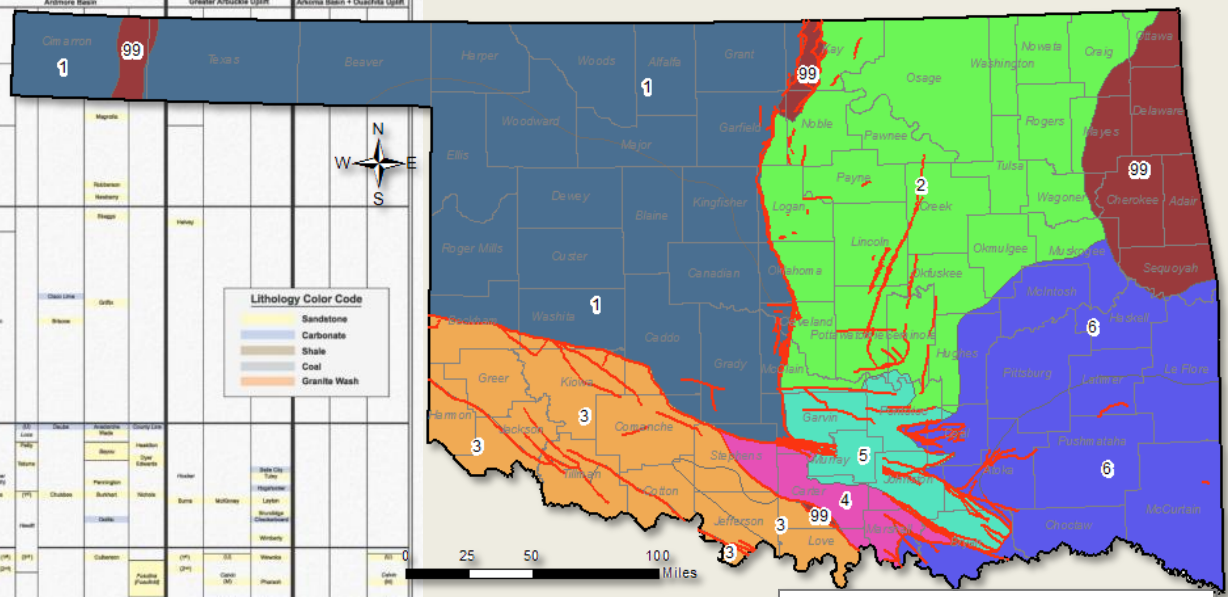
History of Oil and Gas Production for Oklahoma

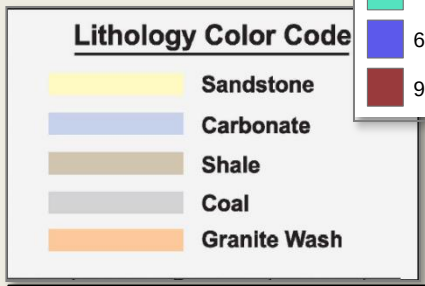
- More than 100 years of oil and gas production
- Peak oil prod. of ~270 MMBO in 1927
- Peak gas prod. of ~376–399 MMBOE in 1990
- Oil production of ~128 MMBO in 2014
- Gas production of ~385 MMBOE in 2014



Geologic Provinces, Formations and Production Zones in Oklahoma





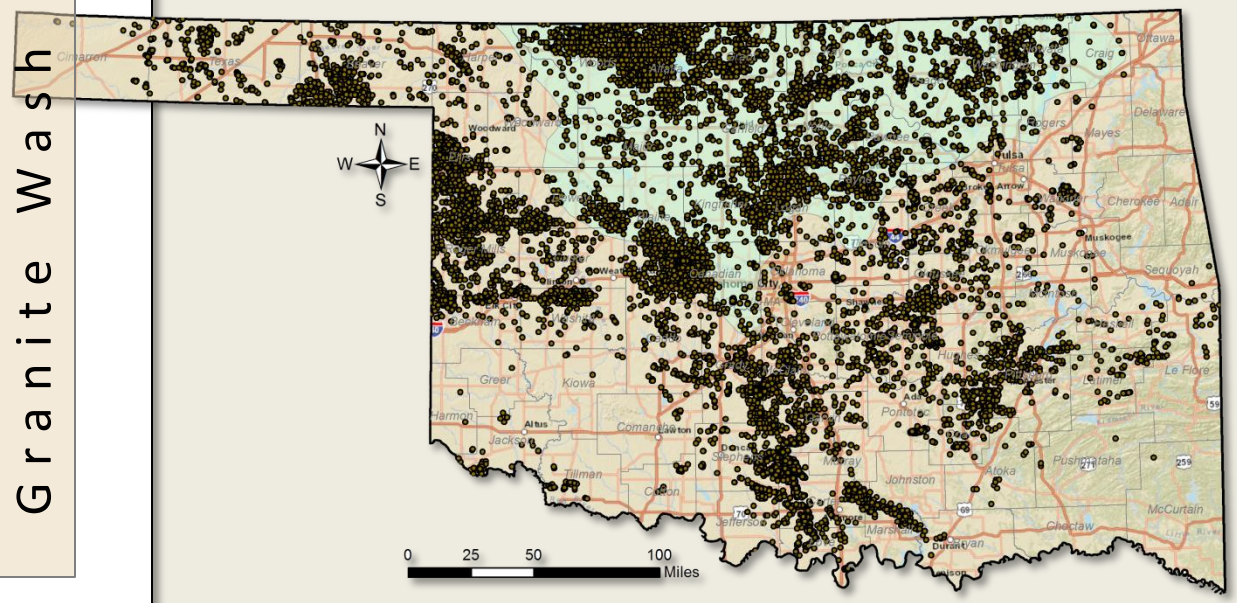


Geologic Provinces from OGS: Northcutt and Campbell (1995)
SP2008-1 Stratigraphic Guide from OGS: Boyd (2008)

Zones of Exploration & Production (E&P)

Zone	Group	Formation
Permian		Garber
	Chase	Brown Dolomite
	Council Grove	Pontotoc
	Admire	Belveal
Virgilian	Wabaunsee	Cisco Lime
	Shawnee	Pawhuska
		Endicott
	Douglas	Tonkawa
Missourian	Hoxbar	Lansing
		Cottage Grove
		Kansas City
		Hogshooter
		Layton
		Cleveland
Desmoinesian	Marmaton	Oswego
	Cabaniss	Skinner
	Krebs	Red Fork
		Burbank
		Bartlesville
		Hartshorne
Atokan-Morrowan	Atoka	Gilcrease
		Dutcher
	Morrow	Cromwell
	Springer	Wamsley
Mississippian	Chester	Manning
		Caney
	Meramec	Miss Lime
		Miss Chat
		St. Louis
		Mayes
	Osage	Sycamore
	Kinderhook	Kinderhook
Woodford	Upper Devonian	Woodford
Dev to Mid Ord	Middle Devonian	Misener
	Lower Dev - Silurian	Hunton
	Cincinnatian	Sylvan
		Viola
	Simpson	Bromide
		Wilcox
		McLish
		Oil Creek
Arbuckle	Arbuckle Group	West Spring Creek
		Kindblade
		Butterly Dolomite
Basement & Crystalline Rock	Cambrian	Reagan
	Pre-Cambrian	Granite

Granite Wash

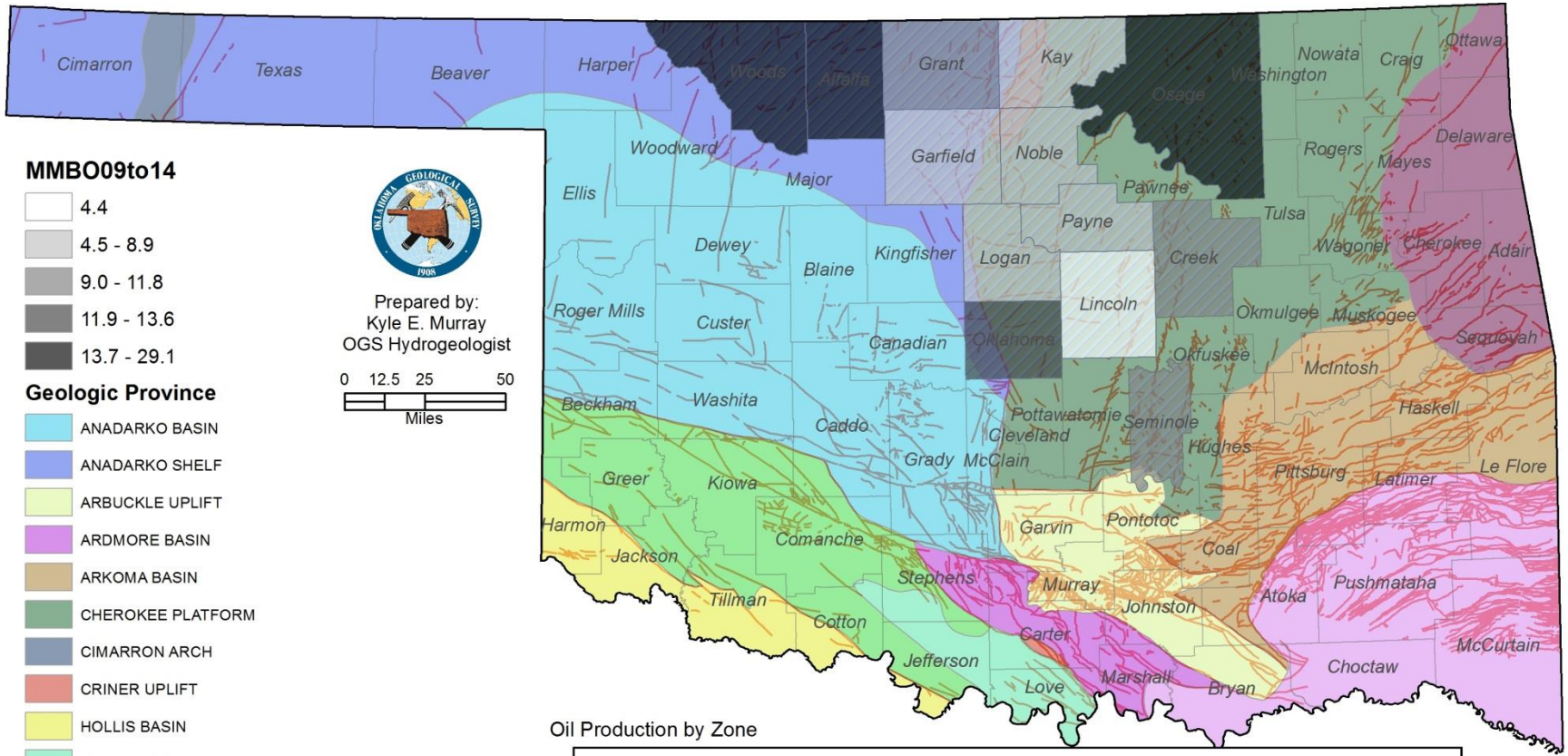


O&G Wells Completed (2010 – May 2014)

Key to Symbols
Sandstone
Carbonate
Shale
Coal
Granite

OKCGS Shale Shaker
(Murray and Holland, 2014)

Oil Production by Zone for 13 Study Area Counties, 2009–2014



MMBO09to14

- 4.4
- 4.5 - 8.9
- 9.0 - 11.8
- 11.9 - 13.6
- 13.7 - 29.1

Geologic Province

- ANADARKO BASIN
- ANADARKO SHELF
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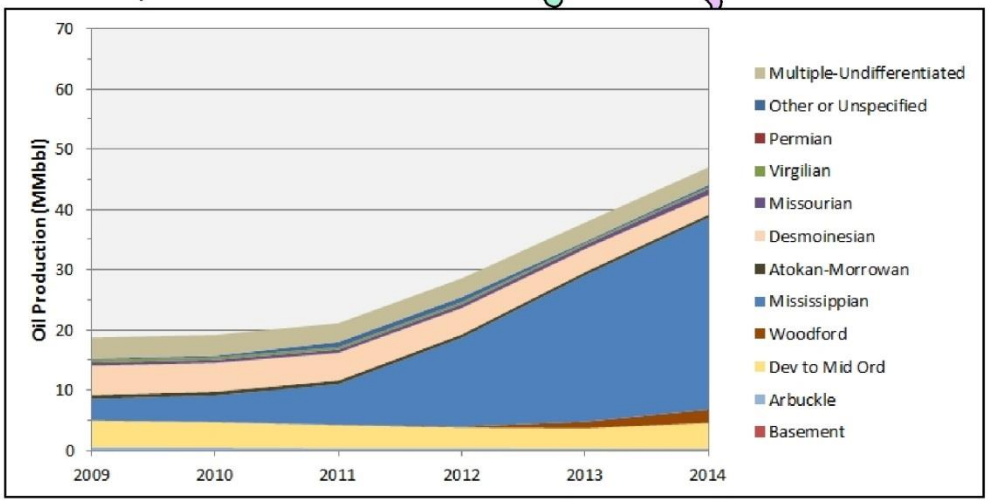
- OZARK UPLIFT
- WICHITA UPLIFT
- Faults, OGS OF3-2015

Prepared by:
Kyle E. Murray
OGS Hydrogeologist

0 12.5 25 50
Miles

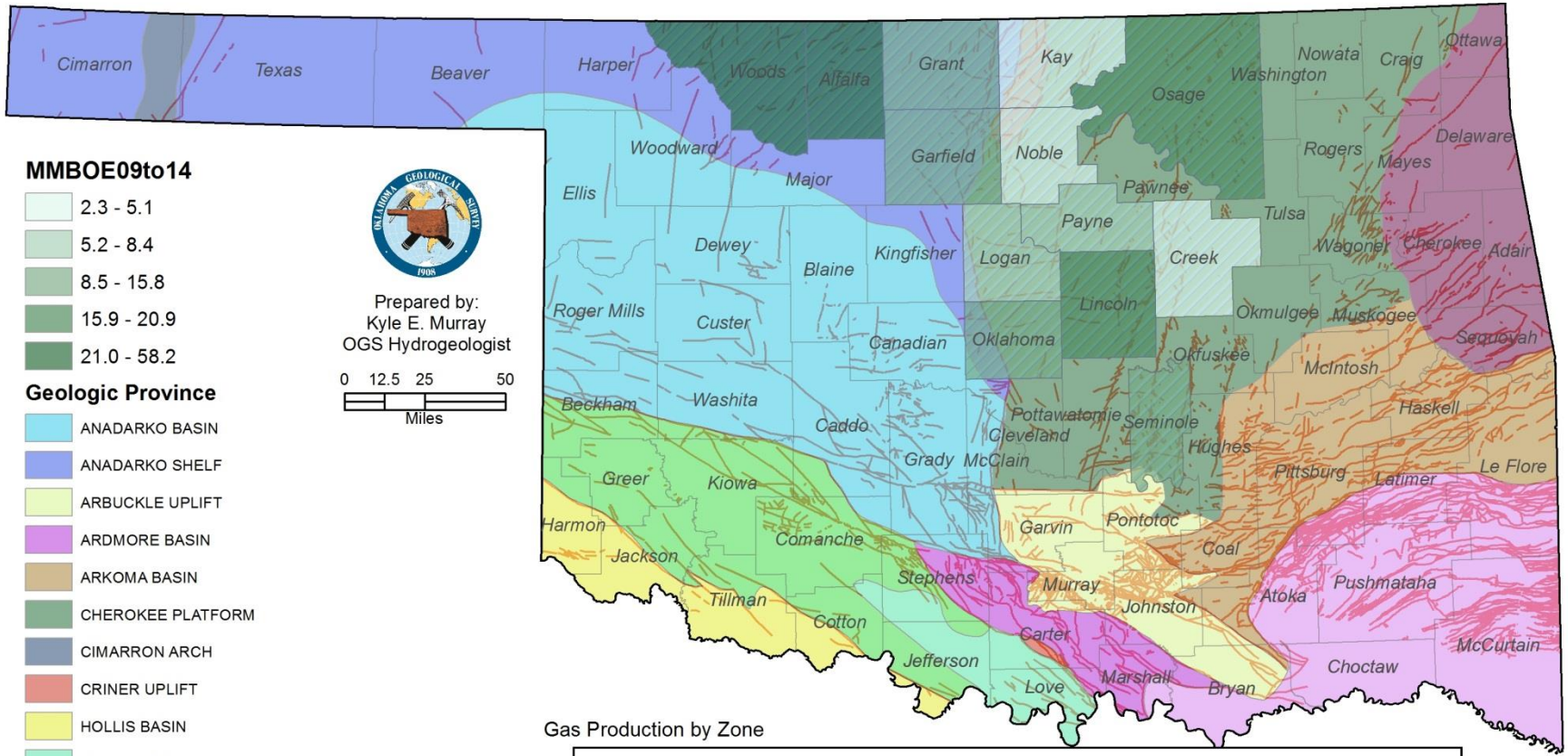
Oil Production by Zone



Compiled from:
Lasser Production Database

N

Gas Production by Zone for 13 Study Area Counties, 2009–2014



MMBOE09to14

- 2.3 - 5.1
- 5.2 - 8.4
- 8.5 - 15.8
- 15.9 - 20.9
- 21.0 - 58.2

Geologic Province

- ANADARKO BASIN
- ANADARKO SHELF
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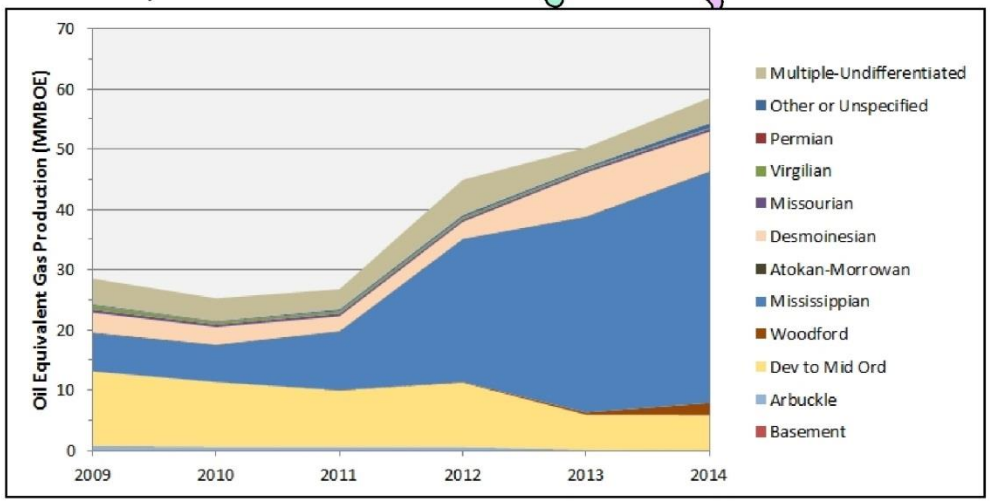
0 12.5 25 50
Miles

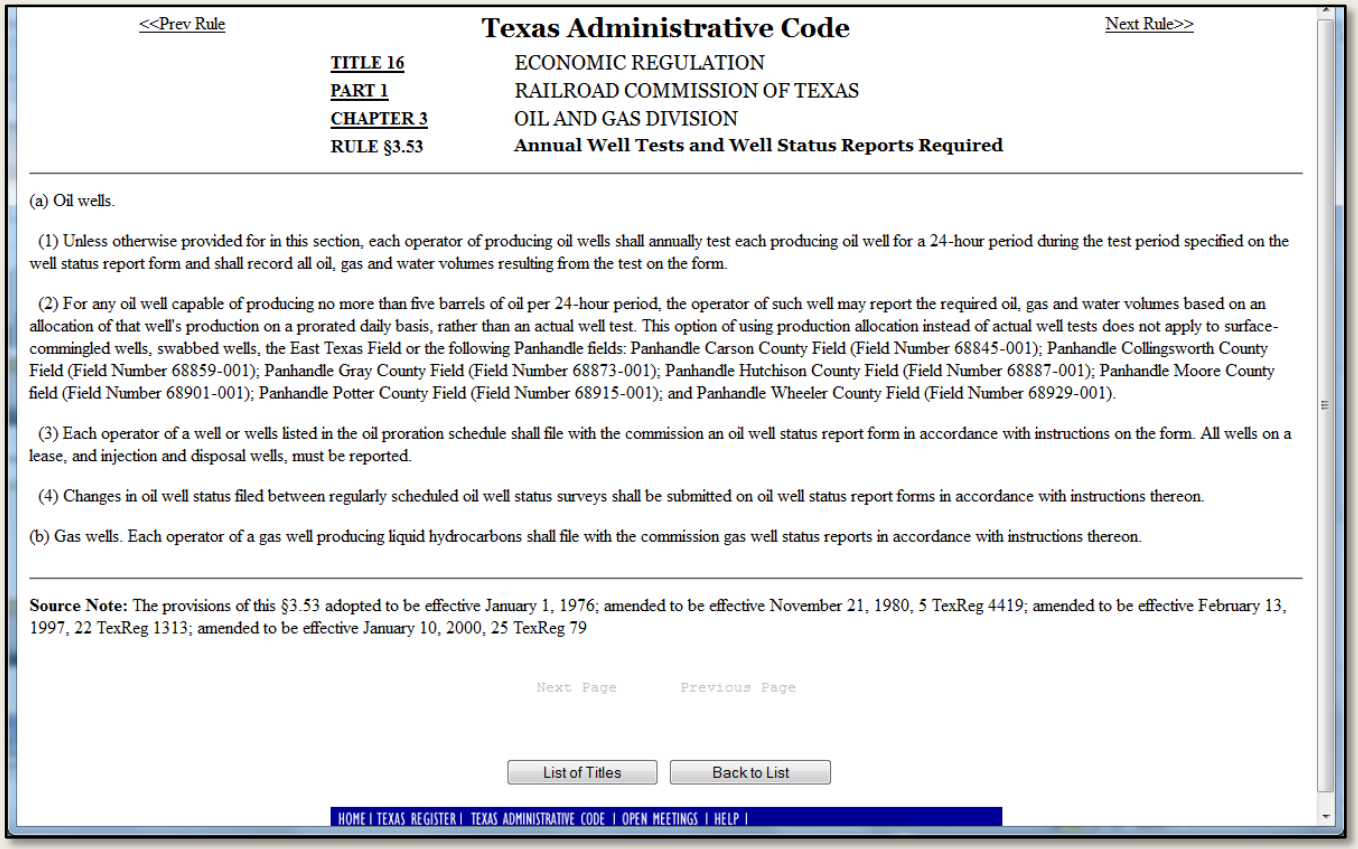
Gas Production by Zone



Compiled from:
Lasser Production Database

Reporting Volume of Produced Water in the Mid-continent?

Kansas: not required to report produced water volumes
Oklahoma: not required to report produced water volumes
Texas: required to report produced water volumes annually to TX Railroad Commission



<<Prev Rule

Texas Administrative Code

Next Rule>>

TITLE 16	ECONOMIC REGULATION
PART 1	RAILROAD COMMISSION OF TEXAS
CHAPTER 3	OIL AND GAS DIVISION
RULE §3.53	**Annual Well Tests and Well Status Reports Required**

(a) Oil wells.

(1) Unless otherwise provided for in this section, each operator of producing oil wells shall annually test each producing oil well for a 24-hour period during the test period specified on the well status report form and shall record all oil, gas and water volumes resulting from the test on the form.

(2) For any oil well capable of producing no more than five barrels of oil per 24-hour period, the operator of such well may report the required oil, gas and water volumes based on an allocation of that well's production on a prorated daily basis, rather than an actual well test. This option of using production allocation instead of actual well tests does not apply to surface-commingled wells, swabbed wells, the East Texas Field or the following Panhandle fields: Panhandle Carson County Field (Field Number 68845-001); Panhandle Collingsworth County Field (Field Number 68859-001); Panhandle Gray County Field (Field Number 68873-001); Panhandle Hutchison County Field (Field Number 68887-001); Panhandle Moore County field (Field Number 68901-001); Panhandle Potter County Field (Field Number 68915-001); and Panhandle Wheeler County Field (Field Number 68929-001).

(3) Each operator of a well or wells listed in the oil proration schedule shall file with the commission an oil well status report form in accordance with instructions on the form. All wells on a lease, and injection and disposal wells, must be reported.

(4) Changes in oil well status filed between regularly scheduled oil well status surveys shall be submitted on oil well status report forms in accordance with instructions thereon.

(b) Gas wells. Each operator of a gas well producing liquid hydrocarbons shall file with the commission gas well status reports in accordance with instructions thereon.

Source Note: The provisions of this §3.53 adopted to be effective January 1, 1976; amended to be effective November 21, 1980, 5 TexReg 4419; amended to be effective February 13, 1997, 22 TexReg 1313; amended to be effective January 10, 2000, 25 TexReg 79

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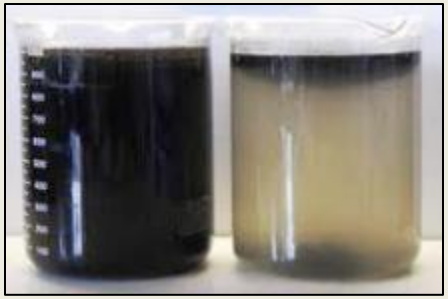
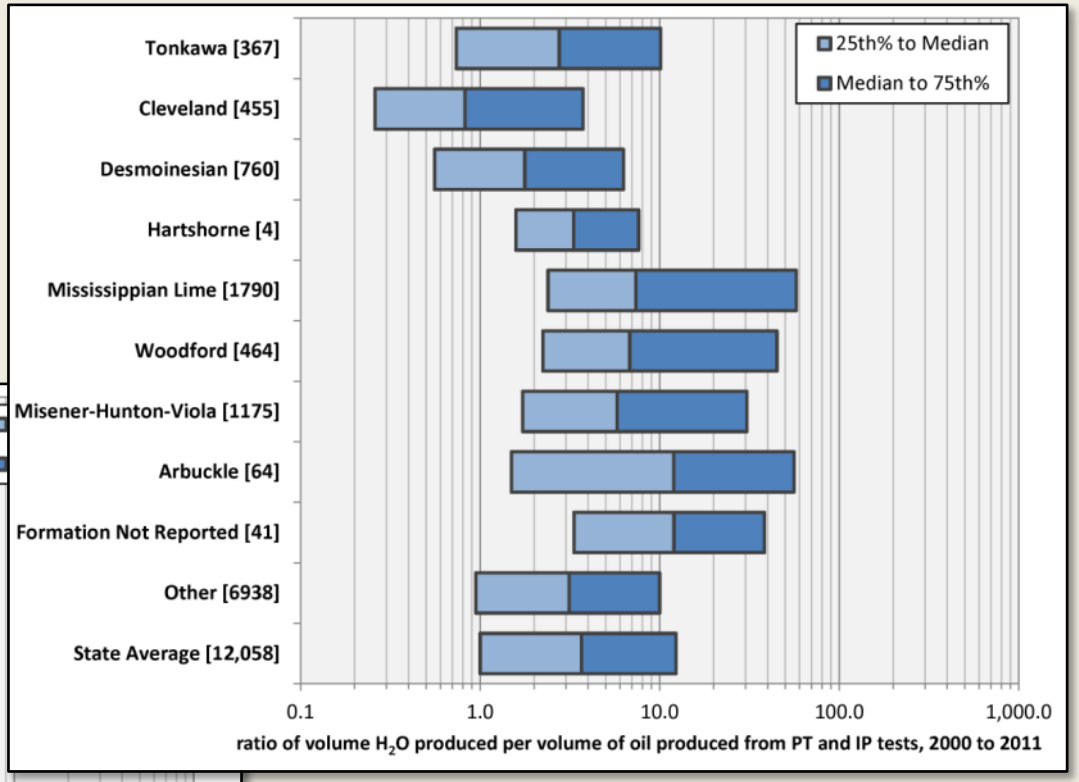
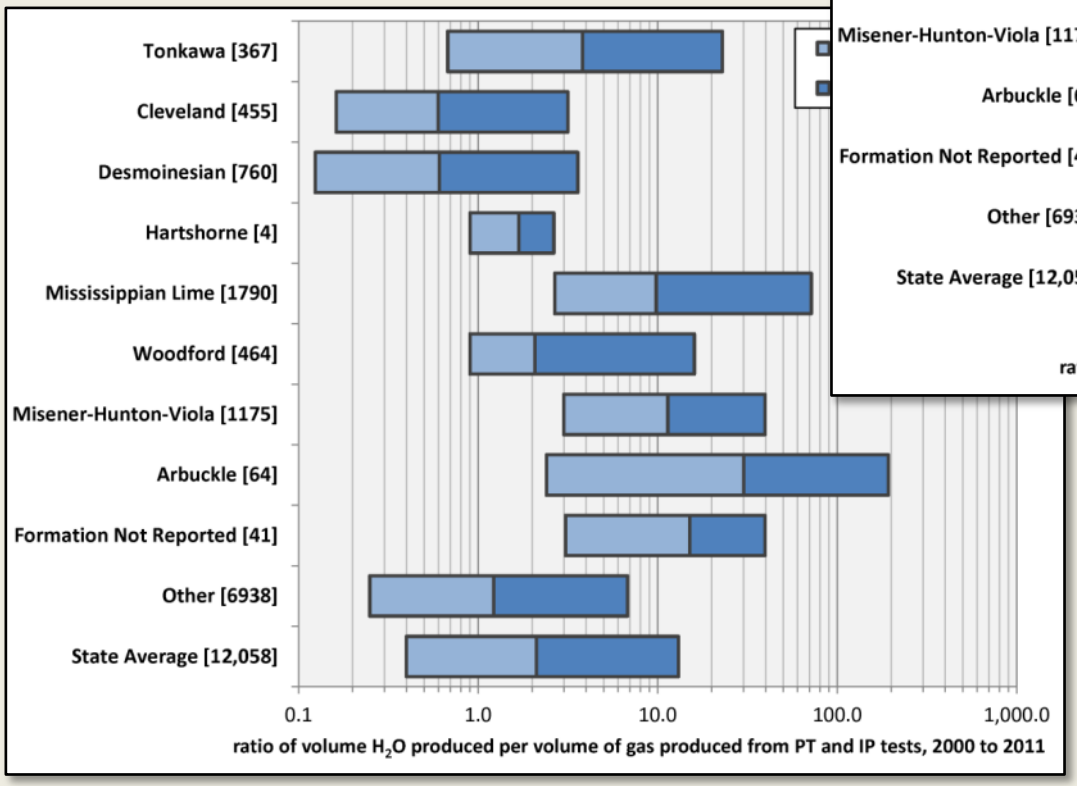
From 2000-2011, newly completed wells in OK's Mississippian averaged:

- **7.4 bbl of H_2O produced for 1 bbl of oil**
- **9.8 bbl of H_2O produced for 1 bbl oil equivalent gas**

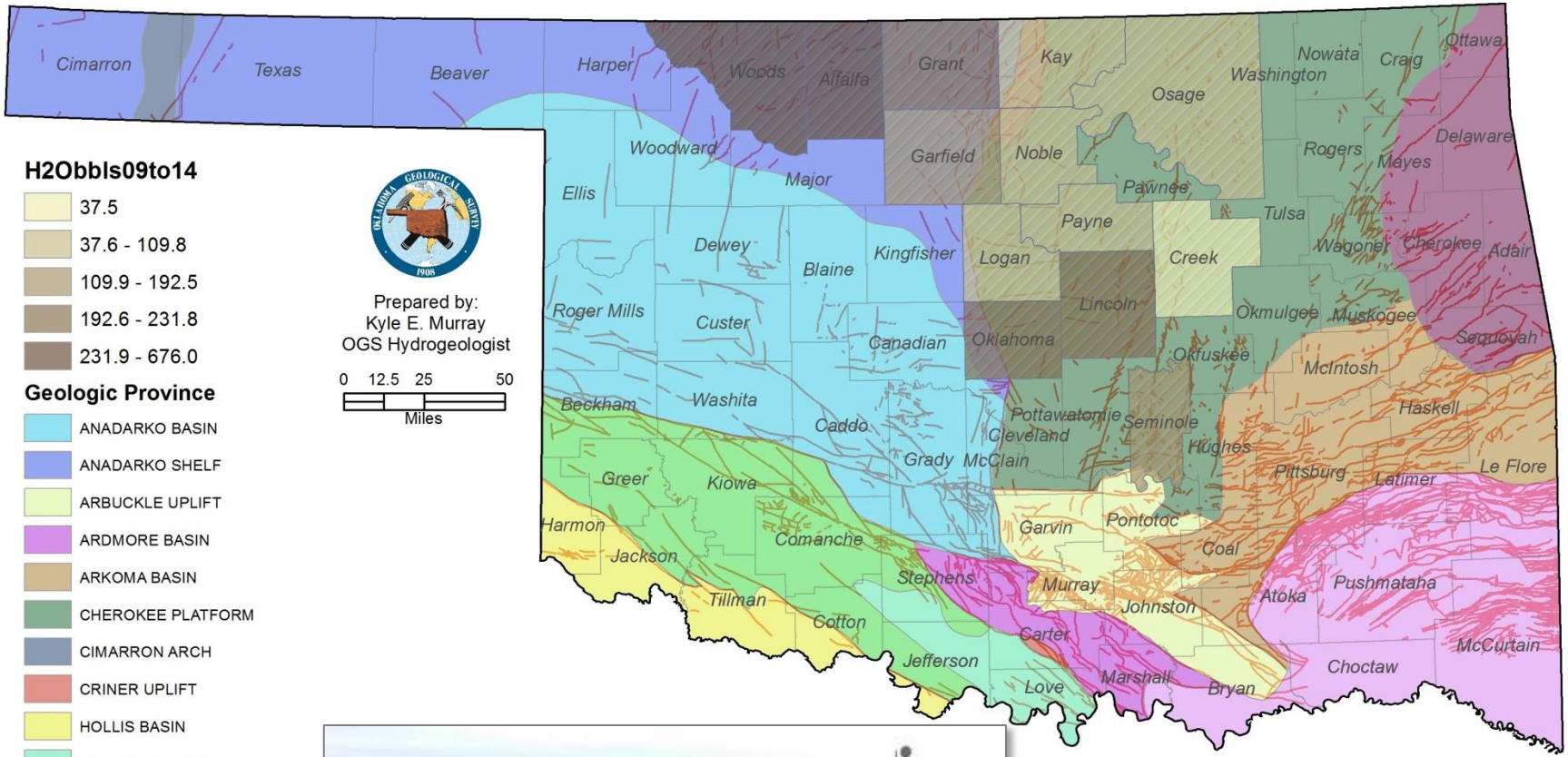






(Murray, 2013)

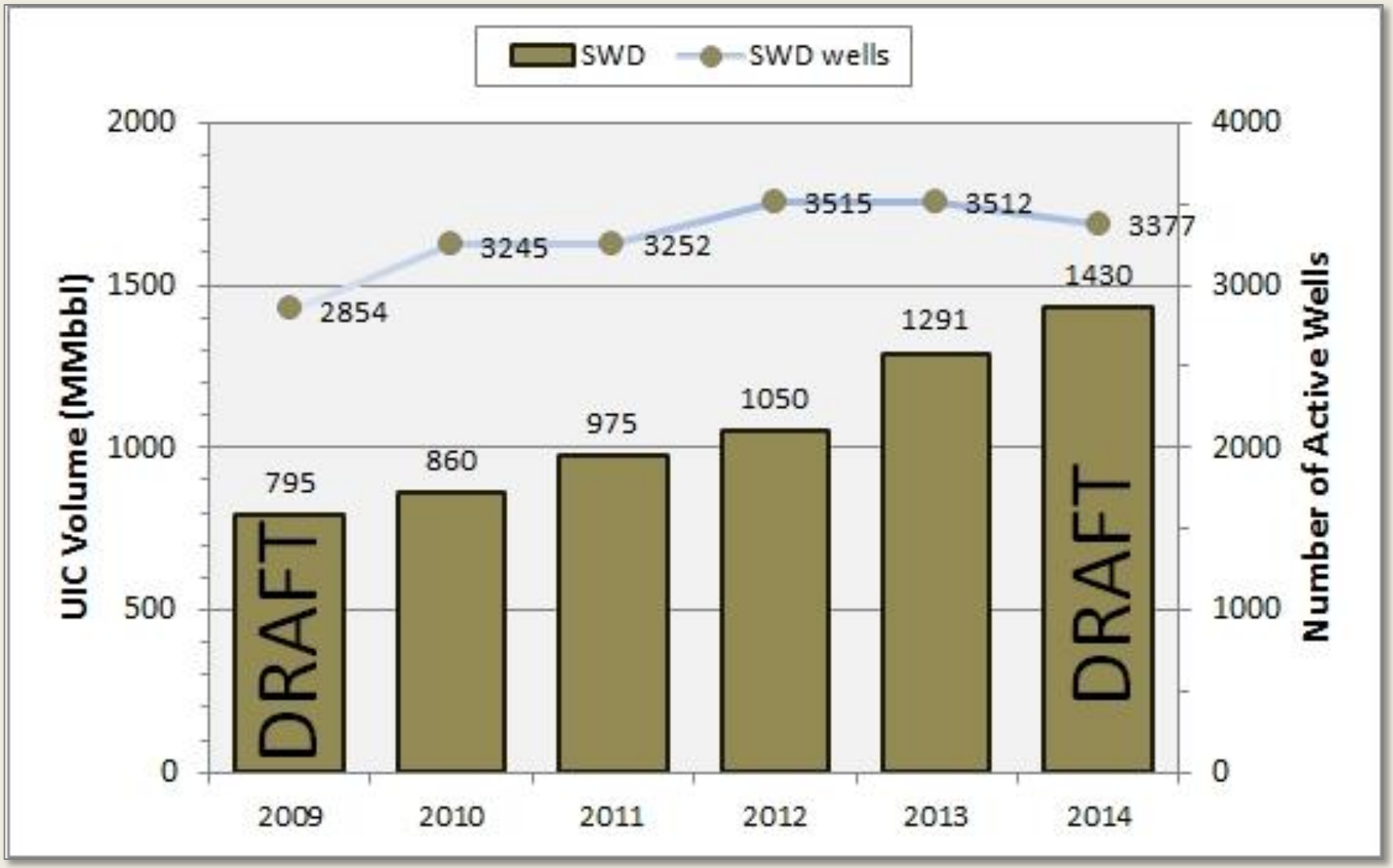
Est. H2O Production for 13 Study Area Counties, 2009–2014



What do we do with the co-produced saltwater?

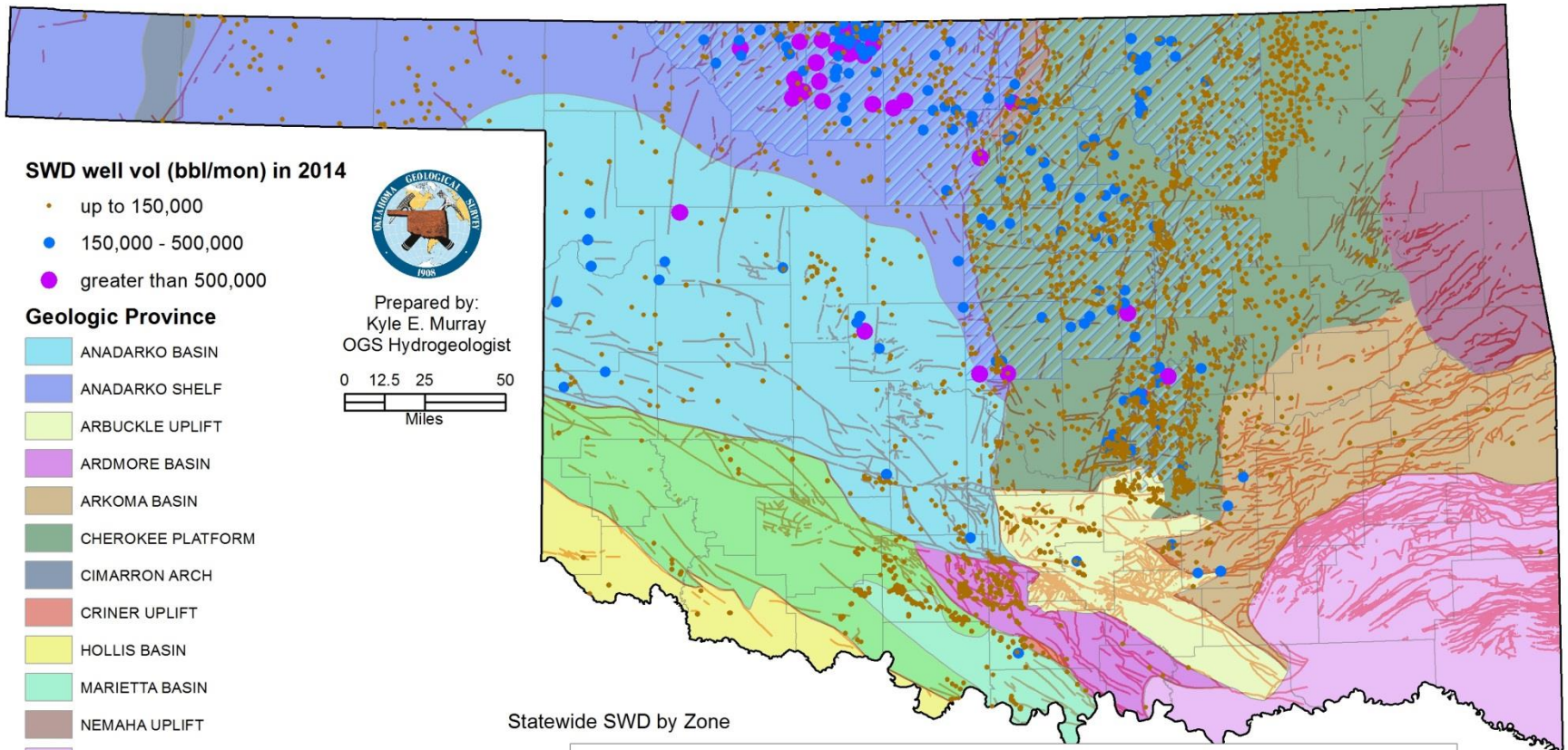
SaltWater Disposal (SWD) Wells

Statewide annual SWD volumes versus time

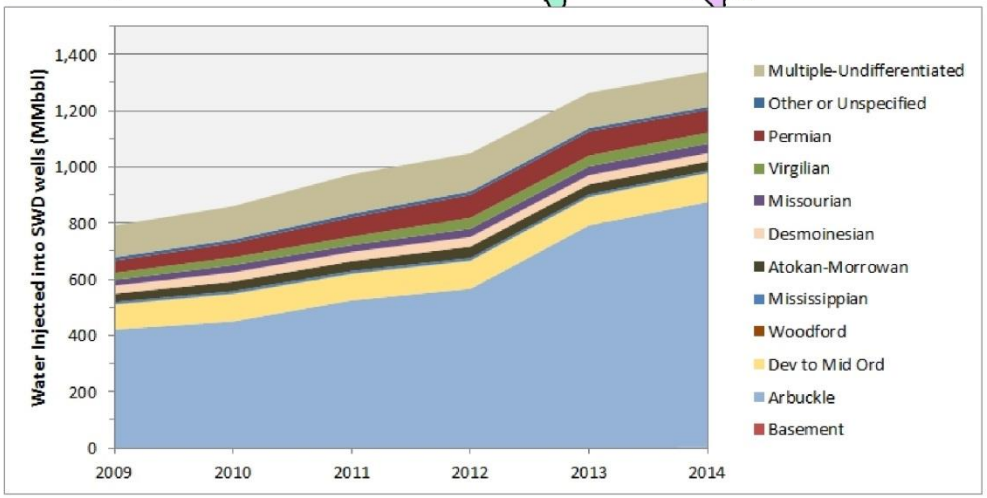


(Murray, 2015 – in preparation)

Map of SWD Class II UIC wells, chart of SWD vols by county

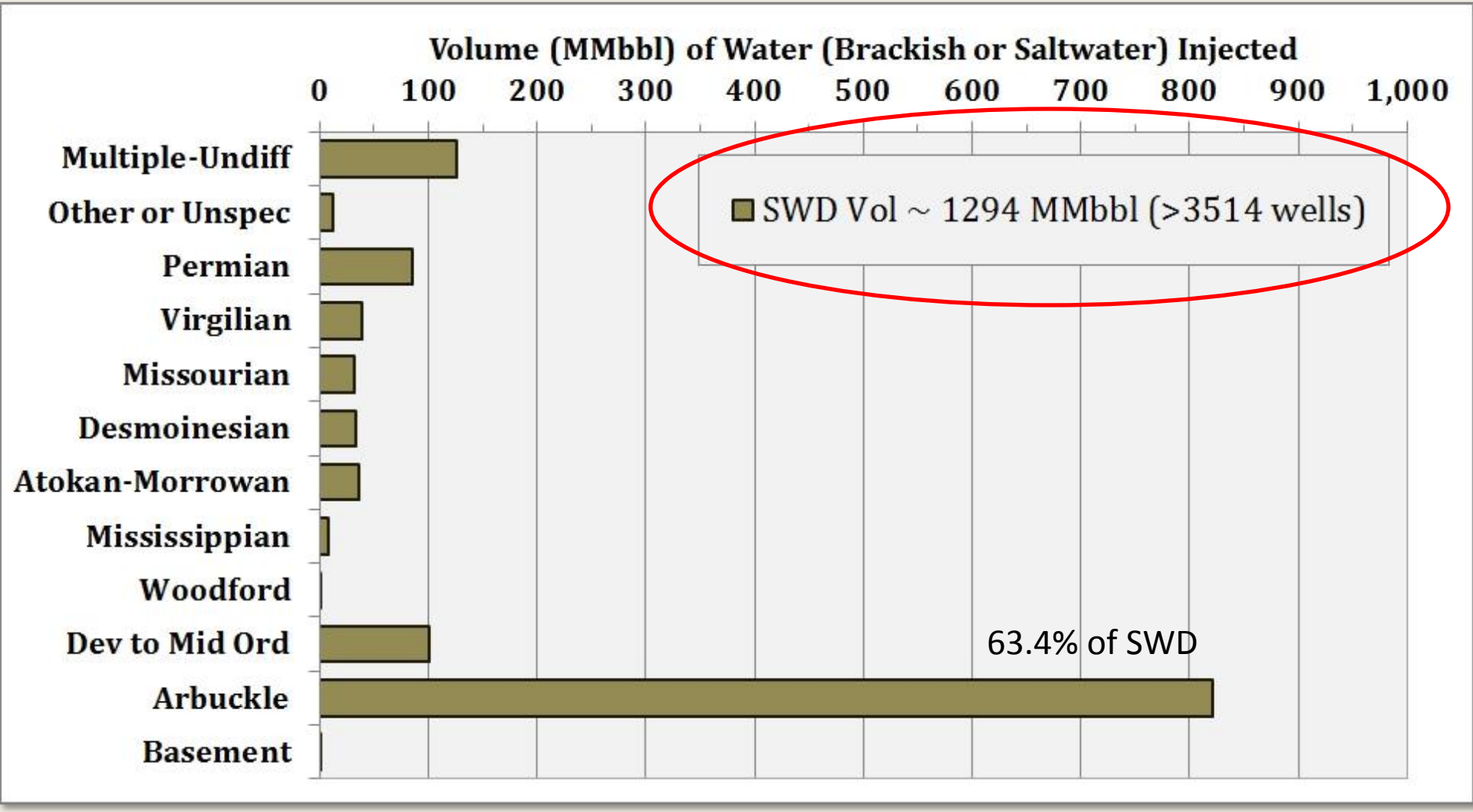


Statewide SWD by Zone



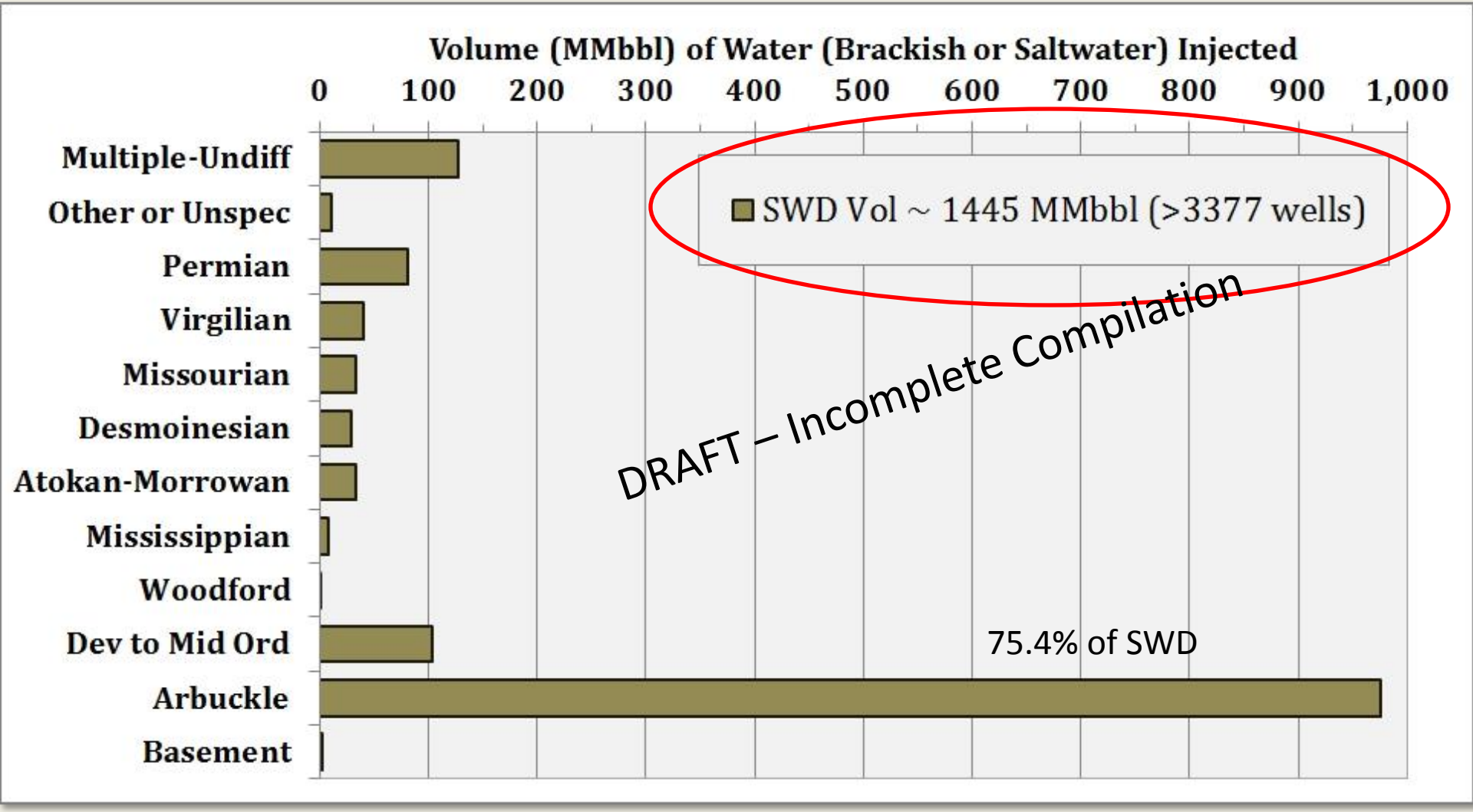
(Murray, 2015 – in preparation)

SWD Volumes during 2013 by Geologic Zone of Completion



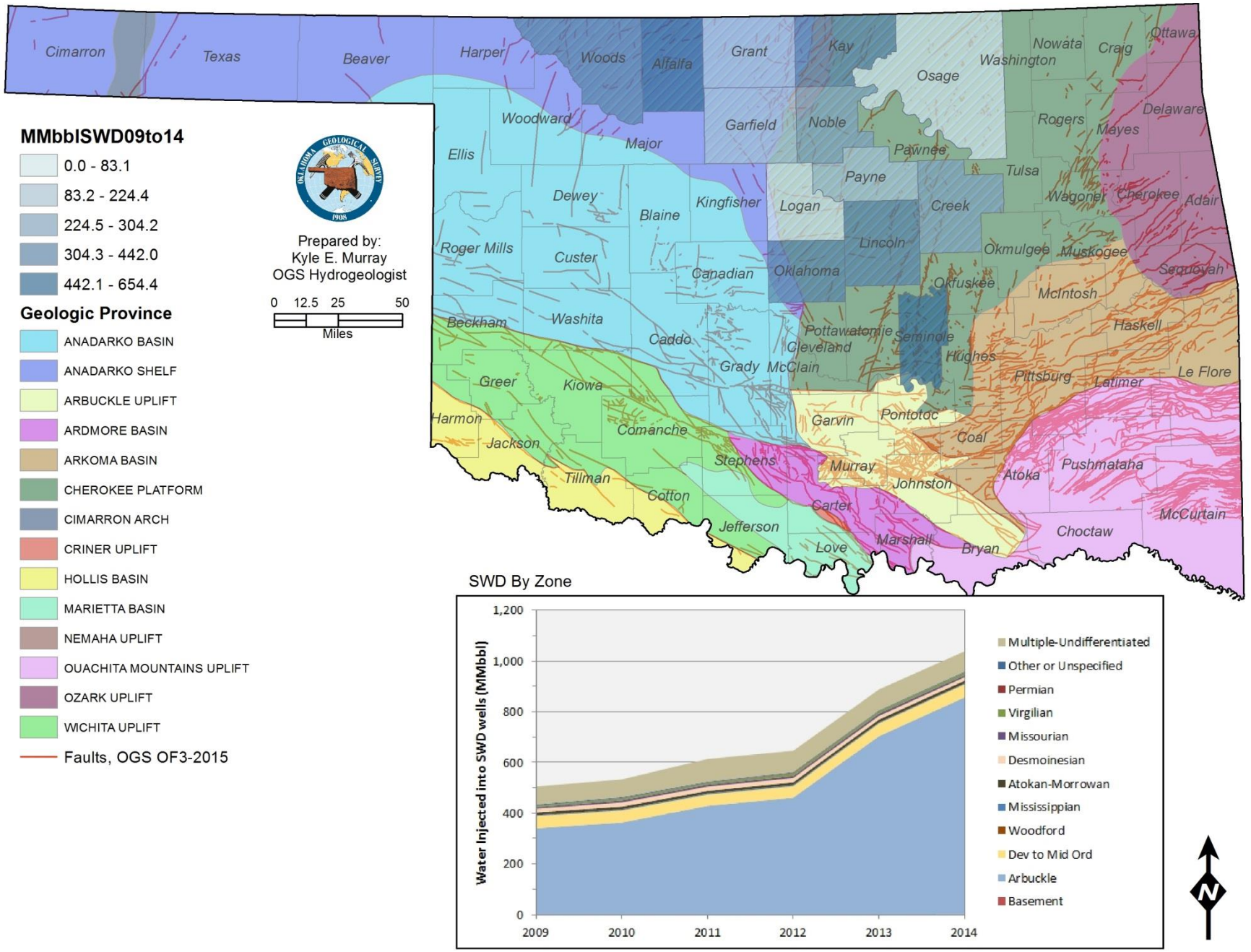
(Murray, 2015 – in preparation)

SWD Volumes during 2014 by Geologic Zone of Completion

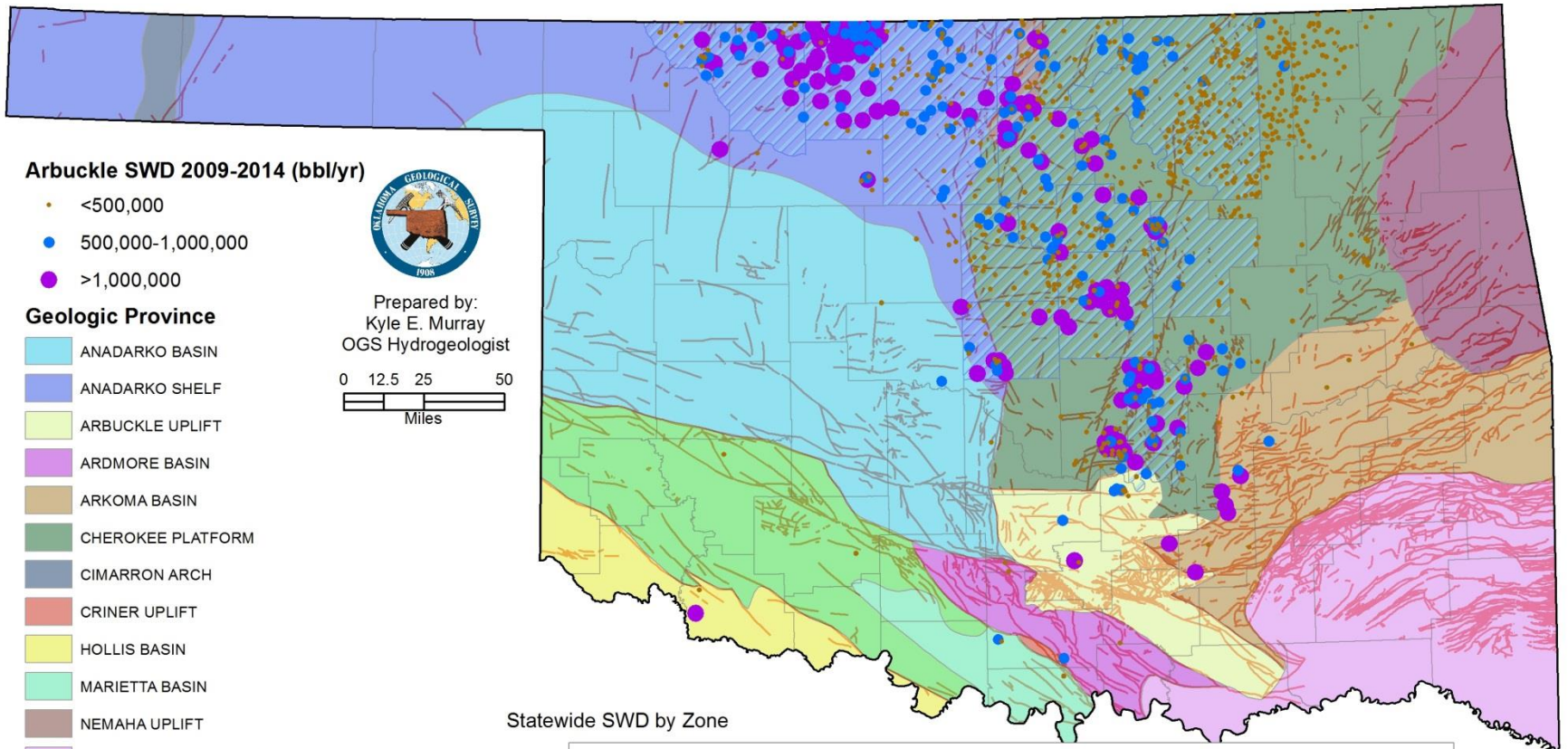


(Murray, 2015 – in preparation)

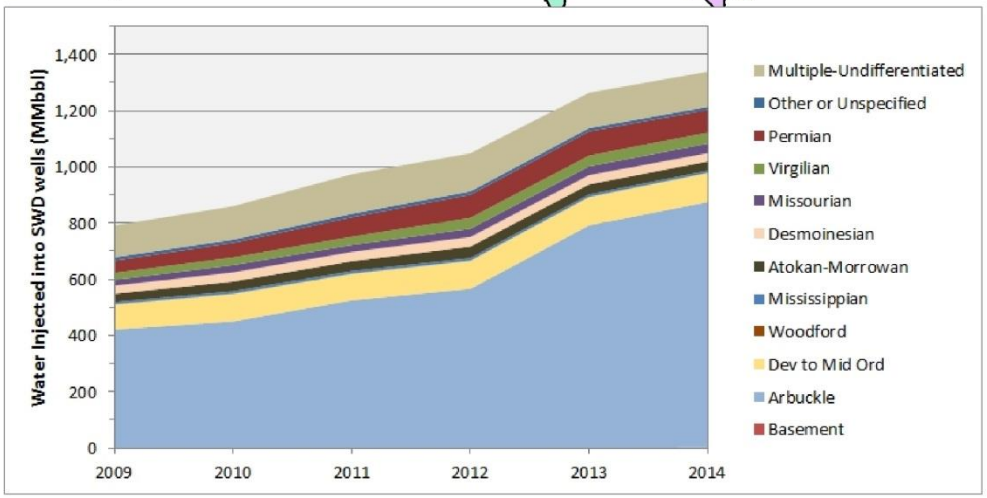
SWD by Zone for 13 Study Area Counties, 2009–2014



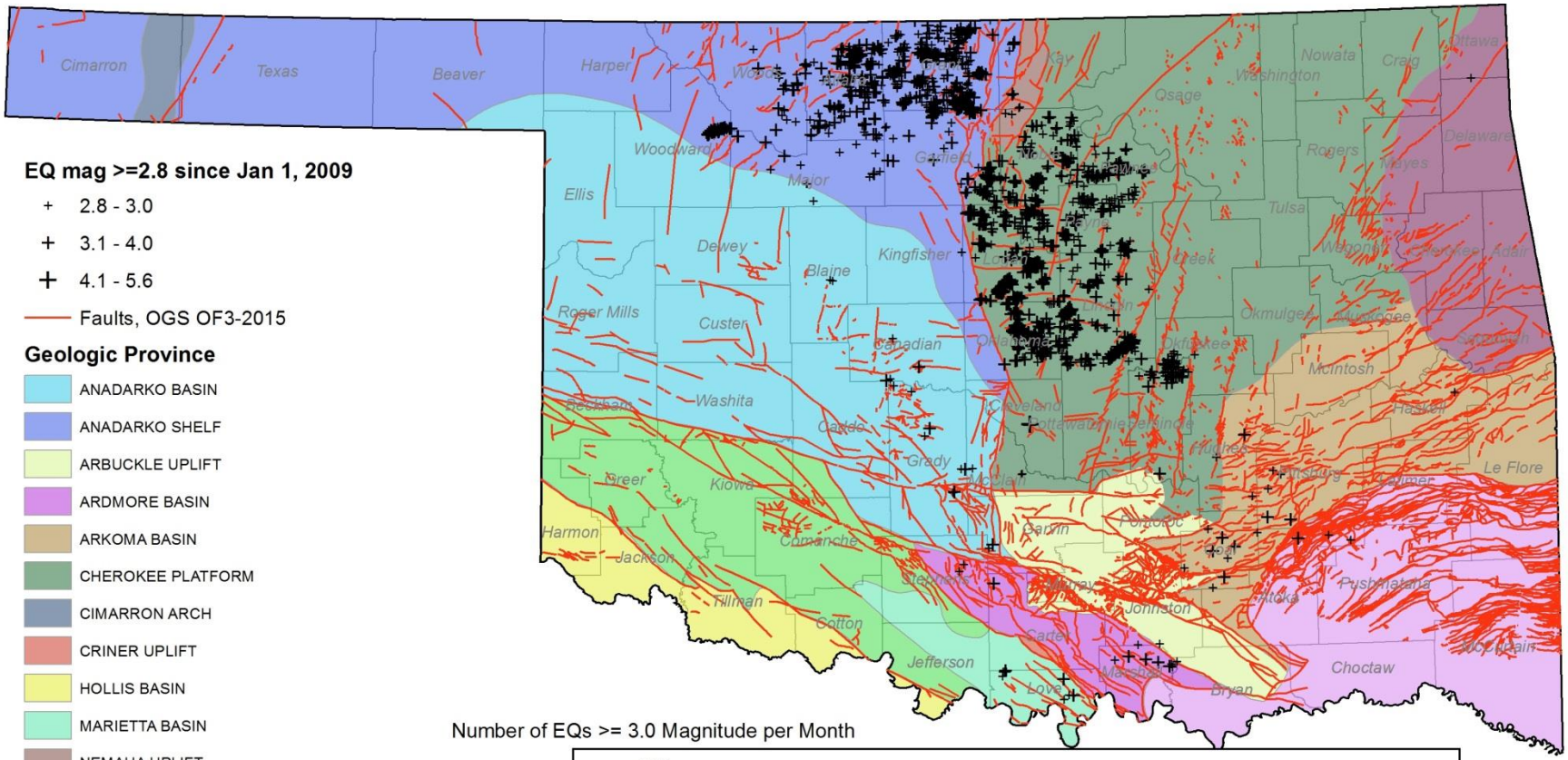
Active Arbuckle SWD wells in Oklahoma, 2009–2014



Statewide SWD by Zone



Map of Earthquakes Mag >=2.8 since Jan 1, 2009



EQ mag >=2.8 since Jan 1, 2009

- \+ 2.8 - 3.0
- \+ 3.1 - 4.0
- \+ 4.1 - 5.6
- Faults, OGS OF3-2015

Geologic Province

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- WICHITA UPLIFT
- County

Prepared by:
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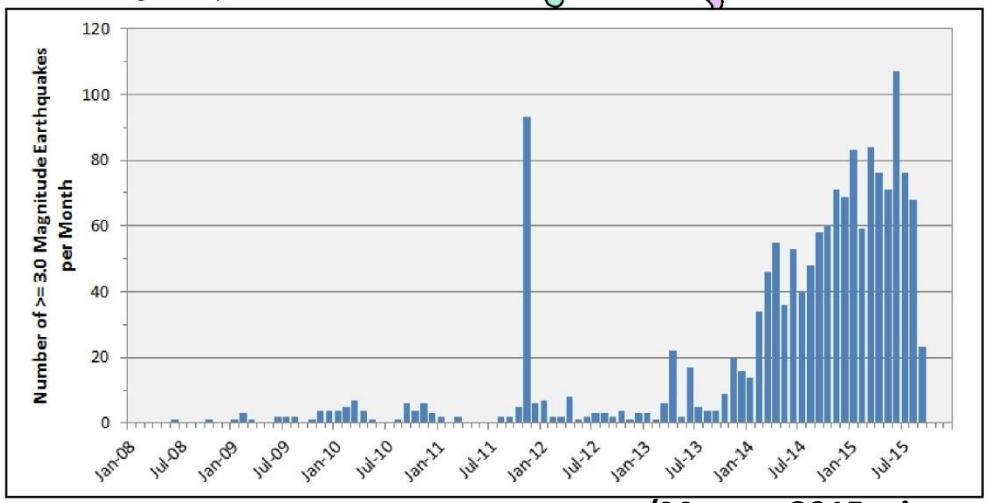
OGS Hydrogeologist

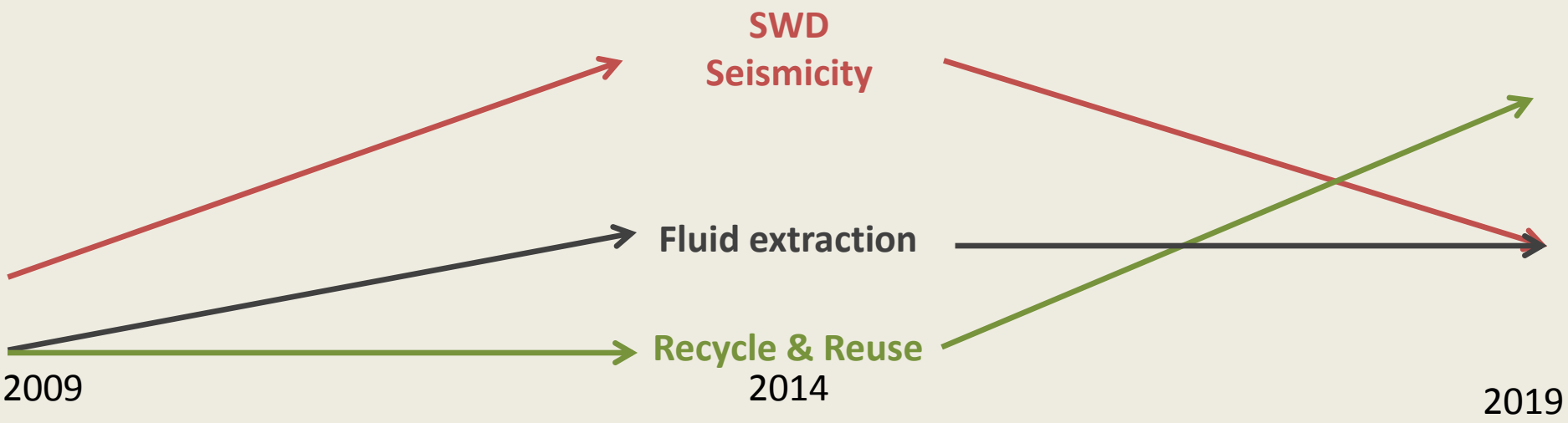
30 15 0 30 Miles

Number of EQs >= 3.0 Magnitude per Month



(Murray, 2015 – in preparation)

Summary and Forecast



Research Centers Related to Seismicity

Kyle Murray's

MEWBOURNE COLLEGE OF EARTH AND ENERGY
WATER AND ENERGY RESOURCES CONSORTIUM
The UNIVERSITY of OKLAHOMA

Collaborative Agreement between Kyle Murray and OU
and Mark Zoback, Jack Baker, Greg Beroza and others at Stanford

STANFORD UNIVERSITY
Stanford Center for Induced and Triggered Seismicity
SCHOOL OF EARTH SCIENCES

Ze'ev Reches, Xiaowei Chen, Kyle Murray, and others

SCHOOL OF GEOLOGY & GEOPHYSICS
INTRAPLATE SEISMICITY IN THE CENTRAL U.S.
The UNIVERSITY of OKLAHOMA

Email: Kyle.Murray@ou.edu
Website: http://faculty-staff.ou.edu/M/Kyle.E.Murray-1/
Phone: (405) 325-7502

PETROLEUM AND FLUID EXTRACTION & INJECTION WORKSHOP & FIELD TRIP

NOVEMBER 10 –12, 2015

The Oklahoma Geological Survey will present a one-day workshop on **Petroleum and Co-Produced Fluid Extraction & Injection.** The workshop will be held on November 11th at the Reed Conference Center, 5750 Will Rogers Road, in Midwest City, Oklahoma. The workshop is designed to cover recent developments of petroleum-rich carbonate reservoirs in the Mid-Continent which have led to large-scale water-disposal practices. Understanding local and regional characteristics of reservoirs that produce hydrocarbons and the formations that are used for saltwater disposal is critical for continued development of oil and gas resources.

This workshop will examine development trends of the Hunton and Mississippian plays that have significant oil and water extraction histories. Another emphasis will be on the formations comprising the Arbuckle Group that are the primary saltwater disposal zones in Oklahoma. Scientific findings and operator case studies will supplement the workshop.

The field trip on November 10th or 12th will examine outcrop and/or quarry exposures of geologic and structural features that may be extrapolated to subsurface producing and disposal zones. These rock exposures exhibit porosity types, and fracture patterns that not only store hydrocarbons but also enable widespread and large-scale water disposal/migration into the Arbuckle Group.

Technical Questions: Kyle Murray at 405/325-7502 or 800/330-3996
E-mail: kyle.murray@ou.edu
Contact: Michelle Summers, 405/325-7313 or 800/330-3996
E-mail: mjsummers@ou.edu
Website: http://www.ogs.ou.edu

MEWBOURNE COLLEGE OF EARTH & ENERGY
THE UNIVERSITY OF OKLAHOMA

Sponsored by Oklahoma Geological Survey
University of Oklahoma
Mewbourne College of Earth & Energy
Sheraton Midwest City Hotel at the
Reed Conference Center
Midwest City, Oklahoma