

Horizontal Drilling of Deep Granite Wash Reservoirs, Anadarko Basin, Oklahoma and Texas*

John R. Mitchell¹

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*Adapted from presentation at meeting of Fort Smith Geological Society, April 15, 2014, and an update of article of the same title published in [The Shale Shaker, v. 62/2, p. 118-167](#). (website accessed August 19, 2014).

¹Consulting Geologist / Managing Partner, Fall River Exploration Company LLC, Tulsa, OK (mtgeologist@yahoo.com)

Abstract

More than 1000 horizontal oil and gas wells have been drilled and completed since 2007 in the Granite Wash trend in a five-county area (Wheeler County, Texas; Roger Mills, Beckham, Washita, and Custer Counties, Oklahoma) of the deep Anadarko Basin of Texas and Oklahoma. Over 90% of the horizontal wells drilled to date have targeted Granite Wash strata of Pennsylvanian age and have been drilled since January 2008.

Before 2007, the Granite Wash reservoirs had been exploited by over 2000 vertical wells across the report area. These vertical wells are generally characterized by poor recovery efficiency and economic performance due to the extremely low permeability of the various arkosic sandstone and conglomerate reservoirs. Horizontal drilling and completion technology now provide the oil and gas industry with much better tools for efficiently producing gas, oil and condensate from these reservoirs.

Daily production from horizontal Granite Wash completions in the five-county area, as of late 2013, was reported to be greater than 46,500 barrels of oil and 962 million cubic feet of gas. Total cumulative production from 1048 horizontal wells has reached 69.6 million barrels of oil (MMBO) and 1.5 trillion cubic feet of gas.

This article includes geologic descriptions of the Granite Wash play, including a look at four key oil and gas “sub-play” areas that have been horizontally drilled.

References Cited

Bouma, A.H., 2000, Fine-grained, mud-rich turbidite systems: Model and comparison and coarse-grained, sand-rich systems, *in* A.H. Bouma and C.G. Stone, eds., *Fine-grained Turbidite Systems*: AAPG Memoir 72, p.9-19.

Ham, W.E., R.E. Denison, and C.A. Merritt, 1964, Basement rocks and structural evolution of southern Oklahoma: Oklahoma Geological Survey Bulletin 95, 302 p.

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McConnell, D.A., 1989, Determination of offset across the northern margin of the Wichita Uplift, southwest Oklahoma: GSA Bulletin, v.101, p. 1317-1332.

Moore, G.E., 1979, Pennsylvanian paleogeography of the southern Midcontinent, *in* N.J. Hyne, ed., Pennsylvanian Sandstones of the Mid-Continent: Tulsa Geological Society Special Publication no. 1, p. 2-12.

Horizontal Drilling of Deep Granite Wash Reservoirs Anadarko Basin, Oklahoma & Texas



**John Mitchell, Managing Partner
Fall River Exploration LLC
Tulsa, Oklahoma**

HORIZONTAL GRANITE WASH PLAY: KEY POINTS

- **Located in the deep Anadarko Basin along the northern flank of the Amarillo-Wichita uplift in Oklahoma & Texas**
- **Granite Wash petroleum reservoirs are primarily arkosic sandstones and conglomerates with very low porosity & permeability**
- **Wash sediments were locally sourced from the Amarillo-Wichita uplift**
- **The middle and upper Pennsylvanian-age Granite Wash stratigraphic section exceeds 7000 feet in thickness**
- **Reservoirs were laid down in depositional systems varying from alluvial fans to deep-water turbidite and debris-flow deposits five to thirty miles north of the Amarillo-Wichita uplift**
- **Dozens of individual stratigraphic and structural-stratigraphic oil and gas traps are present in a highly complex “tight oil and gas sandstone” resource system**

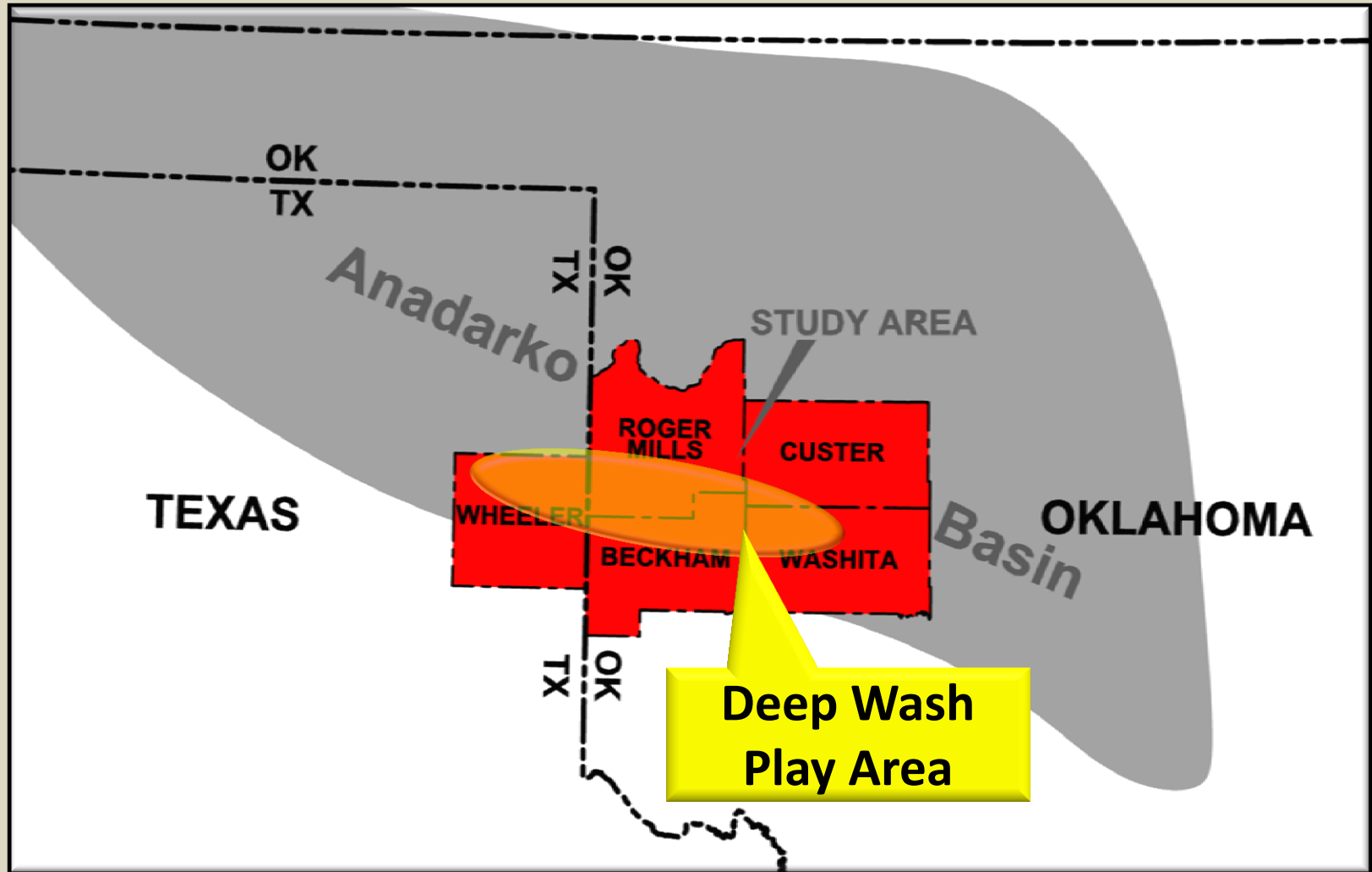
HORIZONTAL GRANITE WASH PLAY: KEY POINTS

- **Production depths range from 9000 to 15,500 feet**
- **Individual petroleum reservoirs are 25 to 150 feet thick**
- **Porosity: 2% to 14%**
- **Permeability generally <0.1 millidarcy**
- **Oil Gravity: 44-60° API**
- **Four Granite Wash sub-play areas have been identified based on structure, stratigraphy, and trapping styles**
- **More than 2000 vertical Granite Wash wells were drilled prior to transition to horizontal drilling in 2007**
- **Since 2007 over 1760 horizontal Granite Wash wells have been drilled with only 86 dry holes**
- **111 active permits currently awaiting drilling**

HORIZONTAL GRANITE WASH PLAY: KEY POINTS

- One thousand forty-eight (1048) horizontal Granite Wash wells have produced 69,600,000 barrels of oil and 1.5 trillion cubic feet of gas since 2007 from the study area
- Late 2013 reported daily production in Wheeler, Hemphill, Beckham, Roger Mills, Custer and Washita Counties was >46,500 barrels oil and 962 million cubic feet of gas from 1408 horizontal wells
- Late 2013 reported daily production in Wheeler County alone was >33,700 barrels oil and 553 million cubic feet of gas from 648 horizontal wells

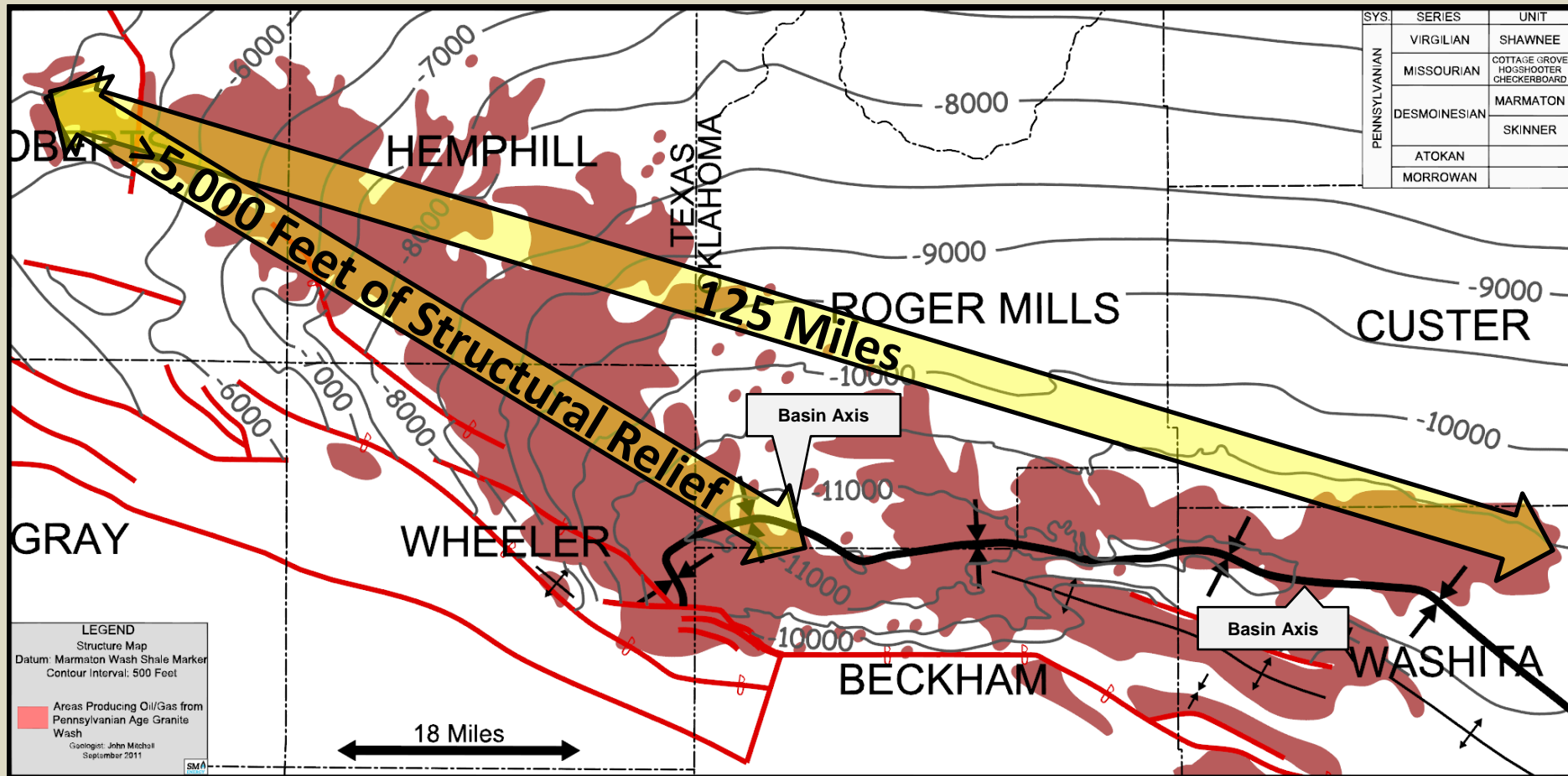
HORIZONTAL GRANITE WASH PLAY LOCATION MAP



HORIZONTAL GRANITE WASH PLAY

Regional Structure Map – U. Desmoinesian Wash

SYS.	SERIES	UNIT
PENNSYLVANIAN	VIRGILIAN	SHAWNEE
	MISSOURIAN	COTTAGE GROVE HOSHOOTER CHECKERBOARD
	DESMOINESIAN	MARMATON SKINNER
	ATOKAN	
	MORROWAN	



Contour Interval = 500 Feet

HORIZONTAL GRANITE WASH PLAY: WHAT IS GRANITE WASH?

Granite Wash ('gran·ət 'wäsh) (geology)

Material eroded from granites and re-deposited, forming a sedimentary rock with the same major mineral constituents as the original rock.

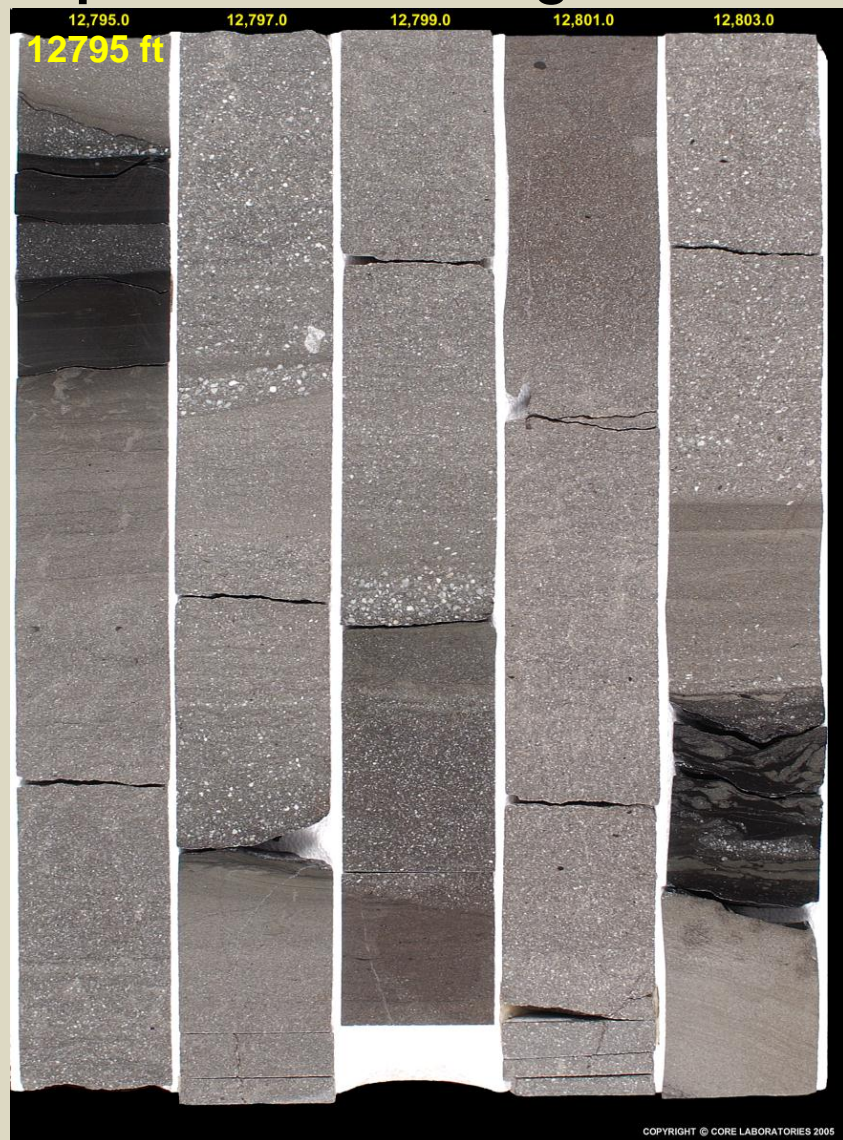
HORIZONTAL GRANITE WASH PLAY

- Core data shows common Granite Wash mineralogical composition to be:
 - 30-40% Quartz (quartz in sand, igneous fragments, quartz overgrowths)
 - 20-30% Plagioclase Feldspar
 - 10-20% Potassium Feldspar
 - 7-18% Clay, primarily authigenic Chlorite
- Cores also show Granite Wash framework grains to be commonly composed of:
 - 10-40% Plutonic and Volcanic rock fragments (granite and rhyolite, varies with conglomeratic vs. sandstone rock types)
 - 20-30% Quartz in individual grains
 - 20-30% Plagioclase Feldspar in individual grains
 - 10-20% Potassium Feldspar in individual grains

Data from Core Lab, published data

DESMOINESIAN WASH – STILES RANCH FIELD, TX

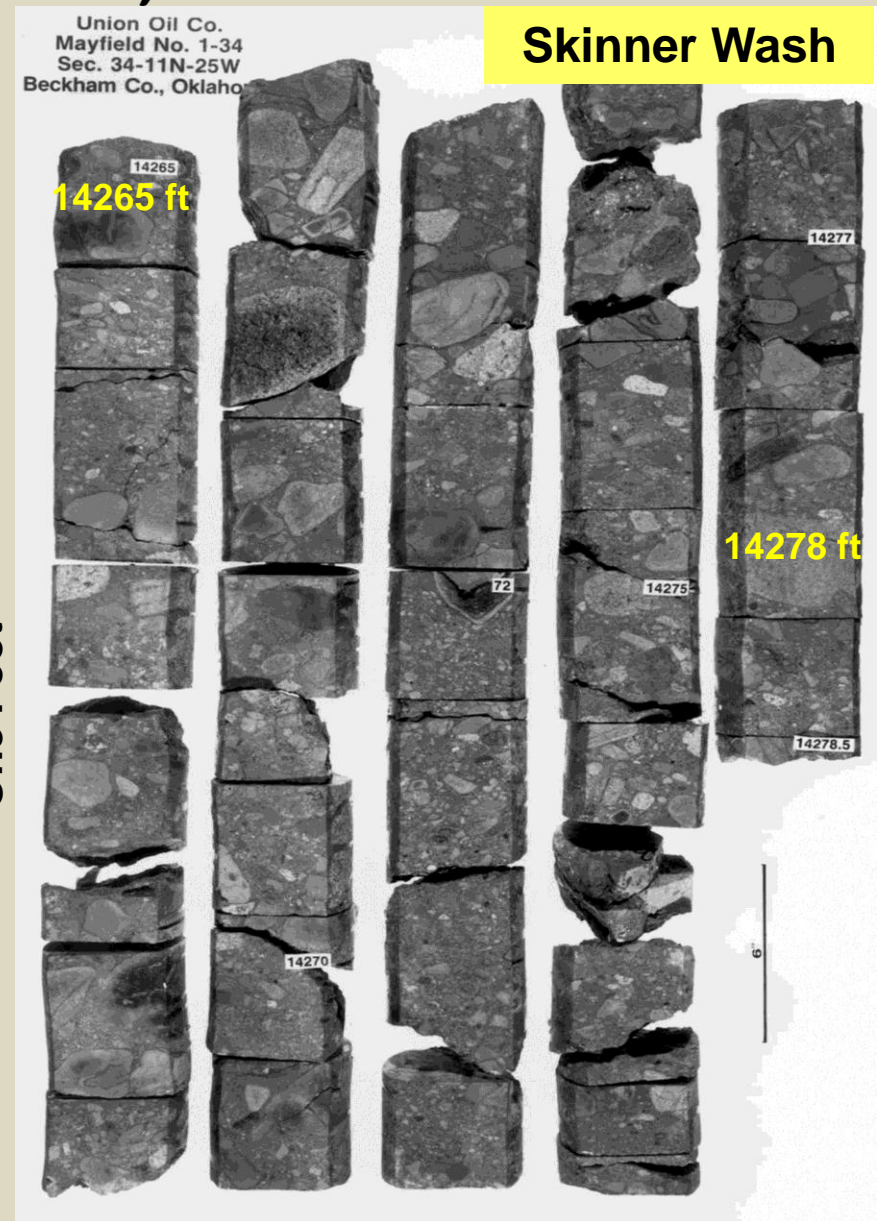
Layered Sheet Sandstone and Shale Distal Lobe Grading Upward into Amalgamated Proximal Lobe Sheet Sandstone



DESMOINESIAN WASH – N.E. MAYFIELD FIELD BECKHAM CO., OK



One Foot



MARMATON WASH – ELK CITY FLD., BECKHAM CO.



Nine feet of conglomeratic sandstone, sandstone and shale from core cut in the Valero #1 Brauchi well

Sec. 36, T11N R23W
Beckham Co., Oklahoma

13021-030'

Core @ Oklahoma Geological Survey

MARMATON WASH – SWEETWATER FIELD

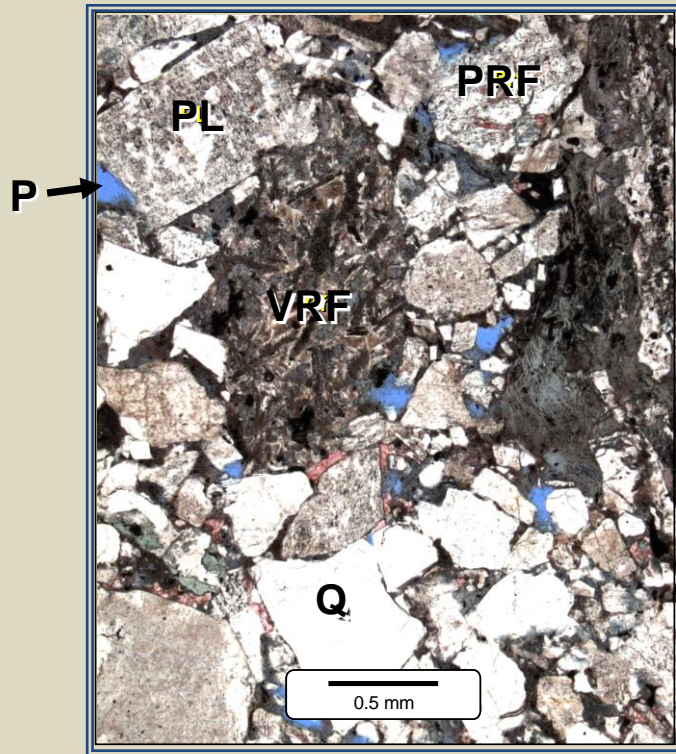
Five feet of conglomeratic sandstone from core cut in the Gulf #1 Payne
Community Sec. 13, T10N R26W, Beckham Co., OK



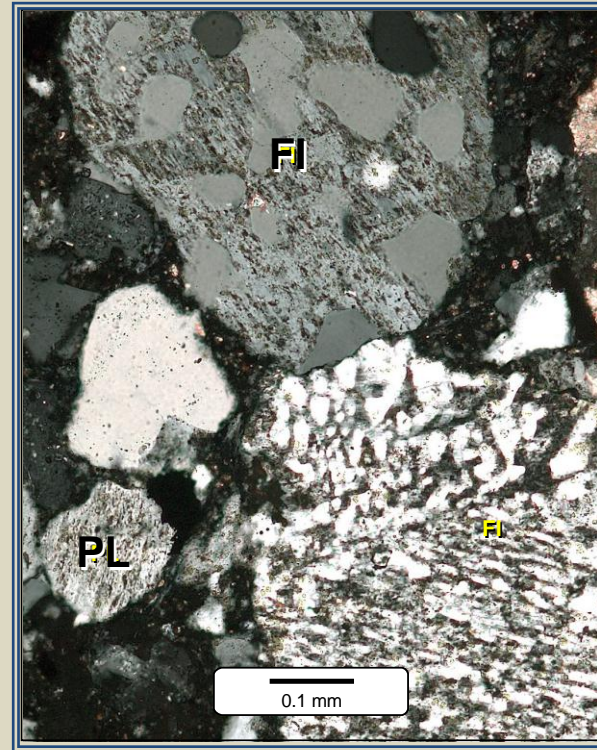
Core @ Oklahoma Geological Survey

HORIZONTAL GRANITE WASH PLAY

Common Framework Grains



**Abundant Plutonic and
Volcanic Lithic Fragments**



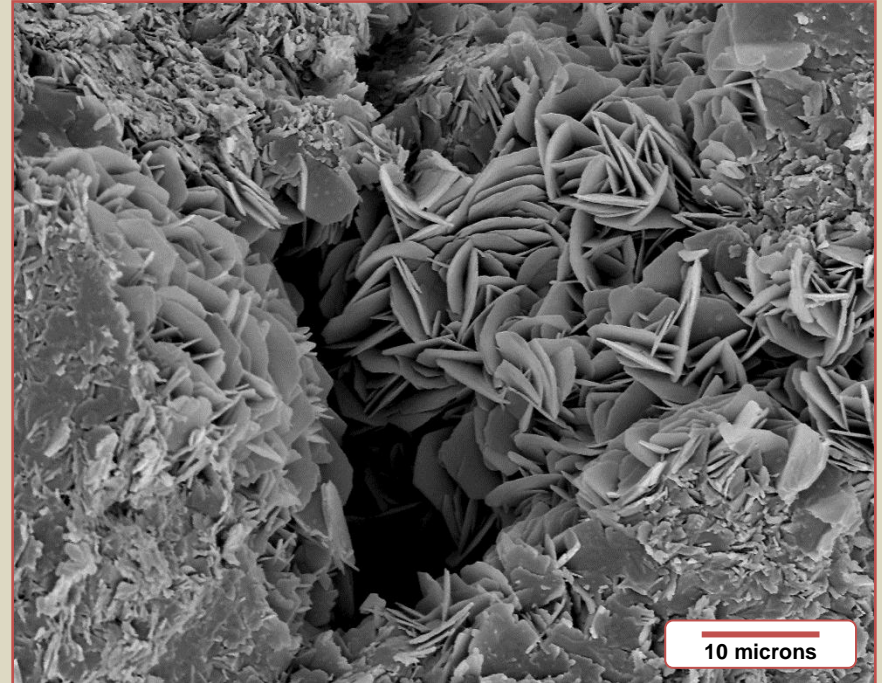
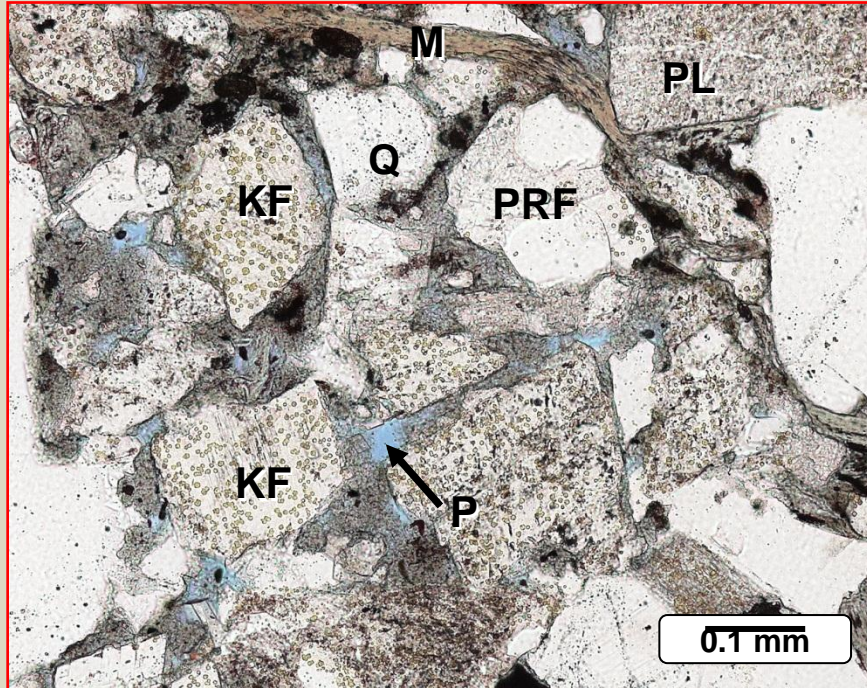
**Feldspar Intergrowths and
Plagioclase**

Vrf = Volcanic Rock Fragment; Prf = Plutonic Rock Fragment;
Q = Quartz; FI = Feldspar Intergrowths; PL = Plagioclase Feldspar
P = Porosity

Photomicrographs Courtesy of Core Lab

HORIZONTAL GRANITE WASH PLAY

Mineralogy, Grain Types, Clay



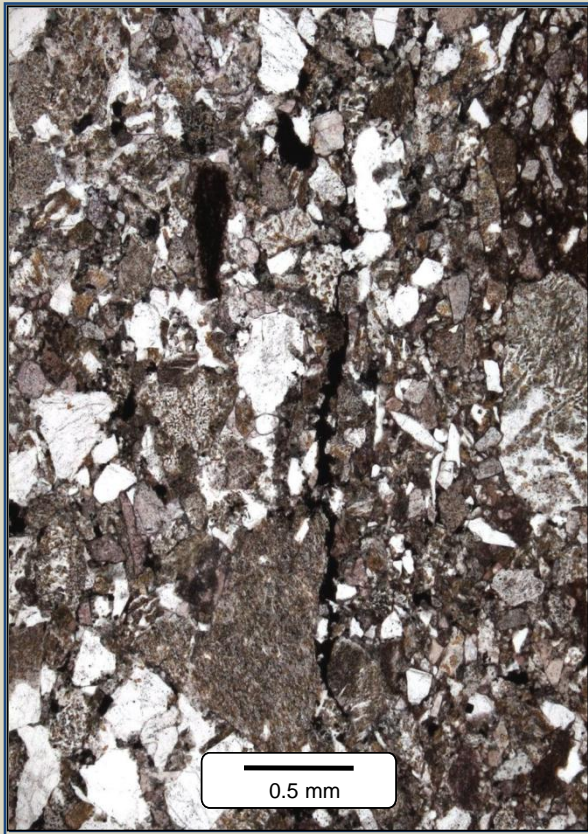
Grain Types/Mineralogy

KF = Potassium Feldspar
M = Muscovite
PL = Plagioclase Feldspar
Q = Quartz
P = Pore Space

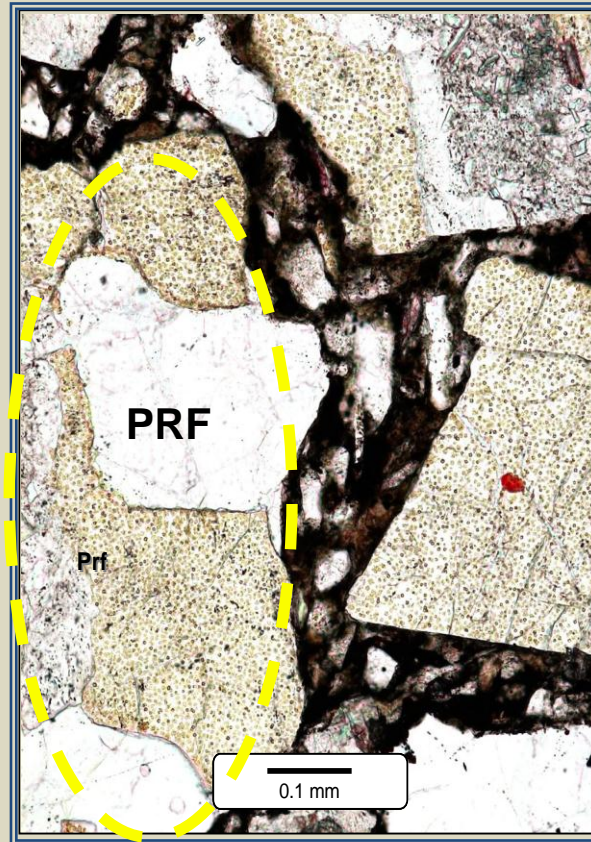
Chlorite Lining Pores

Courtesy of Core Lab

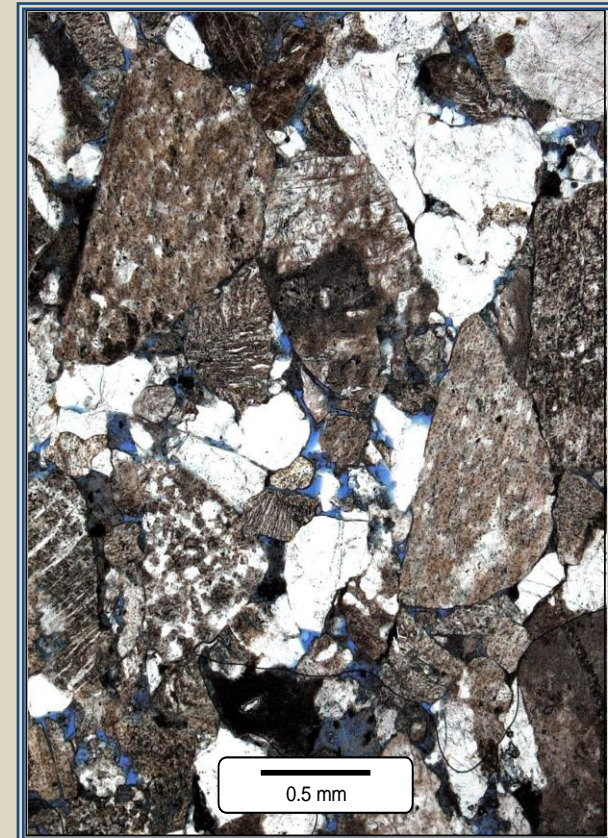
HORIZONTAL GRANITE WASH PLAY Rock Textures



Mechanical
Compaction



Poor Sorting
& Rounding



More Open
Framework

Photomicrographs Courtesy of Core Lab

HORIZONTAL GRANITE WASH PLAY

Granite Wash Porosity and Permeability

- **Porosity averages ~6 %, often as low as 2-3%**
- **Permeability ranges from .0001 to 0.1 md**
- **Porosity dominantly exists as microporosity with minor intergranular porosity**
- **Original porosity was reduced by mechanical compaction and diagenetic cementation**

HORIZONTAL GRANITE WASH PLAY

STRATIGRAPHIC CHART			
SYS.	SERIES / STAGE	GROUP	UNIT
PENNSYLVANIAN	VIRGILIAN	Shawnee/Cisco	☀ Shawnee Wash Heebner Sh
		Douglas/Cisco	Haskell Sh ☀ Tonkawa Ss
	MISSOURIAN	Lansing/Hoxbar	☀ Cottage Grove Wash
		Kansas City/Hoxbar	☀ Hoxbar Wash/Shale
			☀ Hogshooter Wash
			☀ Checkerboard Wash
			☀ Cleveland Wash
	DESMOINESIAN	Marmaton	☀ Marmaton Wash
		Cherokee	☀ Upper Skinner Shale
			☀ Upper Skinner Wash
			Lower Skinner Shale (Pink Ls Marker)
			☀ Lower Skinner Wash
			☀ Red Fork Ss & Sh
	ATOKAN	Atoka	☀ Atoka Wash 13 Finger Ls
	MORROWAN	Morrow	☀ Upper Morrow Squawbelly Ls ☀ L. Morrow (Primrose)
ANADARKO BASIN - MOUNTAIN FRONT - OKLAHOMA			

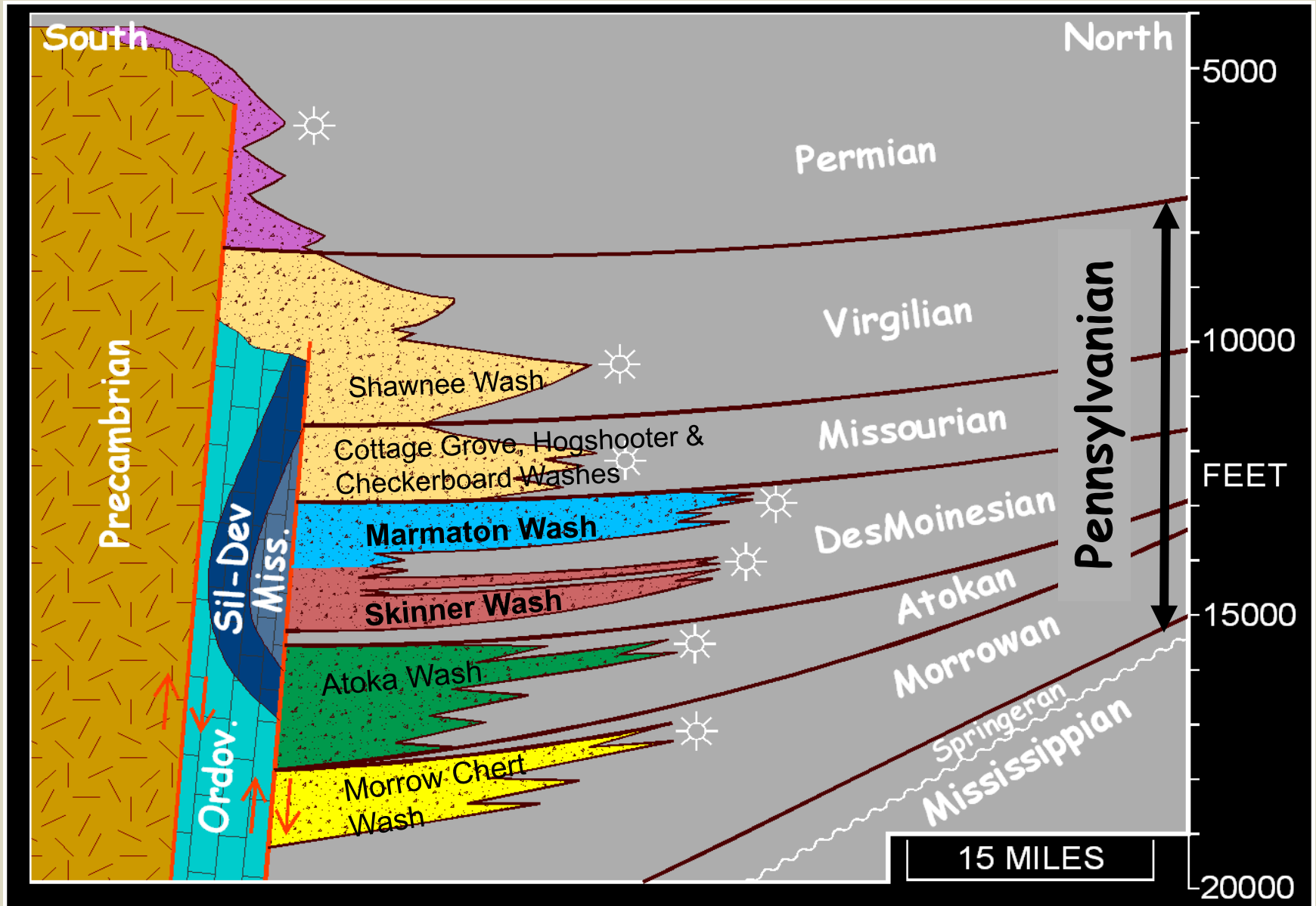
300-315 MMYBP

Pennsylvanian
stratigraphic
column, deep
Anadarko Basin,
Texas &
Oklahoma

GRANITE WASH DEPOSITIONAL SETTING

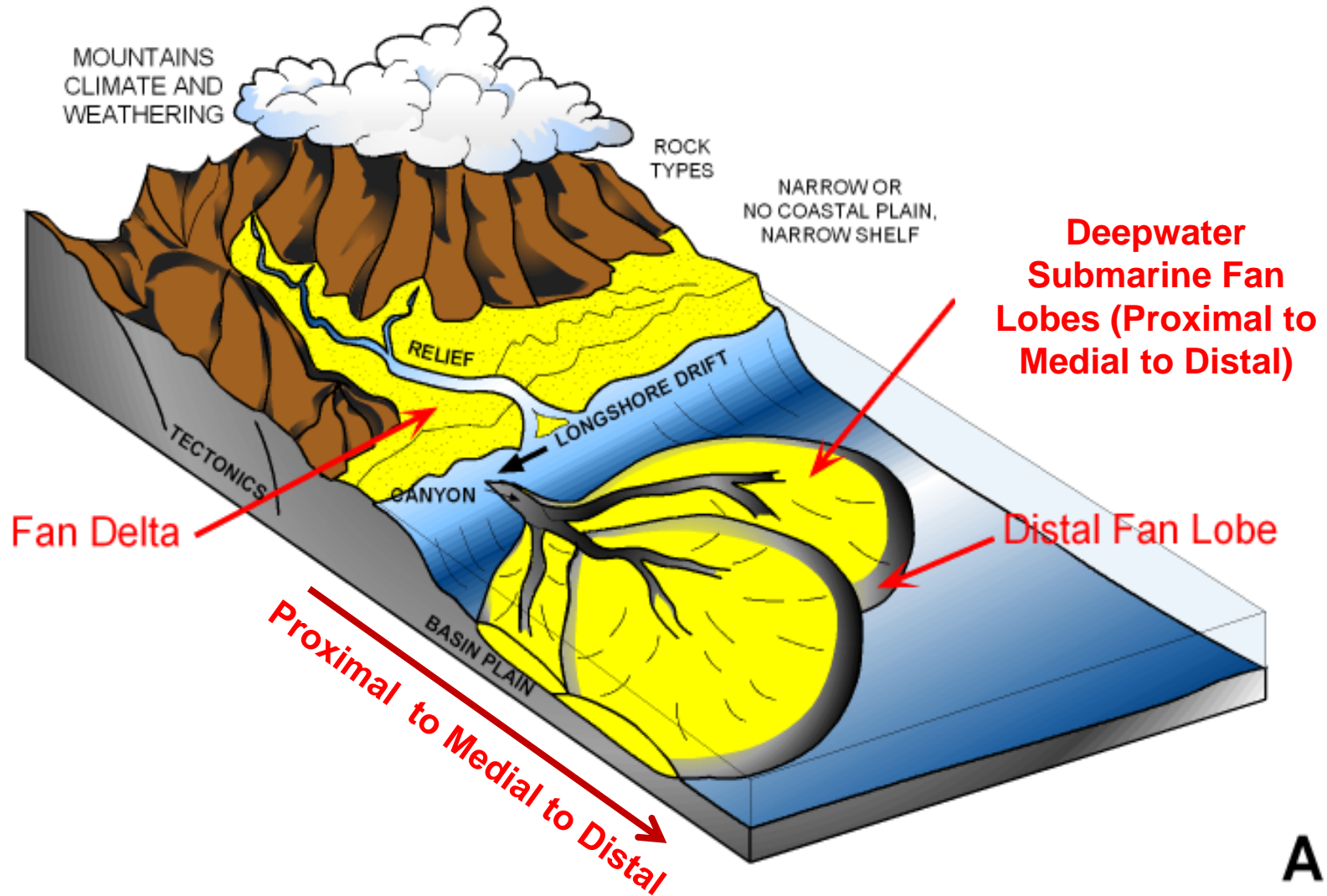


GRANITE WASH PLAY SCHEMATIC CROSS SECTION



GRANITE WASH DEPOSITION

GRANITE WASH PLAY DEPOSITIONAL MODEL



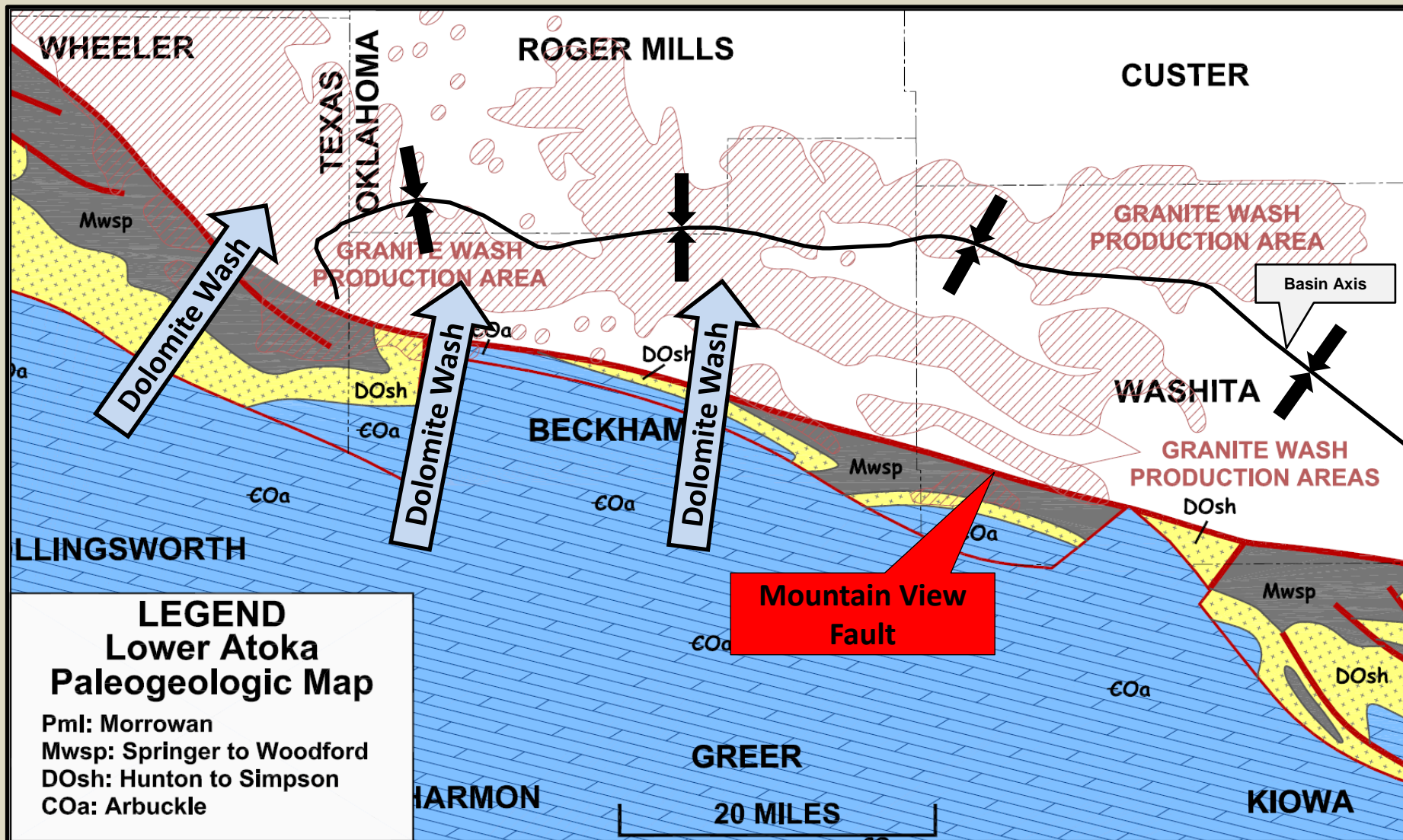
Adapted From Bouma, 2000

GRANITE WASH DEPOSITION

- 7000 feet+ thick succession of conglomerate, sandstone and shale in Middle and Upper Pennsylvanian-age Granite Wash
- “Coarse-grained sand-rich” depositional systems varying from alluvial-fan delta to deep-water turbidite/debris-flow deposits
- Granite Wash oil and gas reservoirs consist primarily of submarine-fan-lobe sequences (50-400 feet thick) separated by highstand correlative shales (5-20 feet thick)
 - Proximal Lobes Most Common (channel to lobe transition)
 - Comprised of conglomerates and amalgamated sheet sandstones to layered-sheet sandstones & minor shale
 - Distal Lobe or Lobe Fringe
 - Comprised of layered-sheet sandstones
 - Shale suspension deposits (highstand) occur between turbidite fan lobe sandstone sequences provide vertical seals

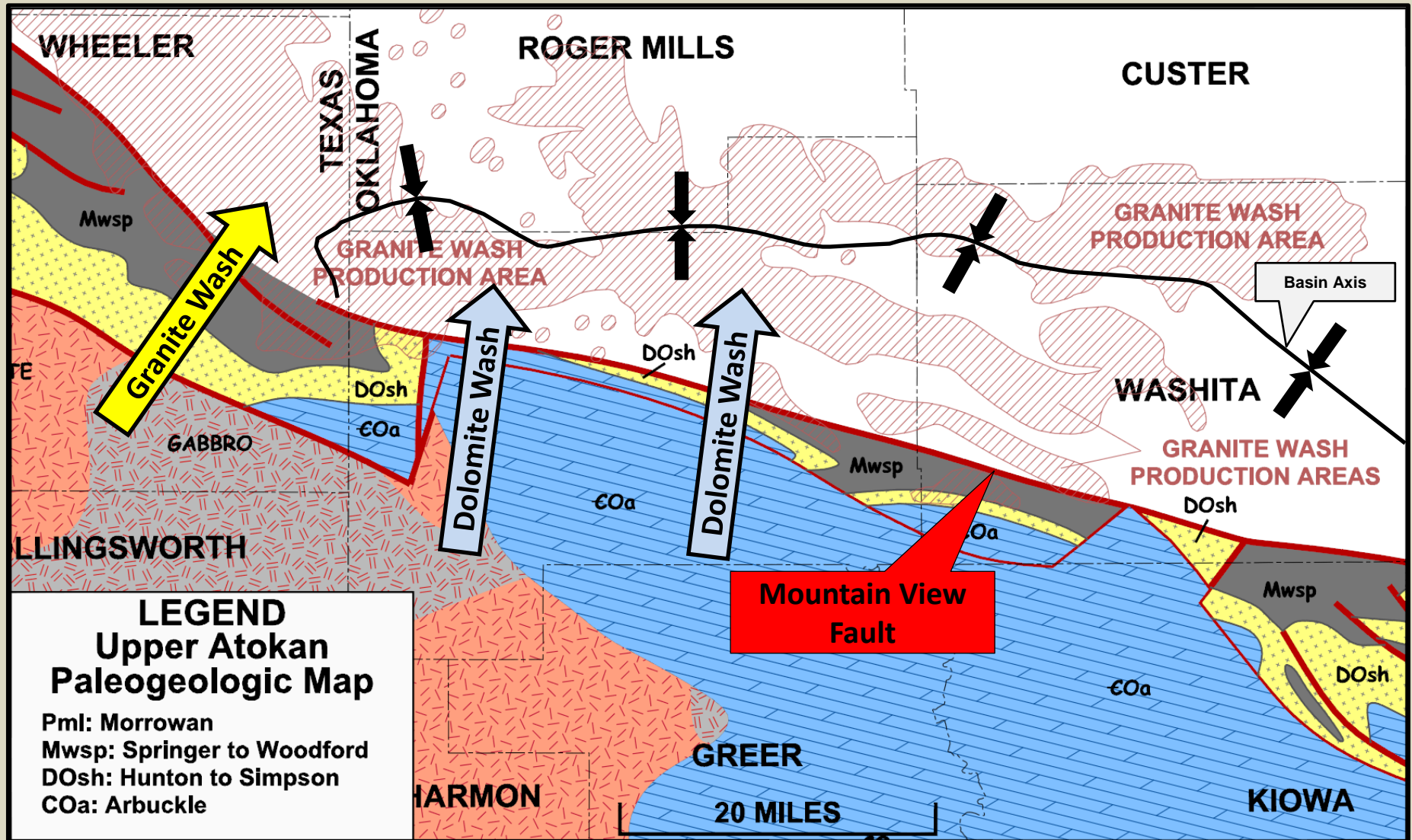
HORIZONTAL GRANITE WASH PLAY

LOWER ATOKAN PALEOGEOLOGIC MAP



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

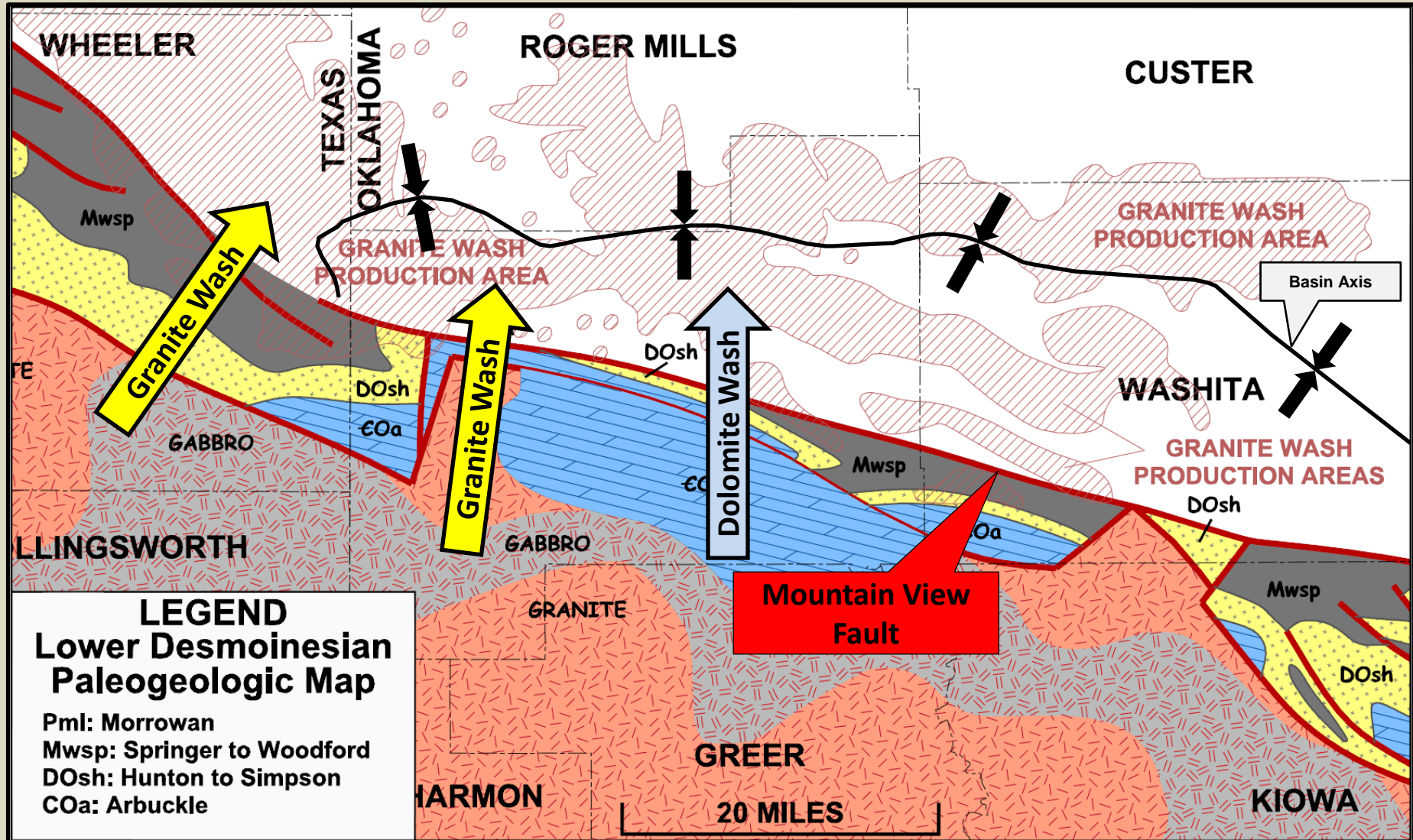
HORIZONTAL GRANITE WASH PLAY UPPER ATOKAN PALEOGEOLOGIC MAP



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

HORIZONTAL GRANITE WASH PLAY

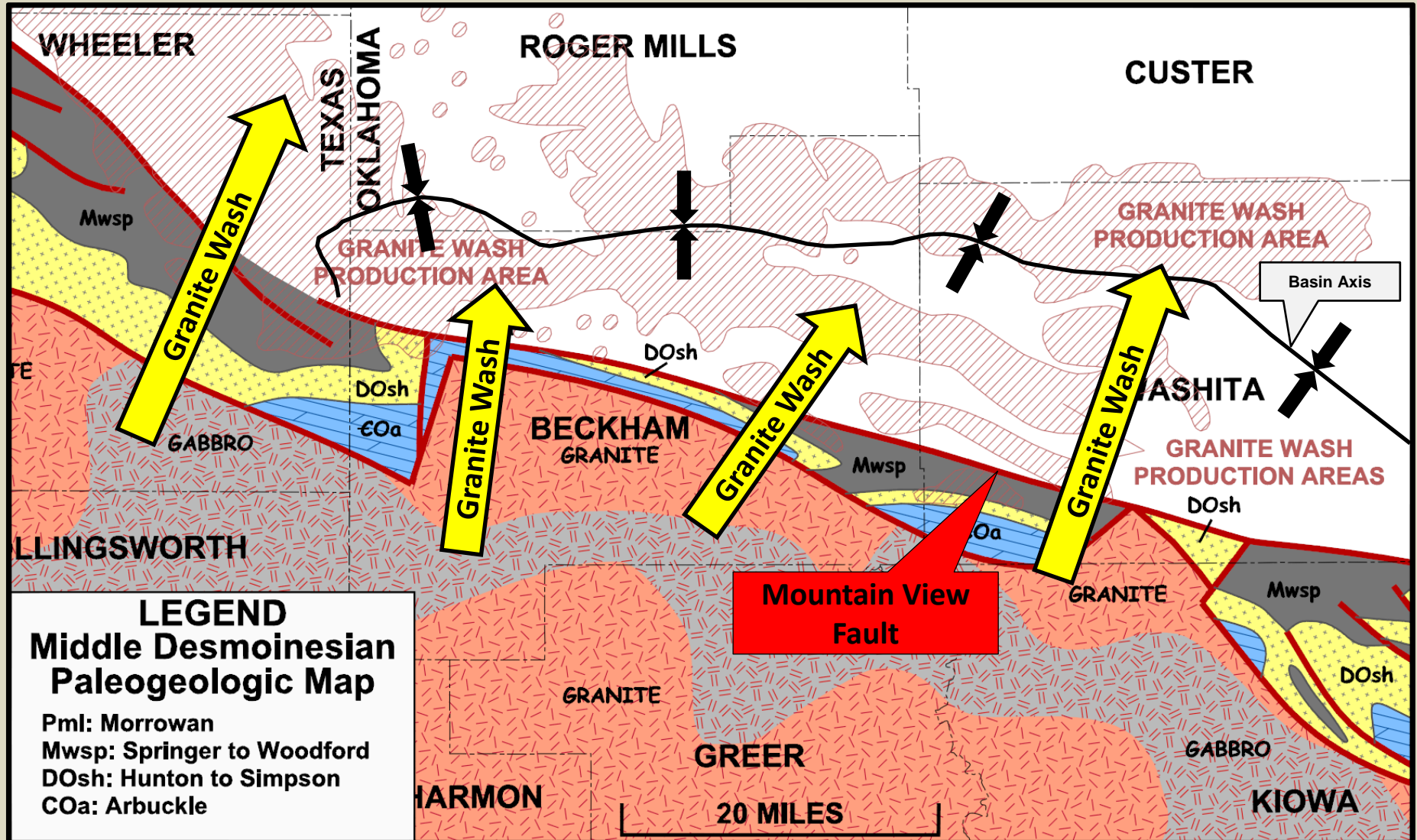
LOWER DESMOINESIAN PALEOGEOLOGIC MAP



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

HORIZONTAL GRANITE WASH PLAY

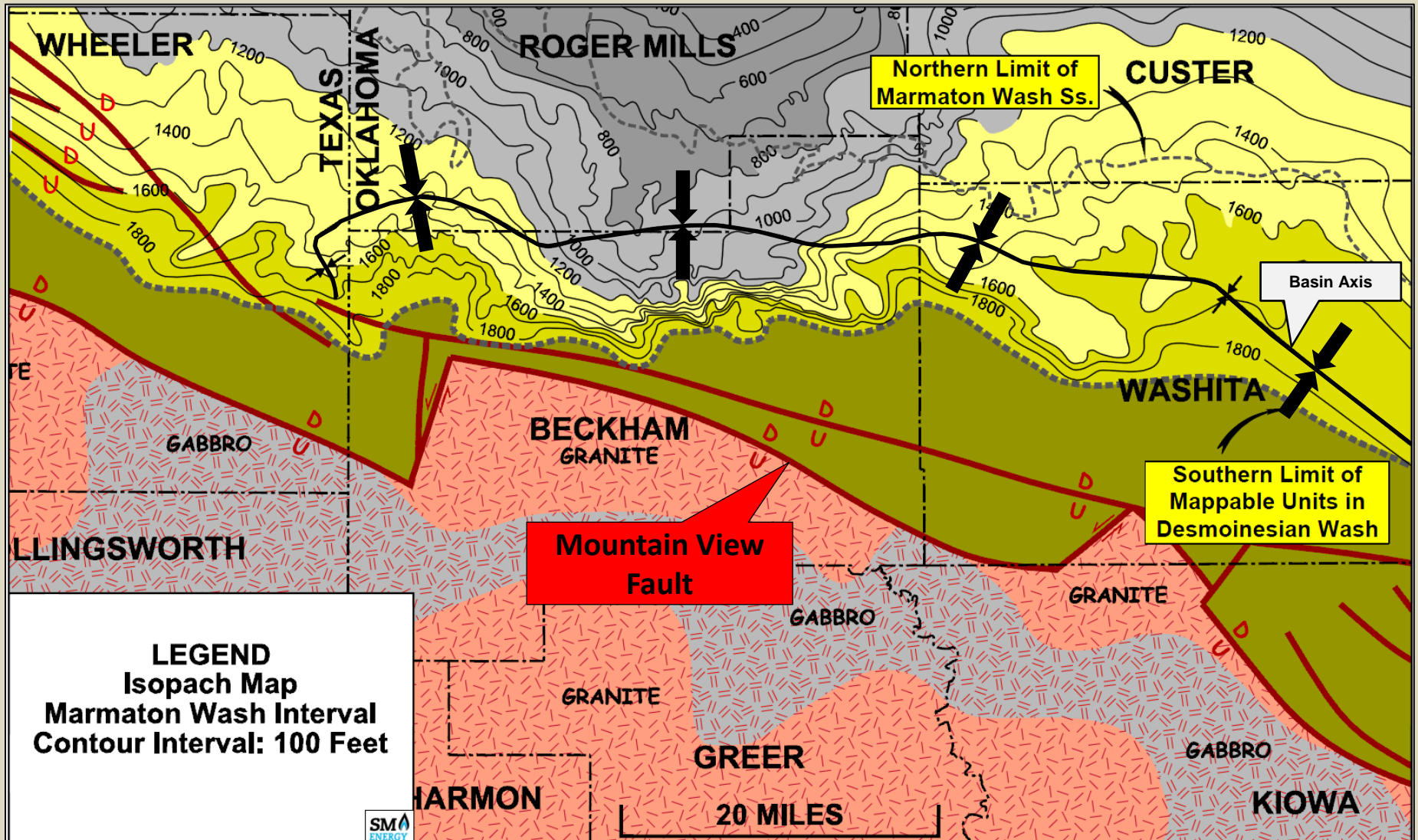
UPPER DESMOINESIAN PALEOGEOLOGIC MAP



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

HORIZONTAL GRANITE WASH PLAY

MARMATON (U. DESMOINESIAN) WASH ISOPACH



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

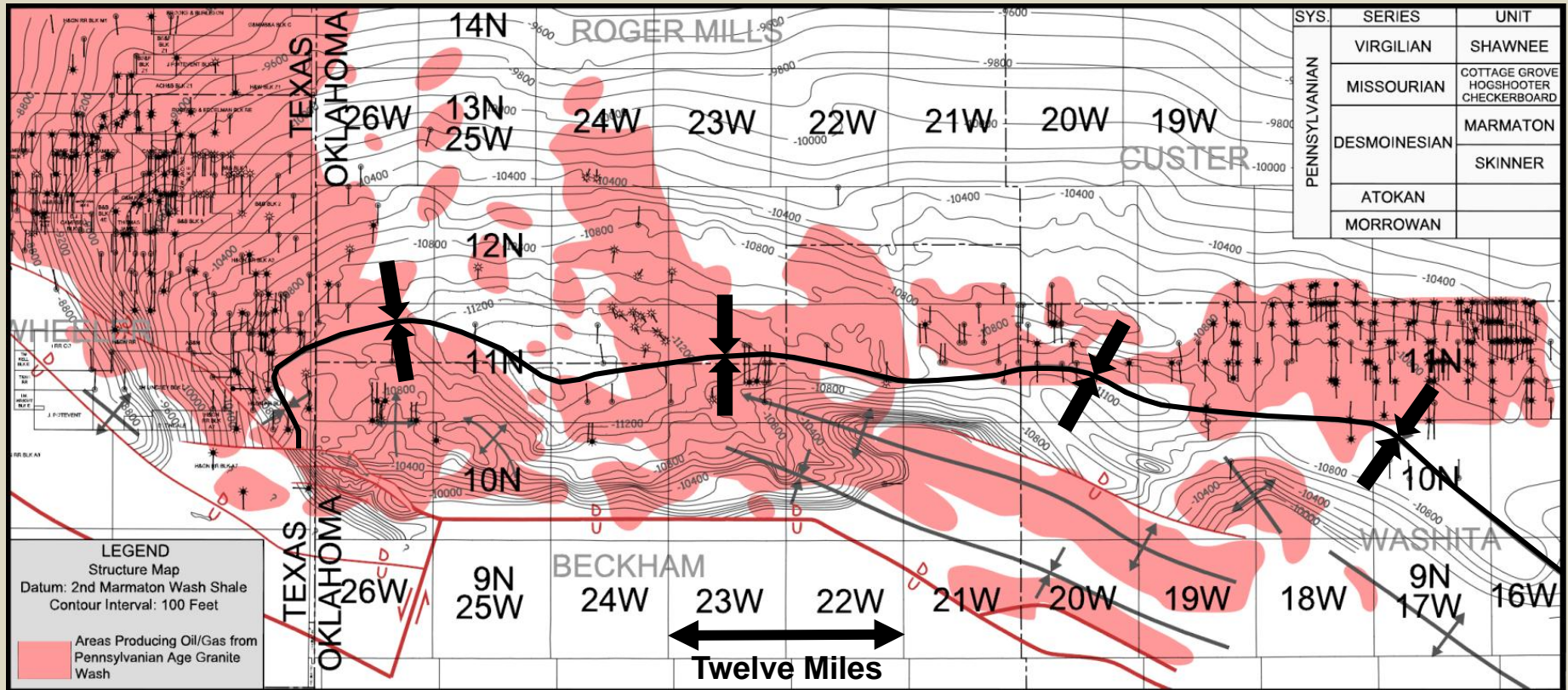
Granite Wash Oil and Gas Production



Mills Ranch Oil Field, Wheeler County, Texas

GRANITE WASH PLAY

OIL AND GAS PRODUCTION AREAS



Granite Wash Reservoir Production Cumulatives:

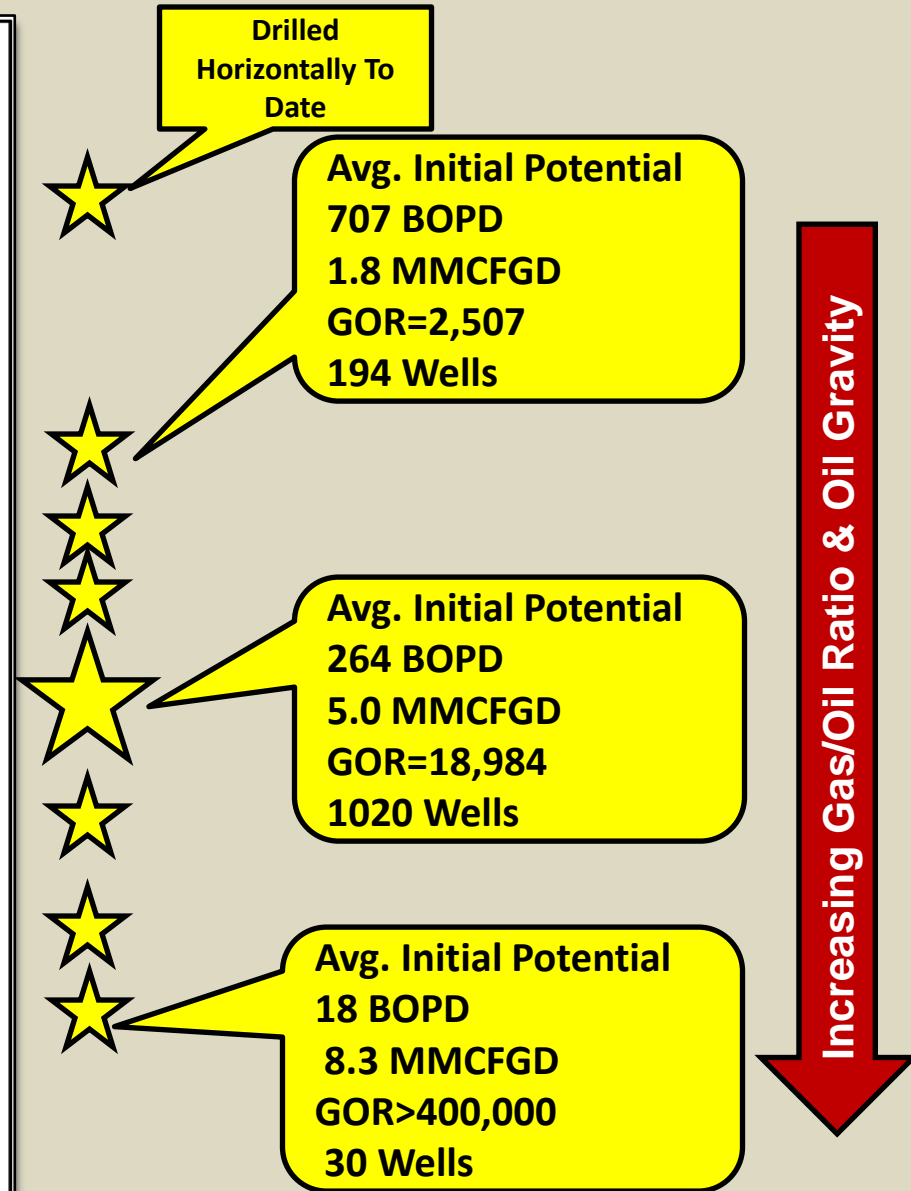
98 MMBO & 1.9 TCFG from ~2,100 Vertical Wells Since 1947

46 MMBO & 856 BCF from 816 Horizontal Wells Mainly Since 2008

HORIZONTAL GRANITE WASH PLAY

STRATIGRAPHIC CHART				
SYS.	SERIES / STAGE	GROUP	UNIT	
PENNSYLVANIAN	VIRGILIAN	Shawnee/Cisco	☀ Shawnee Wash Heebner Sh	
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	MISSOURIAN	Lansing/Hoxbar	☀ Cottage Grove Wash	
		Kansas City/Hoxbar	☀ Hoxbar Wash/Shale ☀ Hogshooter Wash ☀ Checkerboard Wash ☀ Cleveland Wash	
			Marmaton	☀ Marmaton Wash
			Cherokee	☀ Upper Skinner Shale ☀ Upper Skinner Wash Lower Skinner Shale (Pink Ls Marker) ☀ Lower Skinner Wash ☀ Red Fork Ss & Sh
	ATOKAN			Atoka
	MORROWAN	Morrow		☀ Upper Morrow Squawbelly Ls ☀ L. Morrow (Primrose)

ANADARKO BASIN - MOUNTAIN FRONT - OKLAHOMA

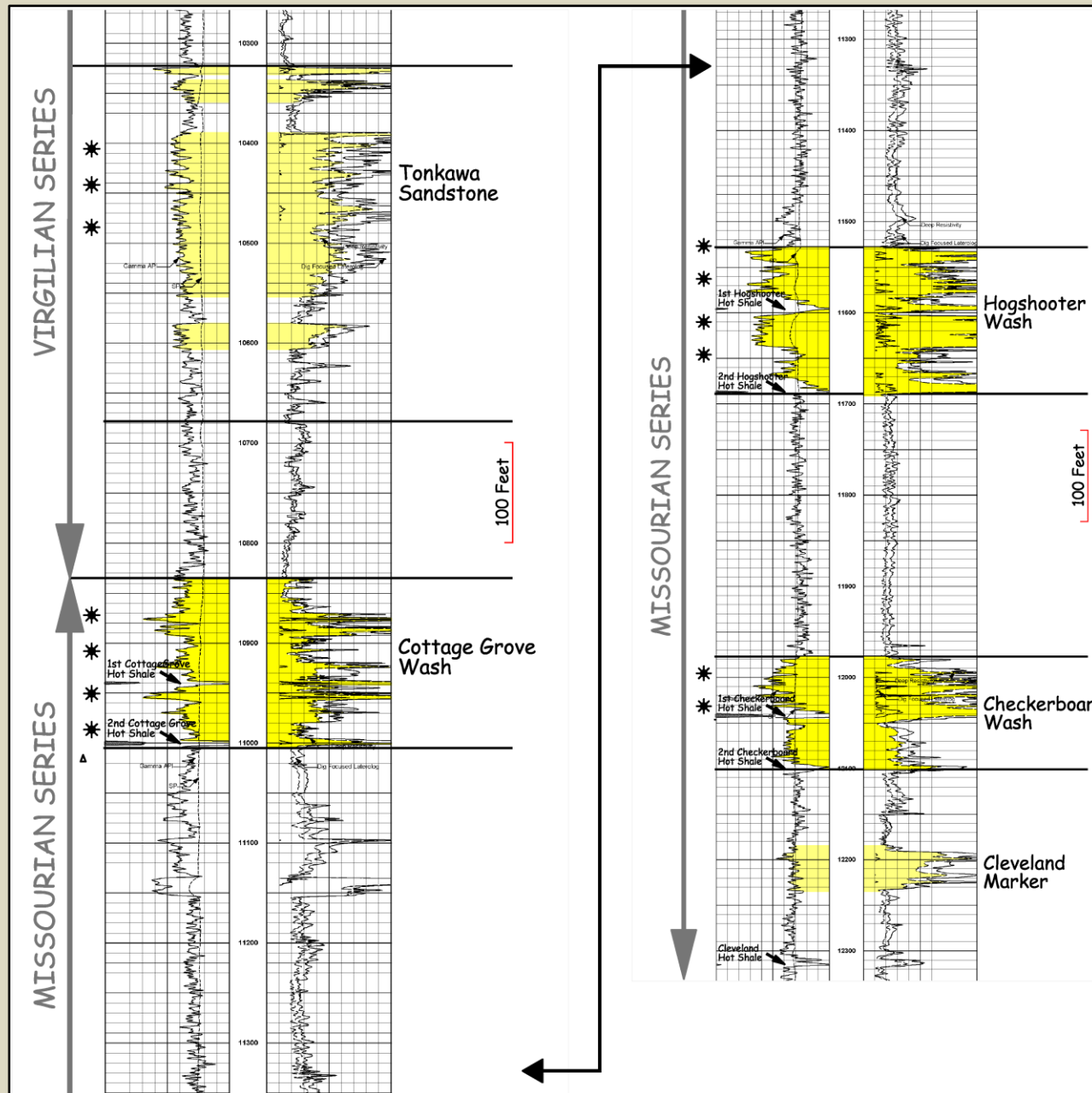


Granite Wash Oil and Gas Production



Virgilian to Atokan Age Oils
44 to 60 Degree API Gravity

HORIZONTAL GRANITE WASH PLAY

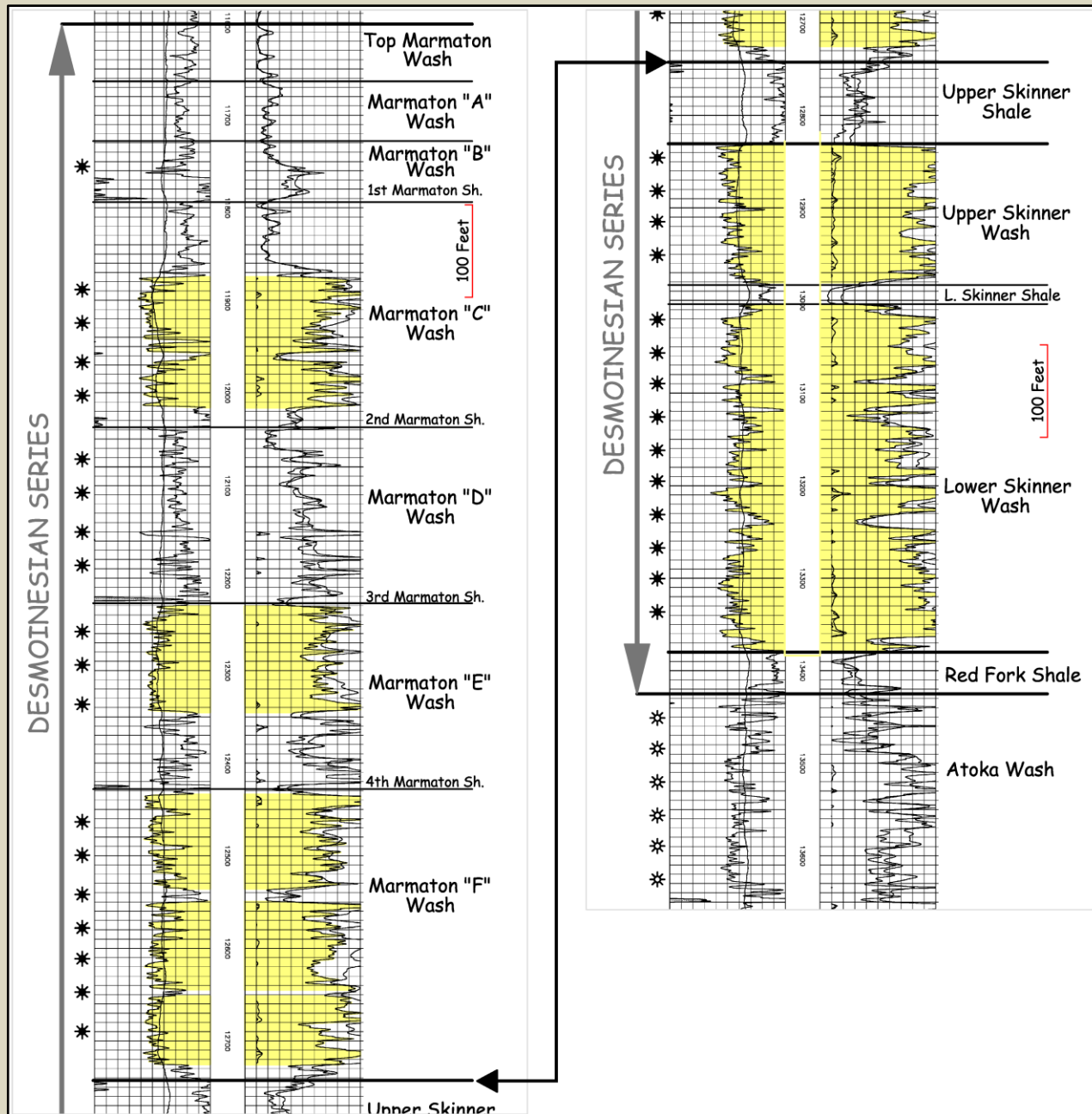


Type Log
Missourian Wash,
Deep Anadarko
Basin, Texas &
Oklahoma;
Chesapeake #1-28
Mary K well,
Sec. 28, T11N R23W,
Beckham Co.,
Oklahoma

1300+ feet of
Missourian Series
Granite Wash section

Missourian Wash Has
Produced 19.6 MMBO
and 78 BCFG from 220
Horizontals Since 2010

HORIZONTAL GRANITE WASH PLAY



Type Log

**Desmoinesian Wash,
Deep Anadarko
Basin, Texas &
Oklahoma:**

**Devon #16-4 Truman-
Zybach, Sec. 16,
Block R&E Survey,
Wheeler Co., Texas**

***2000+ feet of
Desmoinesian Series
Granite Wash section***

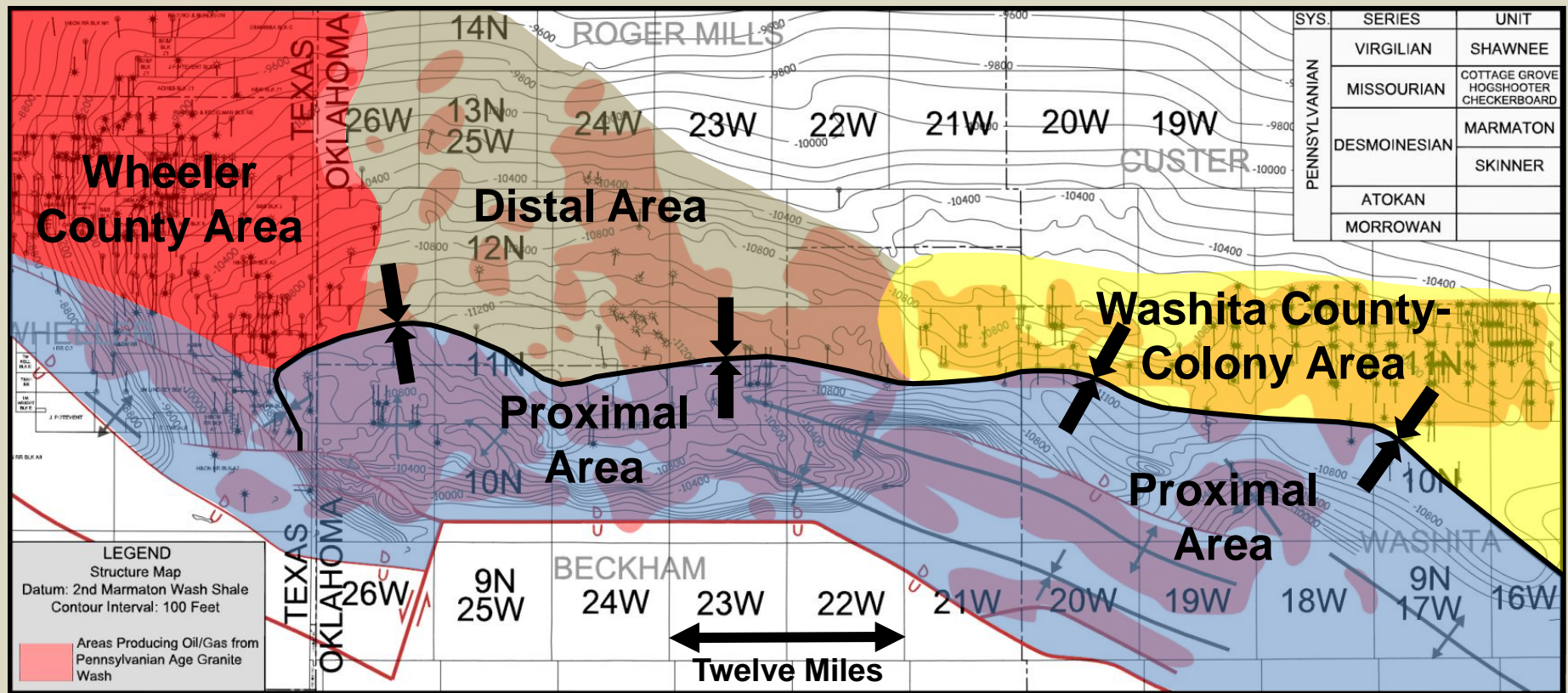
***Desmoinesian Wash Has
Produced 50 MMBO and
1.3 TCFG from 1,132
Horizontals Since 2002***

HORIZONTAL GRANITE WASH PRODUCTION

- One thousand forty-eight (1048) horizontal Granite Wash wells have produced 69,600,000 barrels of oil and 1.5 trillion cubic feet of gas since 2007 from the study area
- Late 2013 reported daily production in Wheeler, Hemphill, Beckham, Roger Mills, Custer and Washita Counties was >46,500 barrels oil and 962 million cubic feet of gas from 1408 horizontal wells
- Late 2013 reported daily production in Wheeler County alone was >33,700 barrels oil and 553 million cubic feet of gas from 648 horizontal wells

HORIZONTAL GRANITE WASH PLAY

FOUR SUB-PLAY AREAS



Granite Wash Reservoir Production Cumulatives:

98 MMBO & 1.9 TCFG from ~2,100 Vertical Wells Since 1947

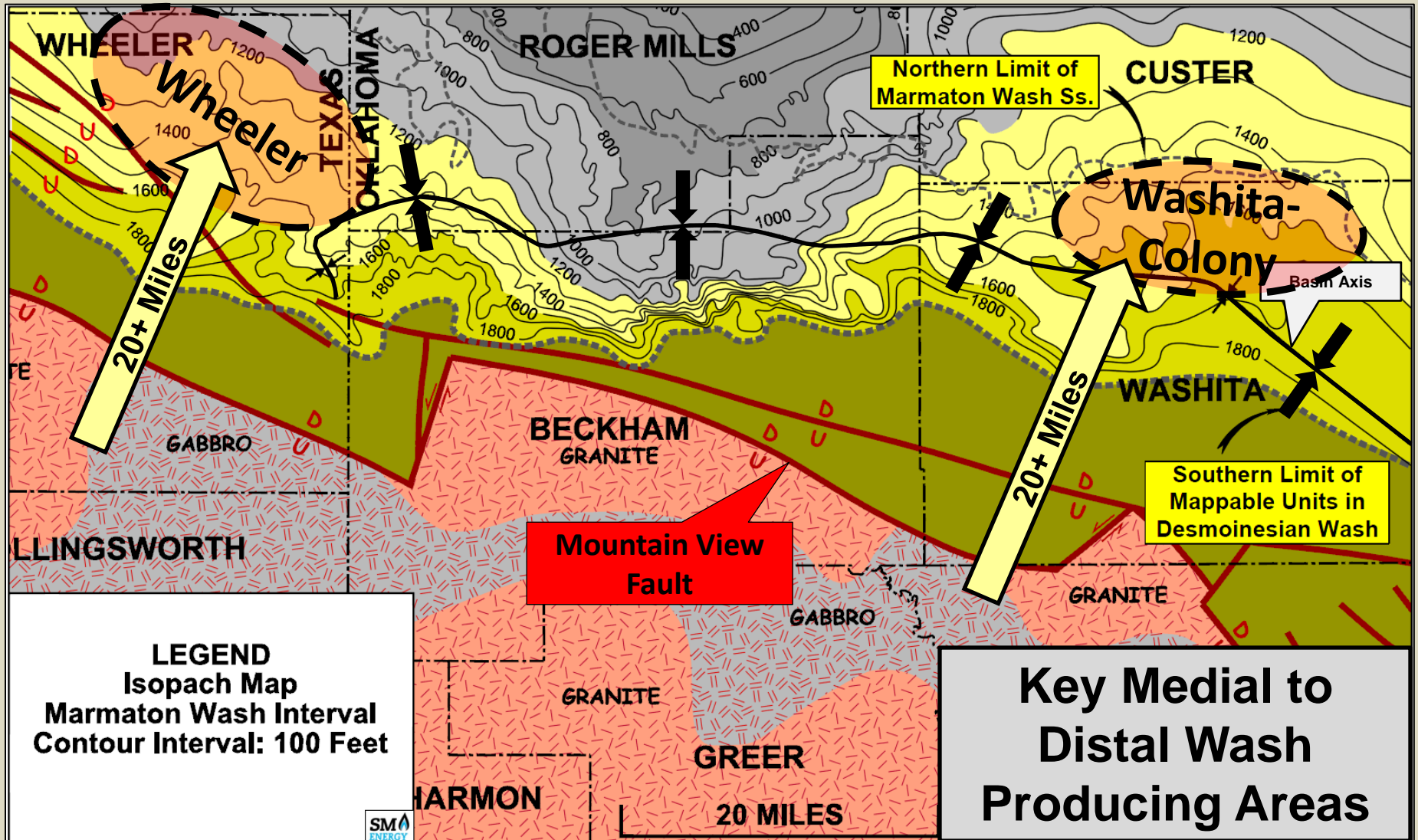
46 MMBO & 856 BCF from 816 Horizontal Wells Mainly Since 2008

Wheeler County Cum. Hrzs. Prod. = 29 MMBO & 565 BCFG

Washita County Cu. Hrzs. Prod. = 14 MMBO & 256 BCFG

HORIZONTAL GRANITE WASH PLAY

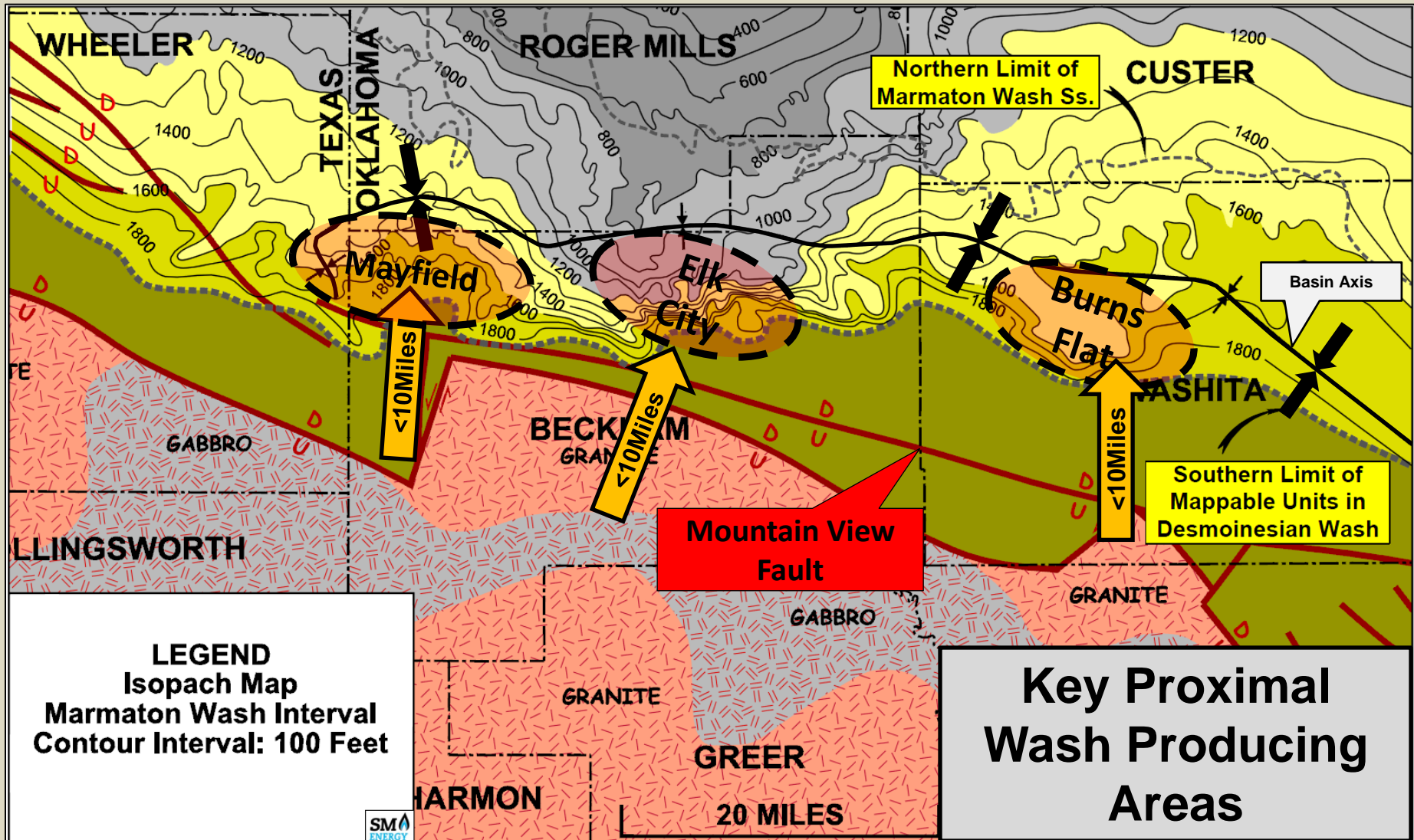
MARMATON (U. DESMOINESIAN) WASH ISOPACH



Tectonic Map From McConnell (1989), Basement Composition from Ham, Denison & Merritt (1964)

HORIZONTAL GRANITE WASH PLAY

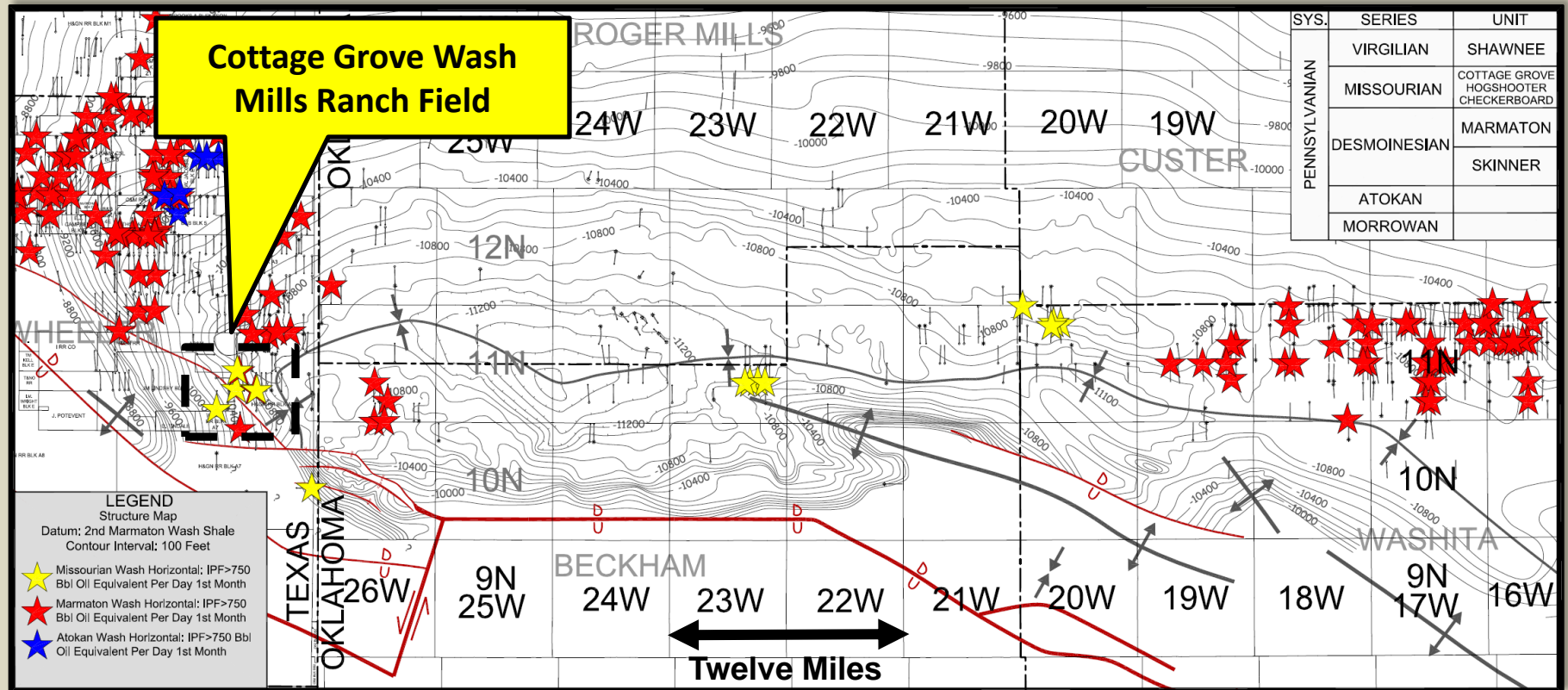
MARMATON WASH ISOPACH (THICKNESS) MAP

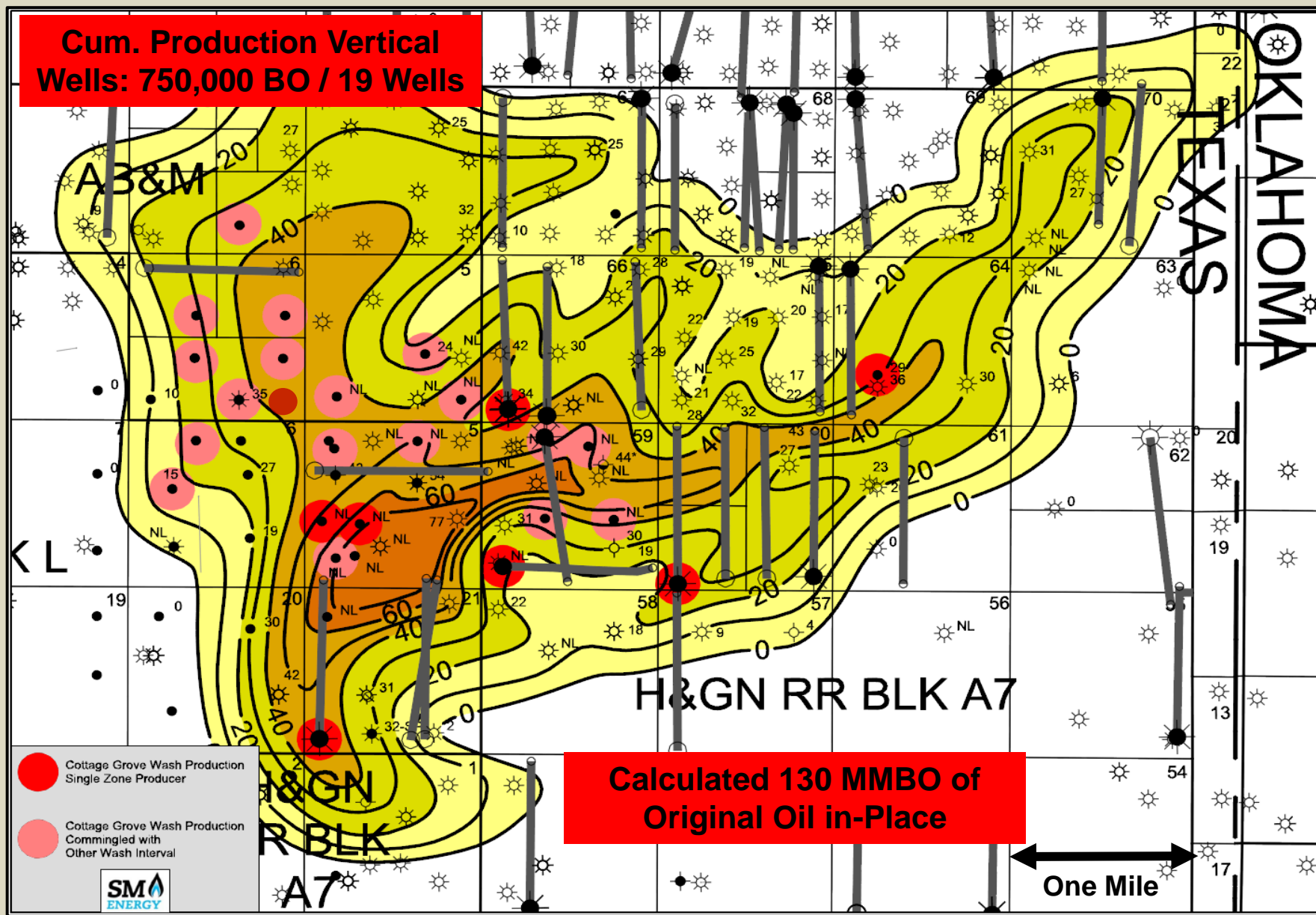


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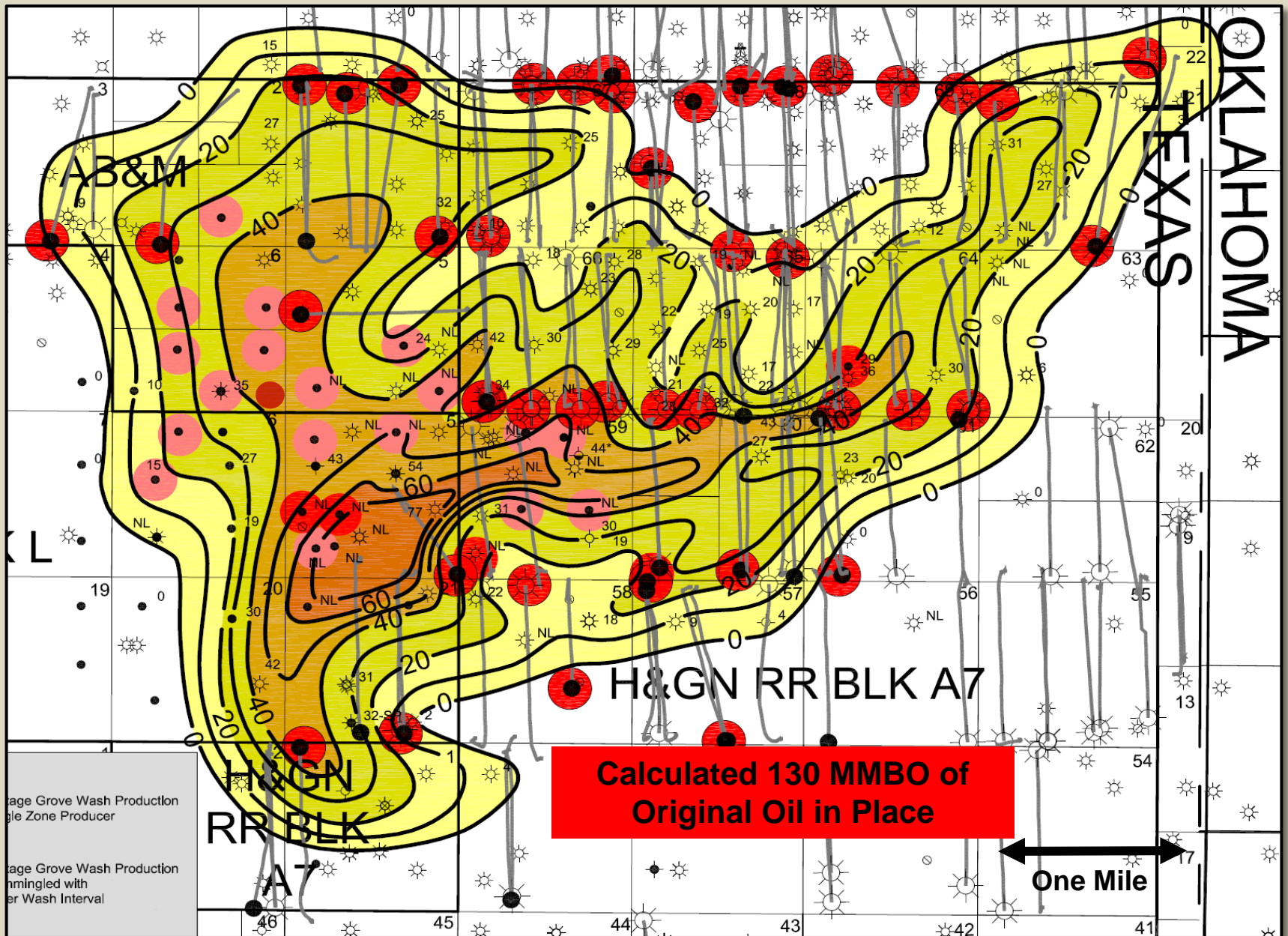
Horizontal Granite Wash Play

Missourian Wash Activity Areas



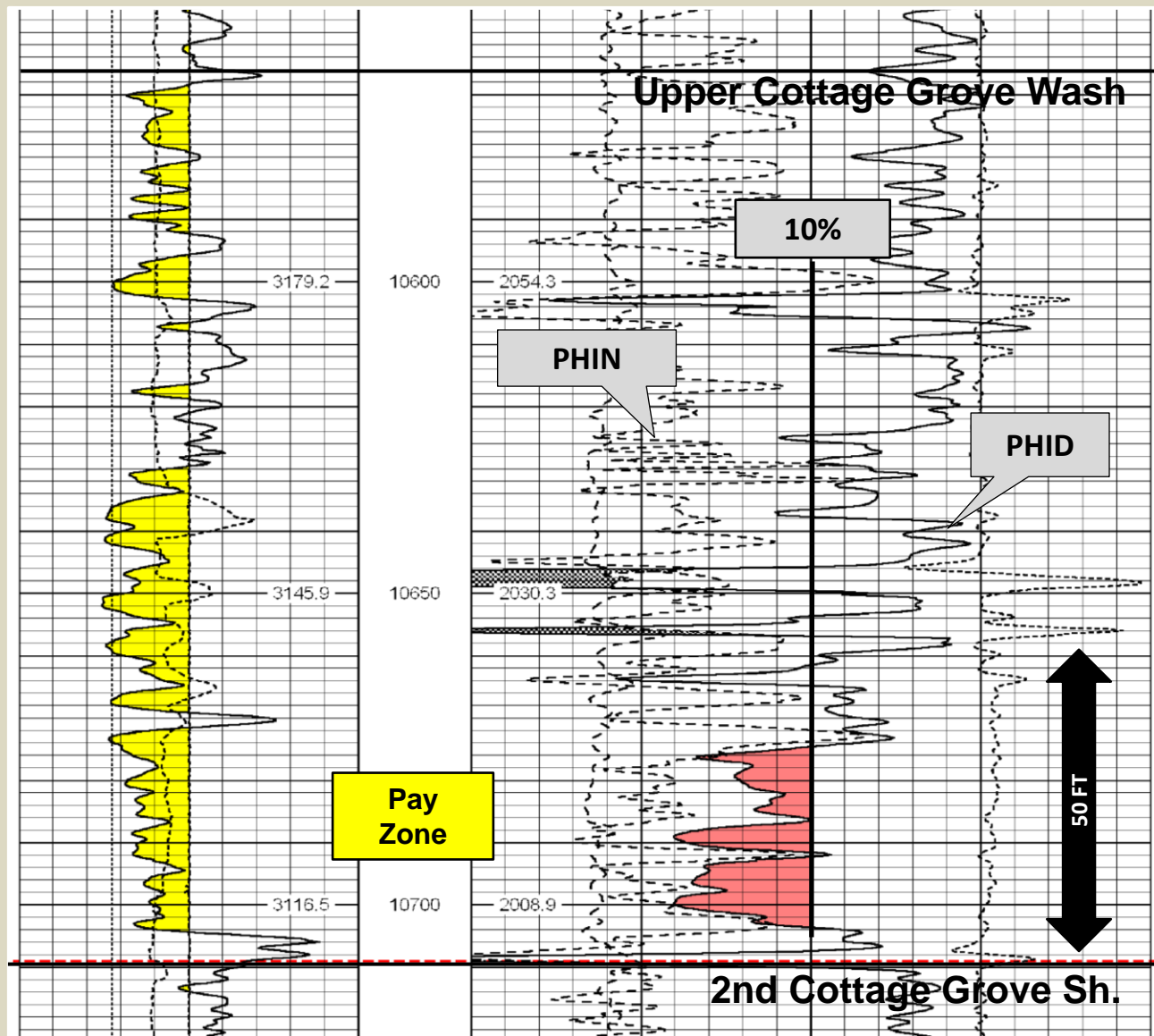


Porosity isolith map of the Upper Cottage Grove Wash with density porosity >10% on 2.71 gm/cc matrix; Contour interval = 10 feet ; Mills Ranch and Stiles Ranch fields, Wheeler Co., TX

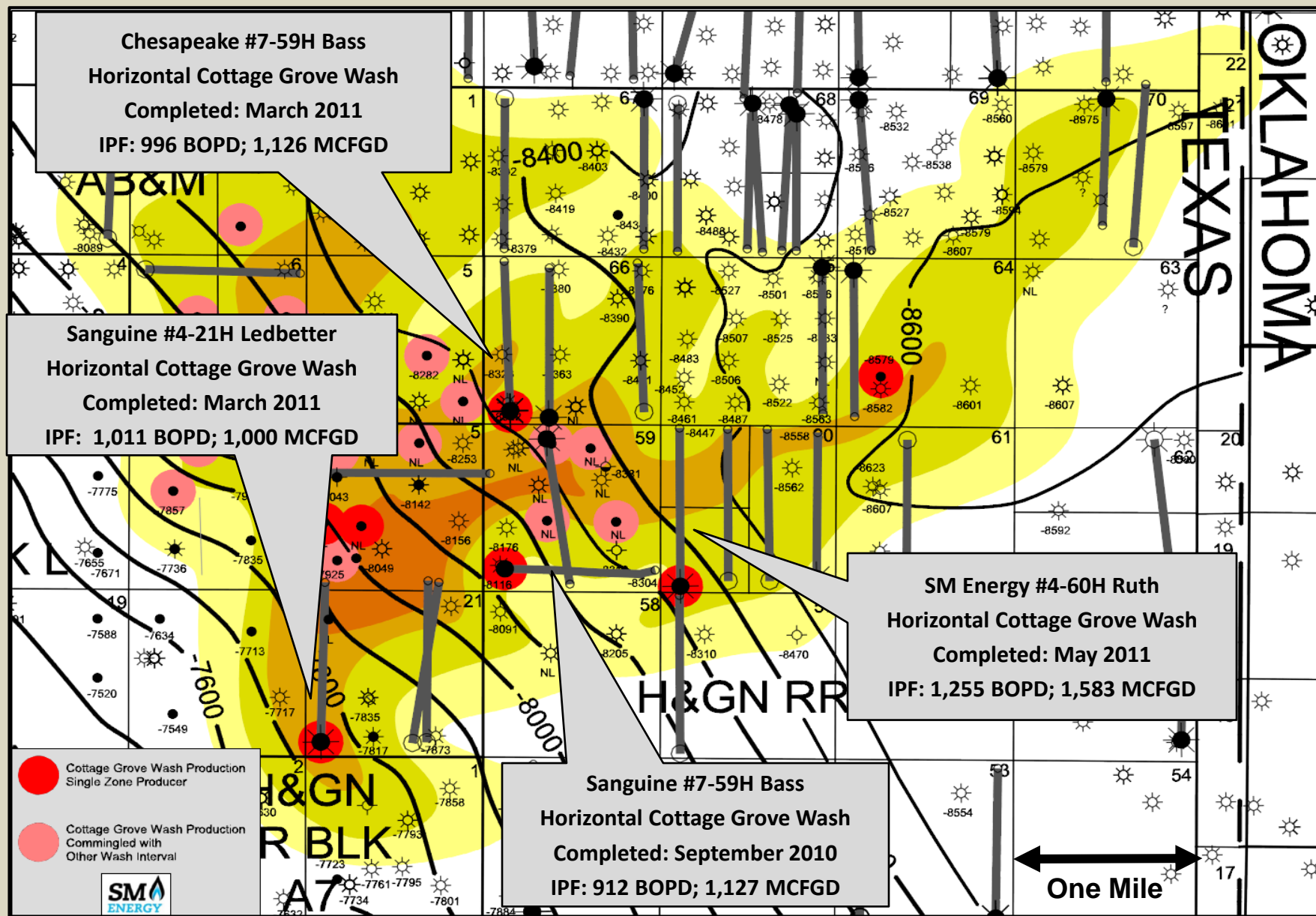


Porosity isolith map of the Upper Cottage Grove Wash with density porosity >10% on 2.71 gm/cc matrix; Contour interval = 10 feet ; Mills Ranch and Stiles Ranch fields, Wheeler Co., TX

HORIZONTAL GRANITE WASH PLAY



Type porosity log,
Upper Cottage Grove
Wash pay zone, SM
Energy #2-60H Ruth
pilot hole; NW NW
NW Sec. 60, Block A-
7, Stiles Ranch field,
Wheeler Co., TX;
porosity on lime
matrix



Structure map of the Upper Cottage Grove Wash; Contour interval = 100 feet
Mills Ranch and Stiles Ranch fields, Wheeler Co., TX

CONCLUSIONS

- **Located in the deep Anadarko Basin along the northern flank of the Amarillo-Wichita uplift in Oklahoma & Texas**
- **Granite Wash petroleum reservoirs are primarily arkosic sandstones and conglomerates with very low porosity & permeability**
- **Wash sediments were locally sourced from the Amarillo-Wichita uplift**
- **The Middle and Upper Pennsylvanian-age Granite Wash stratigraphic section exceeds 7000 feet in thickness**
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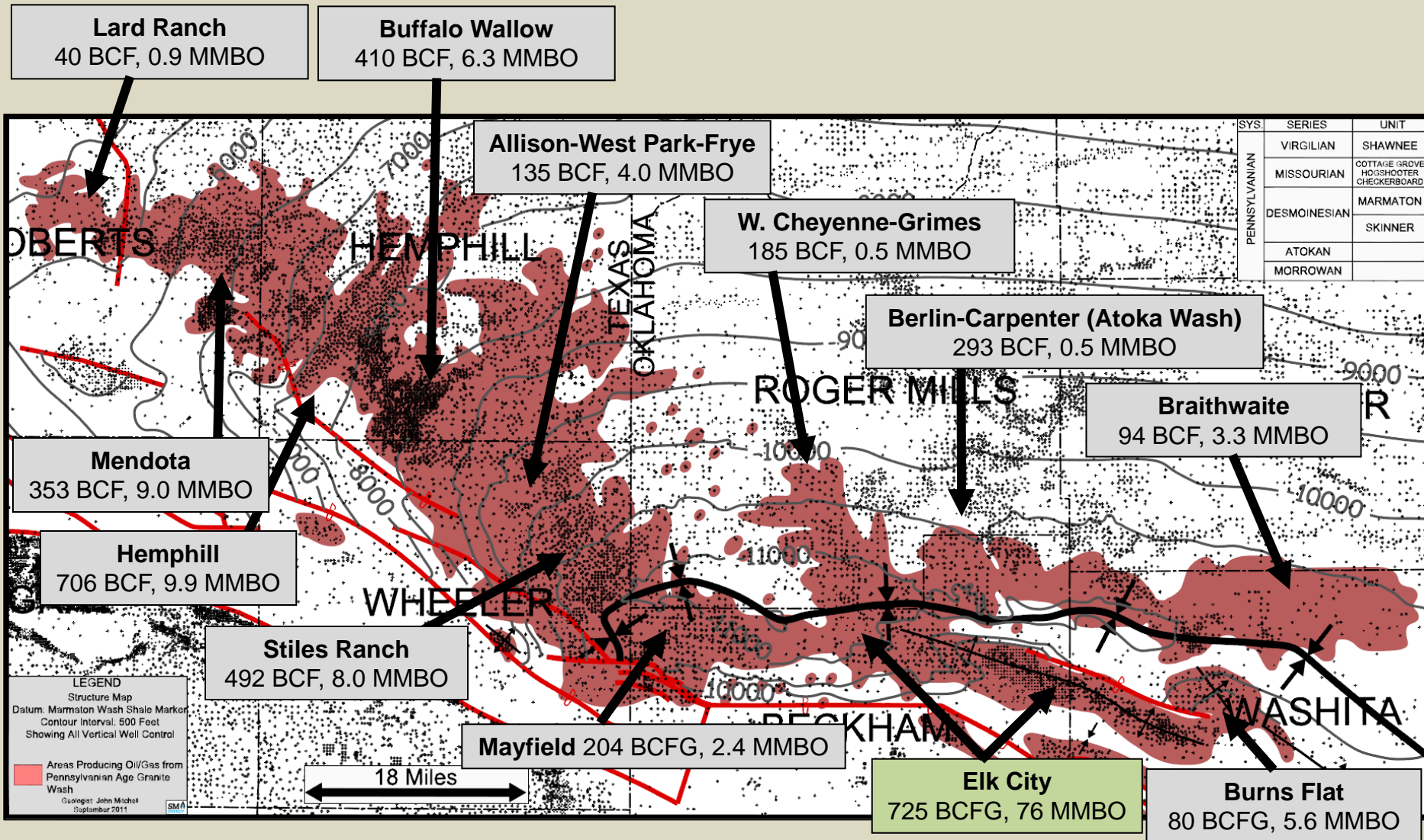
THANKS FOR LISTENING!

I would like to also thank my wife Carol Mitchell for her support and patience over 36 years of marriage to a roving geologist.

Appendix

- Additional illustrations prepared during this study of the Granite Wash Play.

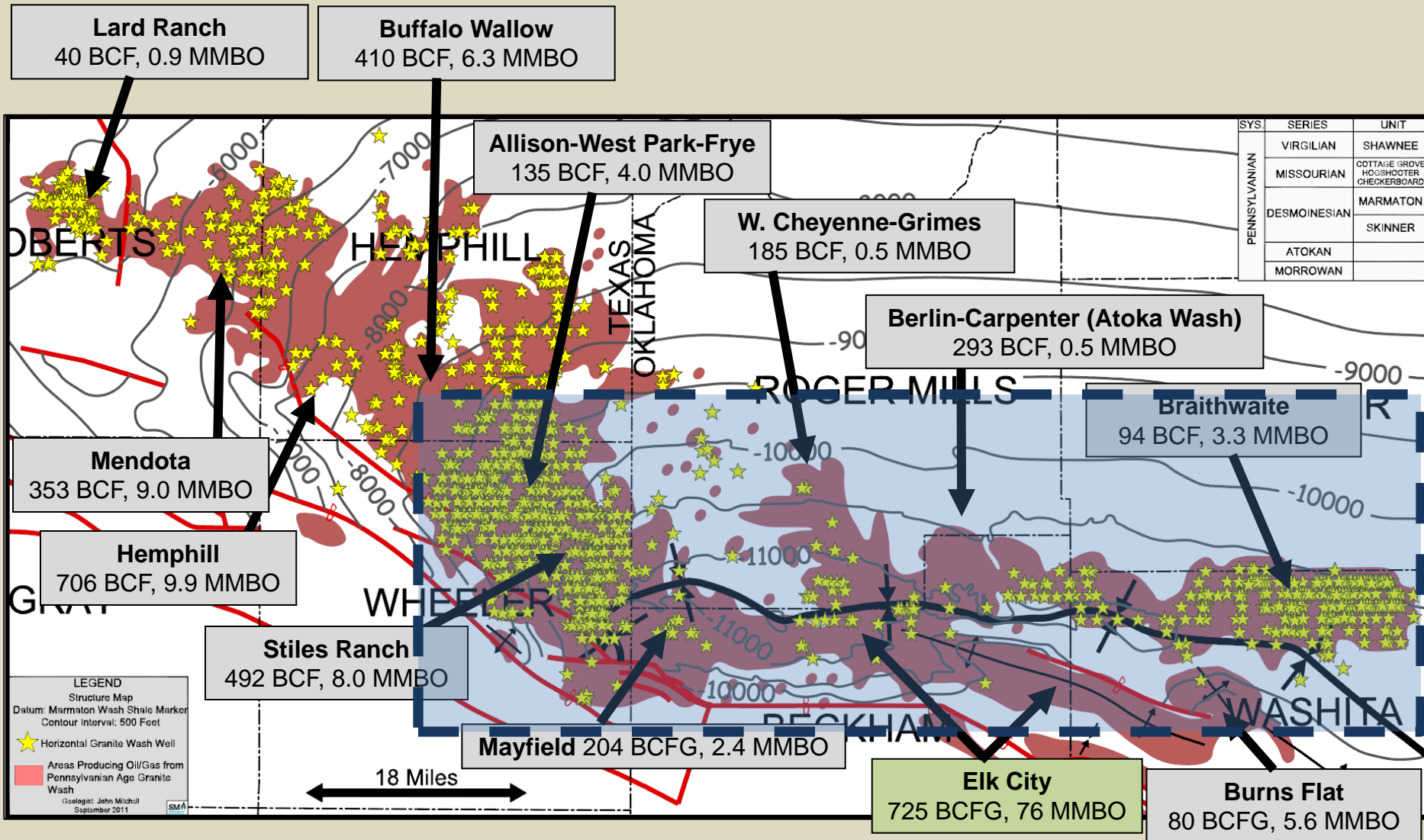
HORIZONTAL GRANITE WASH PLAY



Principal Oil and Gas Field Production Information

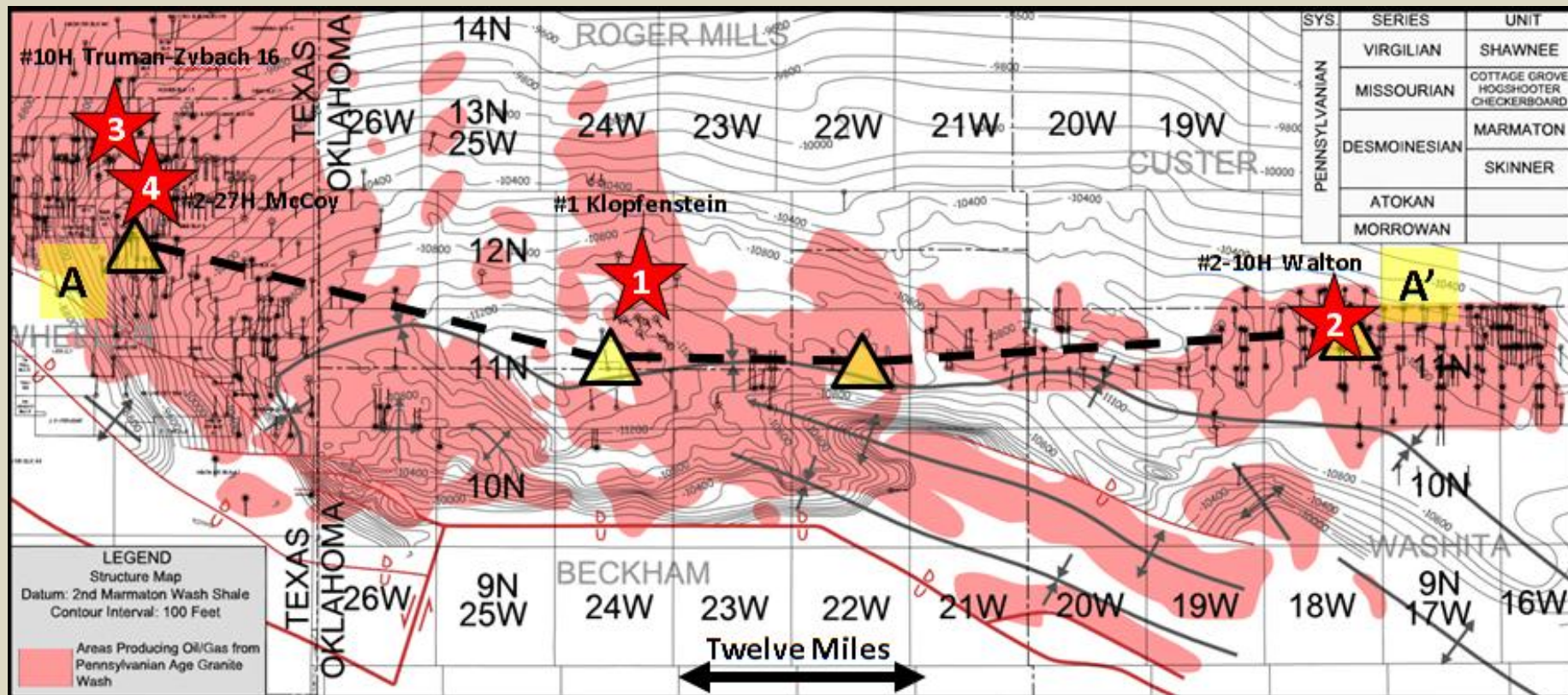
>3.7 TCFG + 126 MMBO Cumulative Production from > 4,000 wells

HORIZONTAL GRANITE WASH PLAY



>1,500 Horizontal Granite Wash Wells
Spud Through April 2012

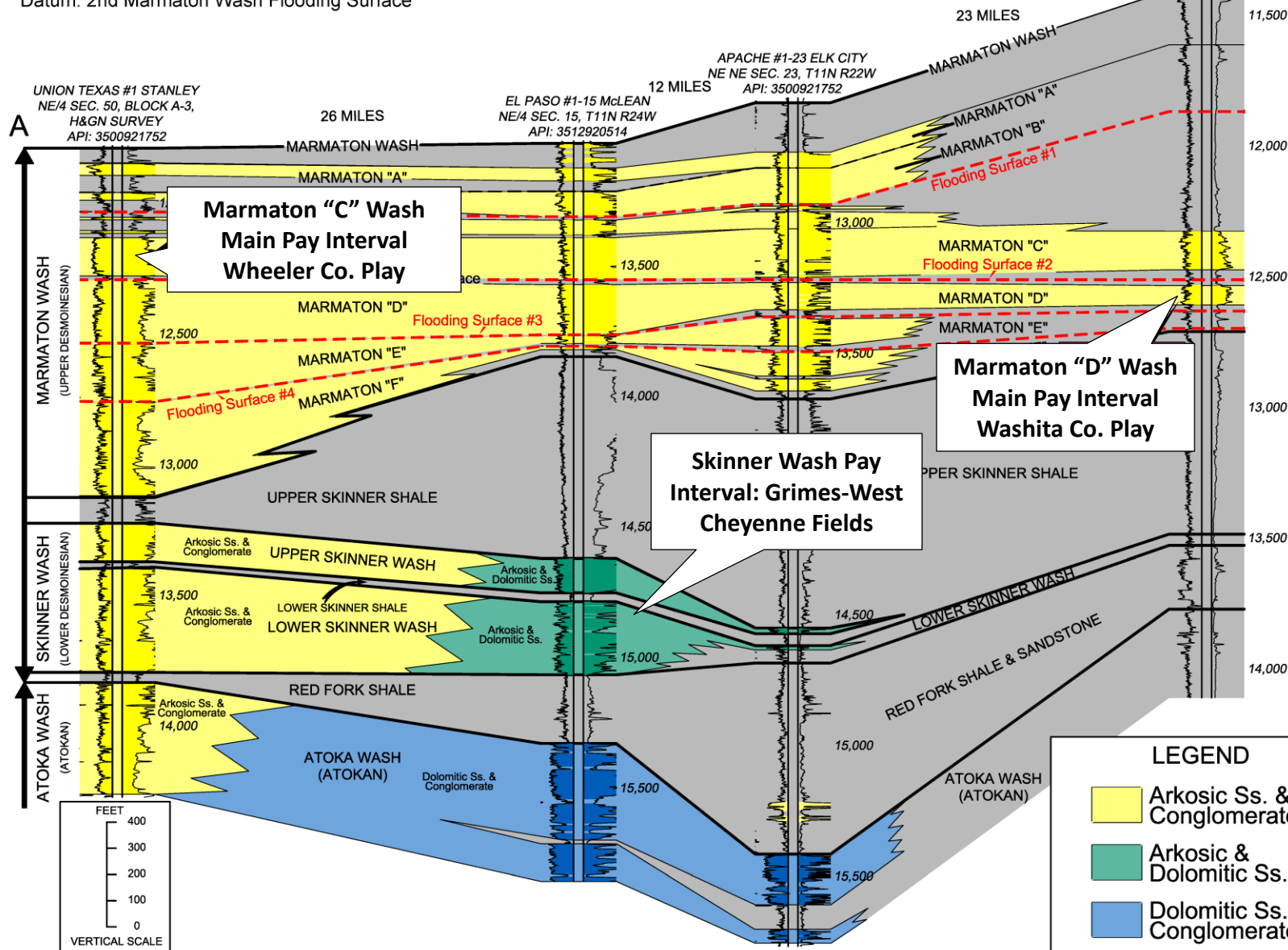
HORIZONTAL GRANITE WASH PLAY



Regional Cross Section Index Map

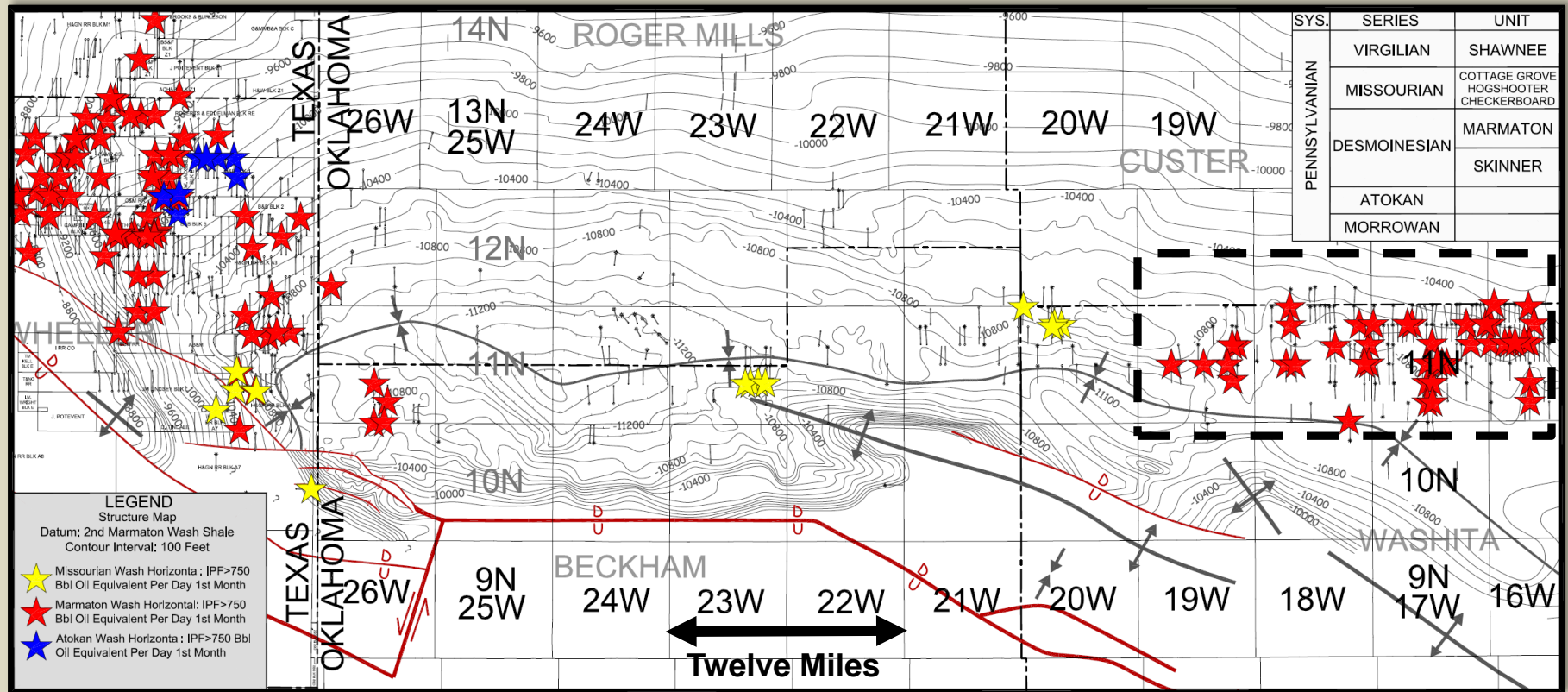
Stratigraphic Cross Section A-A'
Wheeler Co., Texas to Washita Co., Oklahoma
Datum: 2nd Marmaton Wash Flooding Surface

CITIES SERVICE #1 CHARTER
NE SW SEC. 11, T11N R18W
API: 3514920254



Stratigraphic cross section A-A', Desmoinesian & Upper Atoka Wash, Wheeler Co., TX to Washita Co., OK; Datum: 2nd Marmaton shale

Horizontal Granite Wash – Colony-Braithwaite Field



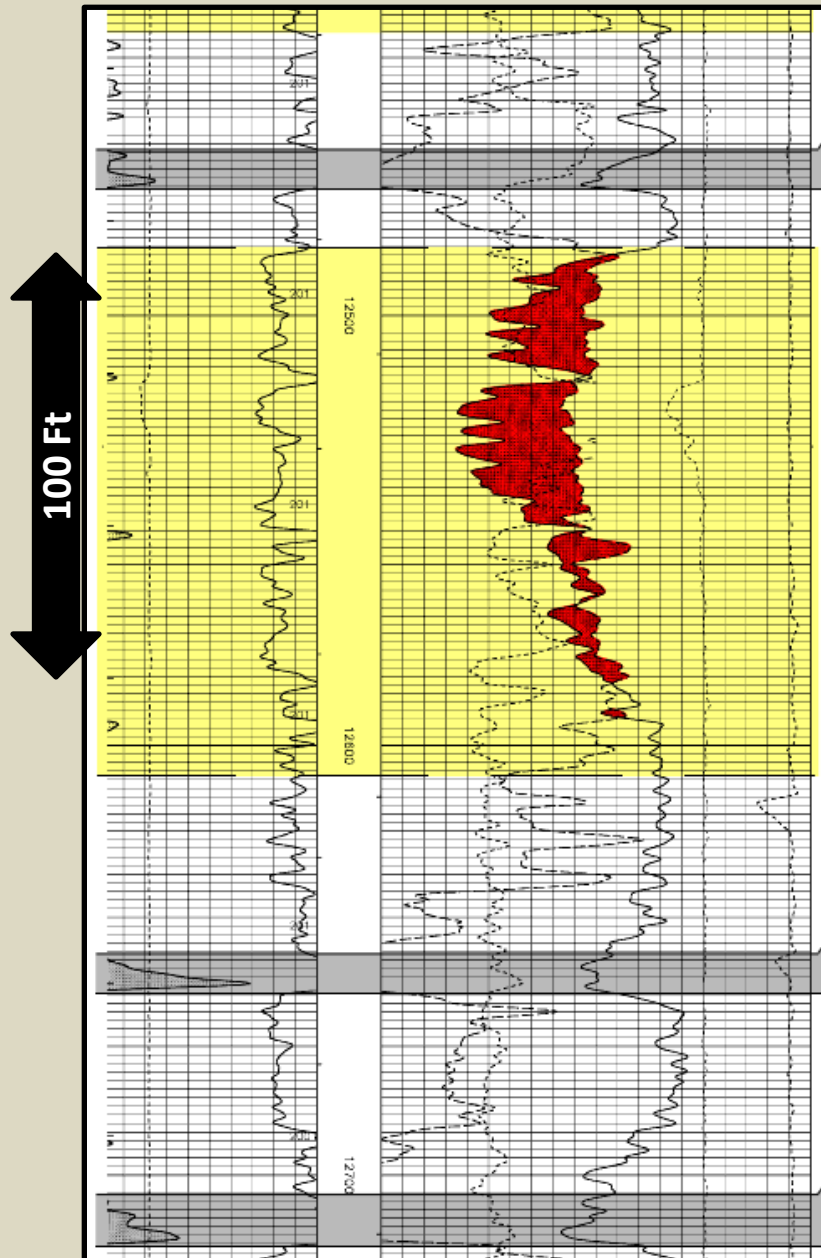
Washita County-Colony Wash Play

Cum. Production: 8.3 MMBO & 117 BCFG from 141 Horizontal Wells

Daily Production: ~8,000 BOPD & 117 MMCFGPD (Feb. 2011)

Estimated Ultimate Recovery: >500 BCFE?

HORIZONTAL GRANITE WASH PLAY



2nd Marmaton Wash
Flooding Surface

Marmaton "D" Wash:
Colony Pay Zone

3rd Marmaton Wash
Flooding Surface
Marmaton "E" Wash

4th Marmaton Wash
Flooding Surface

Type porosity log,
Marmaton "D" Wash
pay zone, CHK #1-
13H Huls pilot hole;
SW SW SW Sec. 13,
T11N R19W,
Breathwaite field,
Washita Co., OK;
porosity on lime
matrix; porosity
exhibits gas effect
(red shading) on log
and is target zone for
horizontals

Horizontal Granite Wash – Colony-Braithwaite Field

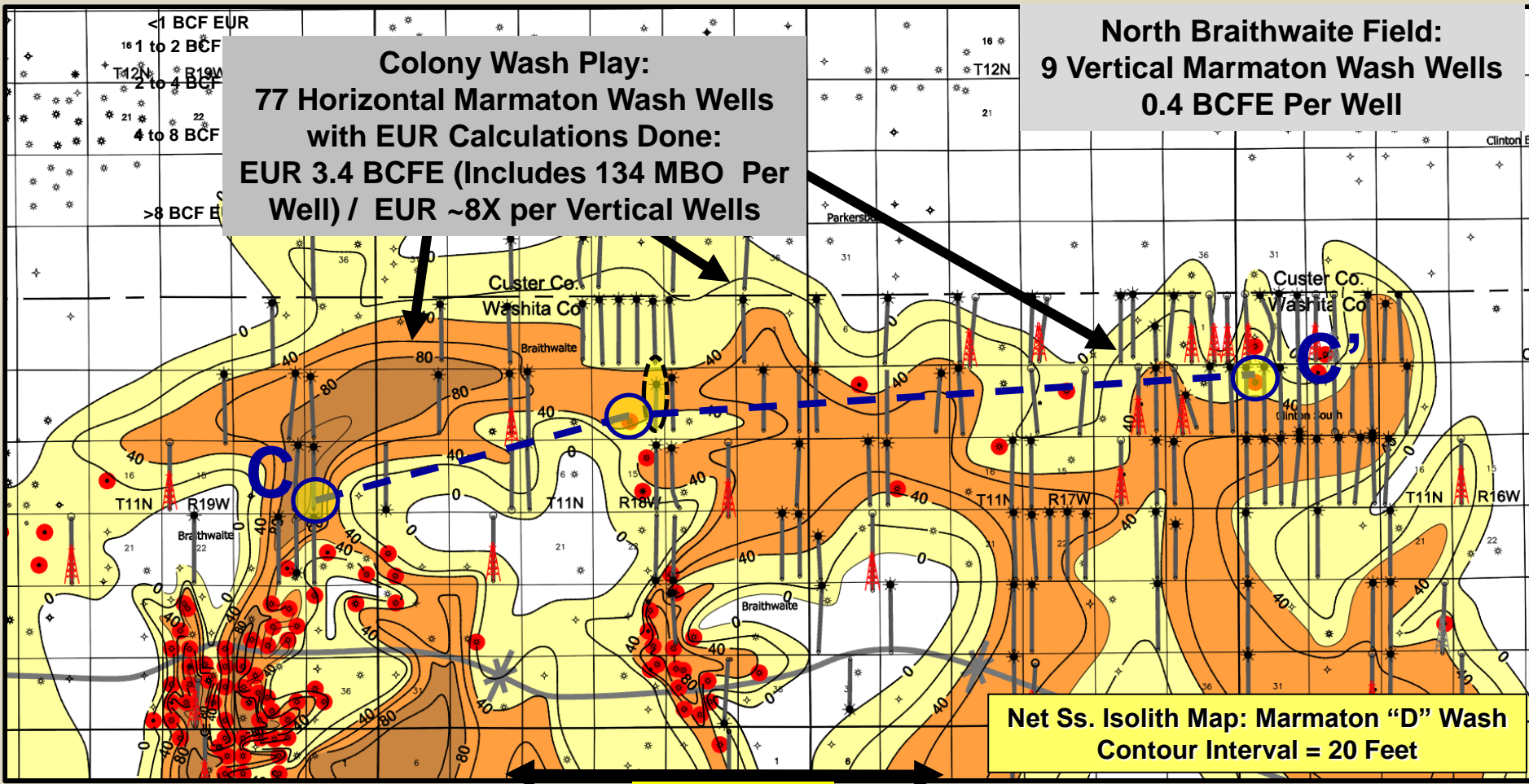
Colony Wash Play:
77 Horizontal Marmaton Wash Wells
with EUR Calculations Done:
EUR 3.4 BCFE (Includes 134 MBO Per
Well) / EUR ~8X per Vertical Wells

North Braithwaite Field:
9 Vertical Marmaton Wash Wells
0.4 BCFE Per Well

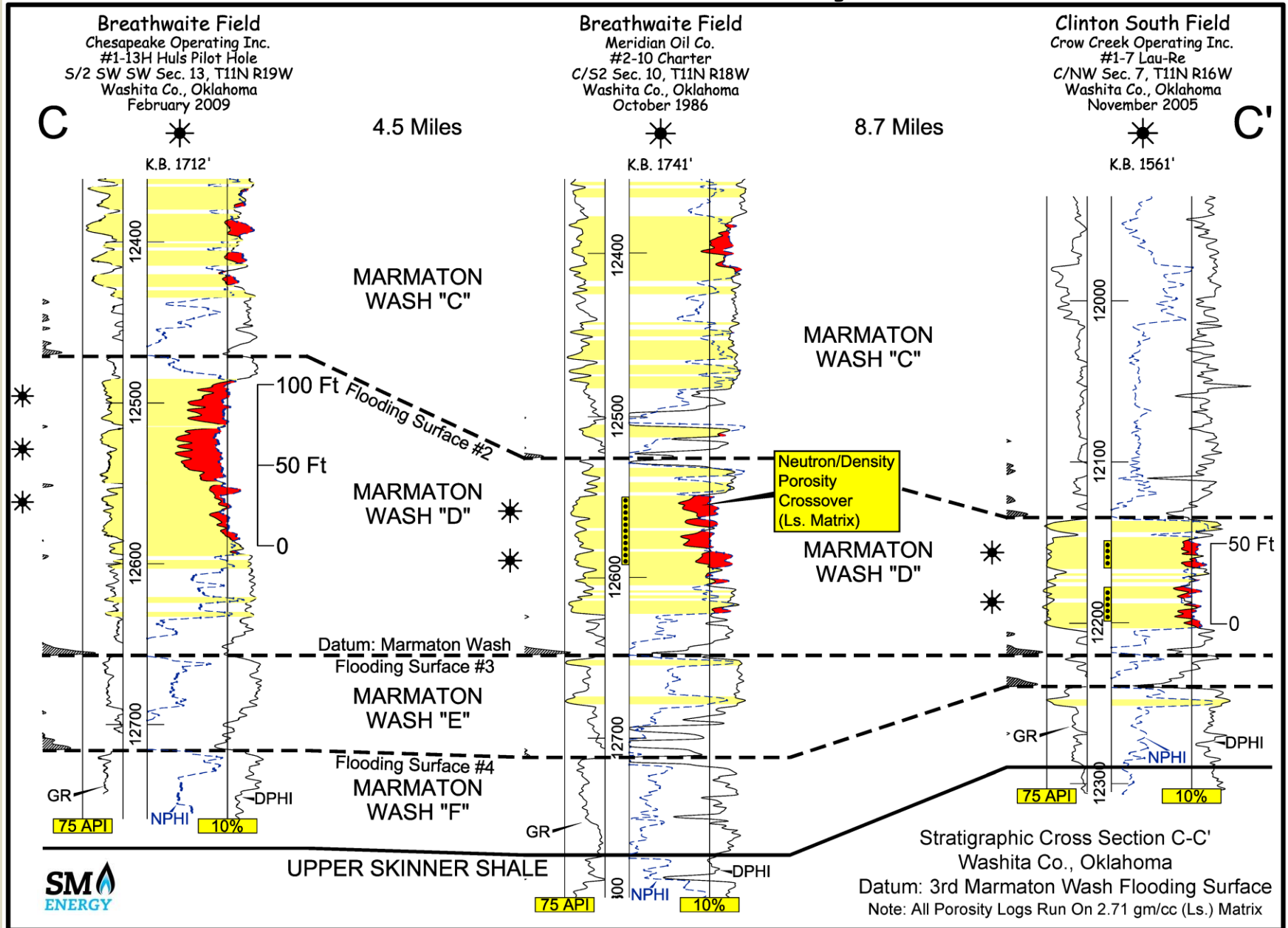
Net Ss. Isolith Map: Marmaton "D" Wash
Contour Interval = 20 Feet

Six Miles

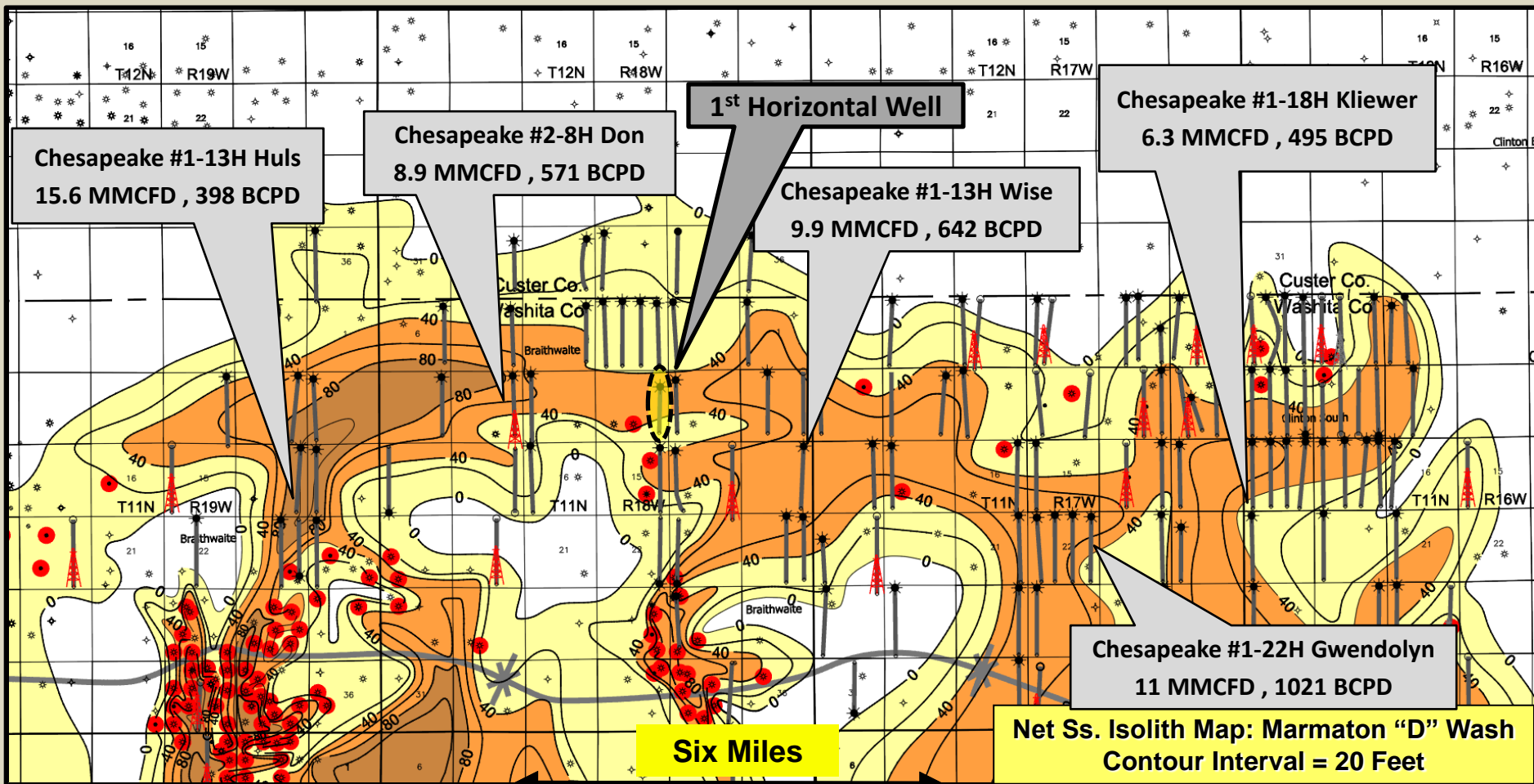
**Horizontal Drilling in
Marmaton "D" Reservoir
Since December 2006**



Horizontal Granite Wash – Colony-Braithwaite Field



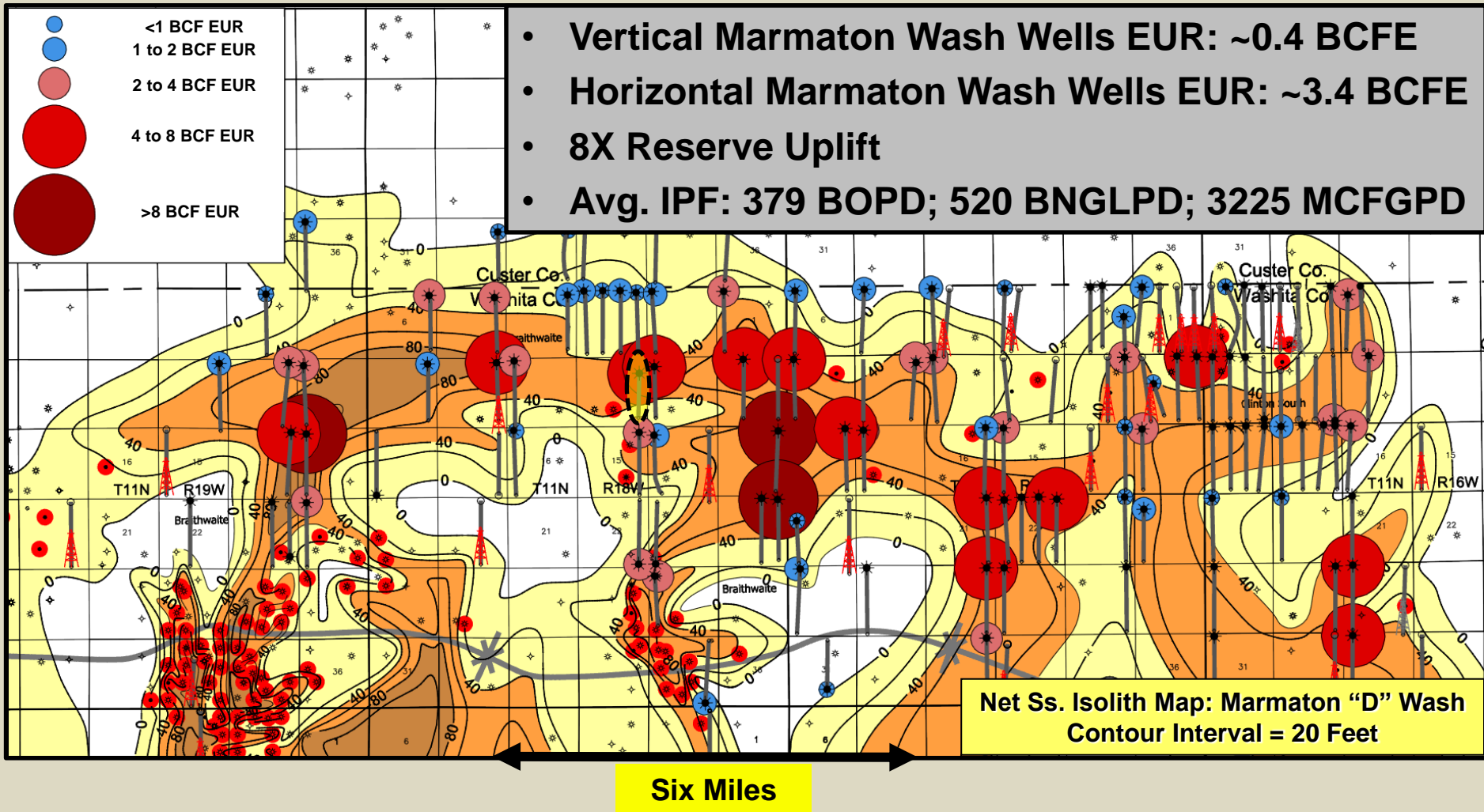
Horizontal Granite Wash – Colony-Braithwaite Field



Washita Co. Marmaton Wash Play: Avg. Max Month Production Data for 90 Horizontals
5.4 MMCFD & 516 BCPD

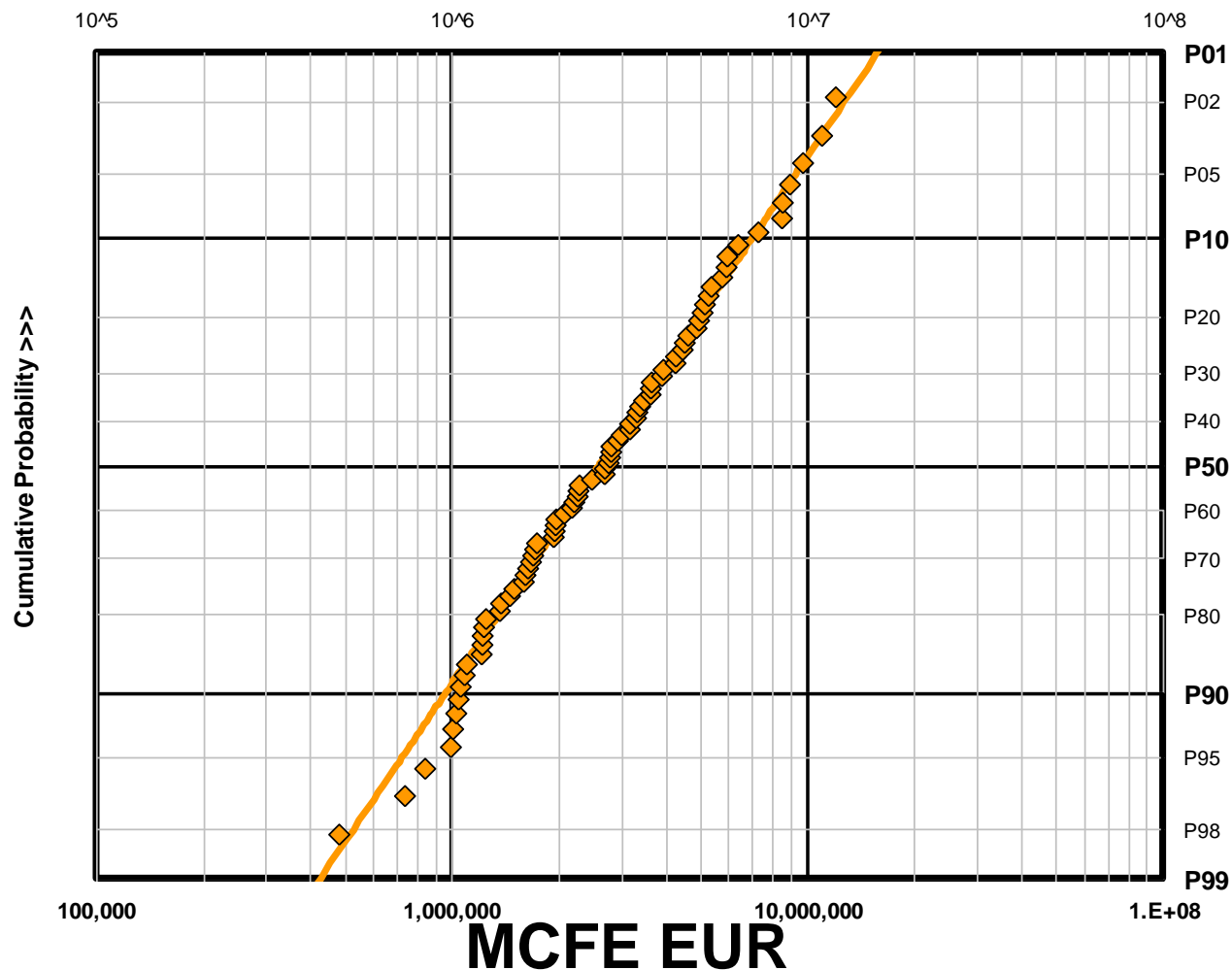
Max Month Production Daily Average Rates Since December 2006

Horizontal Granite Wash – Colony-Braithwaite Field



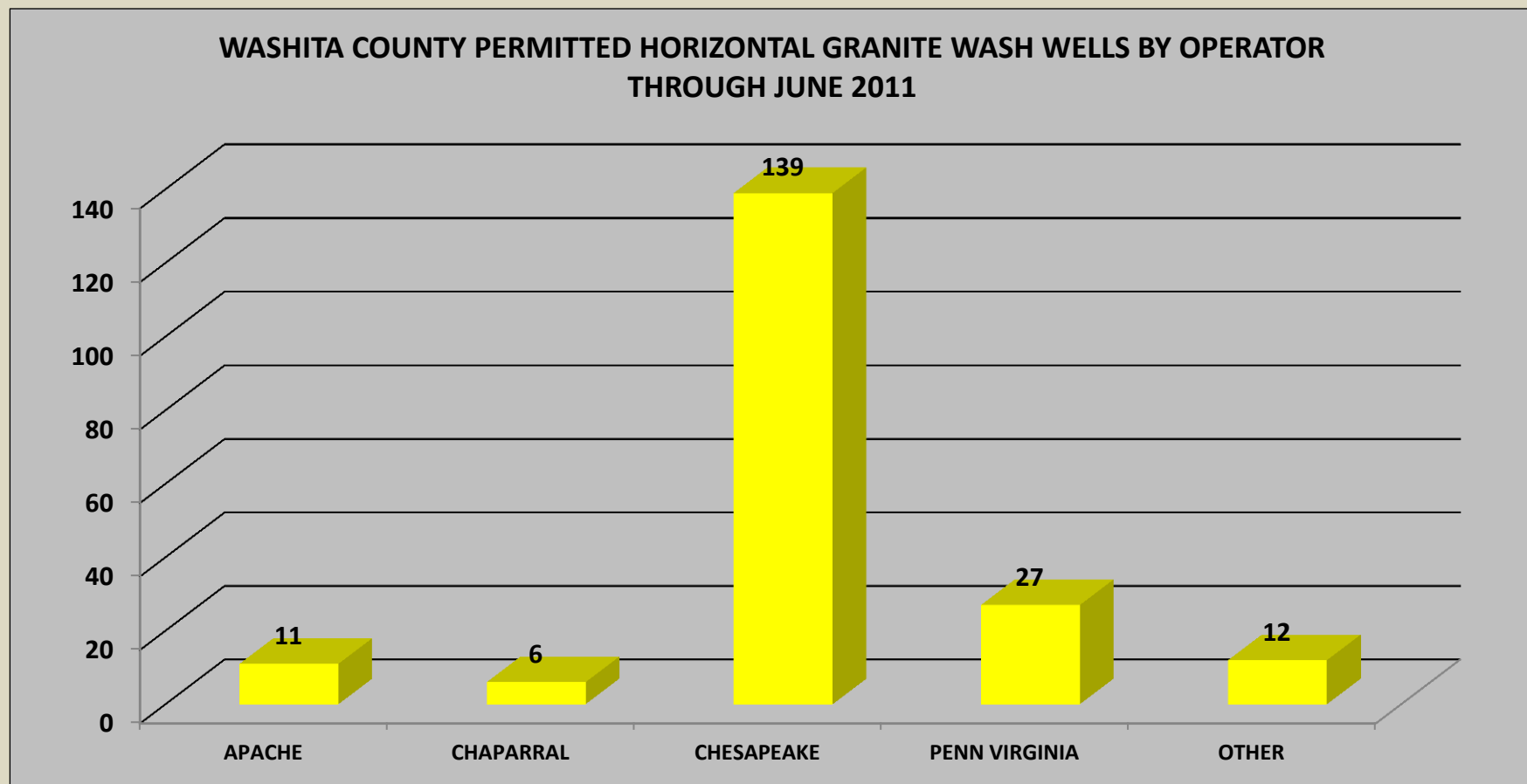
Washita County Marmaton Wash EURs (MCFe)

LOG PROBIT CHART



P10: 6.45 BCFe
P50: 2.72 BCFe
P90: 1.05 BCFe
Mean: 3.40 BCFe
77 Wells

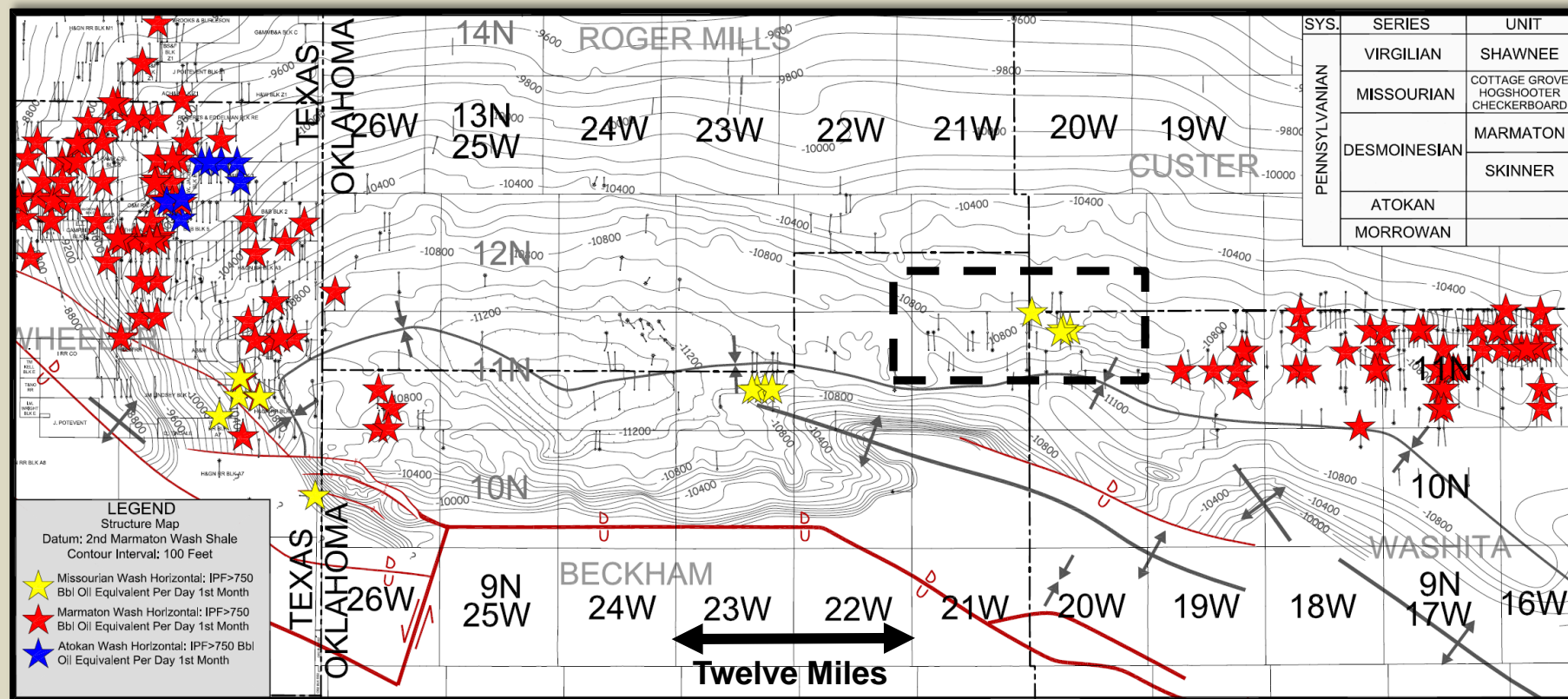
WASHITA CO. DRILLING STATISTICS BY OPERATOR



Graph showing number of permitted horizontal Granite Wash wells by operator in Washita County, Oklahoma through June 30th, 2011.

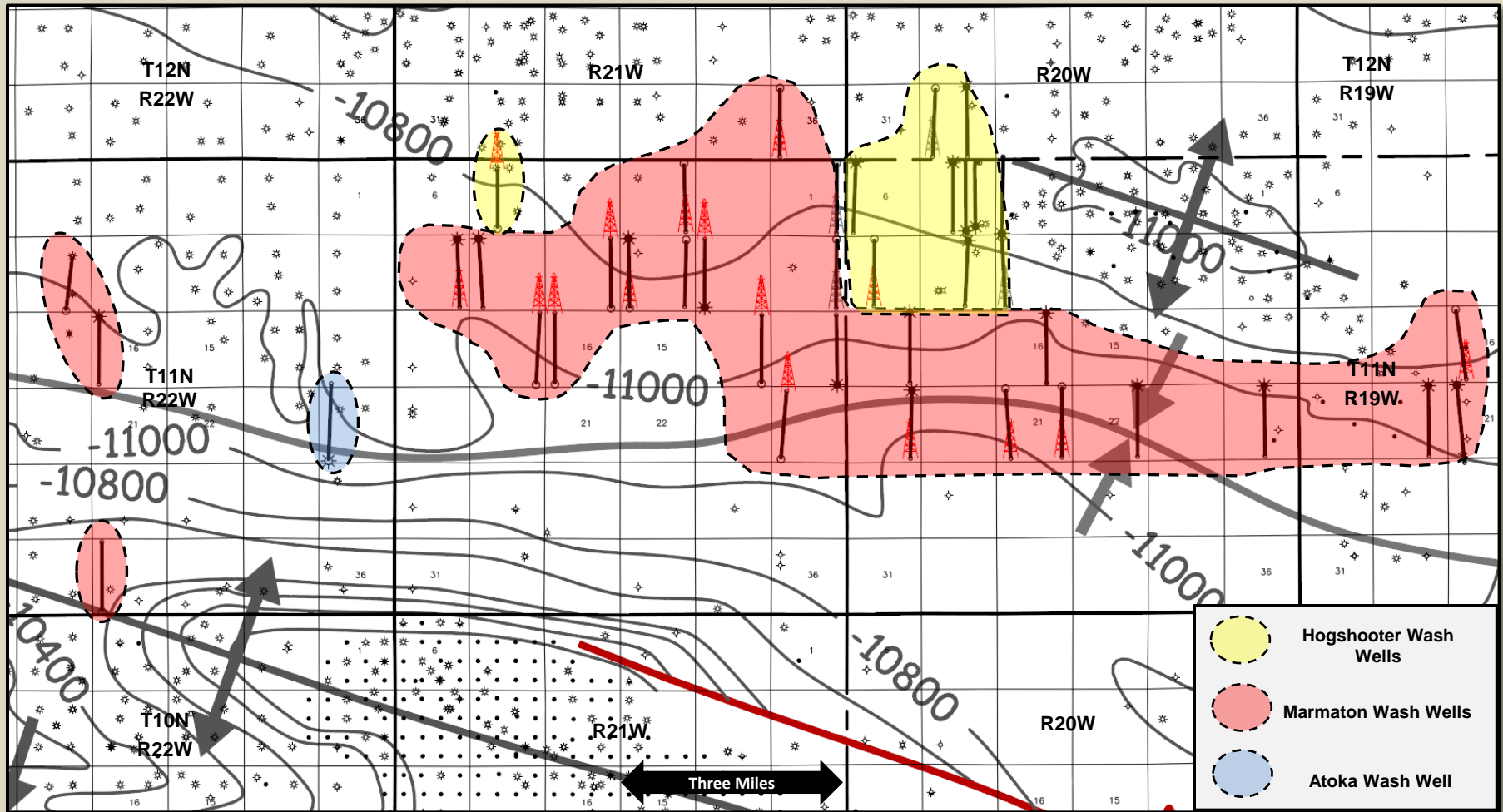
Horizontal Granite Wash

North Canute to Elk City Area



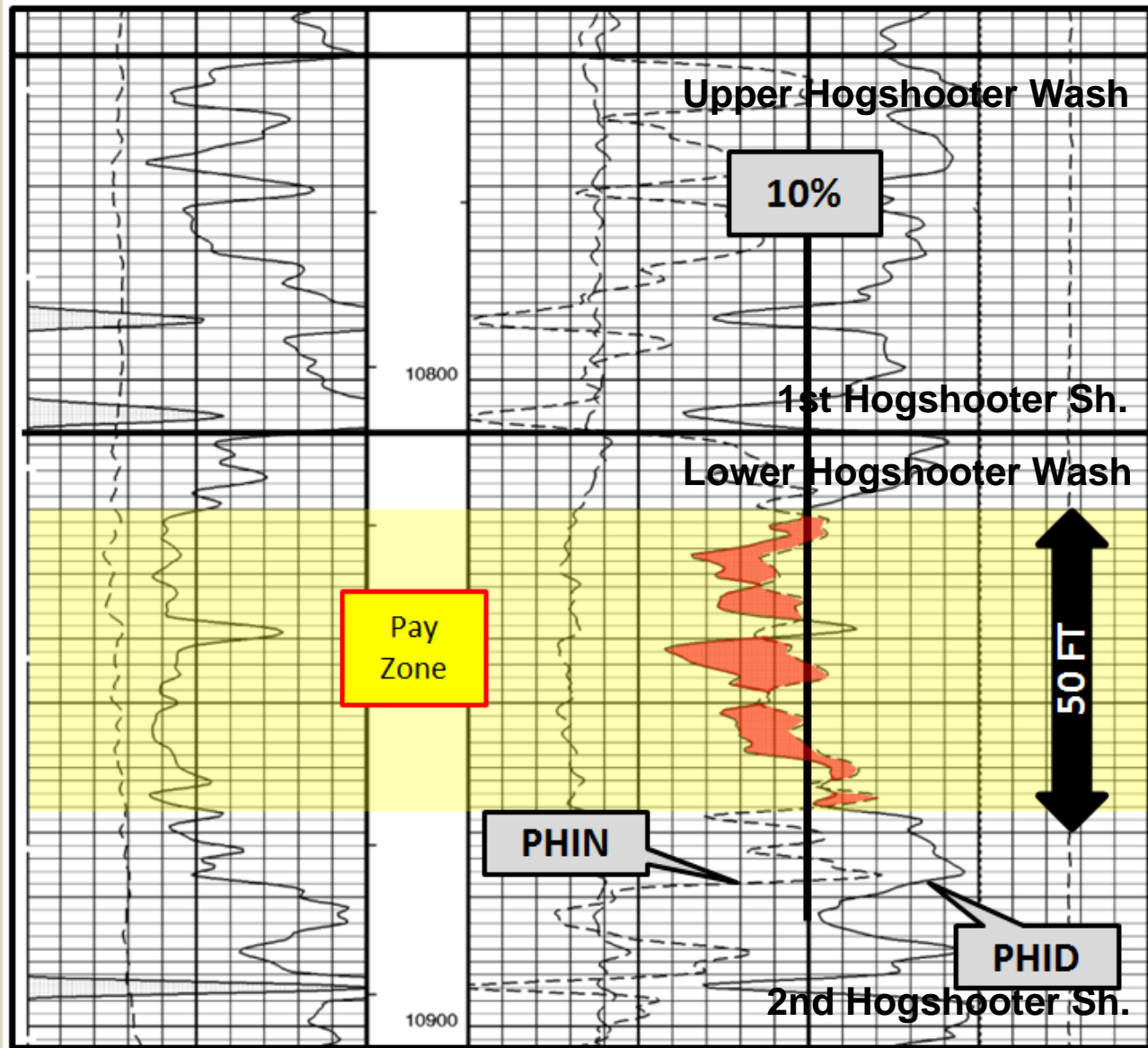
Hogshooter Wash (Missourian)

Horizontal Granite Wash North Canute to Elk City Area



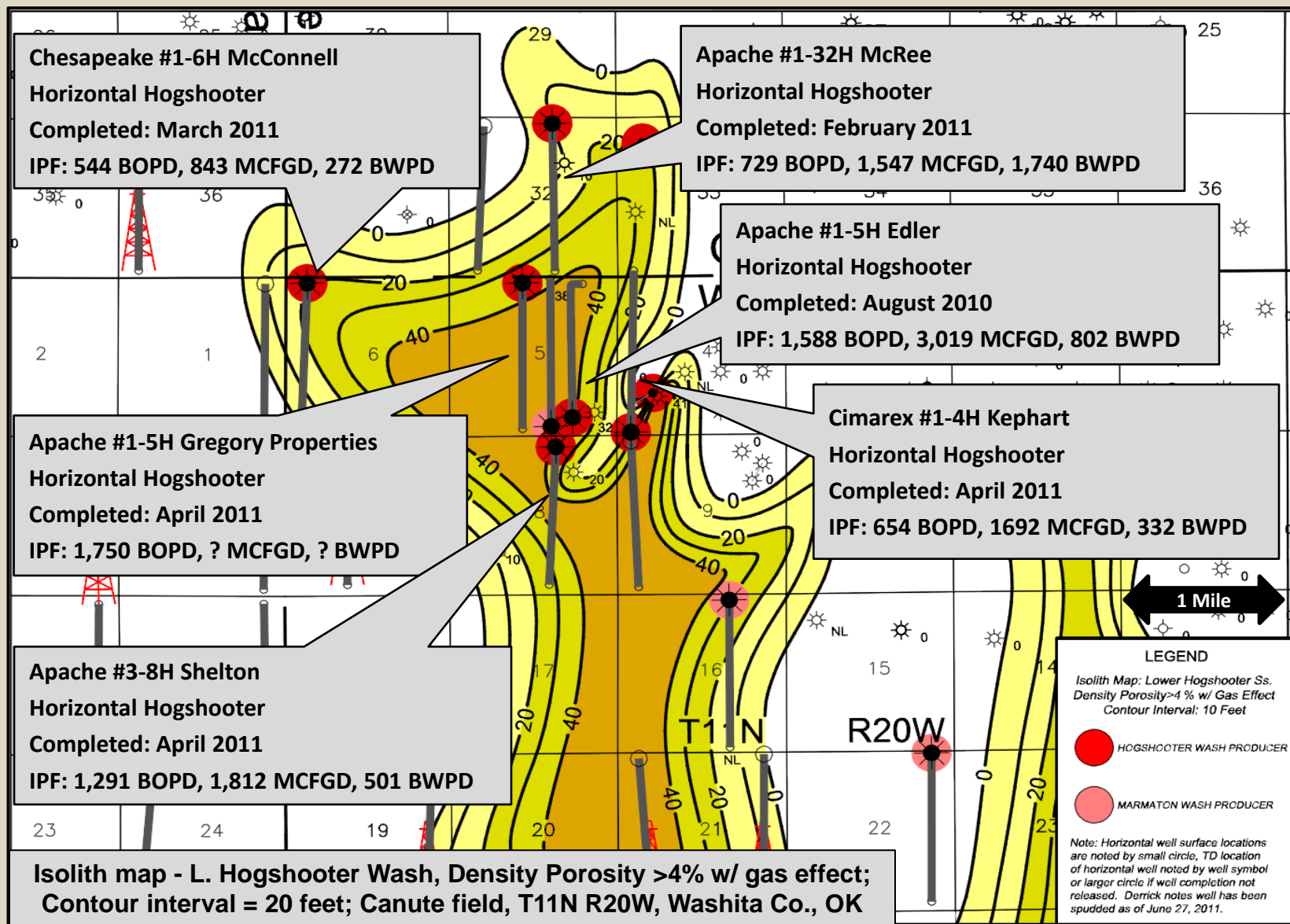
Structure map on 2nd Marmaton Shale, Contour Interval = 200 feet; color fills show areas of recent expansion of horizontal Wash drilling in T11-12N, R20-22W, Washita, Beckham, and Custer Cos. , Oklahoma; rig symbols indicate wells being actively drilled, completed or permitted in June 2011

HORIZONTAL GRANITE WASH PLAY

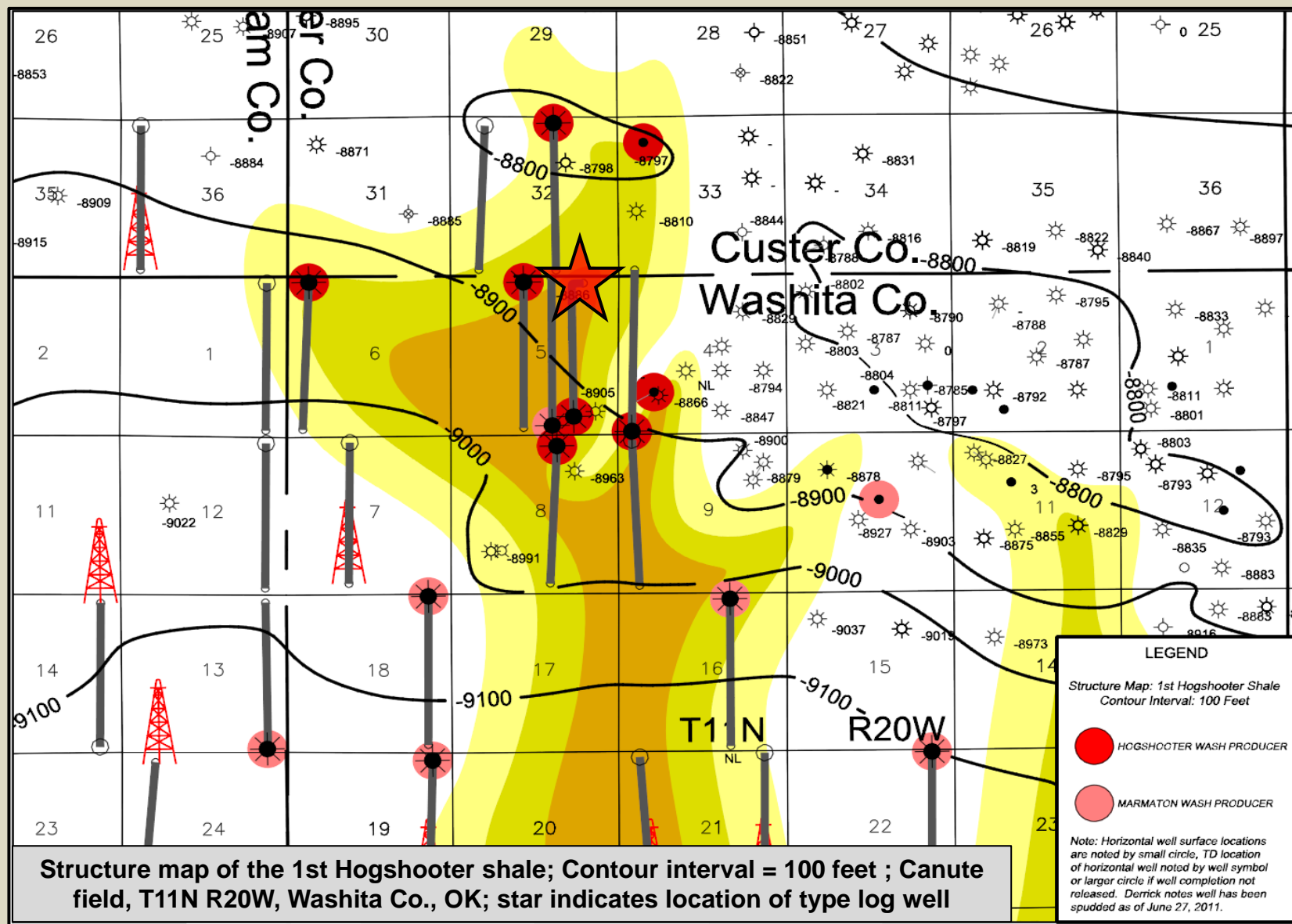


Type porosity log, Hogshooter Wash pay zone, Apache #1-5H McRee pilot hole; NW NW NE Sec. 5, T11N R20W, Canute field, Washita Co., OK; porosity on lime matrix; porosity exhibits gas effect (red shading) on log and is target zone for horizontals

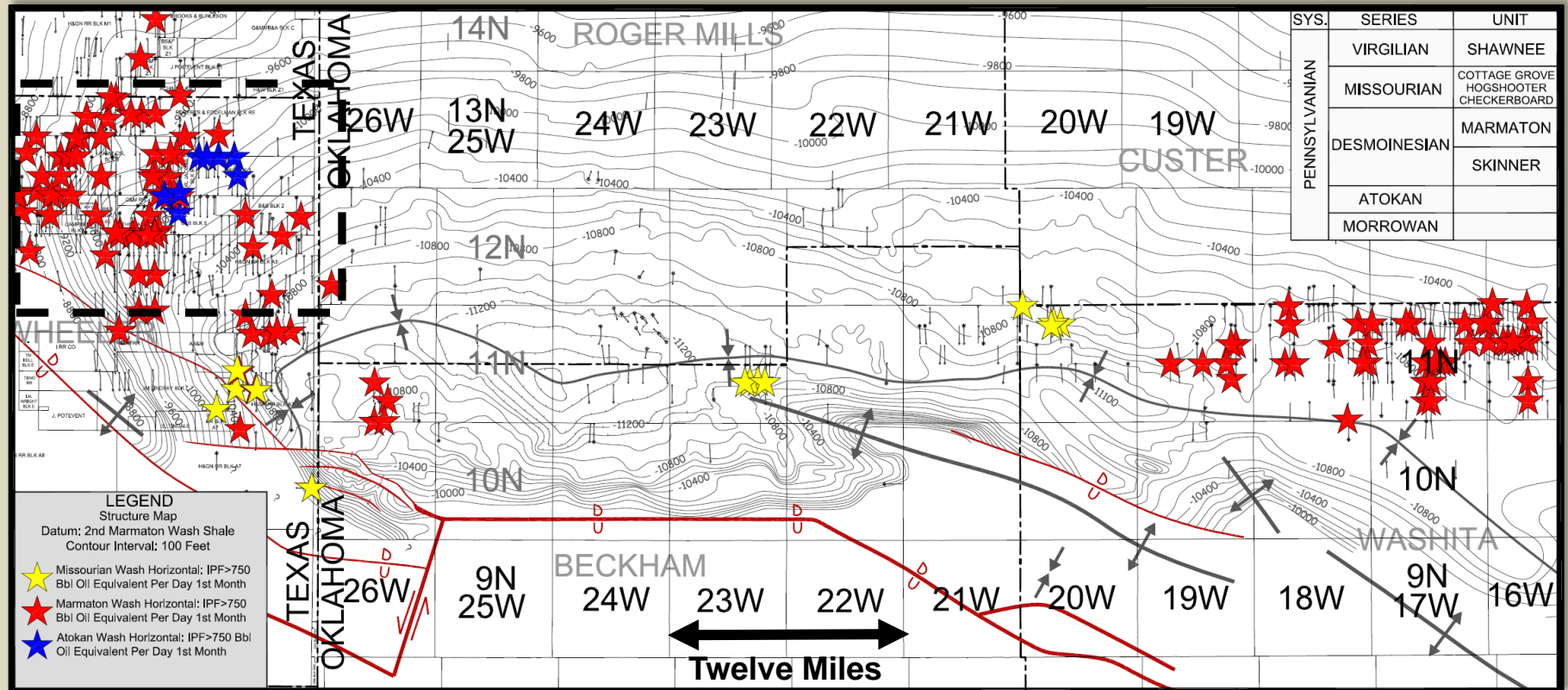
Horizontal Granite Wash - North Canute Area



Horizontal Granite Wash - North Canute Area



Horizontal Granite Wash-Wheeler County Play Area

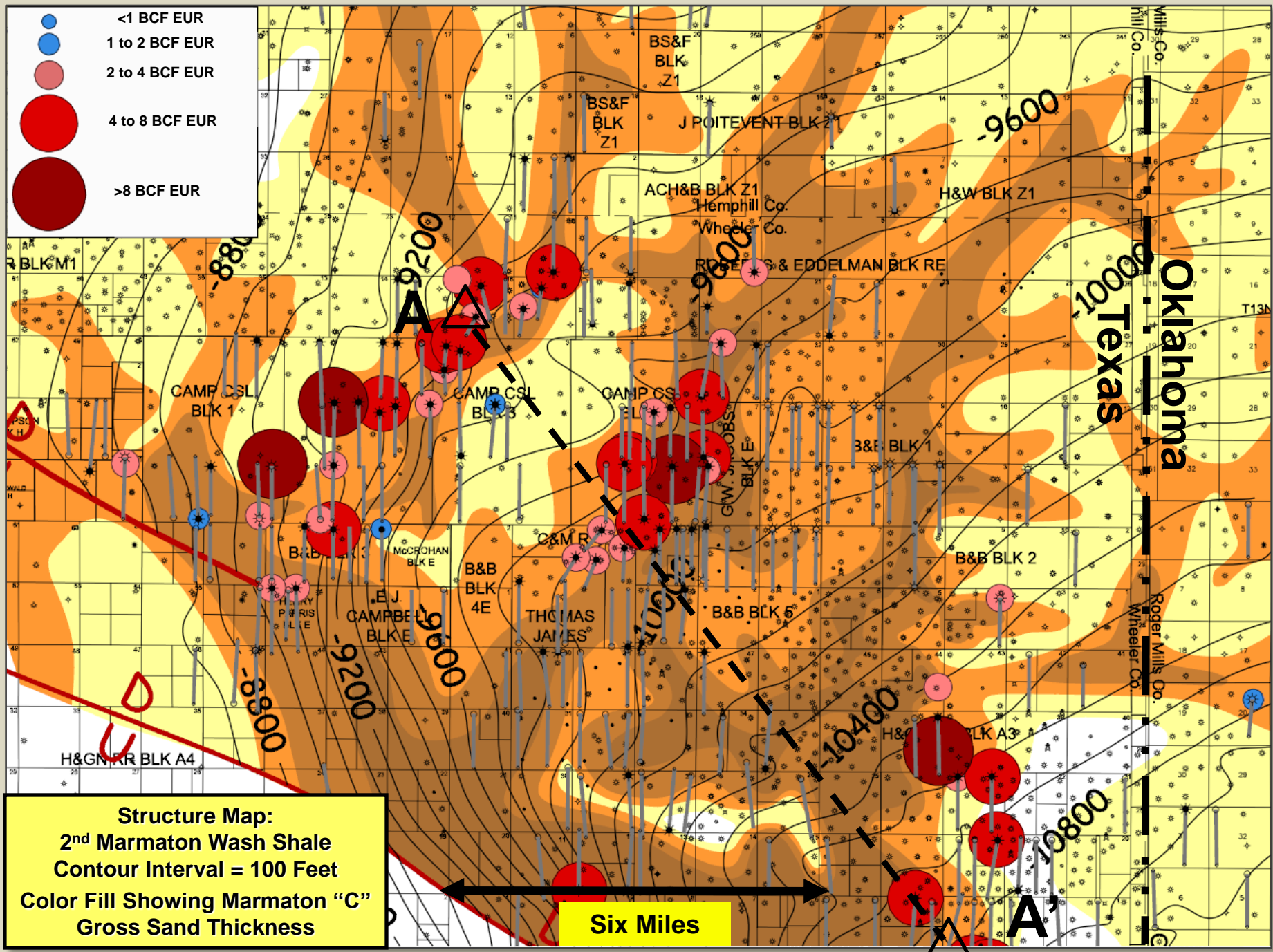


Wheeler County Wash Play

Cum. Production: 6.3 MMBO & 194 BCFG from 181 Horizontal Wells

Daily Production: ~20,000 BOPD & 455 MMCFGPD (June 2011)

Estimated Ultimate Recovery: ?



Stratigraphic Cross Section **A-A'**
Wheeler Co., Texas
Datum: 2nd Marmaton Wash Flooding Surface
Note: All Porosity Logs Run on 2.71 gm/cc (Ls.) Matrix

Stiles Ranch Field

Apache Corp.
#10-68 Stiles
NE SE, Sec. 68, Block A7, H&GN Survey
Wheeler Co., Texas
November 2004

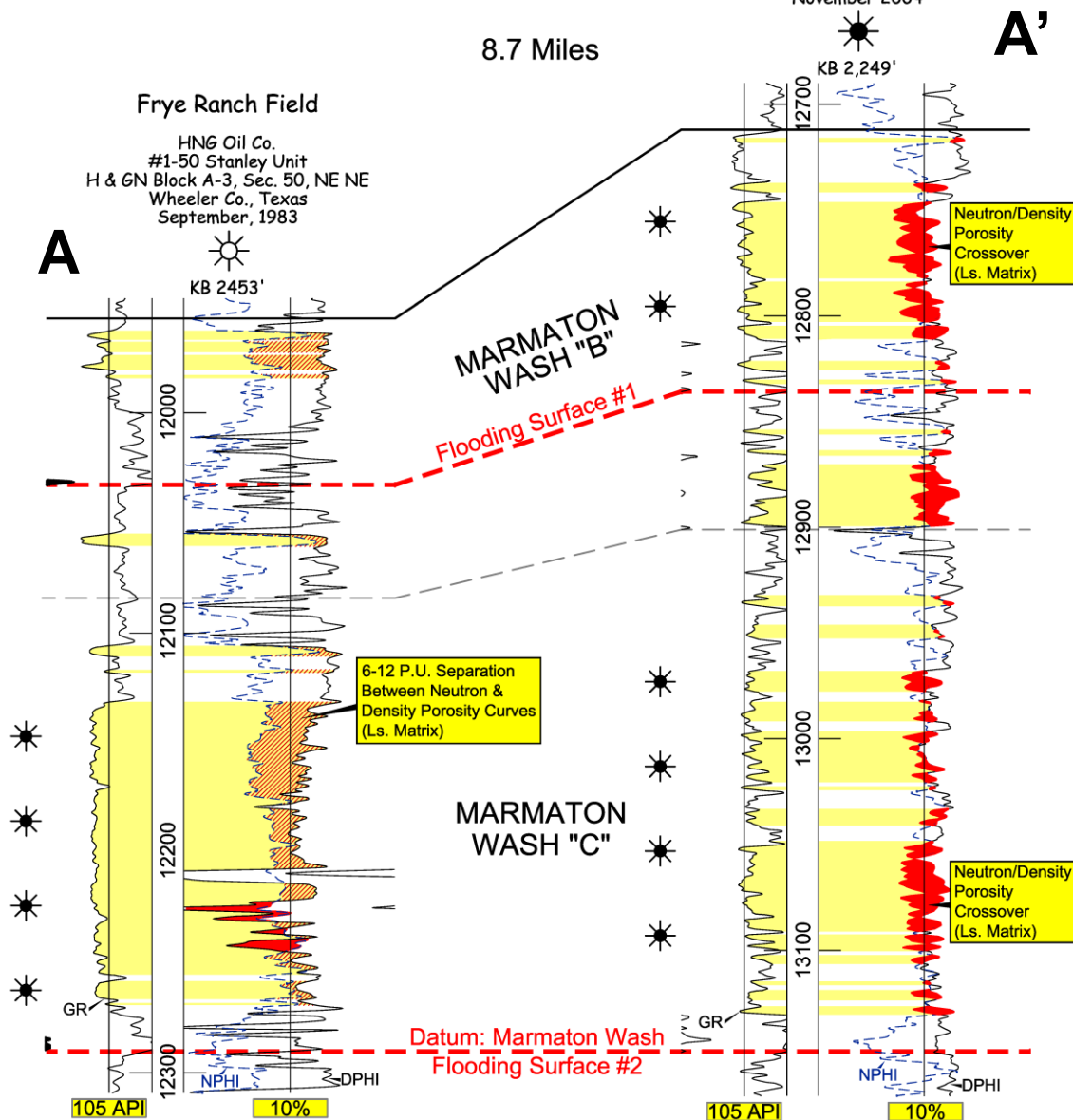
8.7 Miles

Frye Ranch Field

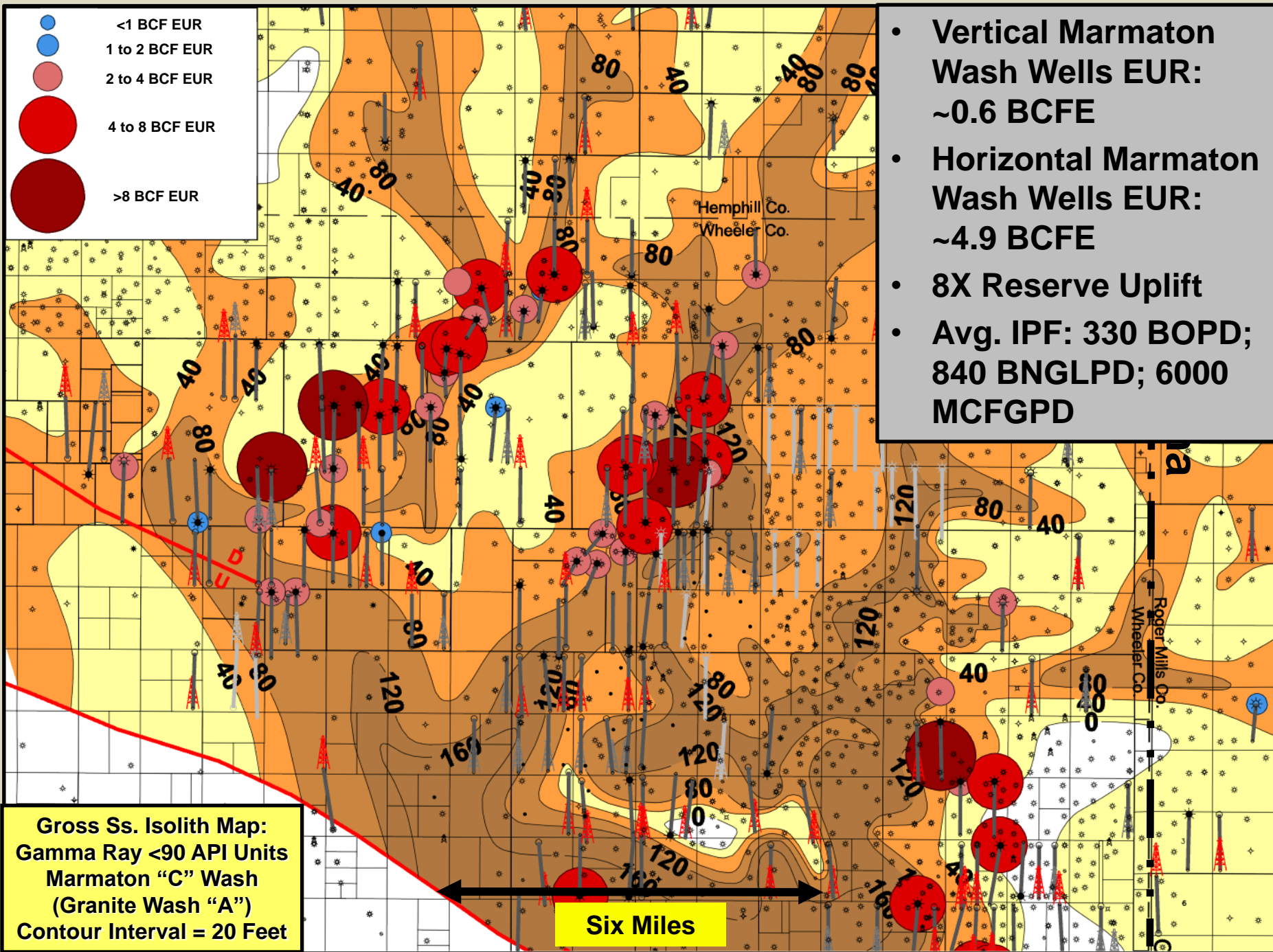
HNG Oil Co.
#1-50 Stanley Unit
H & GN Block A-3, Sec. 50, NE NE
Wheeler Co., Texas
September, 1983

A'

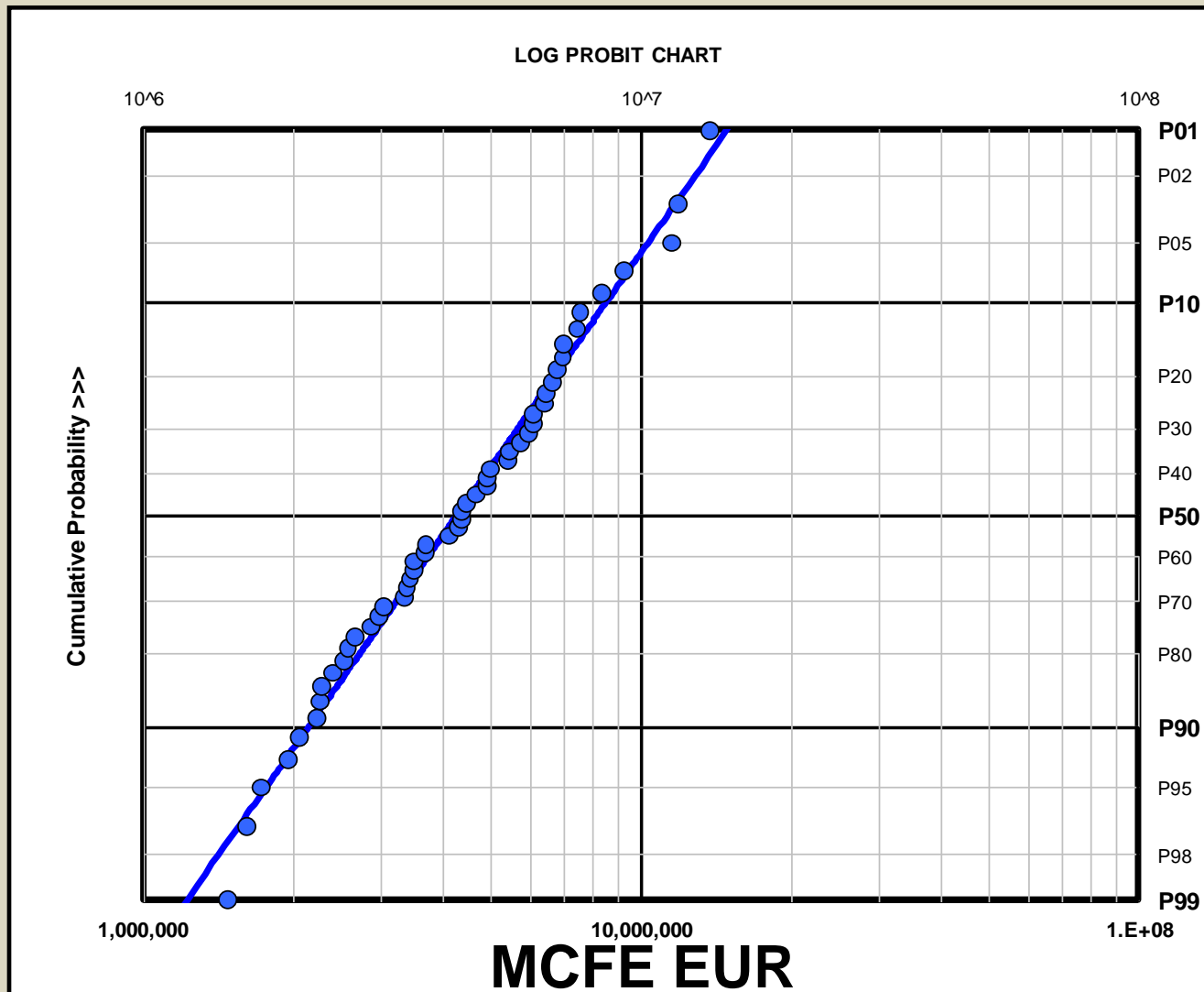
A



Horizontal Granite Wash Play – Wheeler Co., Texas

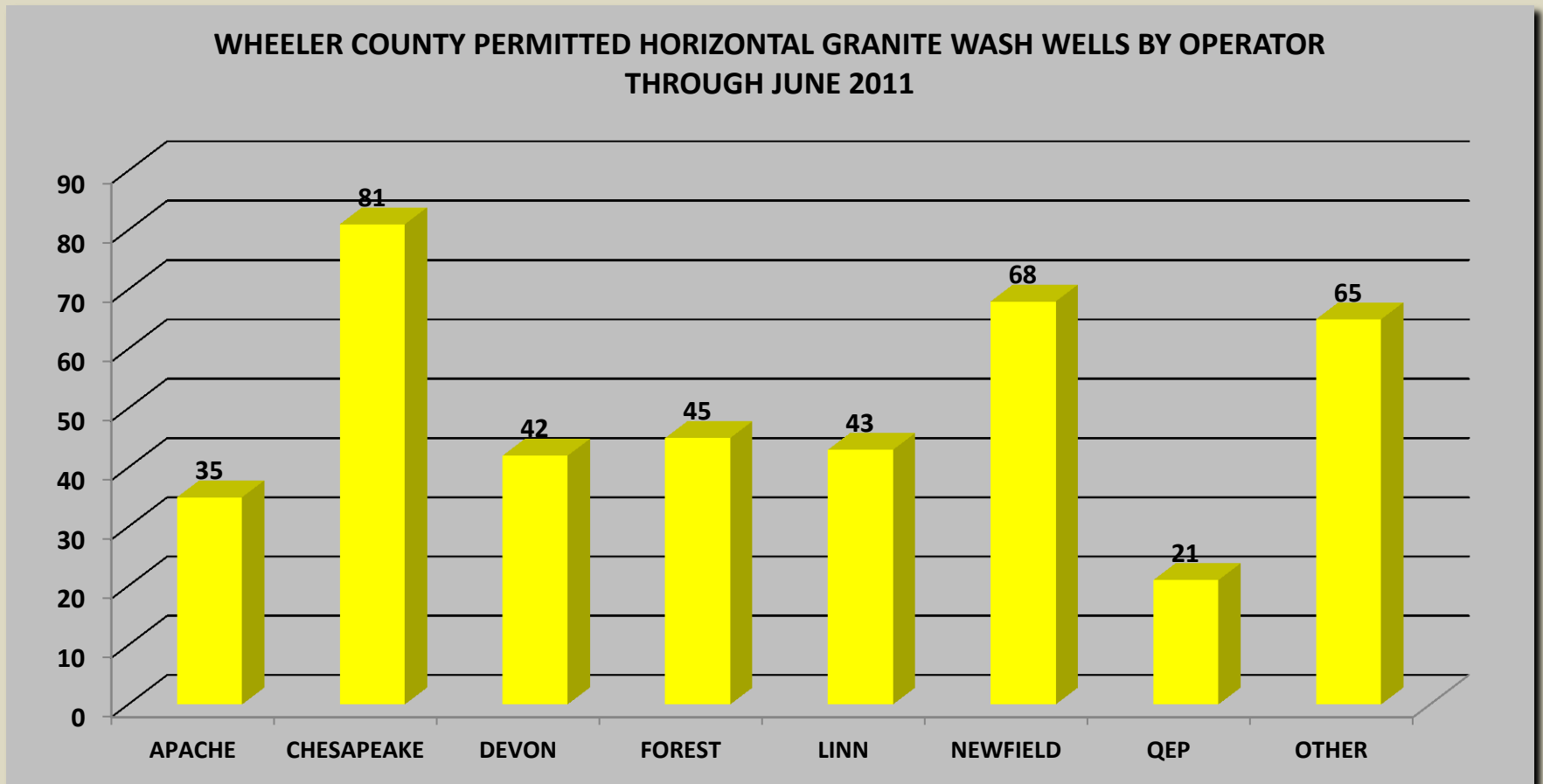


Wheeler County Marmaton Wash EURs (MCFe)



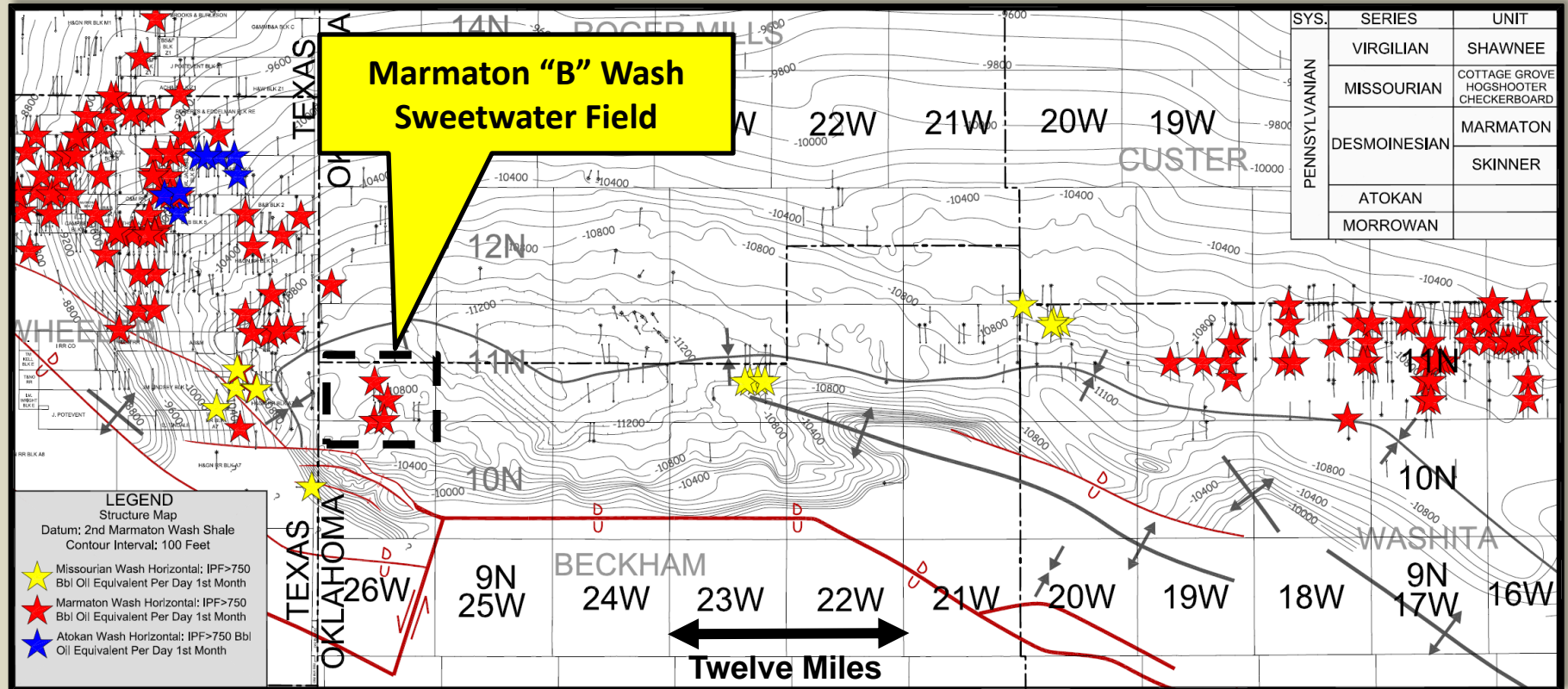
P10: 7.61 BCF_e
P50: 4.36 BCF_e
P90: 2.21 BCF_e
Mean: 4.88 BCF_e
86 Wells

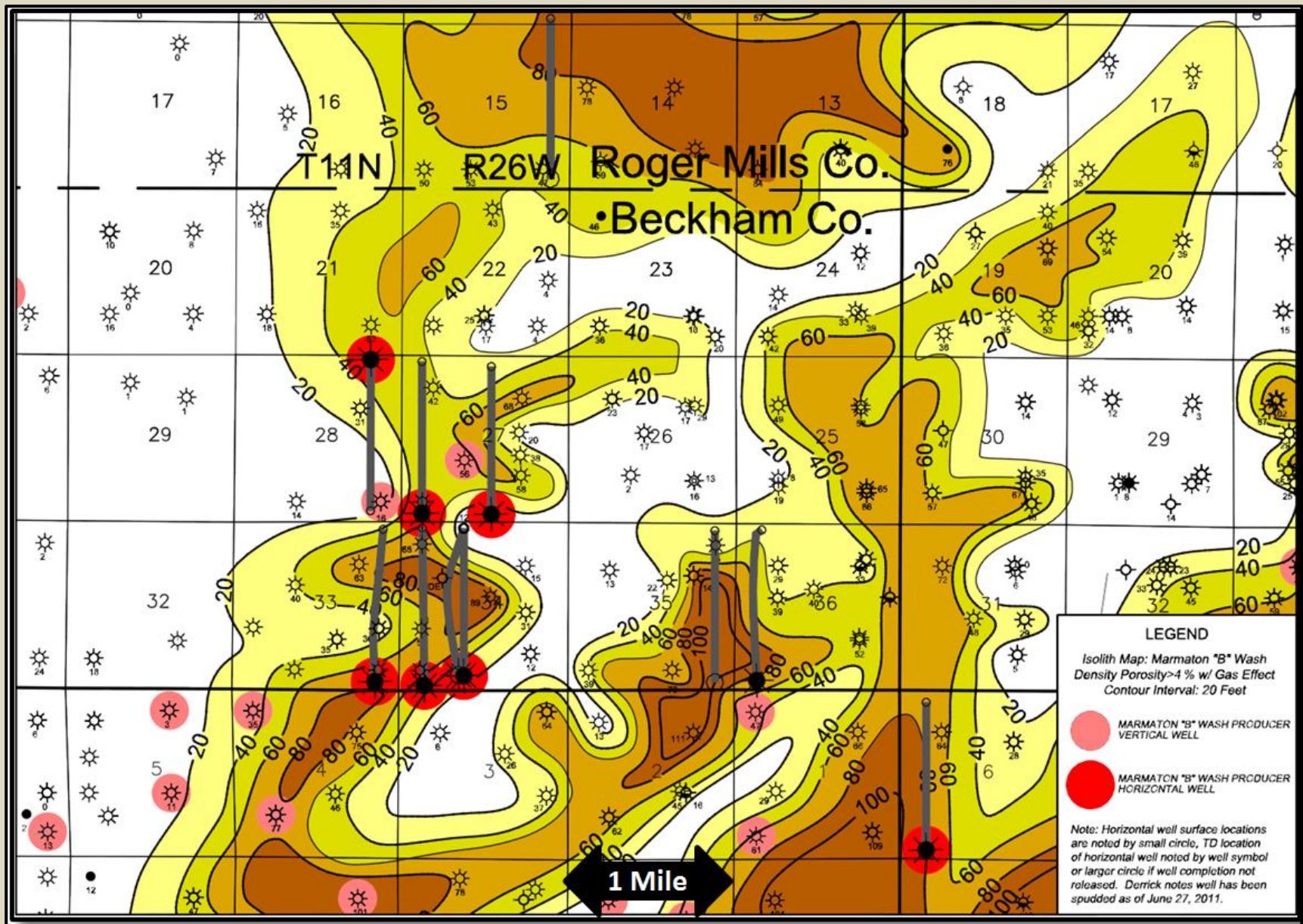
WHEELER CO. DRILLING STATISTICS BY OPERATOR



Graph showing number of permitted Granite Wash horizontal wells by operator in Wheeler County, Texas through June 30th, 2011.

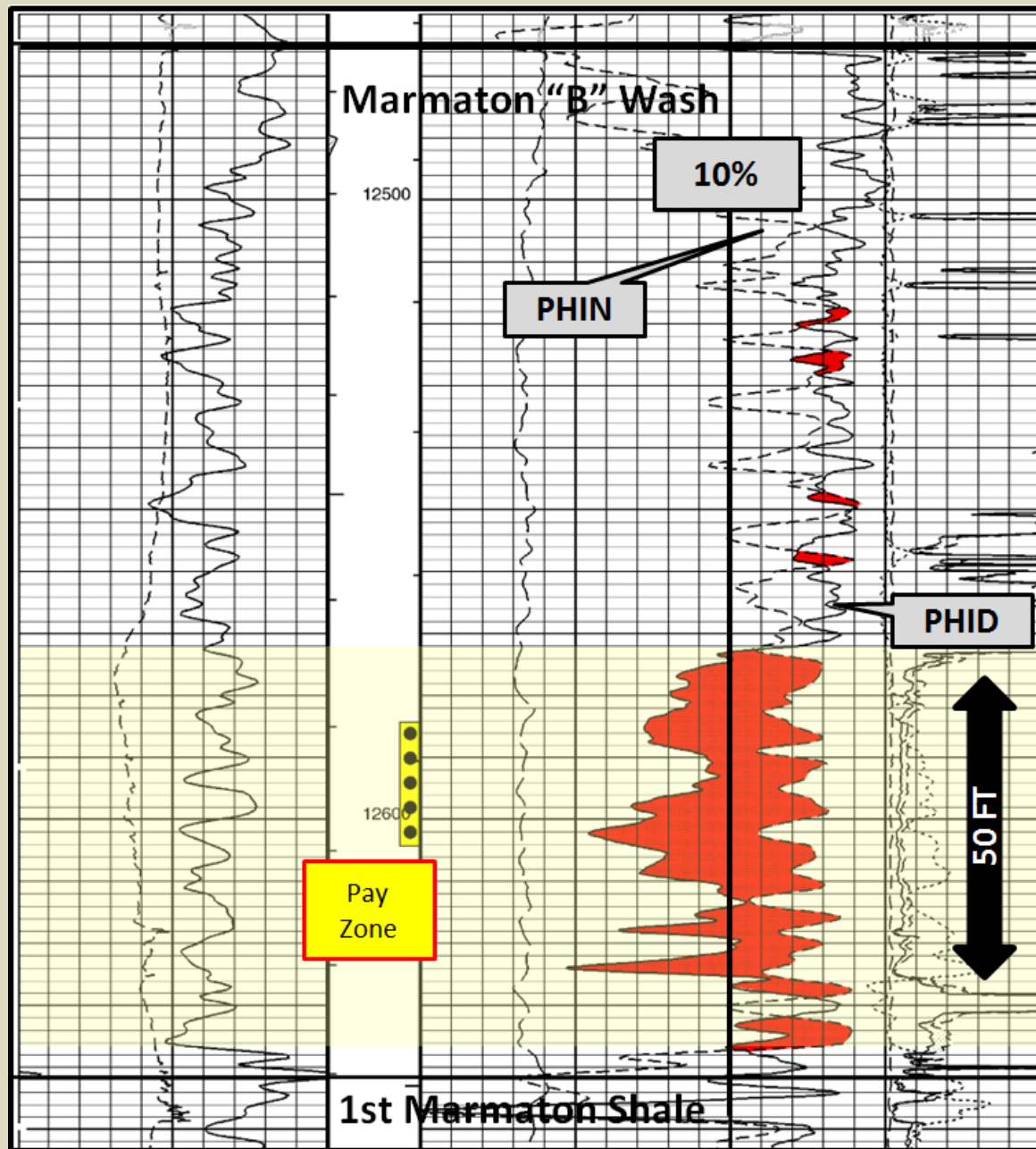
Horizontal Granite Wash Play Proximal Wash Activity Area – Marmaton “B” – Sweetwater Field



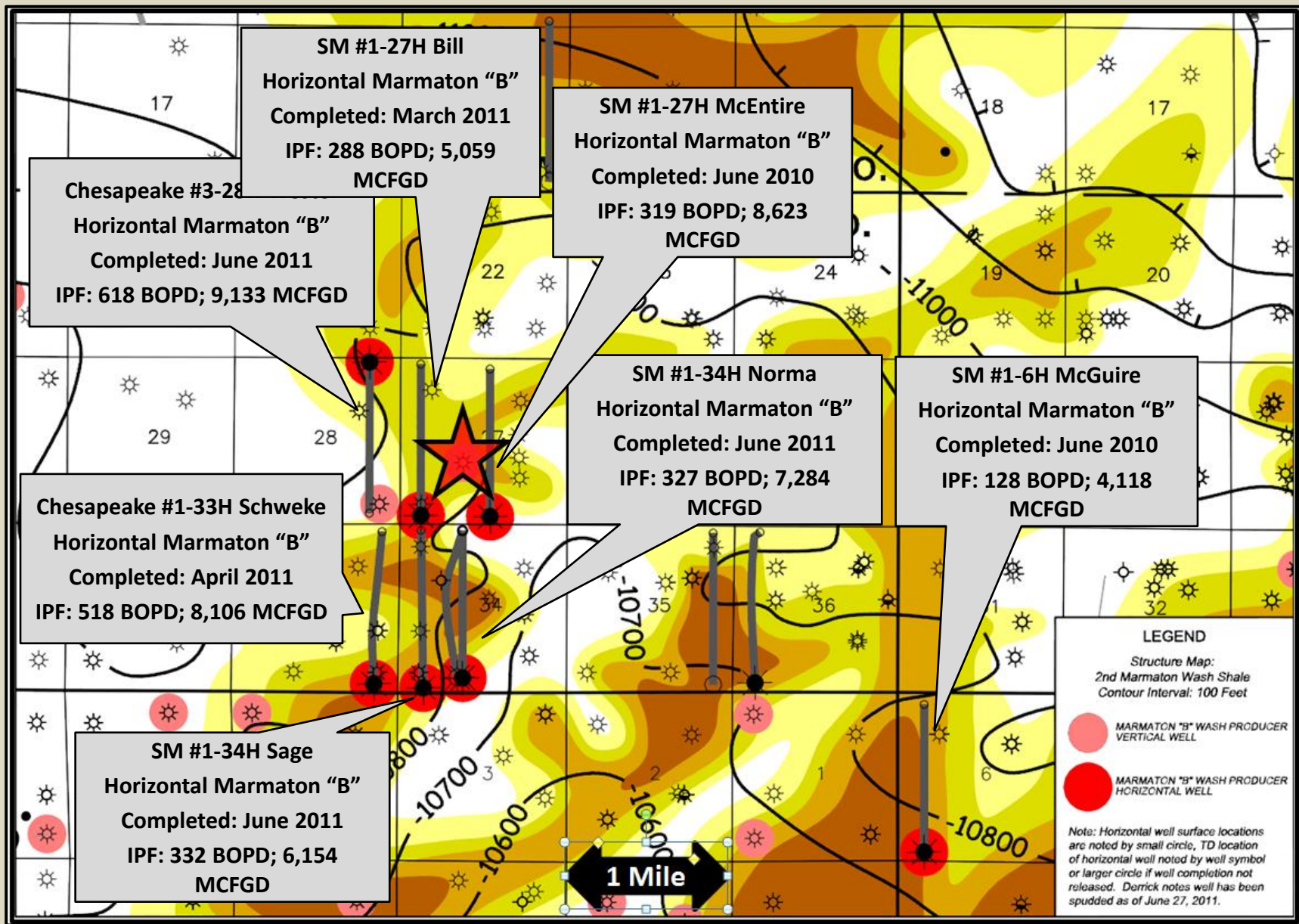


Porosity isolith map of the Marmaton "B" Wash w/ neutron-density crossover & density porosity >8% on lime matrix; Contour interval = 20 feet ; Sweetwater field, T11N R26W, Beckham Co., OK

HORIZONTAL GRANITE WASH PLAY



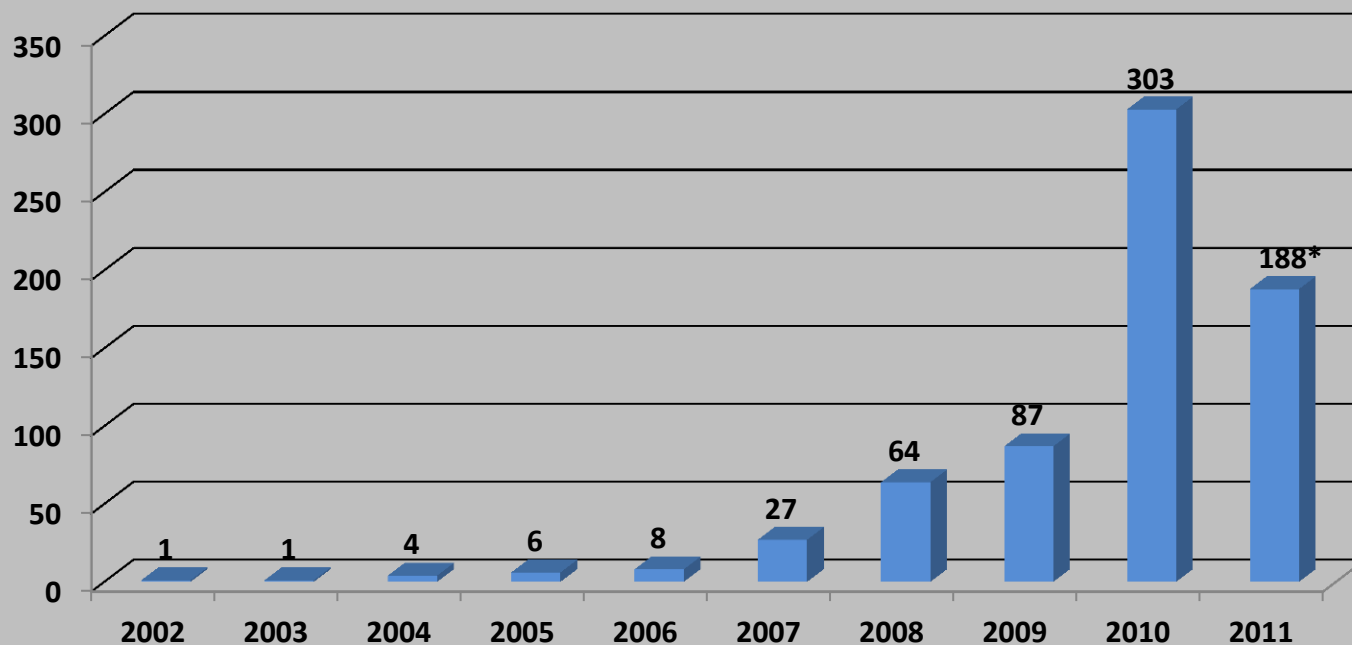
Type porosity log,
Marmaton "B" Wash
pay zone, St. Mary #1-
27 McEntire; NE SW
Sec. 27, T11N R26W,
Sweetwater field,
Beckham Co., OK;
porosity on lime
matrix; lower portion
of Marmaton "B" has
better porosity,
exhibits gas effect
(red shading) on log
and is target zone for
horizontals in
Sweetwater field.



Structure map on the 2nd Marmaton Shale; Contour interval = 100 feet ; Sweetwater field, T11N R26W, Beckham Co., OK; star indicates location of type log well

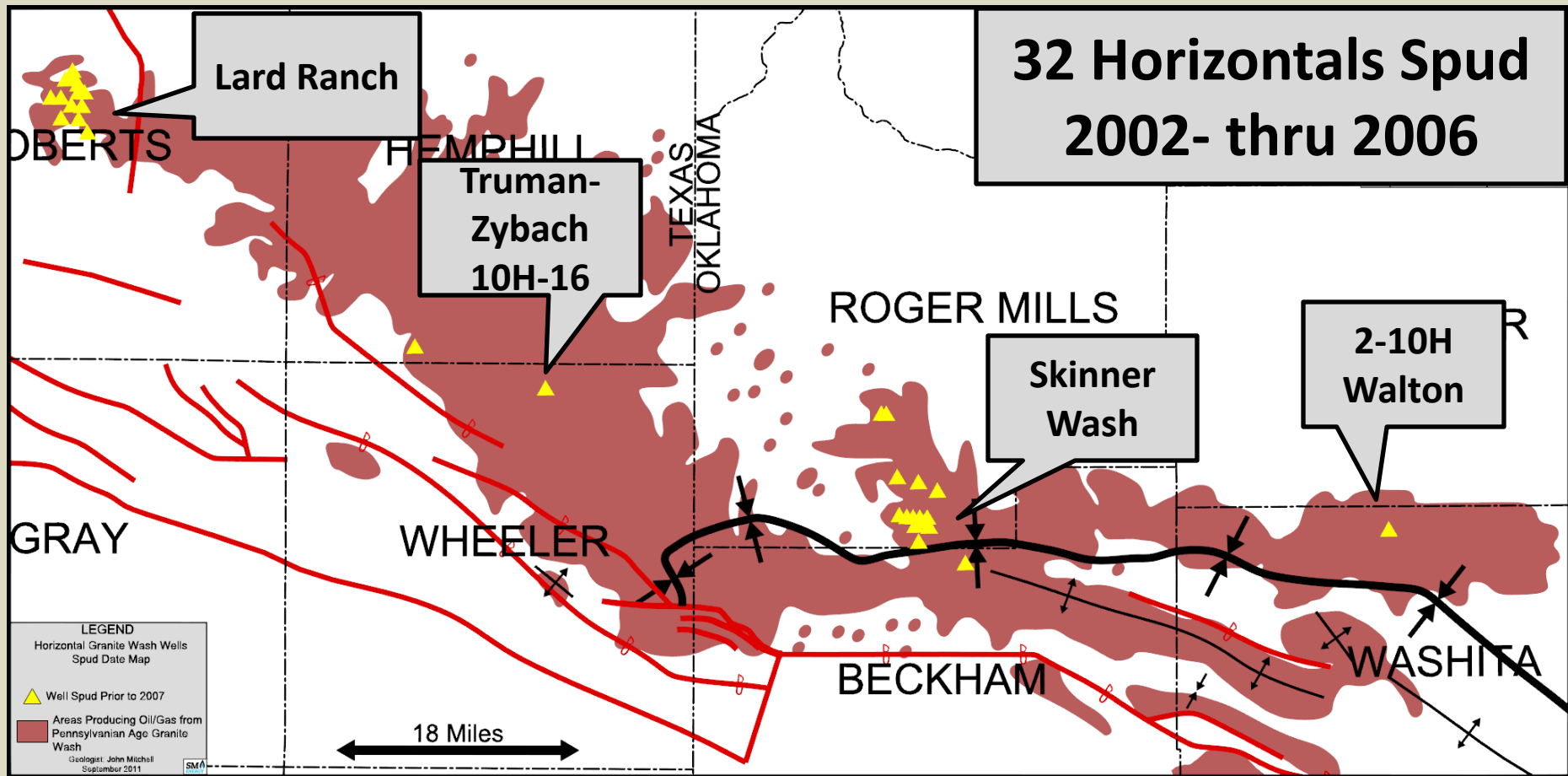
DRILLING STATISTICS BY YEAR

PERMITTED HORIZONTAL GW WELLS BY YEAR

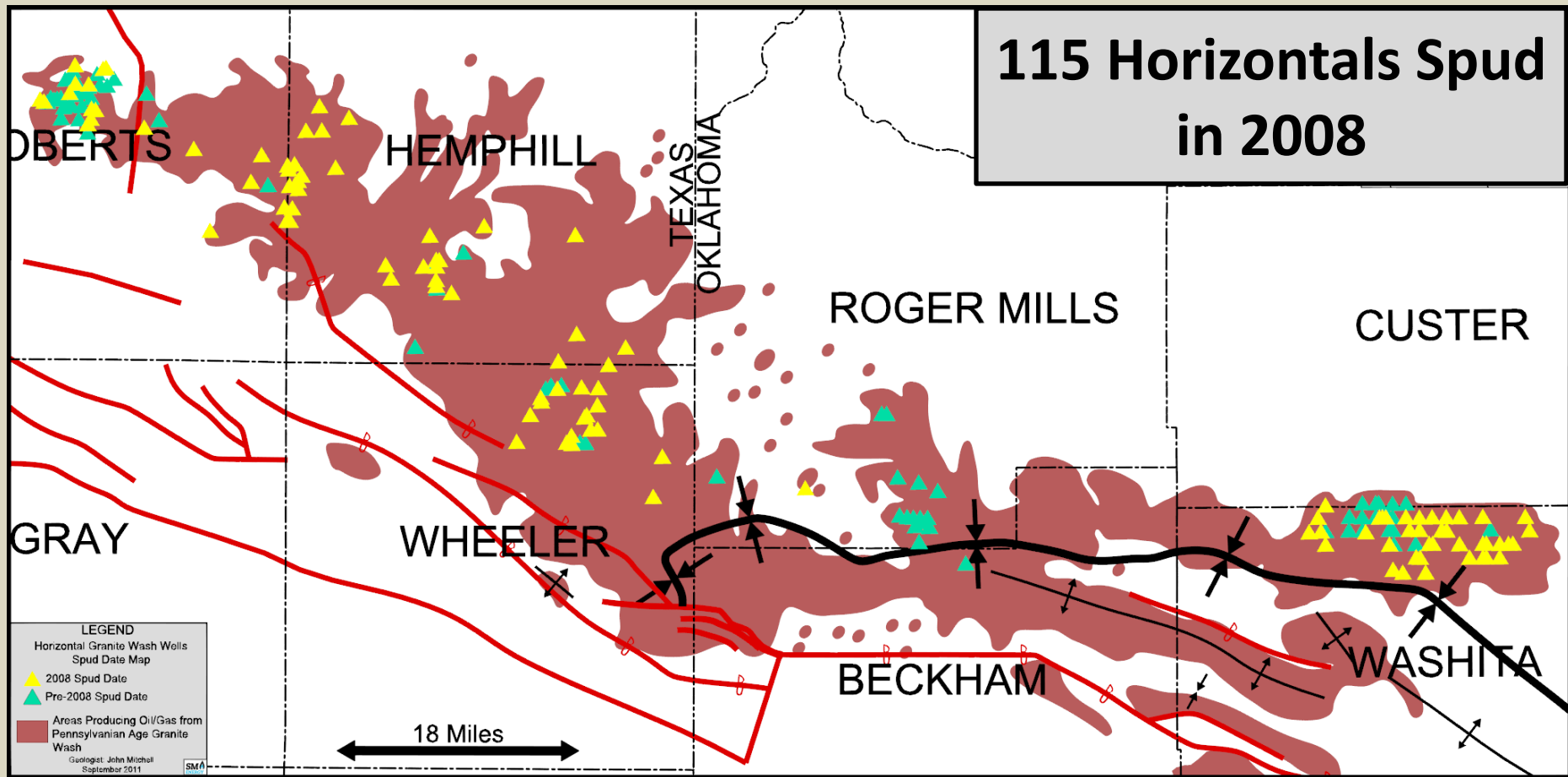


Graph showing number of permitted horizontal Granite Wash wells by year in study area through June 30th 2011. * Note that permits for 2011 are for the first half of the year only.

HORIZONTAL GRANITE WASH PLAY

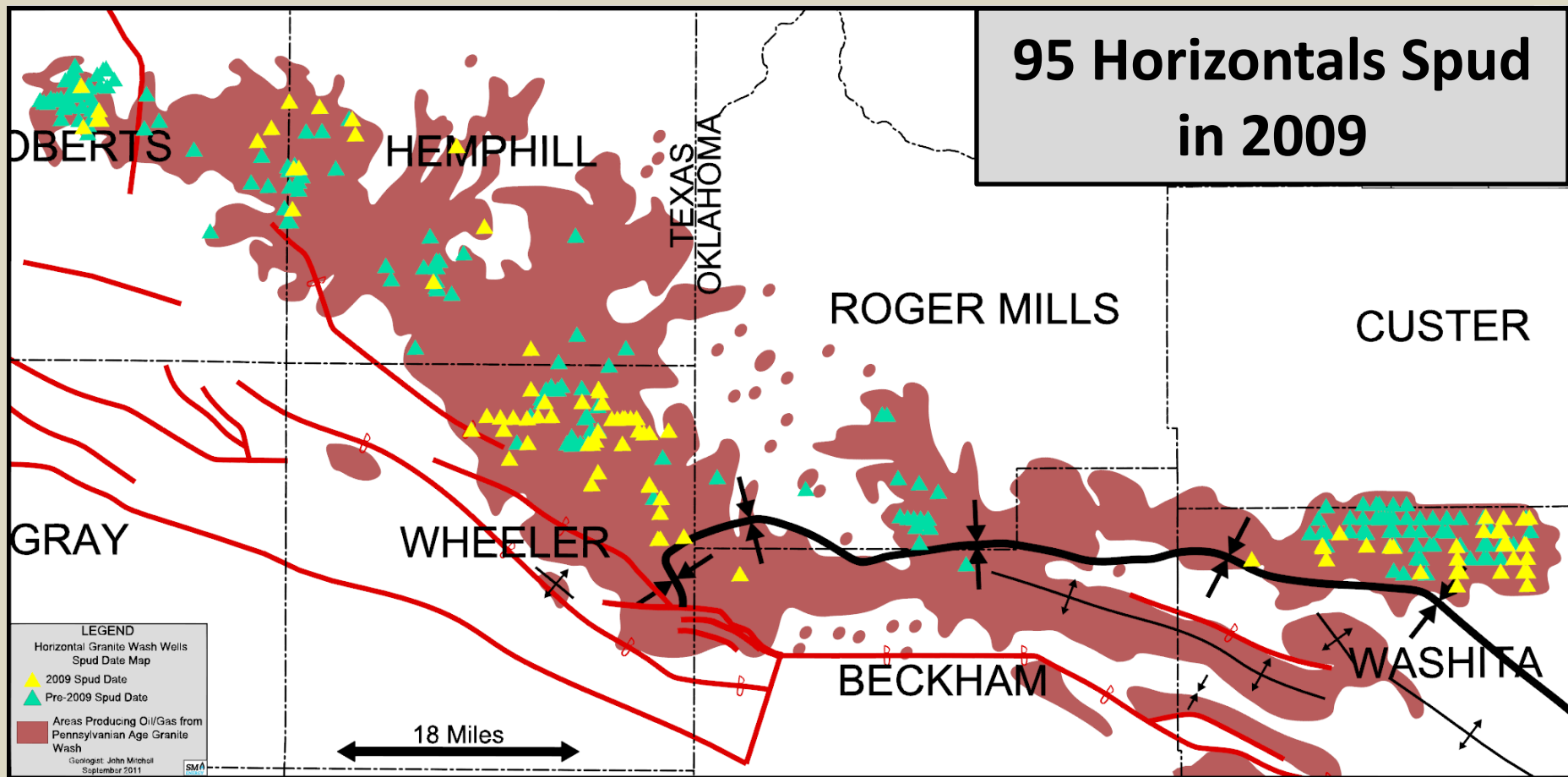


HORIZONTAL GRANITE WASH PLAY



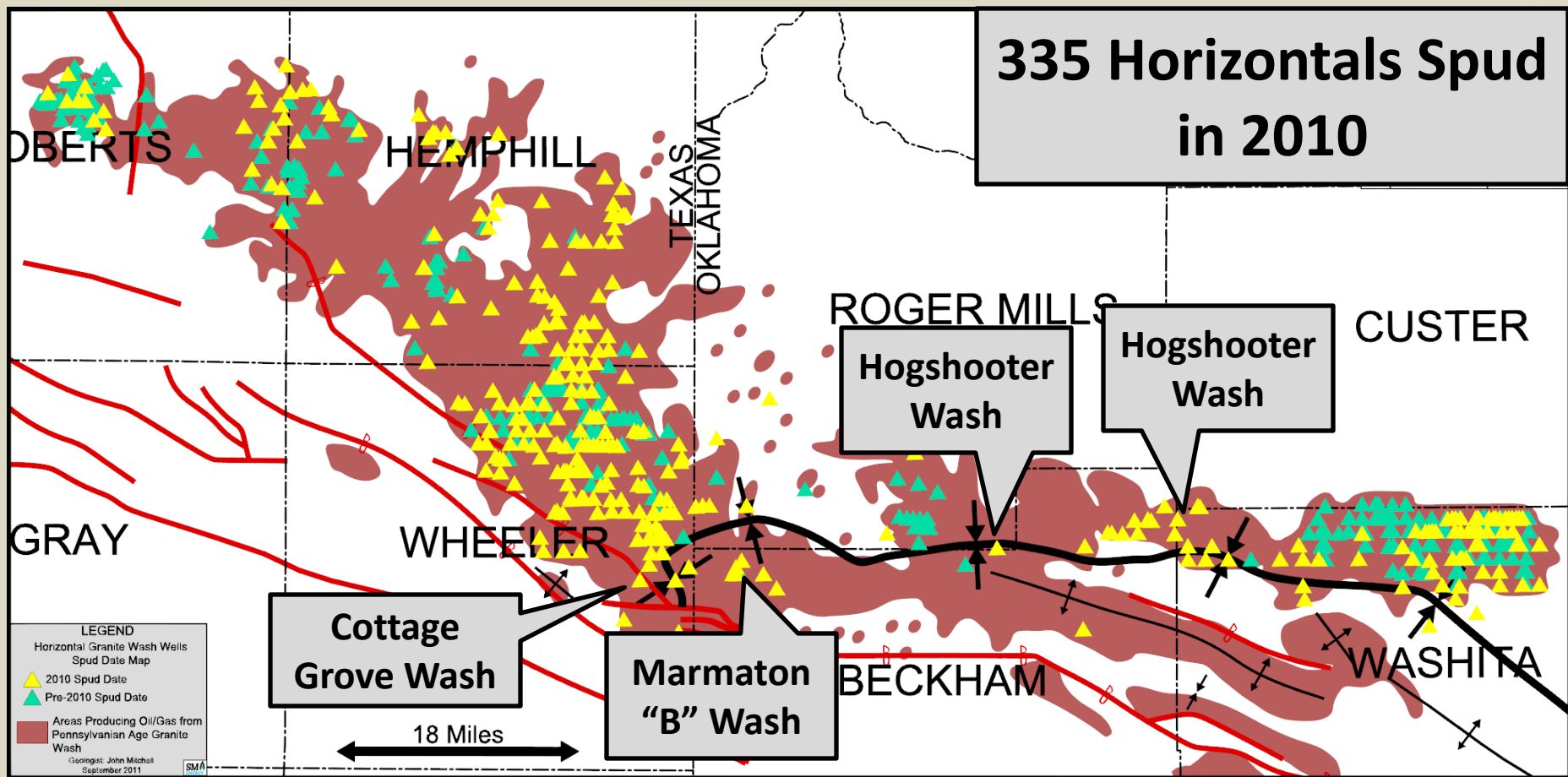
Yellow symbols on map showing locations of 115 horizontal Granite Wash wells during 2008

HORIZONTAL GRANITE WASH PLAY



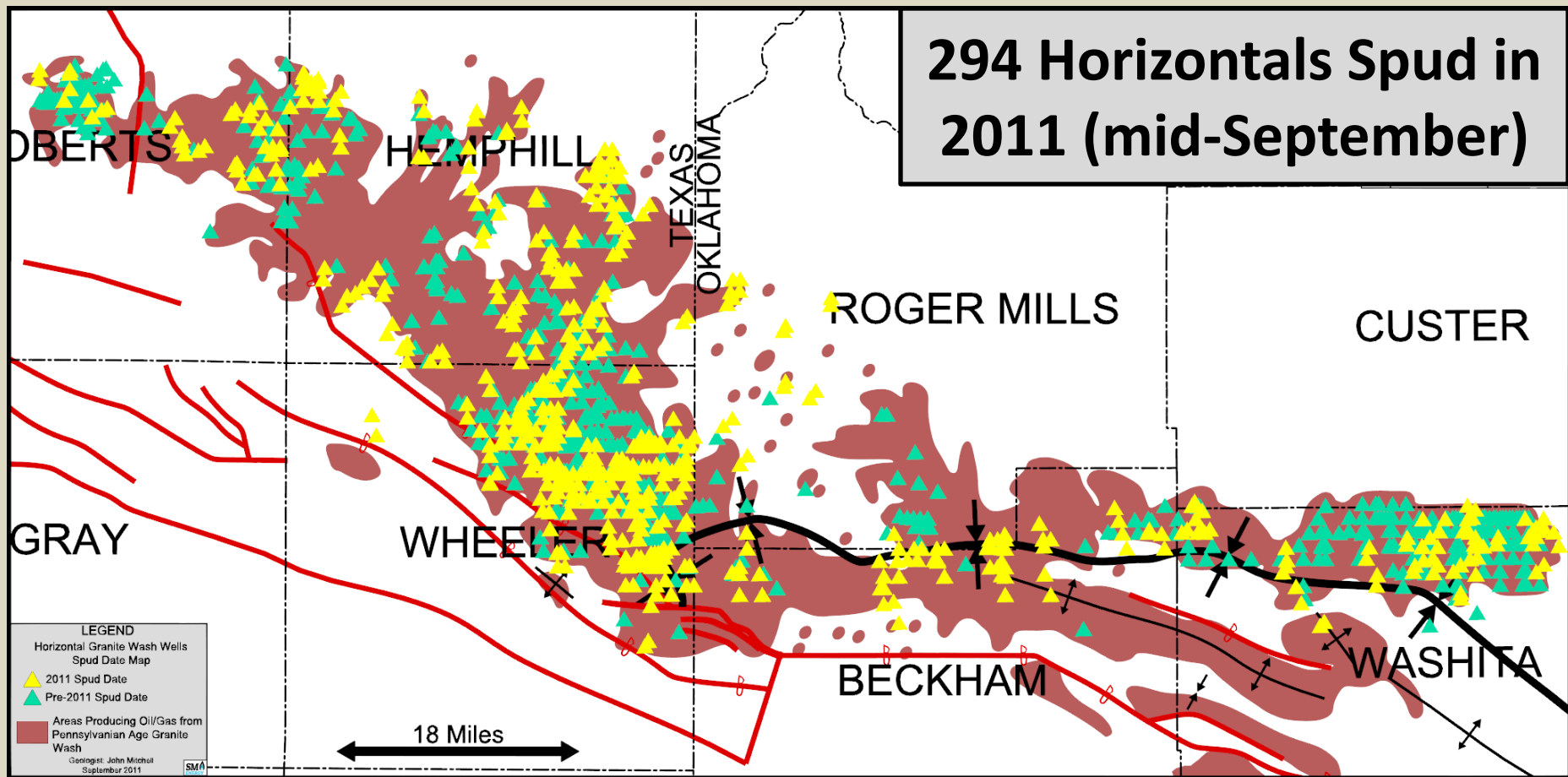
Yellow symbols on map showing locations of 95 horizontal Granite Wash wells spudded during 2009

HORIZONTAL GRANITE WASH PLAY



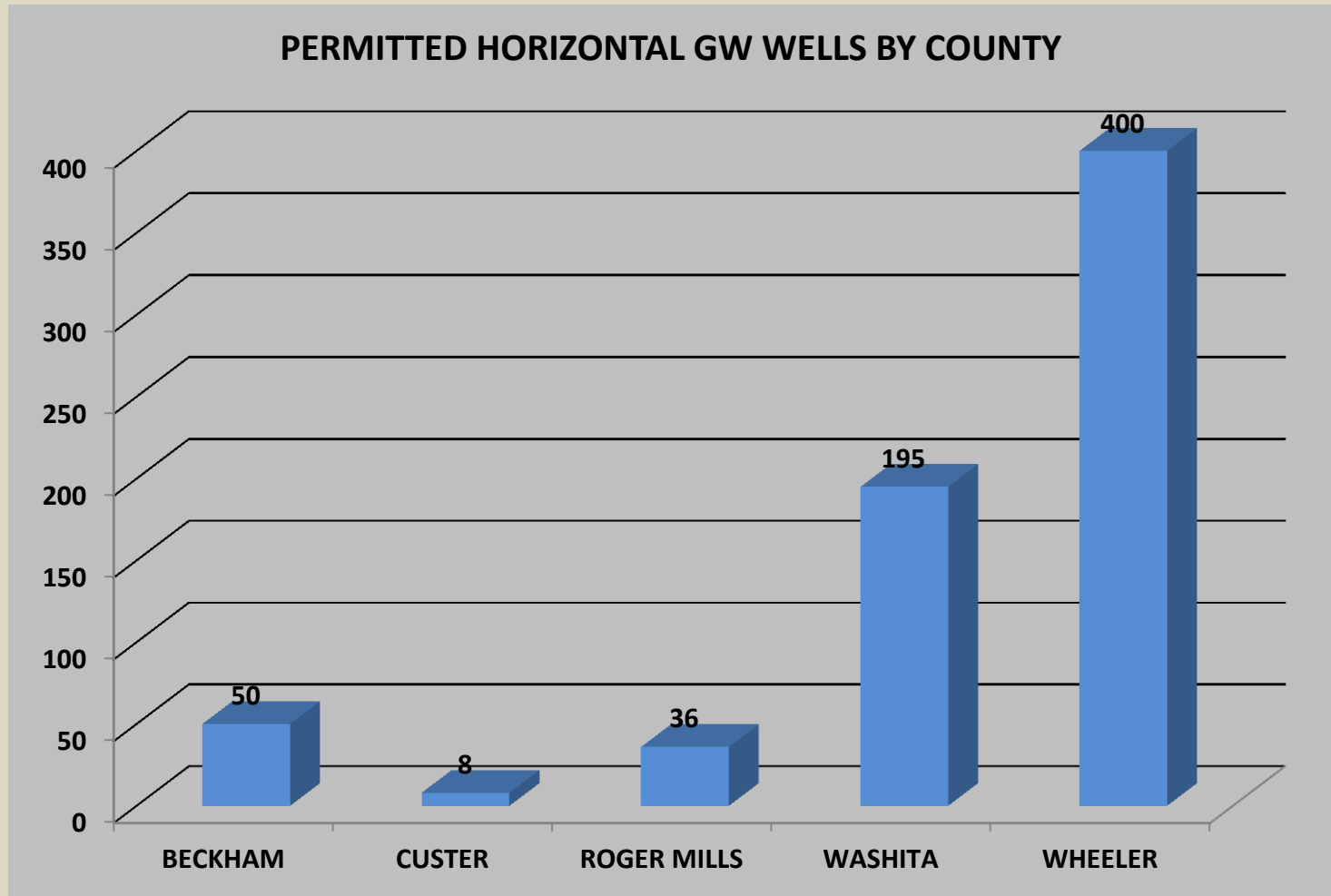
Yellow symbols on map showing locations of 335 horizontal Granite Wash wells spudded during 2010

HORIZONTAL GRANITE WASH PLAY



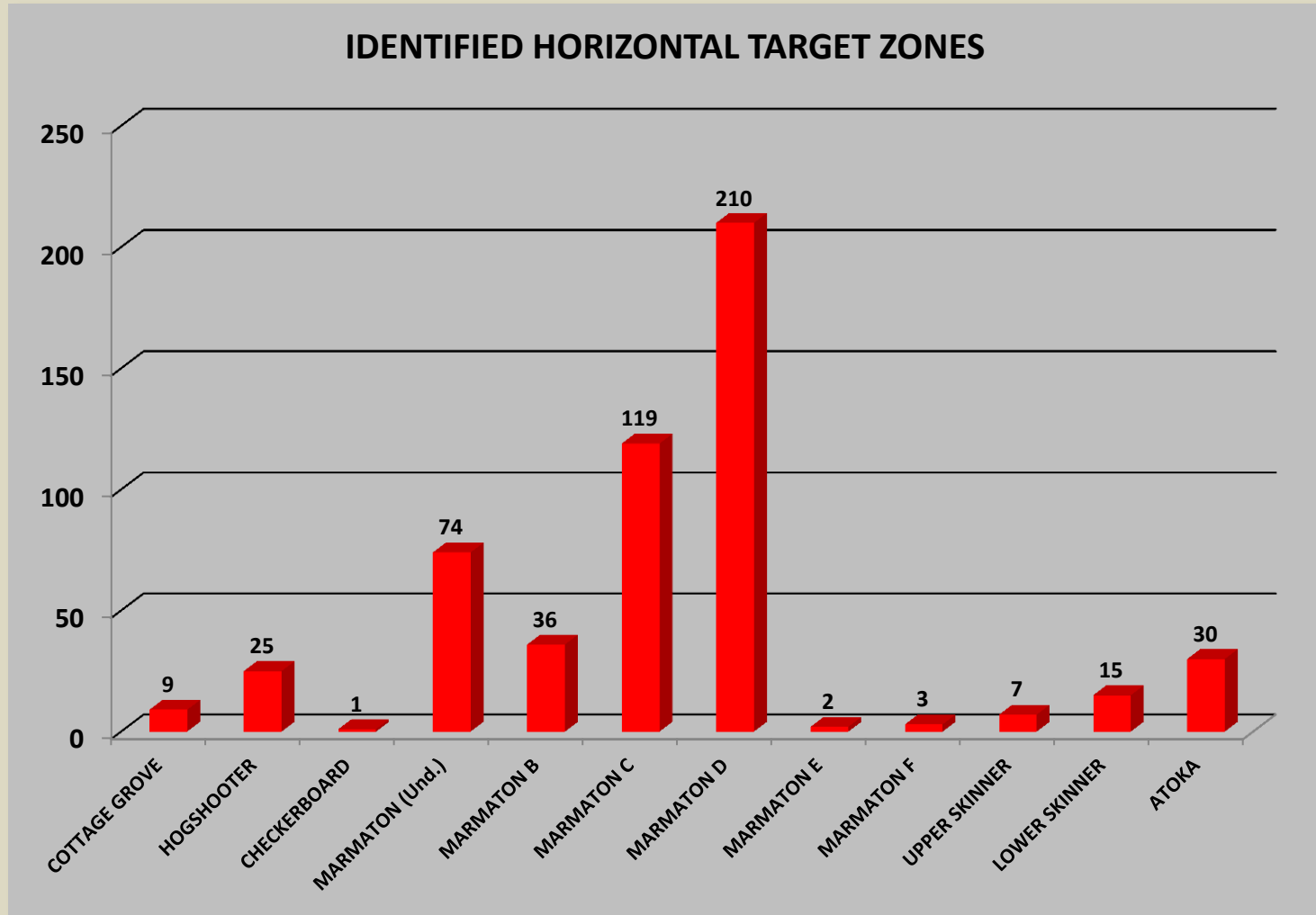
Yellow symbols on map showing locations of 294 horizontal Granite Wash wells spudded to date (mid-September) in 2011

DRILLING STATISTICS BY COUNTY



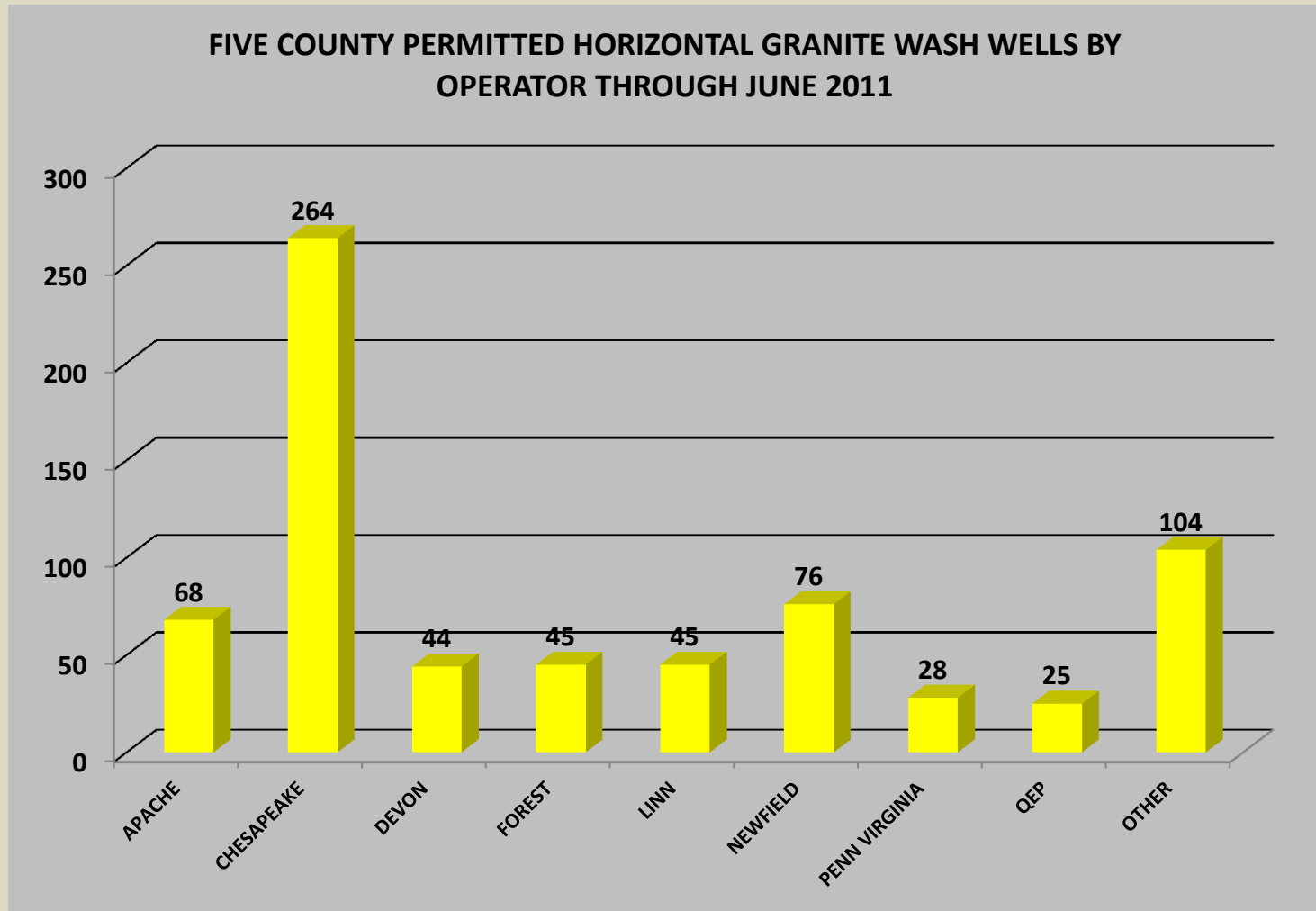
Graph showing number of permitted horizontal Granite Wash wells by county in study area through June 30th 2011.

DRILLING STATISTICS BY TARGET



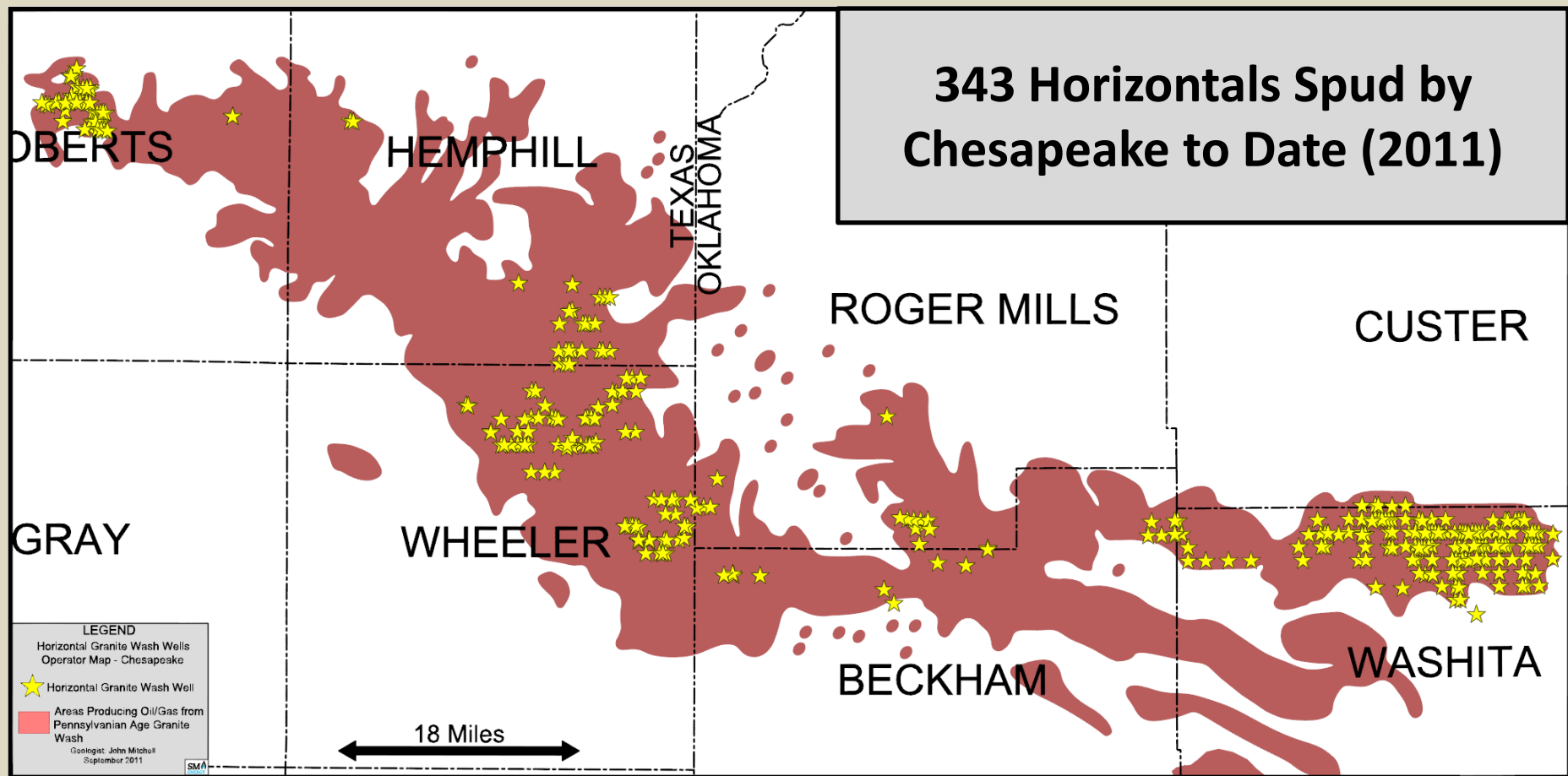
Graph showing number of horizontal Granite Wash wells per target interval as identified by author in study area through June 30th, 2011.

DRILLING STATISTICS BY OPERATOR



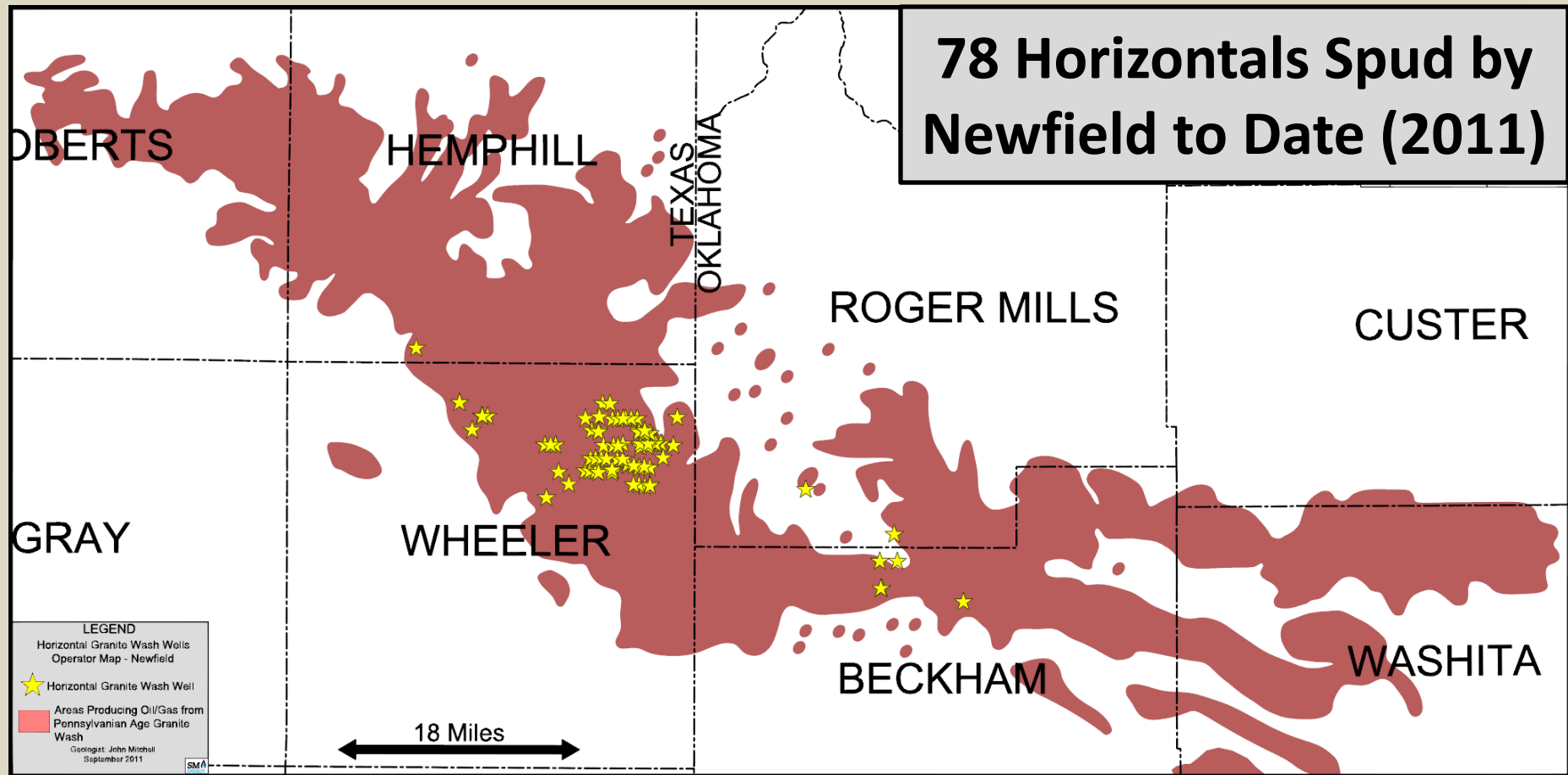
Graph showing numbers of permitted horizontal Granite Wash wells by operator in the study area through June 30th, 2011. Total permits issued are six-hundred and ninety-nine (699).

HORIZONTAL GRANITE WASH PLAY



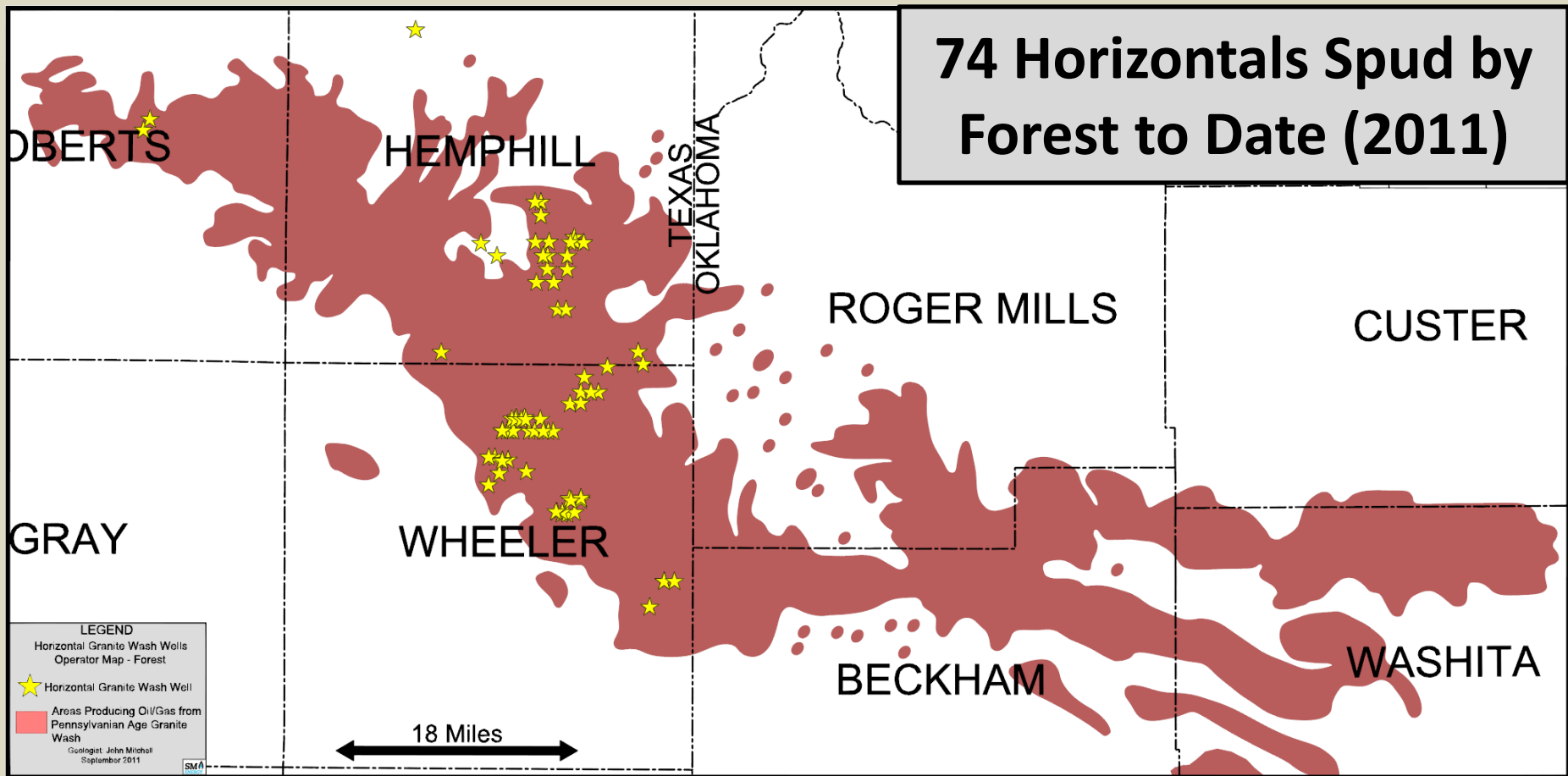
Yellow symbols on map showing locations of 343 horizontal Granite Wash wells spudded to date by Chesapeake

HORIZONTAL GRANITE WASH PLAY



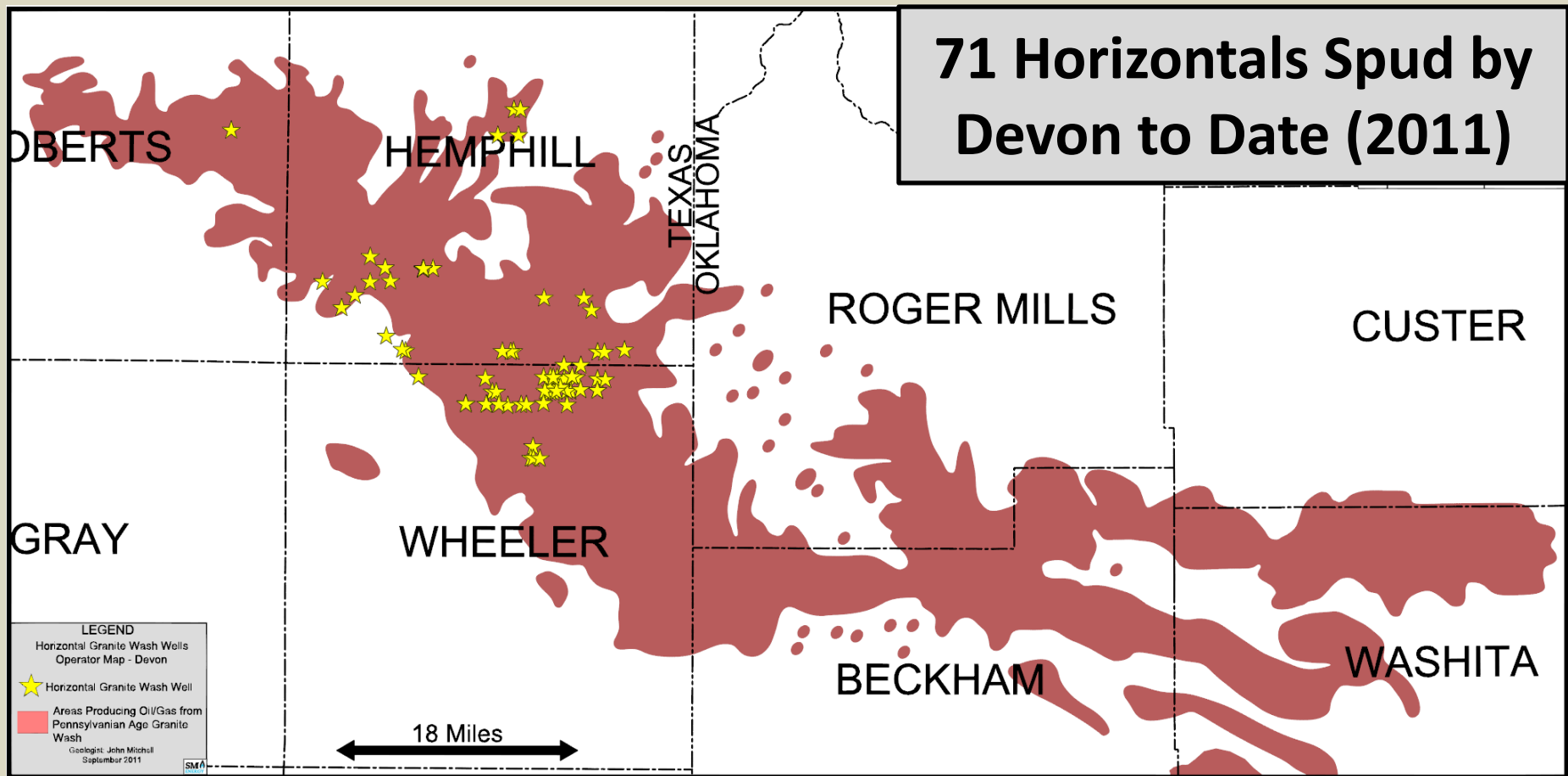
Yellow symbols on map showing locations of 78 horizontal Granite Wash wells spudded to date by Newfield

HORIZONTAL GRANITE WASH PLAY



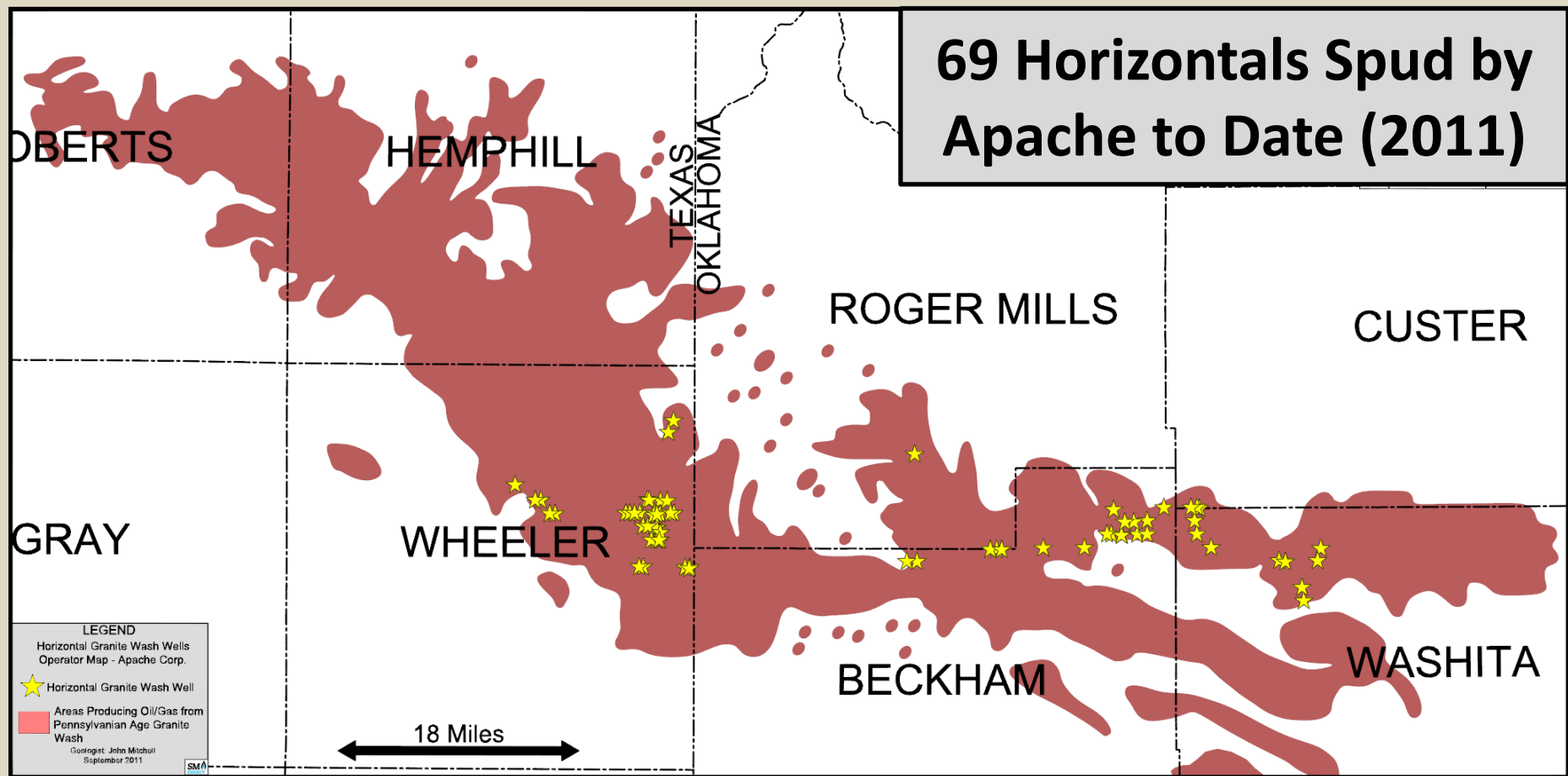
Yellow symbols on map showing locations of 74 horizontal Granite Wash wells spudded to date by Forest

HORIZONTAL GRANITE WASH PLAY



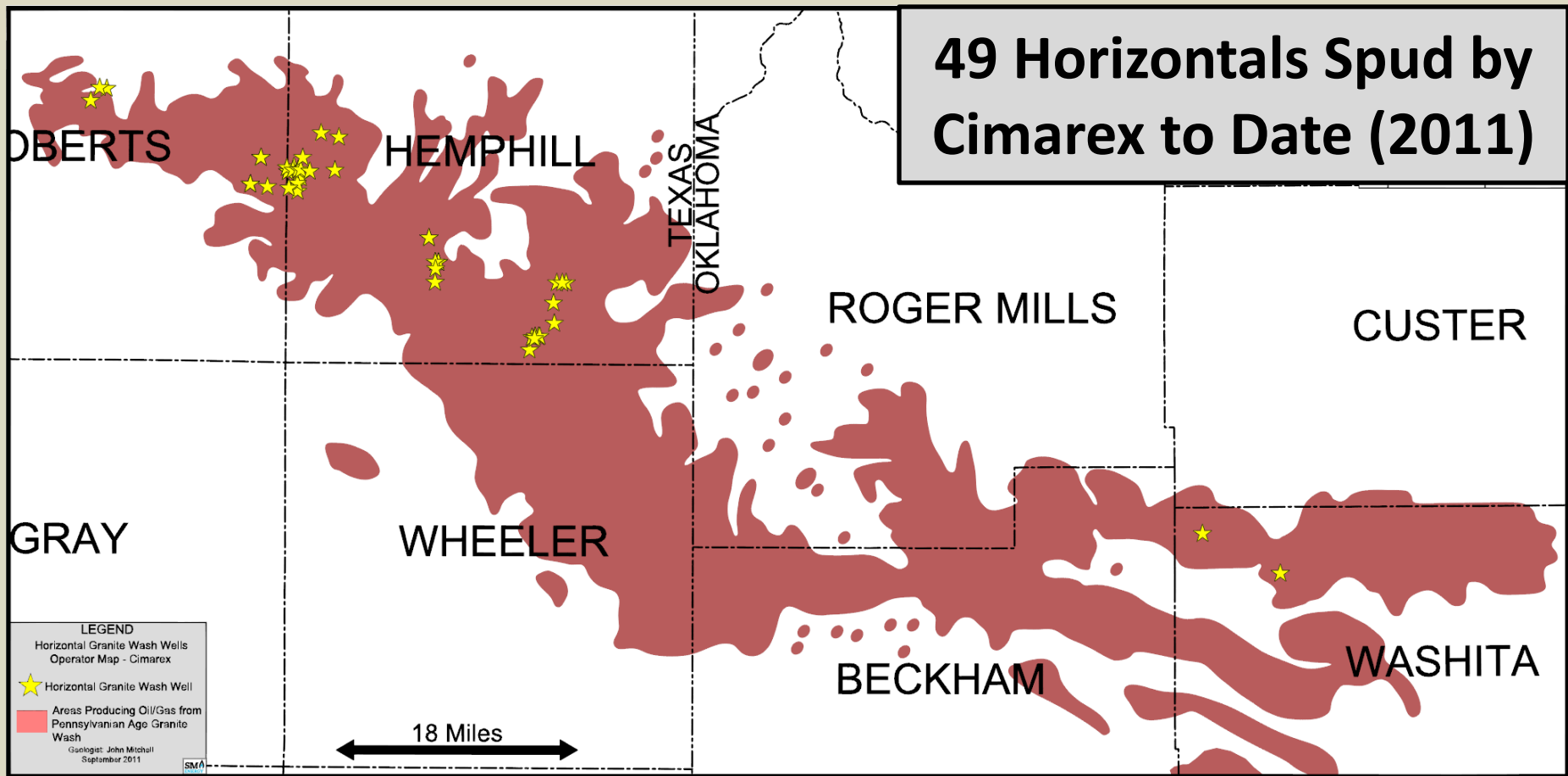
Yellow symbols on map showing locations of 71 horizontal Granite Wash wells spudded to date by Devon

HORIZONTAL GRANITE WASH PLAY



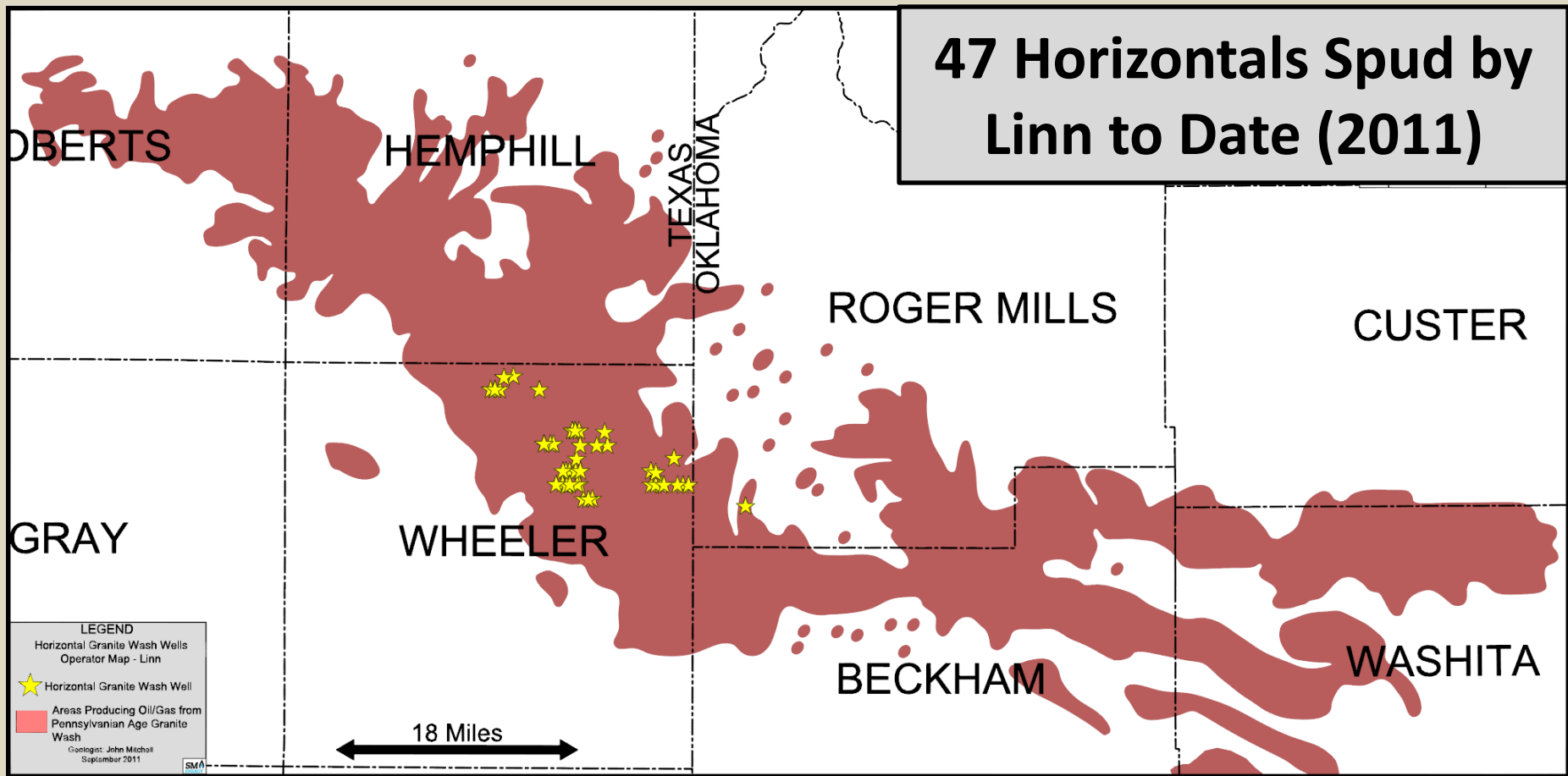
Yellow symbols on map showing locations of 69 horizontal Granite Wash wells spudded to date by Apache

HORIZONTAL GRANITE WASH PLAY



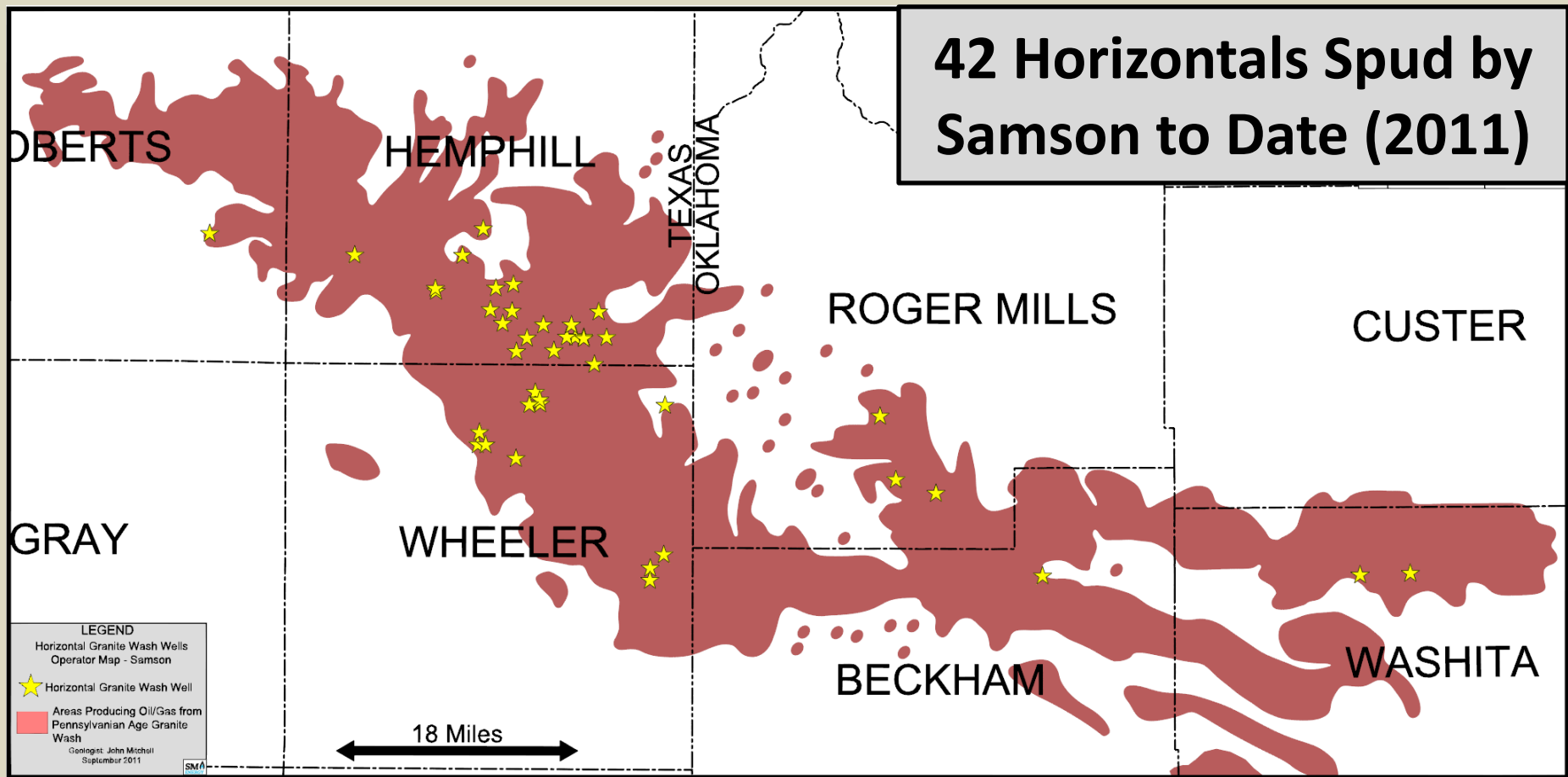
Yellow symbols on map showing locations of 49 horizontal Granite Wash wells spudded to date by Cimarex

HORIZONTAL GRANITE WASH PLAY



Yellow symbols on map showing locations of 47 horizontal Granite Wash wells spudded to date by Linn

HORIZONTAL GRANITE WASH PLAY



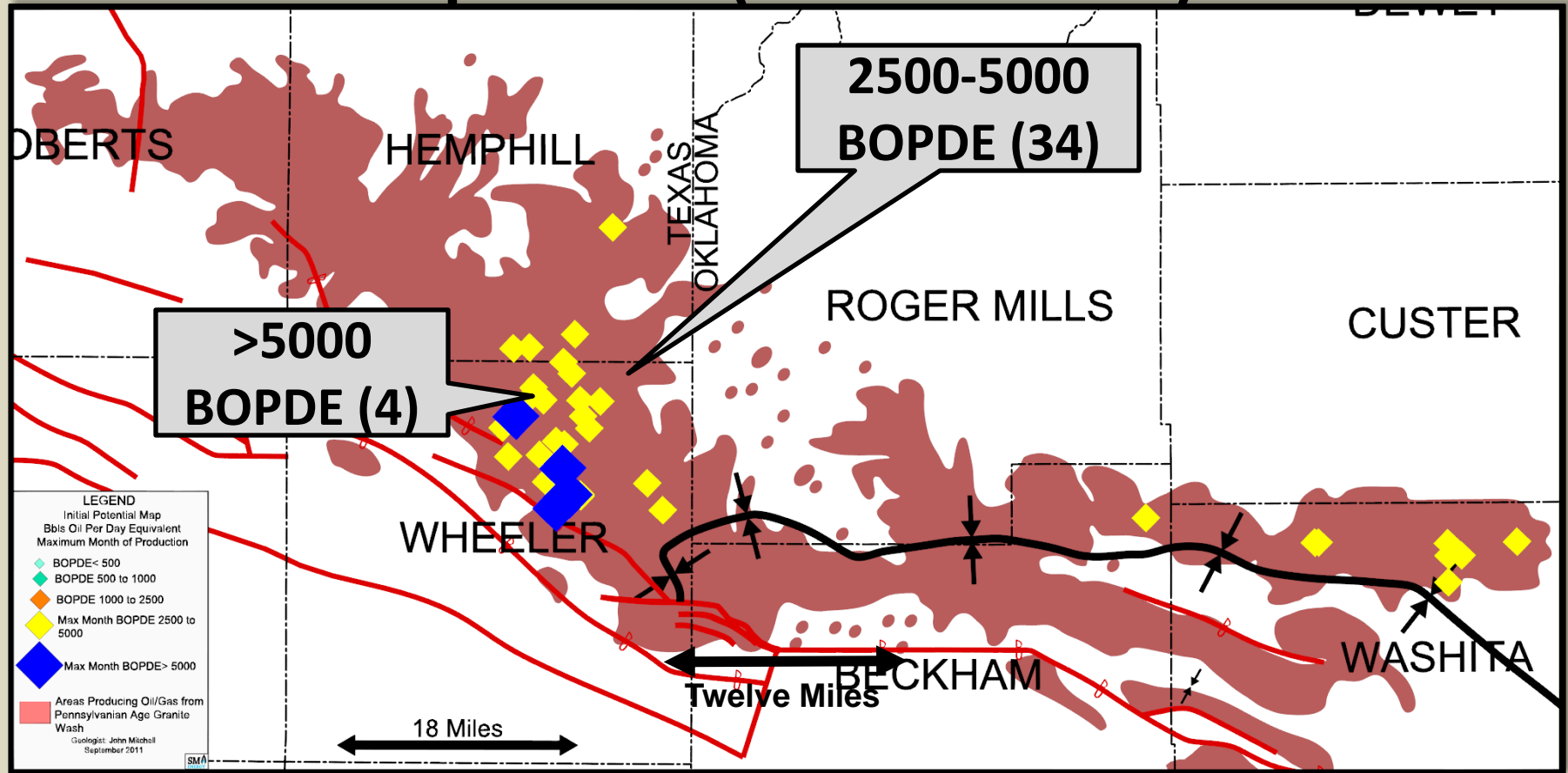
Yellow symbols on map showing locations of 42 horizontal Granite Wash wells spudded to date by Samson

HORIZONTAL GRANITE WASH PLAY

**Granite Wash Horizontal Max Month Initial
Potentials in BOPDE**

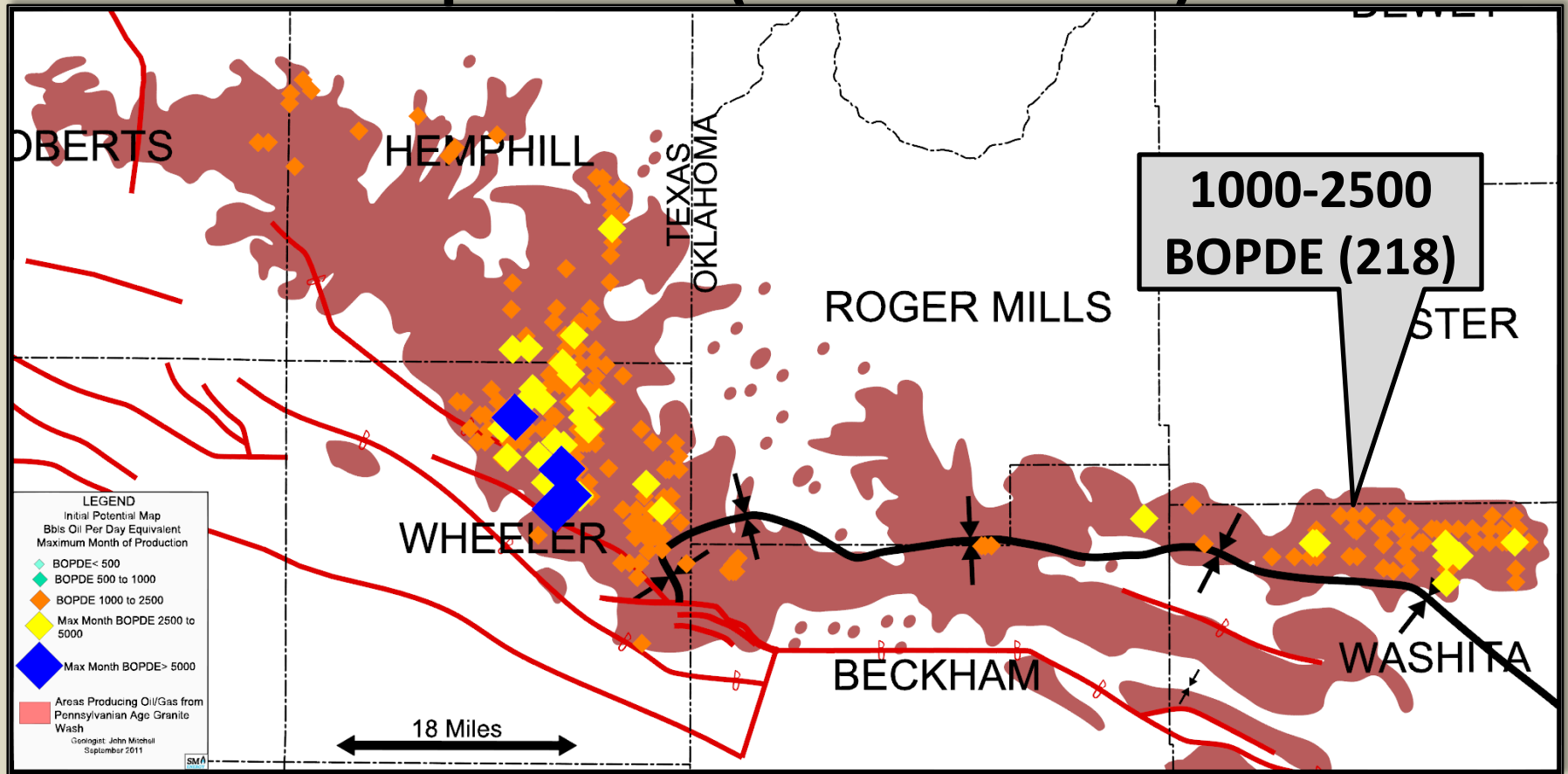
(Bbls of Oil Per Day Equivalent @ 6 mcfg= 1 BO)

Horizontal Granite Wash Wells with >2500 BOPD Equivalent (6 MCFG=1 BO)



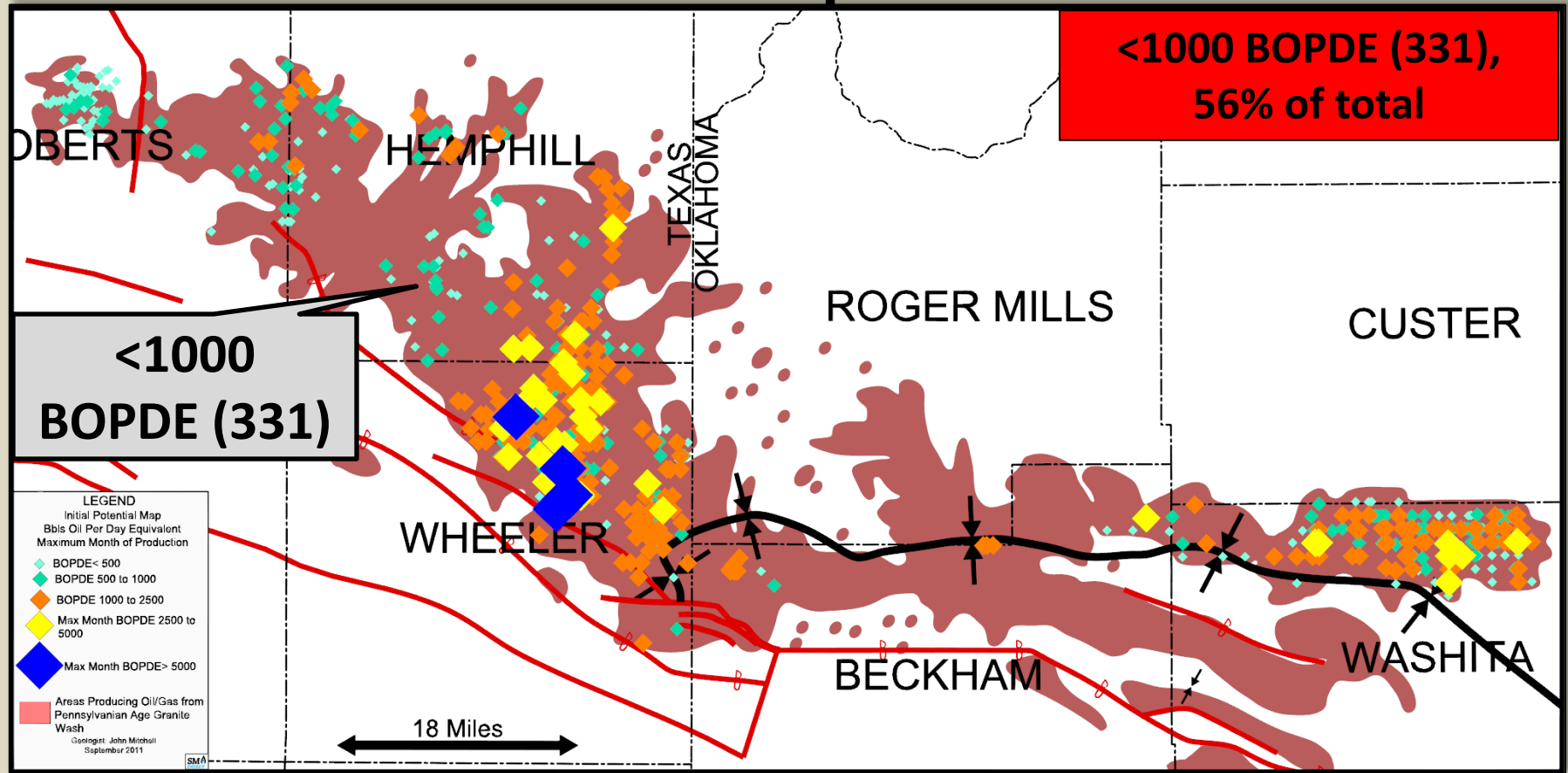
Map showing 38 wells (stars) having available production data September 2011 and with initial daily production rates exceeding 2500 BOPD equivalent @ 6 mcfg/bbl oil

Horizontal Granite Wash Wells with >1000 BOPD Equivalent (6 MCFG=1 BO)



Map showing 256 wells (stars) having available production data September 2011 and with initial daily production rates exceeding 1000 BOPD equivalent @ 6 mcfg/bbl oil

Horizontal Granite Wash Wells - Initial Potential Map



Map showing 587 wells (stars) with available production data
September 2011: 331 wells (56%) had initial daily production rates
below 1000 BOPD equivalent @ 6 mcfg/bbl oil