

*Data & Drilling Methods  
from Horizontal Mississippian Reservoirs  
Across Northern Oklahoma*



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# Contributions

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Spyglass Energy Group

Vitruvian Exploration

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Pablo Energy

Territory Resources

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Kansas & Oklahoma Geological Societies

Beer

# Outline

## Intro

- Play Observations
- Fairways

## Geology

- Depositional
- Targets
- Depth and Thickness Relationships

## West vs. East

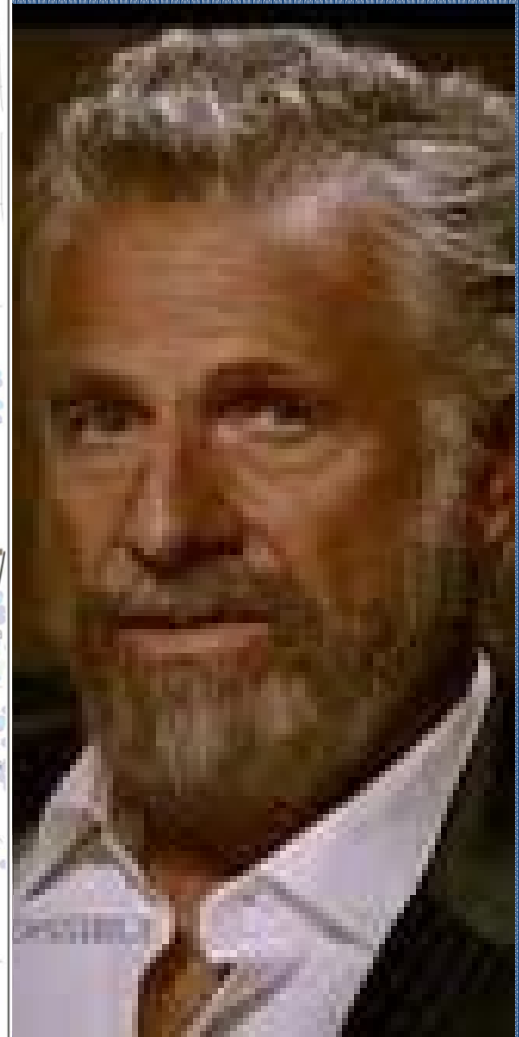
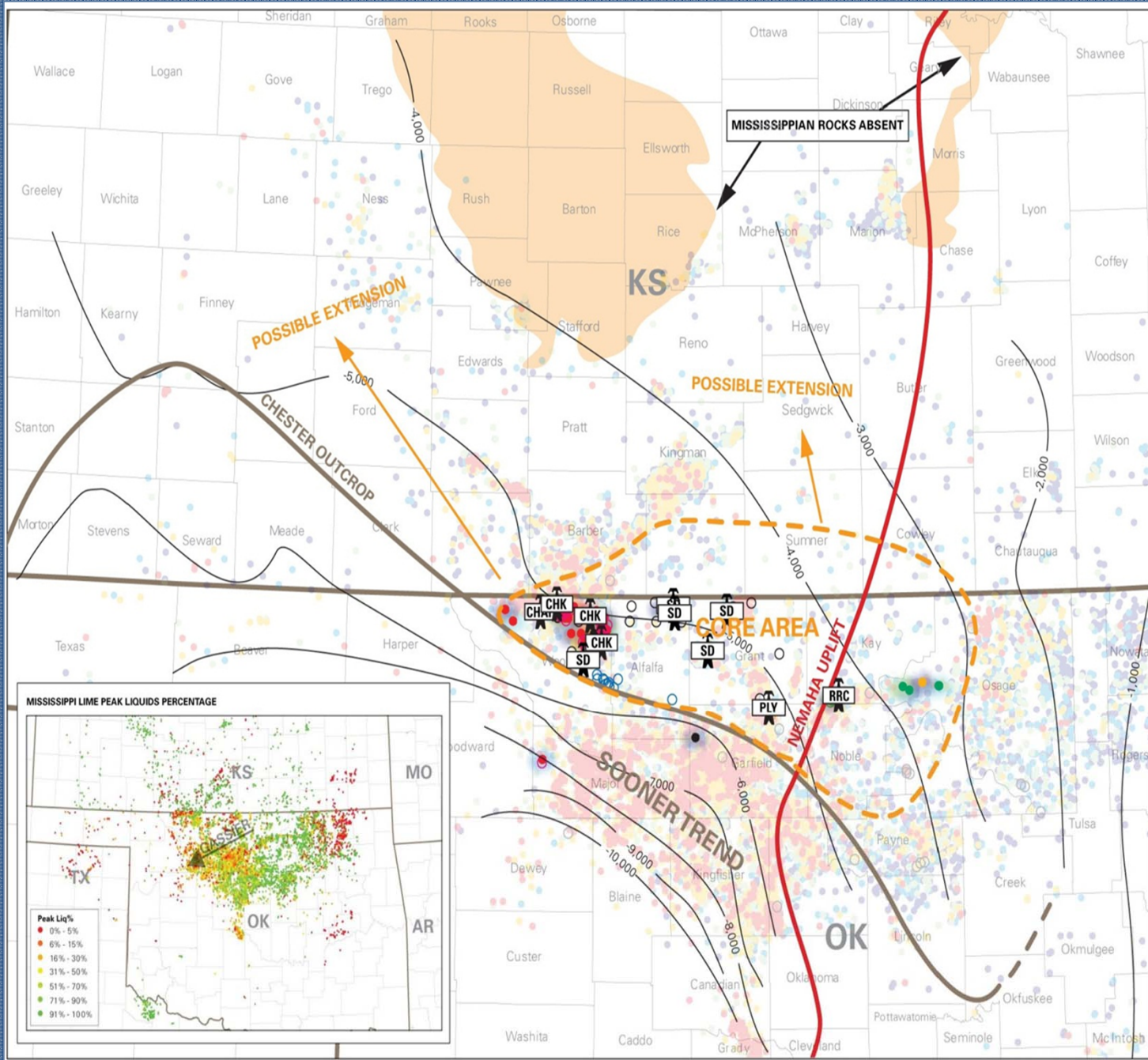
### *Well Results*

- Historical IPs vs Frac Volumes

## Hz Well Completion Methods

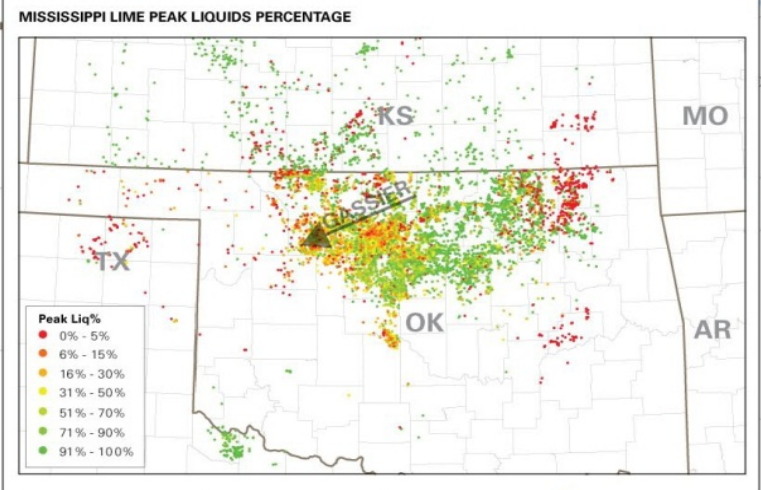
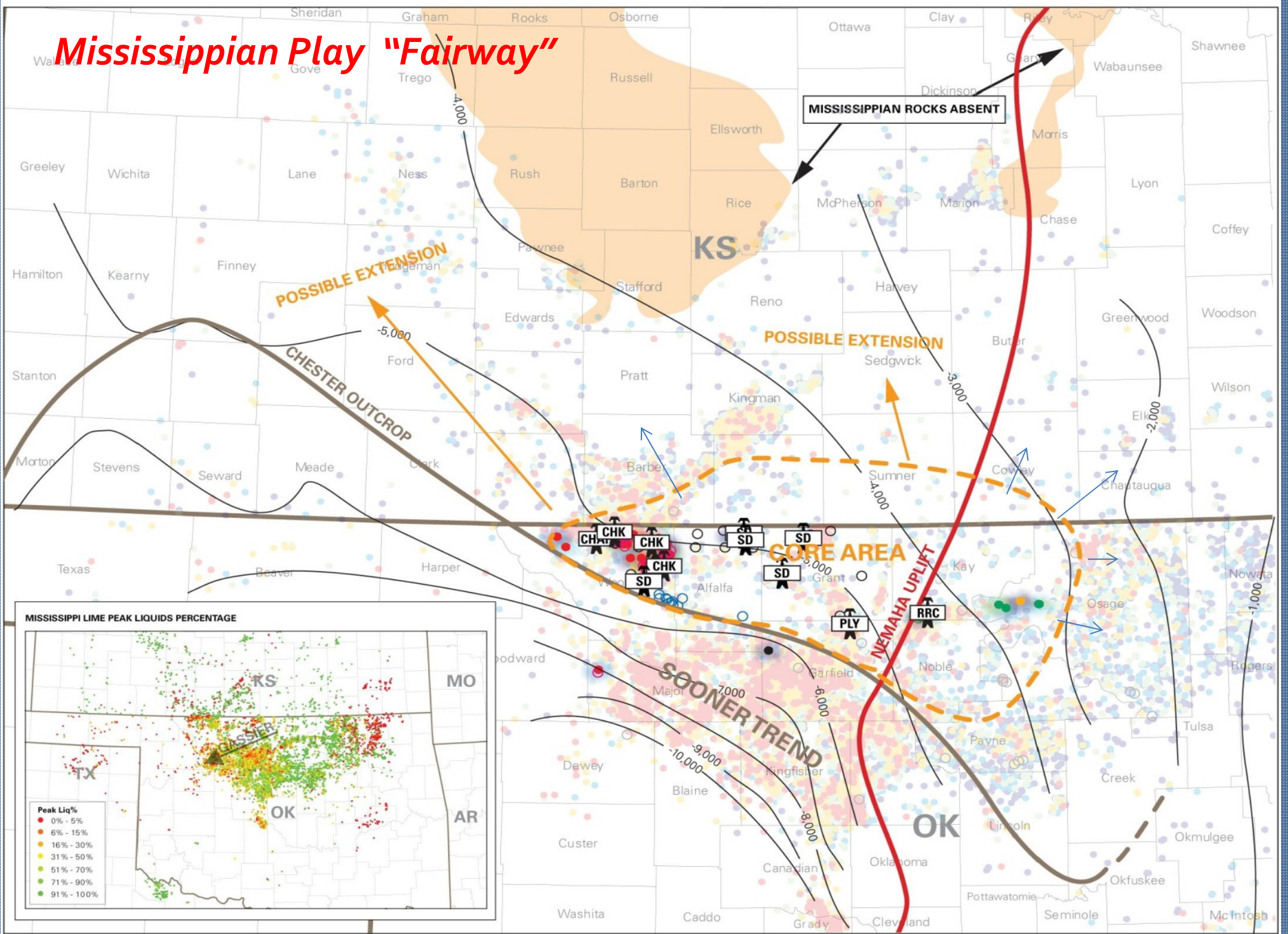
## Conclusions

# INTRODUCTION



*The Most Interesting Play in the World???*

# Mississippian Play "Fairway"



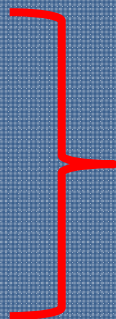
# Observations

- Infrastructure Dependent
  - Wells require SWDs (4-6 Wells per SWD)
  - Artificial Lift
    - ESP
    - Gas Lift
- In some wells, as water is pumped off, oil cut increases
- Differences between facies require stimulation changes
  - Different Geomechanical Properties
  - Brittle:Ductile Couplets
  - Vertically Stacked Pay in Reservoir Seal Pairs
  - Trapping Mechanisms
  - Migration Pathways
- At least 7 Productive Reservoir Facies
  - 3 Cherts, 2 Limestones, 2 Dolomites
  - Chat typically has different trapping mechanisms than the Lime
- Fractures are lithologically controlled; lithology is highly variable in the section. Fracturing correlates to rock brittleness.

# Observations

- IHS Production Codes

- “359MSSP”
- “359MPLM”
- “359MSLM”
- “359MSCH”
- “359CHAT”



*All can represent the same productive interval!!!*

***This is Problematic***

- Generalized Nomenclature

- this data must be mined through to identify the productive reservoir

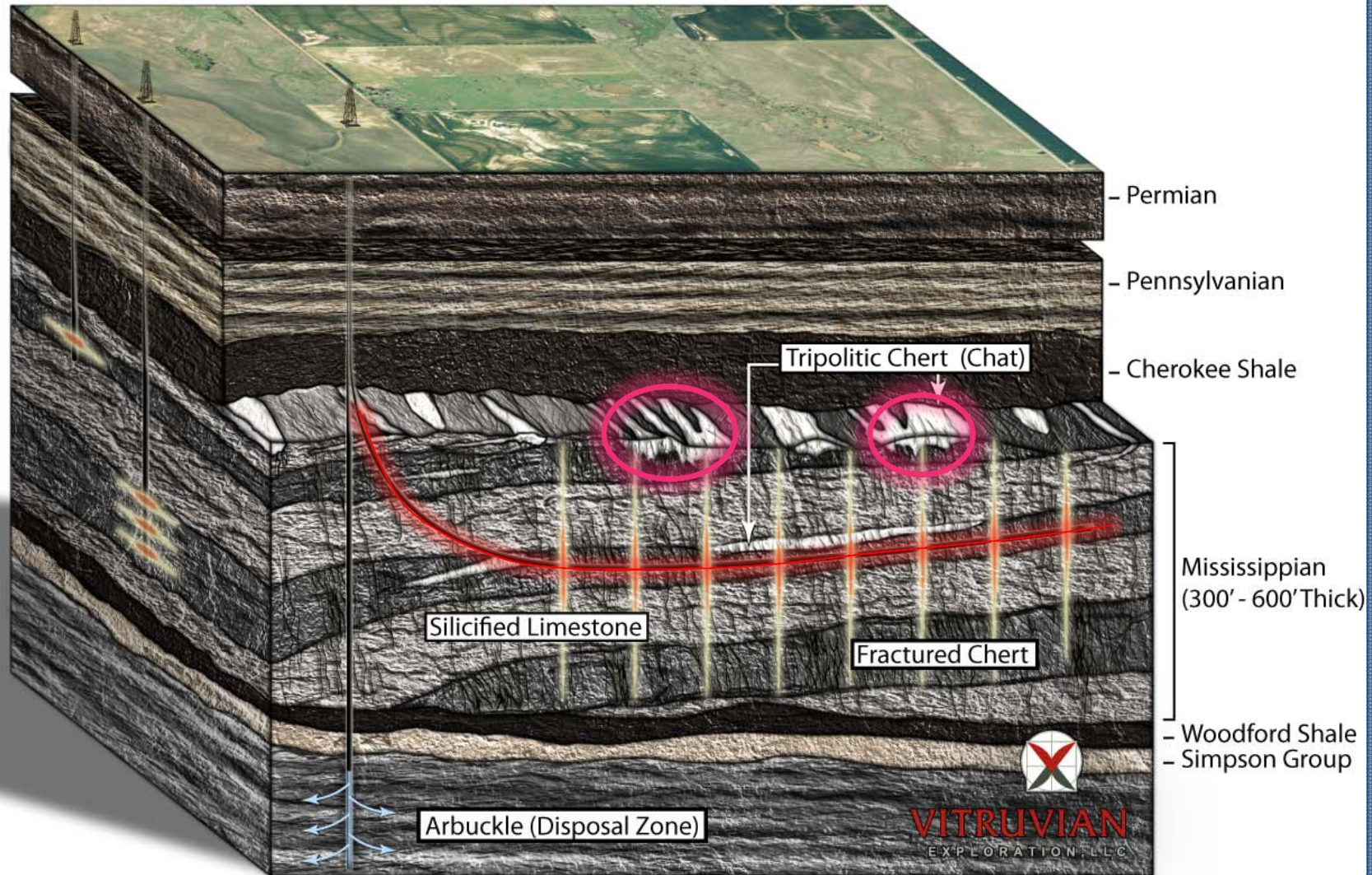


# GEOLOGY



- Progradational Depositional Architecture
- Very fine grained limestones, argillaceous muds, spiculites, tripolites and cherts (penecontemporaneous and diagenetic)
- Inter-Osagean Unconformities
- Several discrete reservoirs facies, with multiple porosity systems
  - Tripolitic (bedded and sheet), Intercrystalline, Spiculitic, Bed Bound Fractures, Vugular, Microporosity

# Target Horizons



# What is the Target?

## Geology

### “Mississippi Chat”

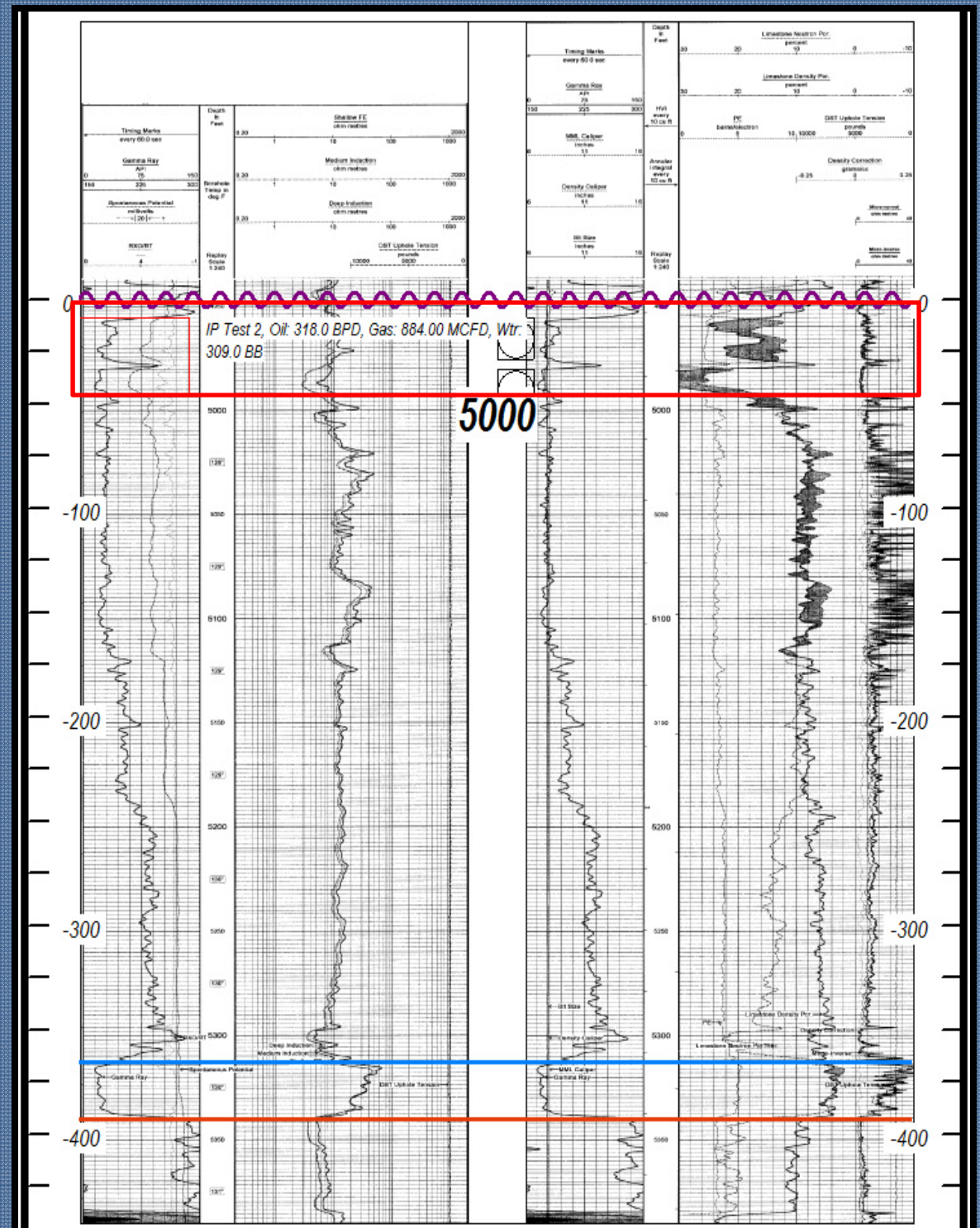
#### Woods County Section

A result of uplift, alteration, erosion and deposition of the original Mississippi limestone, several different levels of weathered cherts occur along the major Pennsylvanian-Mississippian unconformity.

Characteristics – low permeability, high porosity, often compartmentalized, stratigraphic combo traps by nature. The Chat drills very fast.

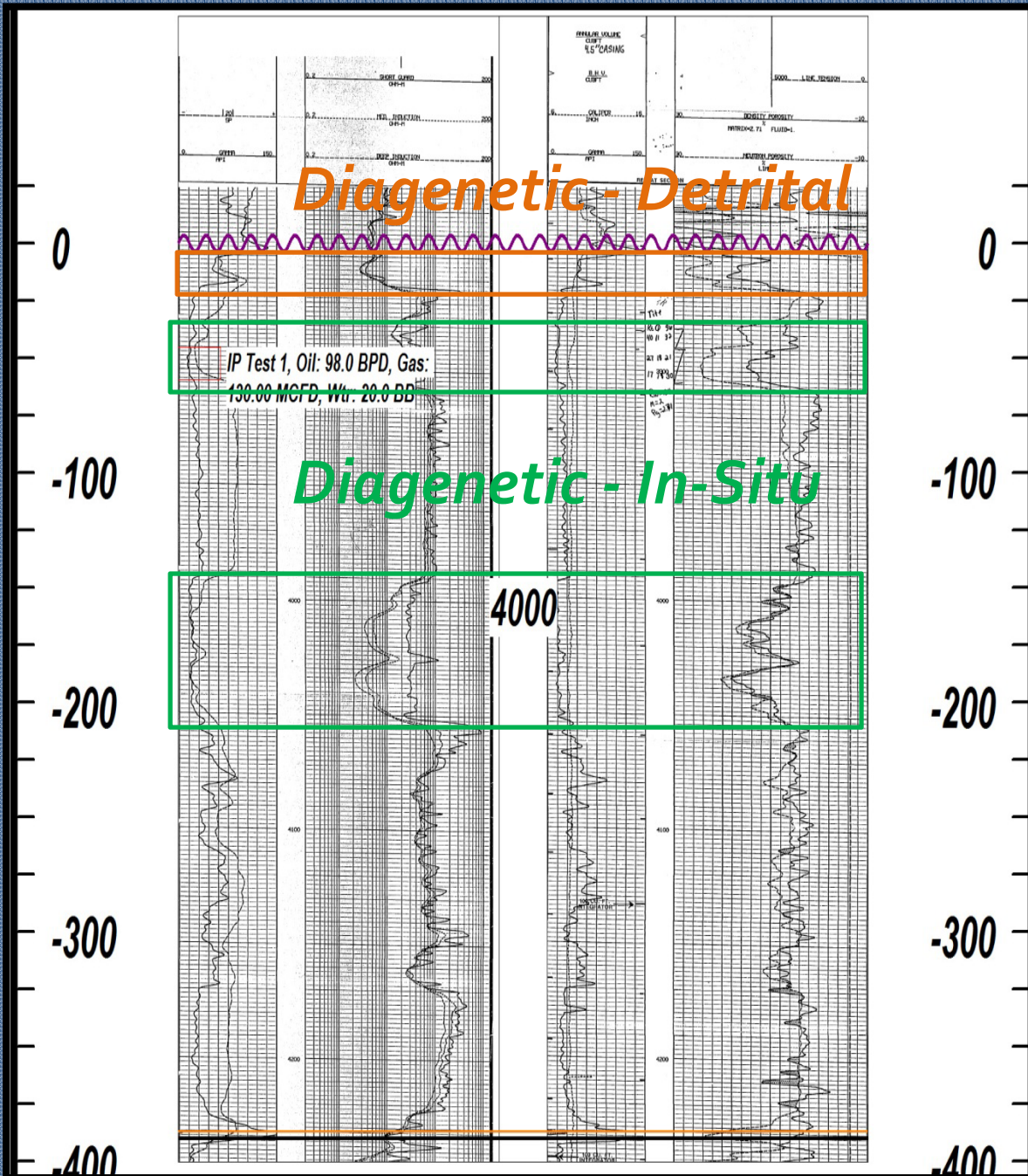
Rock with > 30% porosity can be produced open hole no stimulation. Sooner Trend style frac jobs of over 10,000 bbls fluid typically produced higher IPs, with cumulative production ~ 75,000 bbls.

#### Woods Co. Section



# What is the Target?

## Geology



## “Mississippi Chat”

### Osage County Section

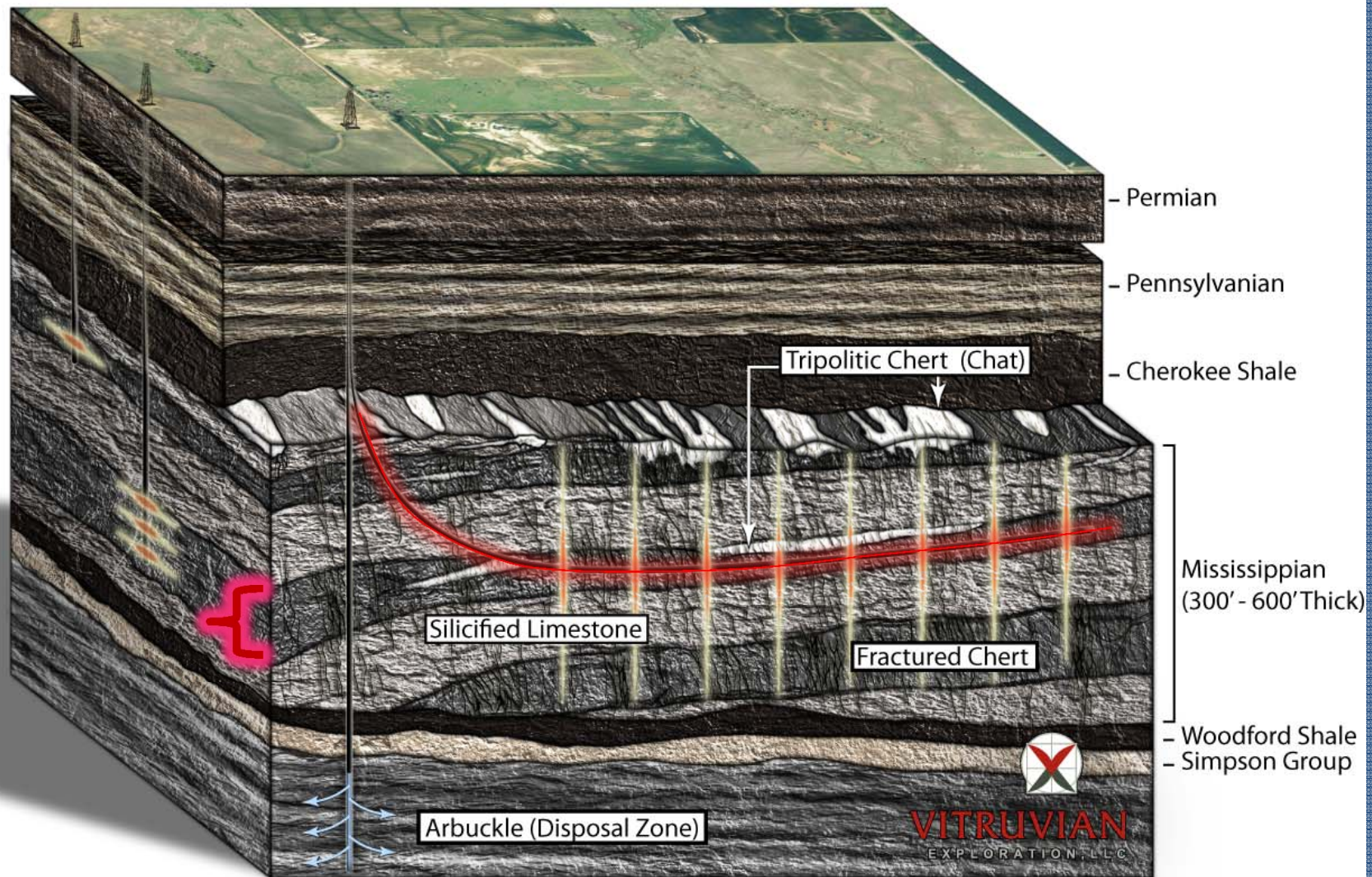
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Originally Produced Naturally, then Sooner Trend style frac jobs of over 10,000 bbls fluid typically produced higher IPs, with cumulative production ~ 75,000 bbls

Osage County

# Target Horizons



# What is the Target?

Geology

Mississippi Lime

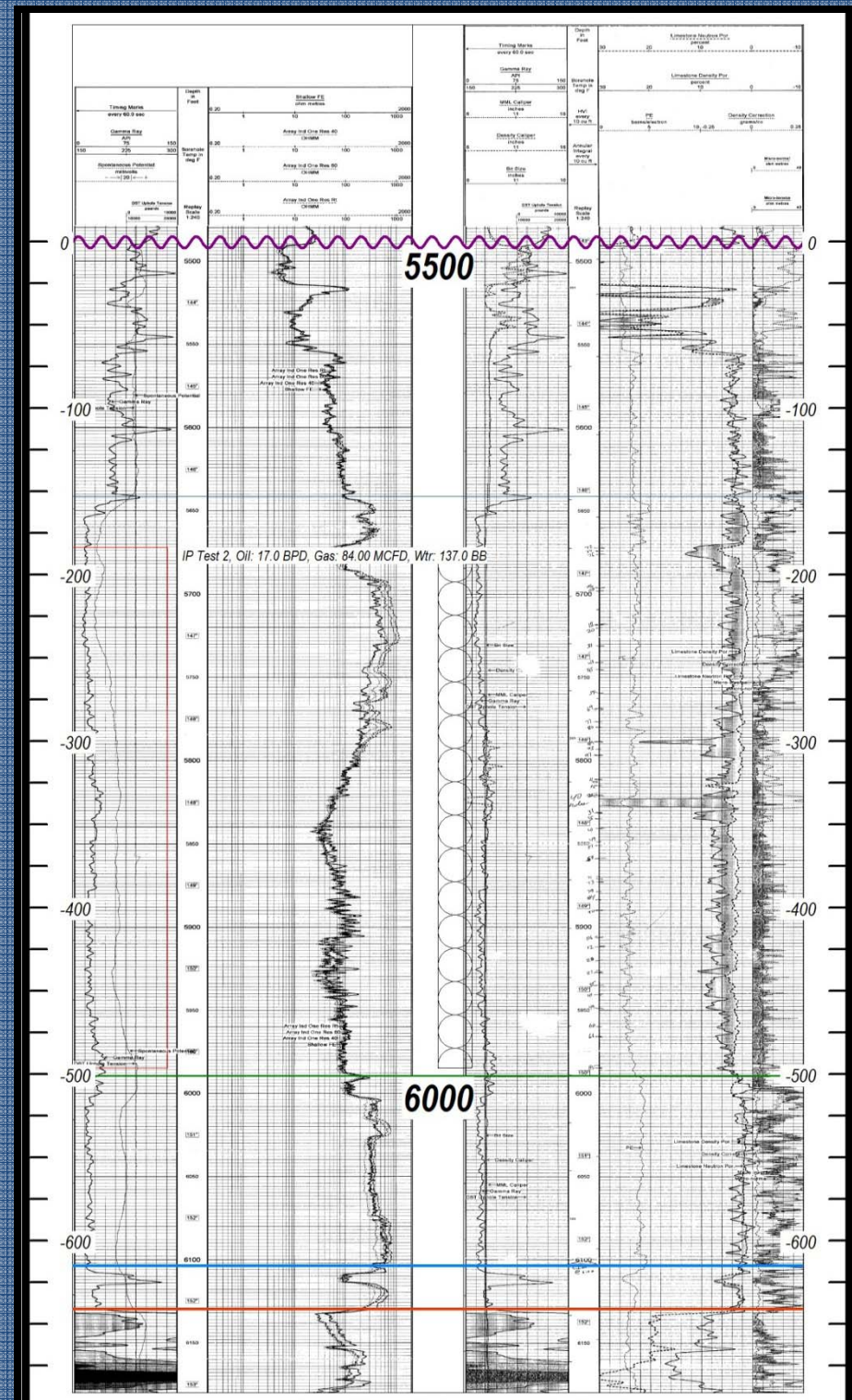
Garfield County Section

The Miss Lime has typically been produced from porosity streaks, or open natural fractures since the 1950's in Oklahoma

Lithologically – occurs as alternating beds of chert and limestone. Streaks of high porosity alternating with tight limestone

Characteristics – low permeability, low-moderate porosity, combo traps beneath sub-unconformity surfaces

Originally Produced Naturally, then Sooner Trend style frac jobs of over 10,000 bbls fluid typically produced higher IPs.



# Understanding the “Tight” Mississippi Lime

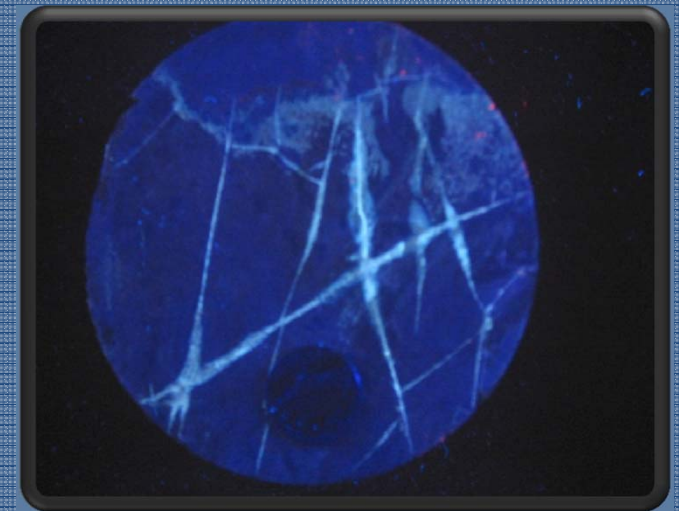
*Fully Cored Interval taken by Orion 1.1.2011*

Vertical barriers are created by several cycles of deposition. Resulting thin-beds of alternating argillaceous limestones and cherts act as stratigraphic traps for hydrocarbons.



*Hydrocarbons (green) occur in matrix & oriented along azimuth of fracture planes, proving the East to be more than a fracture play*

Fracture  $\phi$  is necessary to create matrix permeability. Fractures occur in intense pockets or “swarms”. The horizontal drill we can encounter *multiple* swarms, in contrast to a vertical wellbore which would be lucky to encounter the edge of a single swarm.





Pawnee County, Oklahoma  
31-22N-4E

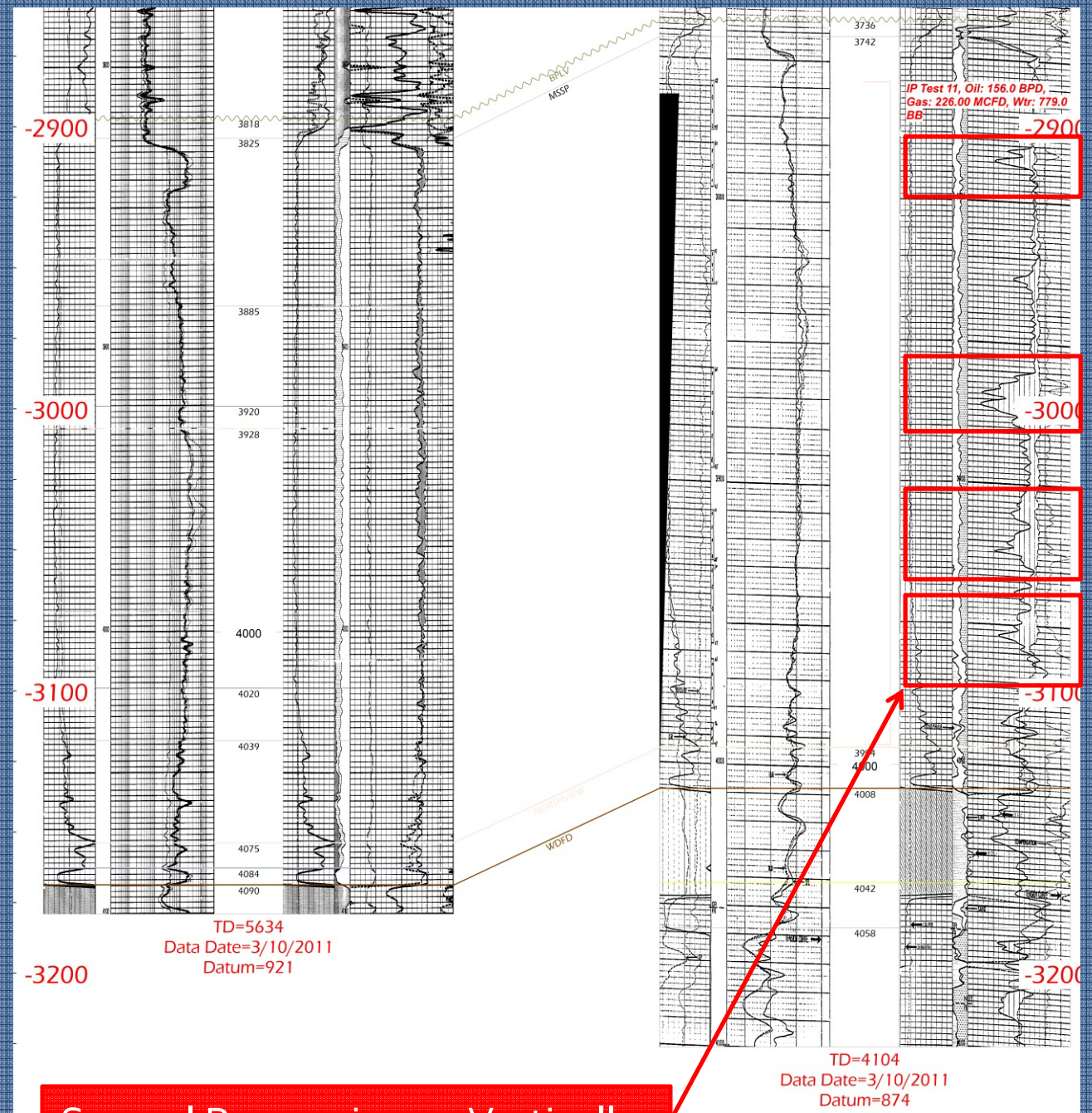
Facies

- Tight Dense Lime

**Ripley 1-31H**

**~55,000 bbls**

- First 12 Months Production
- Little Historical Miss. Production
  - 1 Vertical Well – Produced 28,000 bbls
- Large Frac Job
  - connecting the matrix porosity to the fracture porosity



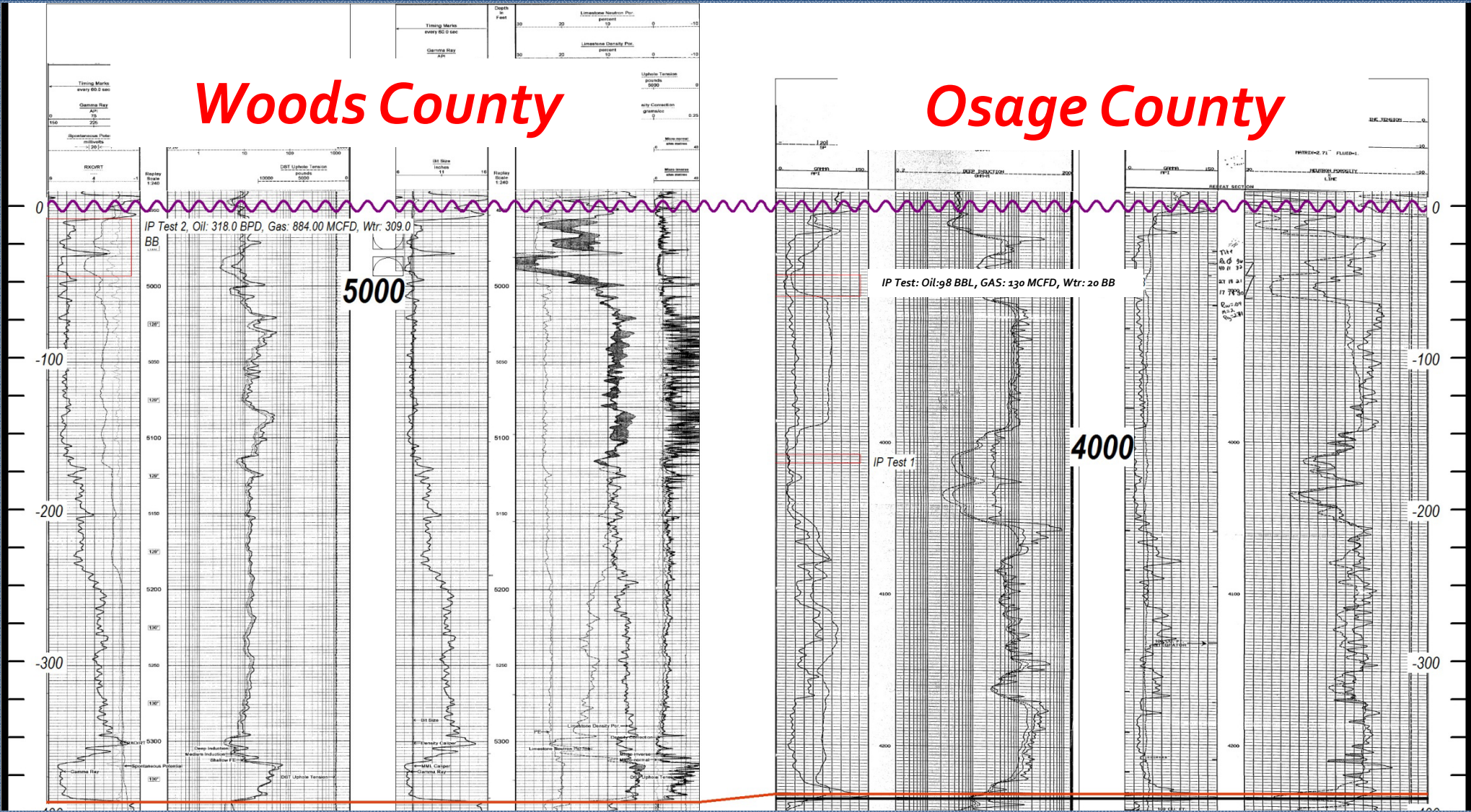
Several Reservoirs are Vertically Segregated within the Silicified Mississippian Lime

Is the West similar to the East?

*It is the same, in that, it is different,  
but has similar characteristics*

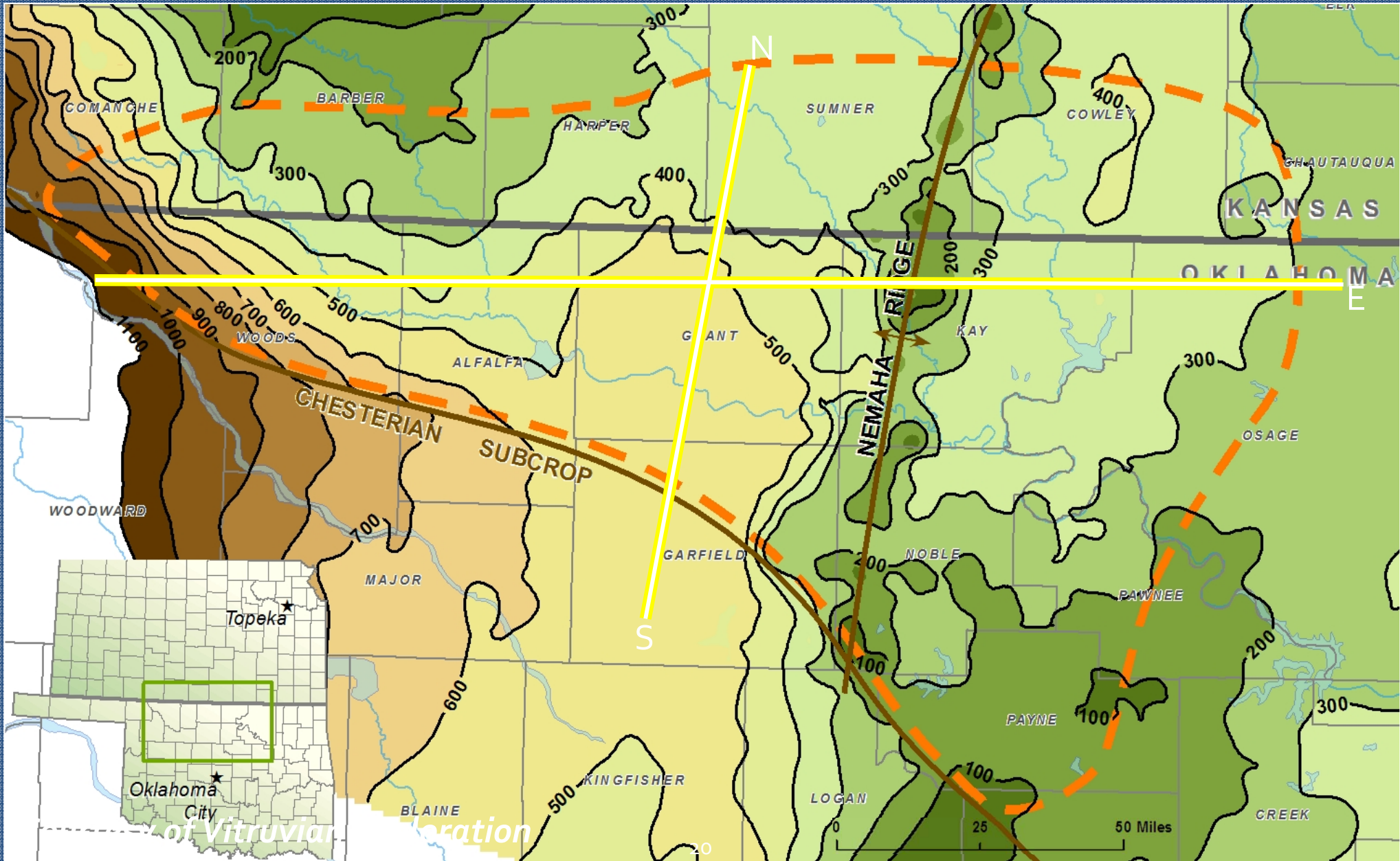
# Woods County

# Osage County

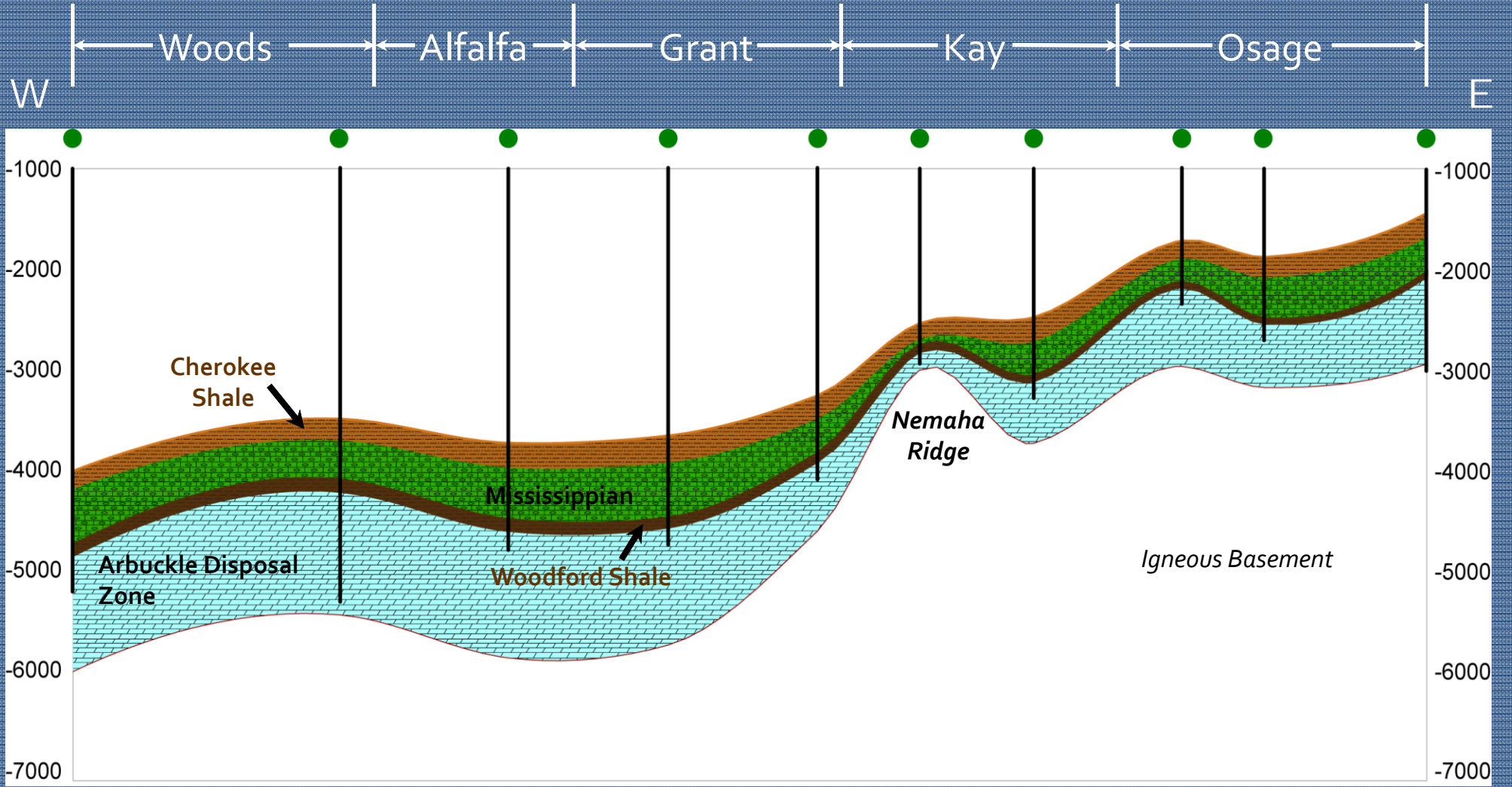


Is the West similar to the East?

# Thickness Relationships Mississippian Isopach Map

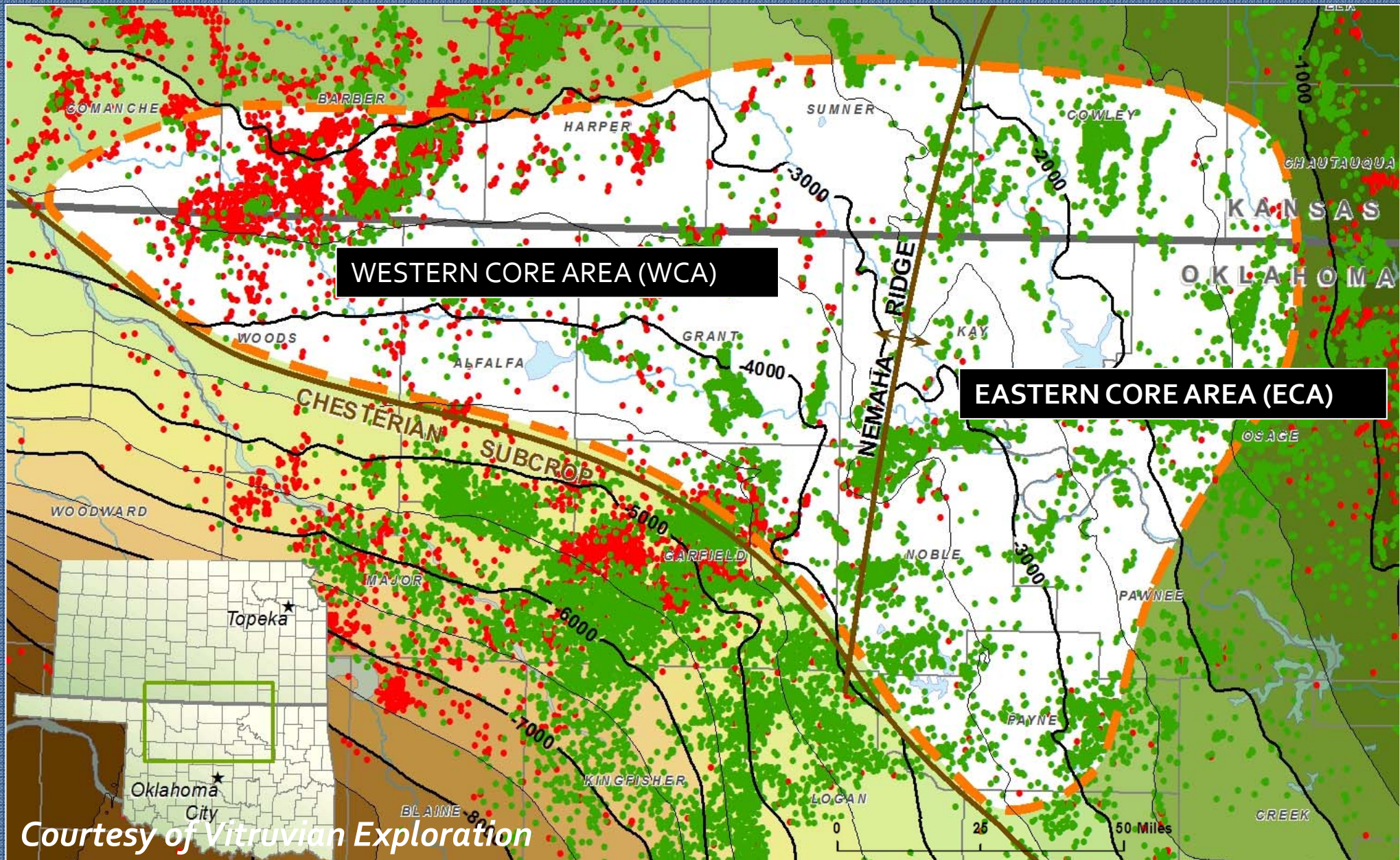


# Schematic Cross Sections



# Top Mississippian Structure Map

(Shows only vertical productive wells in Mississippian)



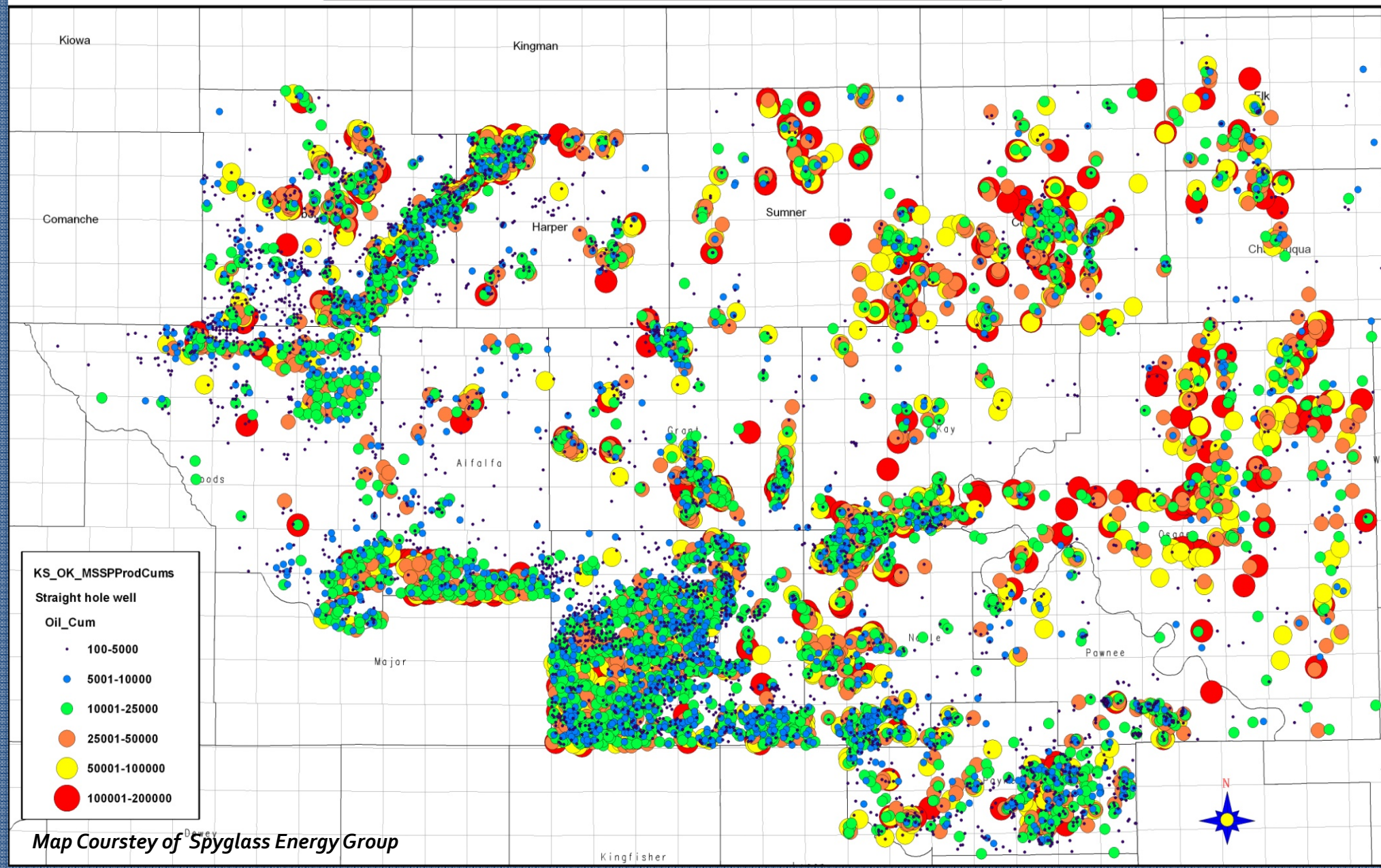
Courtesy of Vitruvian Exploration

What Does the Production and Completions from Vertical Wells Really Tell Us?

# FRAC VOLUMES

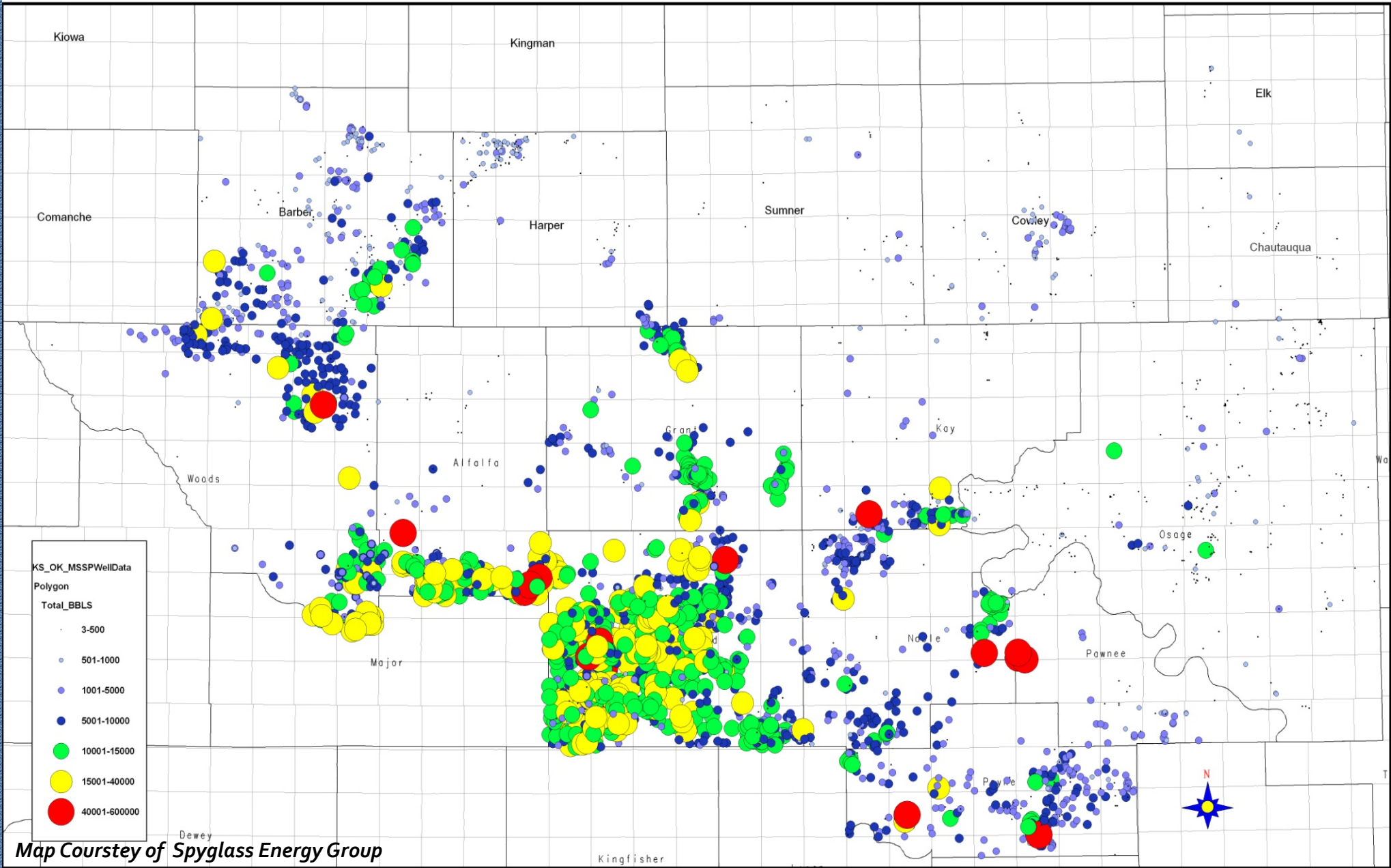


# MSSP Cum Oil Production

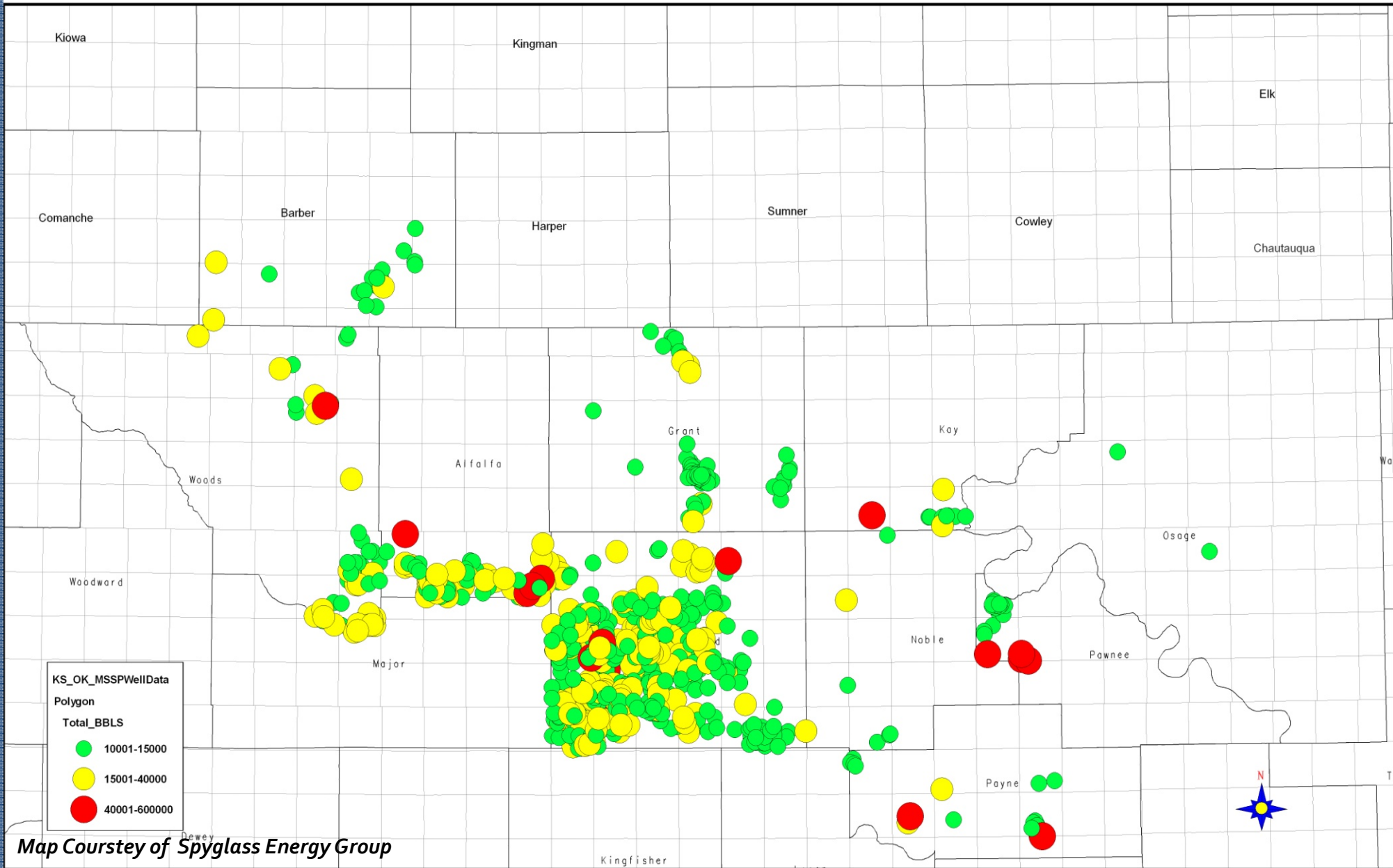




# MSSP Frac Volume's (in Bbls)



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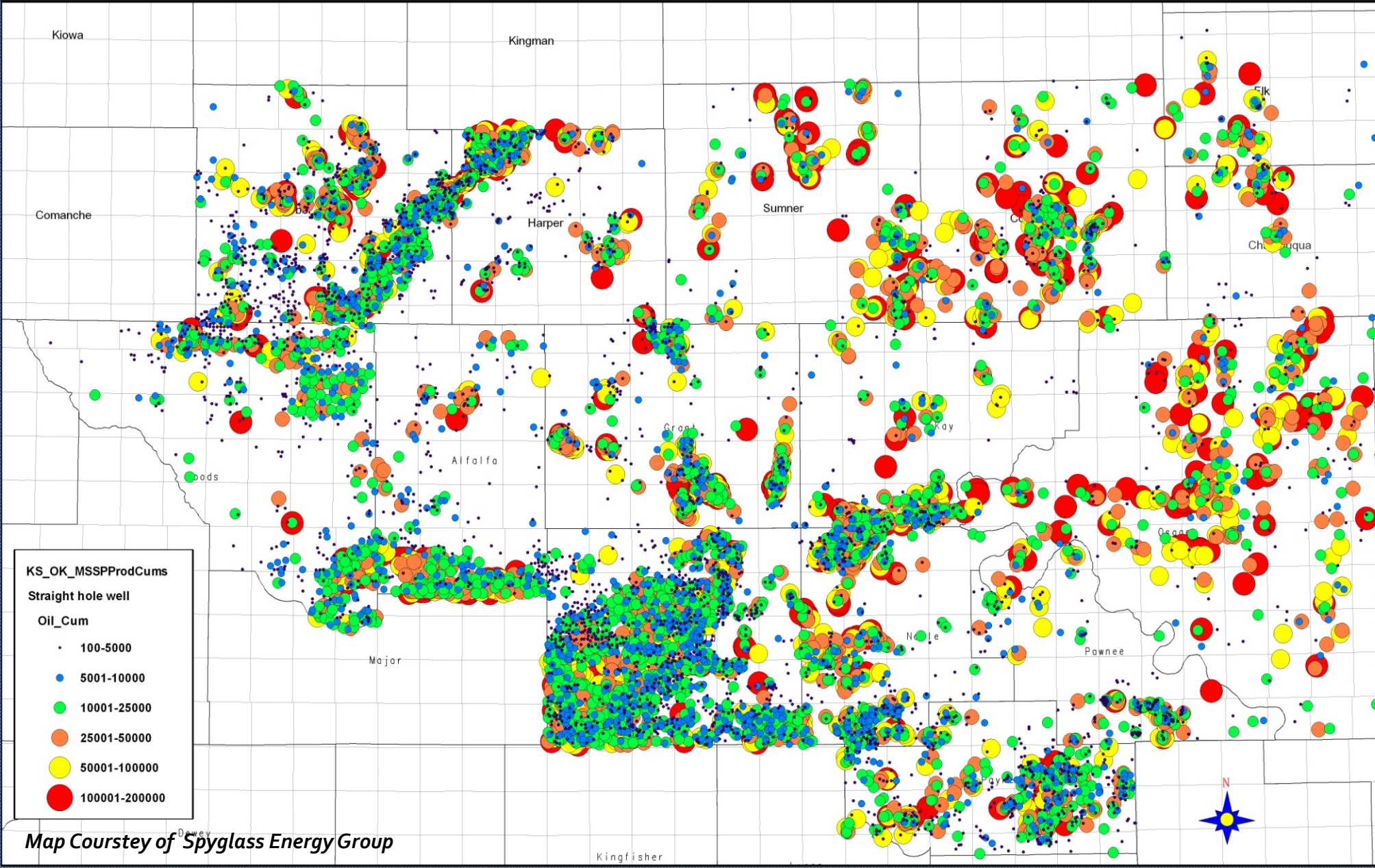


Map Courtesy of Spyness Energy Group

Completions Greater than 10,000 Bbls

IHS Data

# MSSP Cum Oil Production



# HORIZONTAL COMPLETIONS



# Considerations

- Integrate hydraulic fractures w/ specific type of reservoir
  - Lithology
  - Rate
  - Lateral Length
- Number of Stages
  - Placement
    - Shows?
    - Intervals?
  - Number of Shots
  - Spacing between Shots
  - Hydraulic Diversion

# Frac Fluids

- Slickwater
  - *How Much Sand??*
  - *Gel?*
    - X-Link
    - Linear
- How Much Acid?
- Hybrids
  - Alternating Stages
- Formation Water?

# Early Fracs Sandridge & Chesapeake

~ 6,000 barrels per stage

4 to 5 sets of perfs per frac stage  
(6 shots per foot over 2' every 100' of lateral)

~1,000-1,200 barrels per set of perfs

# Early Fracs Sandridge & Chesapeake

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(6 shots per foot over 2' every 100' of lateral)

~1,000-1,200 barrels per set of perfs



# Very Different Approaches

## More Holes vs. Less Holes

### Limited Entry

- 350'
- 3 2' clusters and 6 shots psf
  - 12 shots per foot cluster
  - 36 shot holes per stage
- 80-90 bpm
- 3750 bw/stage
- .05#/gal water

*LE wells have seen large decreases in fluid production*

### Hydraulic Diversion

- 300'
- 4 5' perf clusters, 6 spf
  - 30 shot per foot cluster
  - 150 shot holes per stage
- ~60 bpm
- 10k bw/stage
- .4#/gal water
- Drop 60 "bio ball sealers"  
4x per 2500 bw

# Ideas

- Longer Laterals
- Frac
  - How Much Sand?
    - » .25-.33#/gal
  - More Acid
  - More Stages and ~70 bpm rate
    - » Not as much vertical growth as previously thought
- Casing
  - 7" with 4 1/2" liner
    - » Larger Pumps
  - Open Hole Packers
    - » Packers Plus
      - Can bleed off from packer be overcome?

# Conclusions

1. Eastern Core Area is Analogous to Western Core Area
  - East is More Prospective for Oil
    - Doesn't Need to be Frac'd as Much!
    - Potentially More Trapping Mechanisms
  - More Wells Need to be Drilled for better Comparisons
2. Different Lithologies Require Different Completion Techniques
  - Know Your Lithology!!!
  - ESP's handle fracture water
3. Fracturing is Lithologically Controlled
  - Brittle:Ductile Couplets
4. High Volume Frac Jobs Mechanically Open & Clean Healed Fractures
  - West vs. East Production Volumes Debunked!

Thank You  
and  
Stay Thirsty My  
Friends

