Midland Basin Wolfcamp Horizontal Development*

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Abstract

Energen has begun the first phase of a development drilling program in the Wolfcamp Shale in Glasscock County, Texas. This is a discussion of what we have done so far, and where we are going.

References

Fu, Q., 2011 A synthesis of the Wolfcampian platform carbonate system in the Permian Basin Region: West Texas Geological Society, Presentation 03/08/2011. Website accessed August 4, 2015, http://www.wtgs.org/media/files/None/Synthesis-of-the-Wolfcampian-Platform.pdf.

Galloway, W.E., T.E. Ewing, C.M. Garrett, N. Tyler, and D.G. Bebout, 1983, Atlas of Major Texas Oil Reservoirs: Bureau of Economic Geology, The University of Texas at Austin, 139 p.

Website

Spindletop, April 23, 1904, priweb.org, courtesy of American Petroleum Insitute. Website accessed August 4, 2015, http://www.priweb.org/ed/pgws/history/spindletop/spindletop.html.

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January 14, 2015

What Makes RESOURCE PLAYS Work?

- **Organic Mudstones** (basinal source rocks)
- **Mappable** (significant thickness & areal extent)
- **Richness** (generated oil in place)
- **Repeatable** (predictable results)

What Makes RESOURCE PLAYS Work?
Cont'd

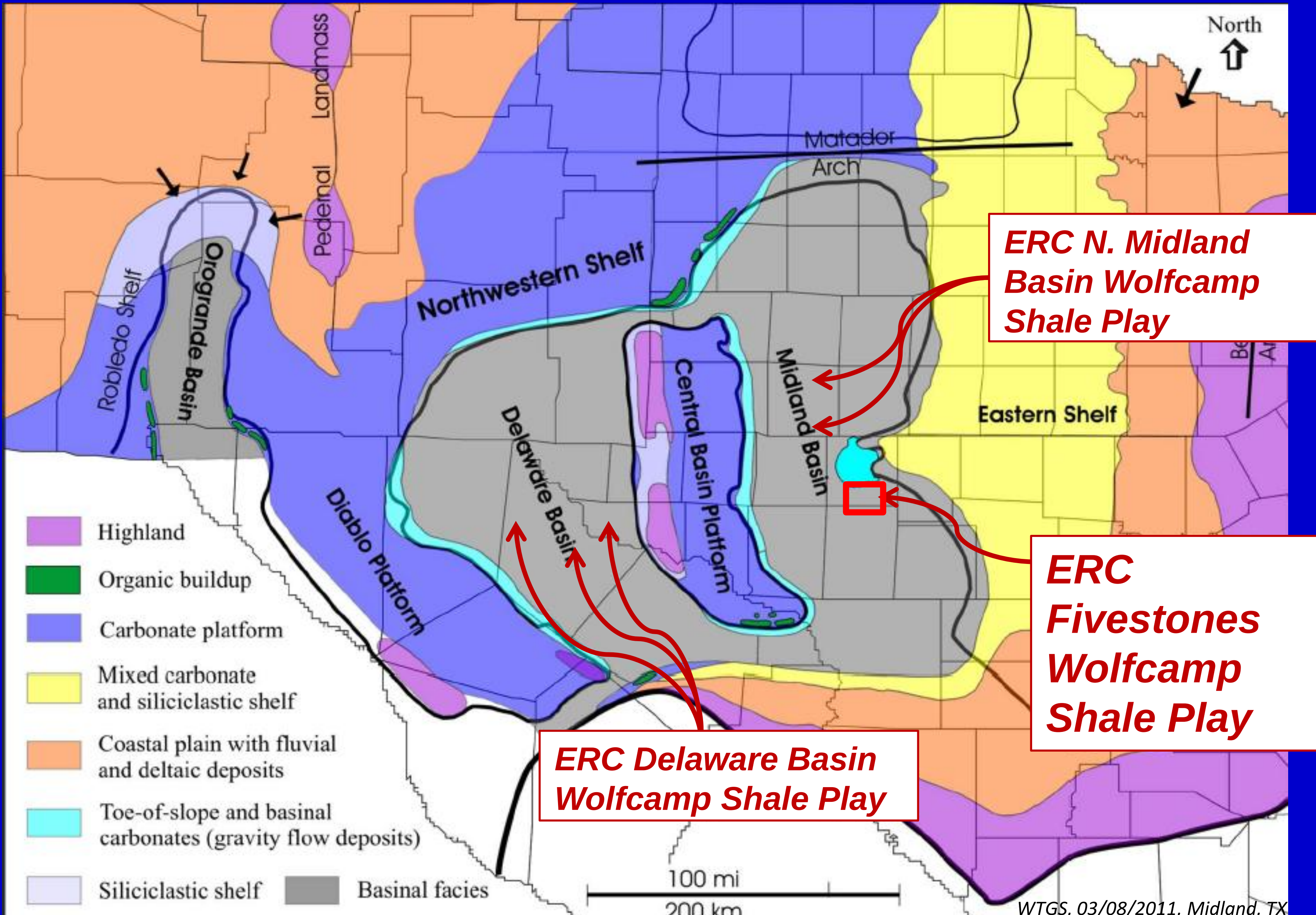
- **Thermal Maturity**
  - Hydrocarbon Generation (Oil / Wet Gas / Dry Gas)
  - Reservoir Quality (porosity & permeability)

- **Petrophysical Properties** (identify, measure, analyze & map)

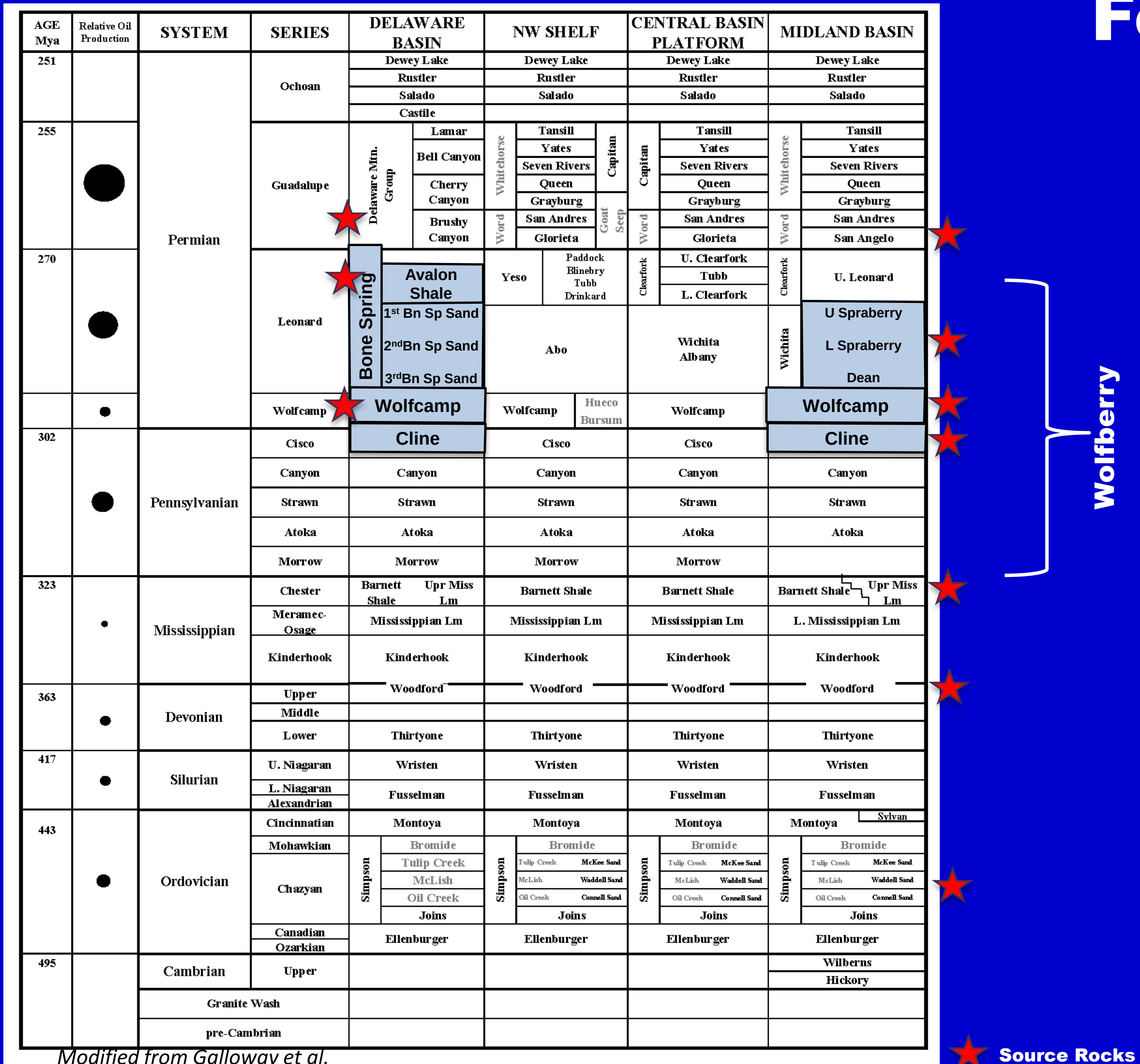
- **Clay Volume** (low to moderate volume, minimal swelling clays)

- **Rock Mechanical Properties**
  - Drillable
  - Fracable

Wolfcamp Paleographical Map



Permian Basin Stratigraphic Column & Focus Plays



Modified from Galloway et al.

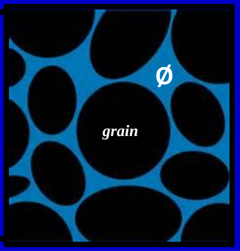
- **Bulk of production comes from the Permian sequence**
- **Major source rocks in the Ordovician, Woodford, Barnett, Cline, Wolfcamp and Leonard**
- **Historical activity and production has been dominated by shelf carbonate plays**
- **Shelf carbonates are still being drilled, but activity today is dominated by basinal plays**
- **Industry activity today is focused on the Leonardian, Wolfcampian and Upper Pennsylvanian basinal lithology in the Delaware and Midland Basins**

Reservoir Quality in a Resource Rock

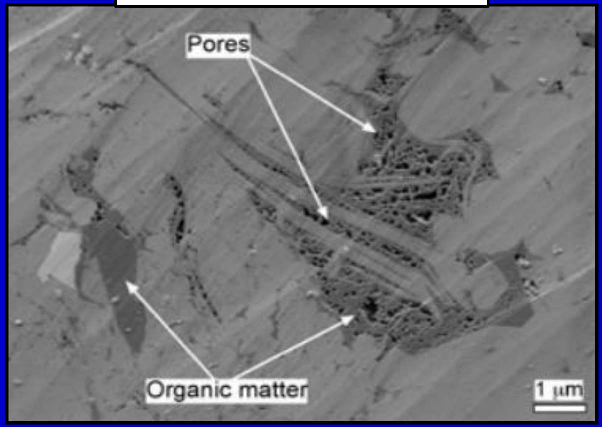
Intergranular and Intra-Kerogen Ø

Intergranular Ø

Rock related



Intra-Kerogen Ø



Maturity related

Reservoir space is a network of Intergranular and Intra-Kerogen pores molded into a complex geometry

Porosity determination from Petrophysics requires careful calibration of wireline logs to core measurements, rock mineralogy and clay content

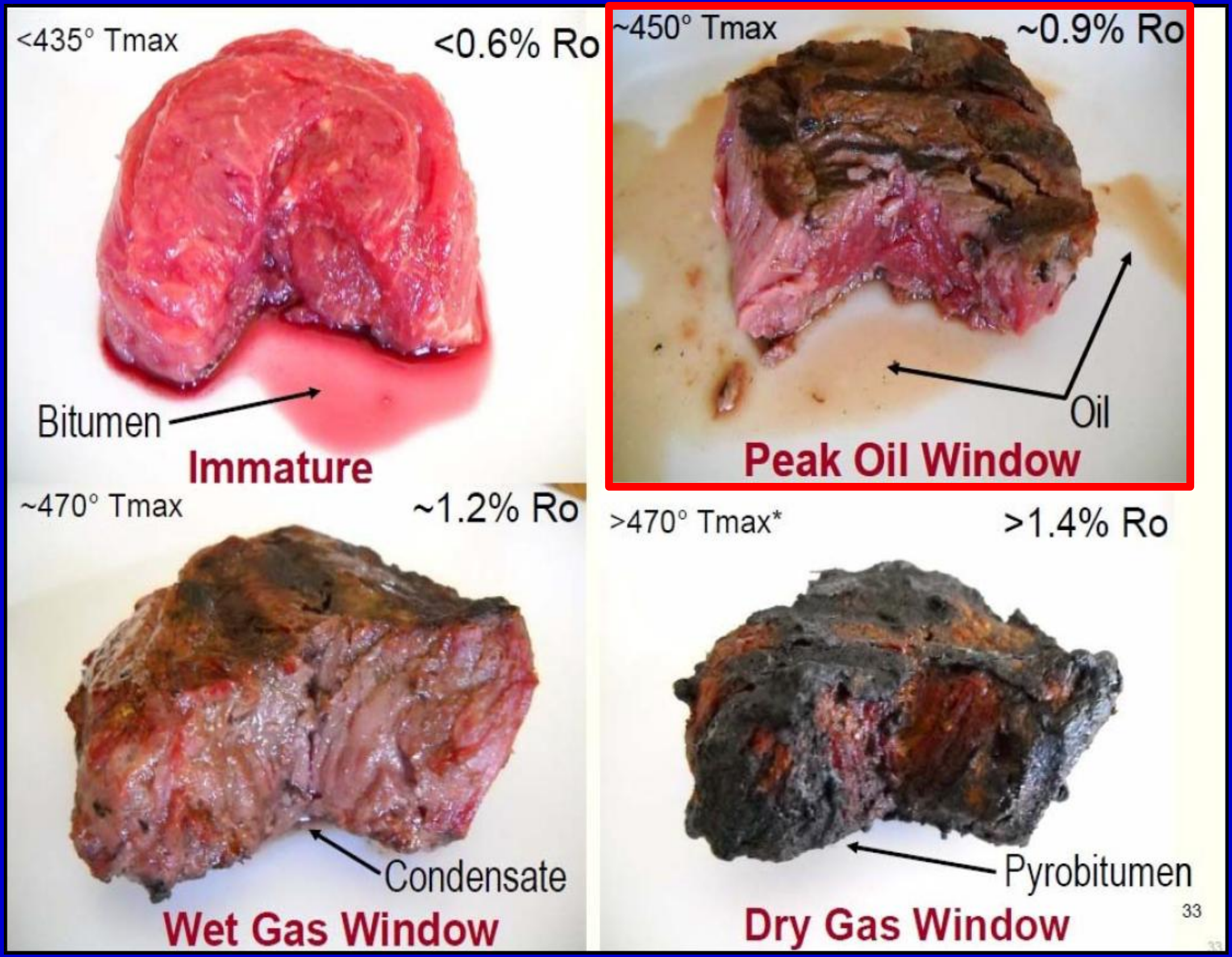
Permeability is dependent upon the pore sizes and their inter-connectivity

Reservoir space is filled with a combination of Oil, Gas & Water

Flow varies with fluid phase, permeability and reservoir pressure

Thermal Maturity

Hydrocarbon Generation and Reservoir Quality



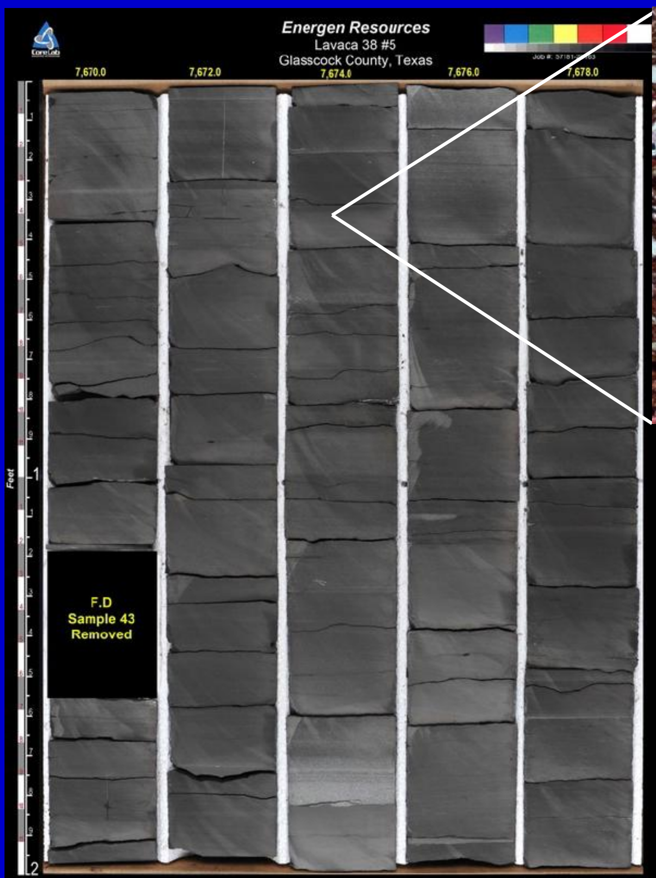
Weatherford Laboratories

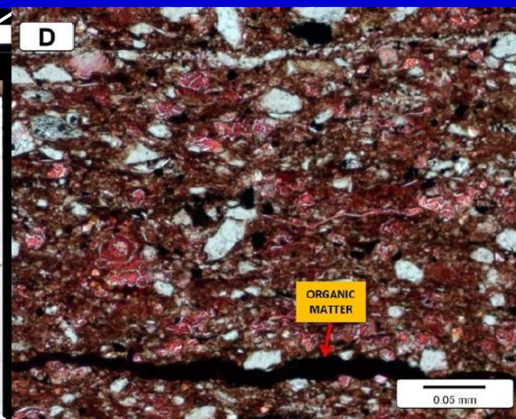
- **% Ro** (vitrinite reflectance) industry standard for maturity assessment
  - Microscopic examination from cuttings/core samples
  - Calculated to equivalent % Ro from laboratory data
- **Tmax** (Temp of max hydrocarbon released in analysis)
  - Measured from laboratory analysis

Wolfcamp “A” Core Data

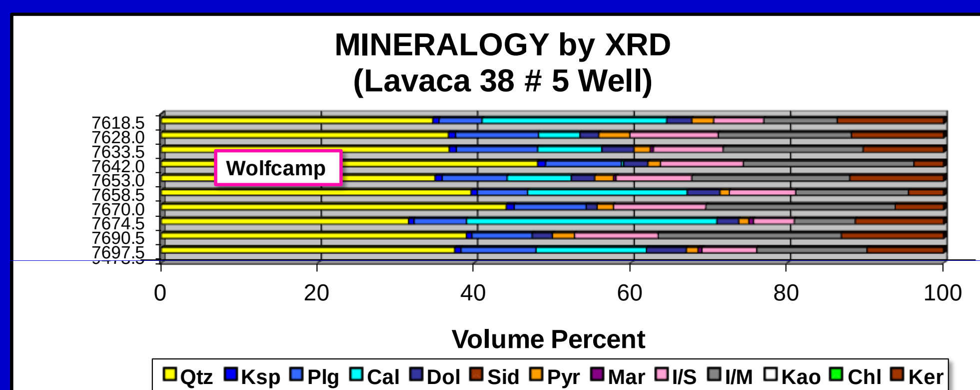
Lavaca 38 #5

Organic Silty Mudstone



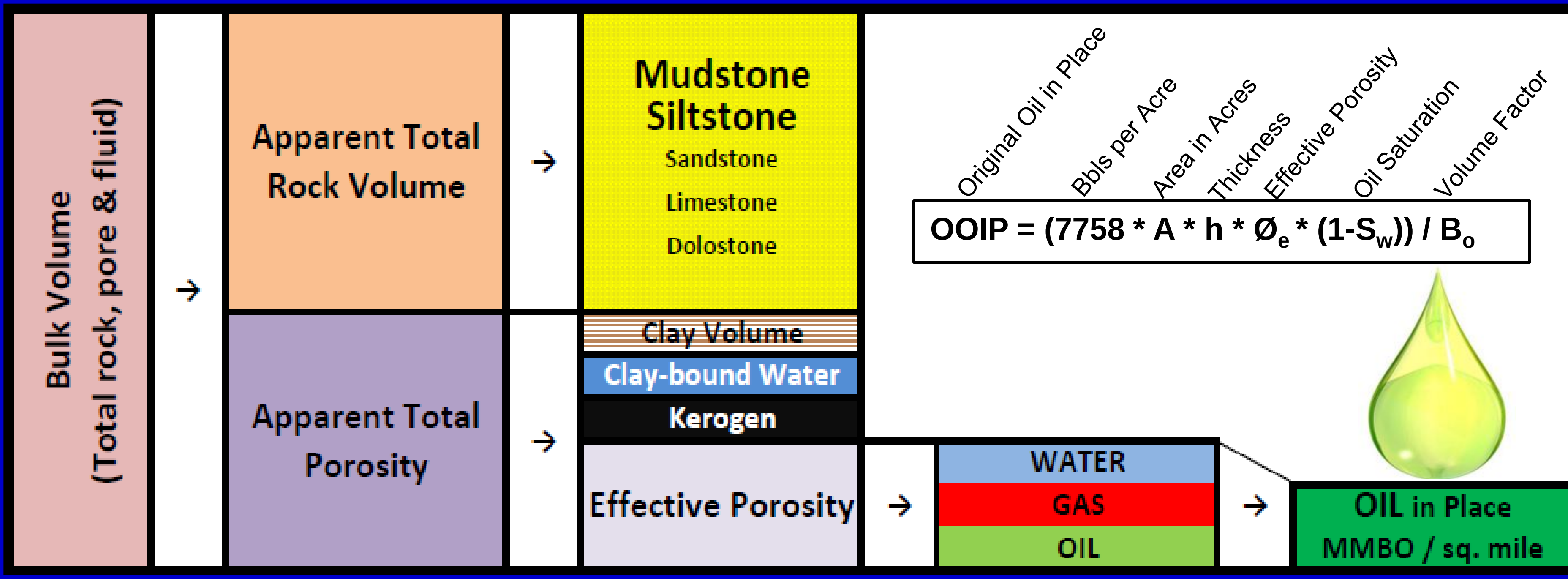


- TOC = 2.0 – 4.6% (wt%)
- Ro (calc) = 0.85 – 0.9%
- Tmax = 445-449 (deg C)
- Total Clay = Avg 35% (vol%)



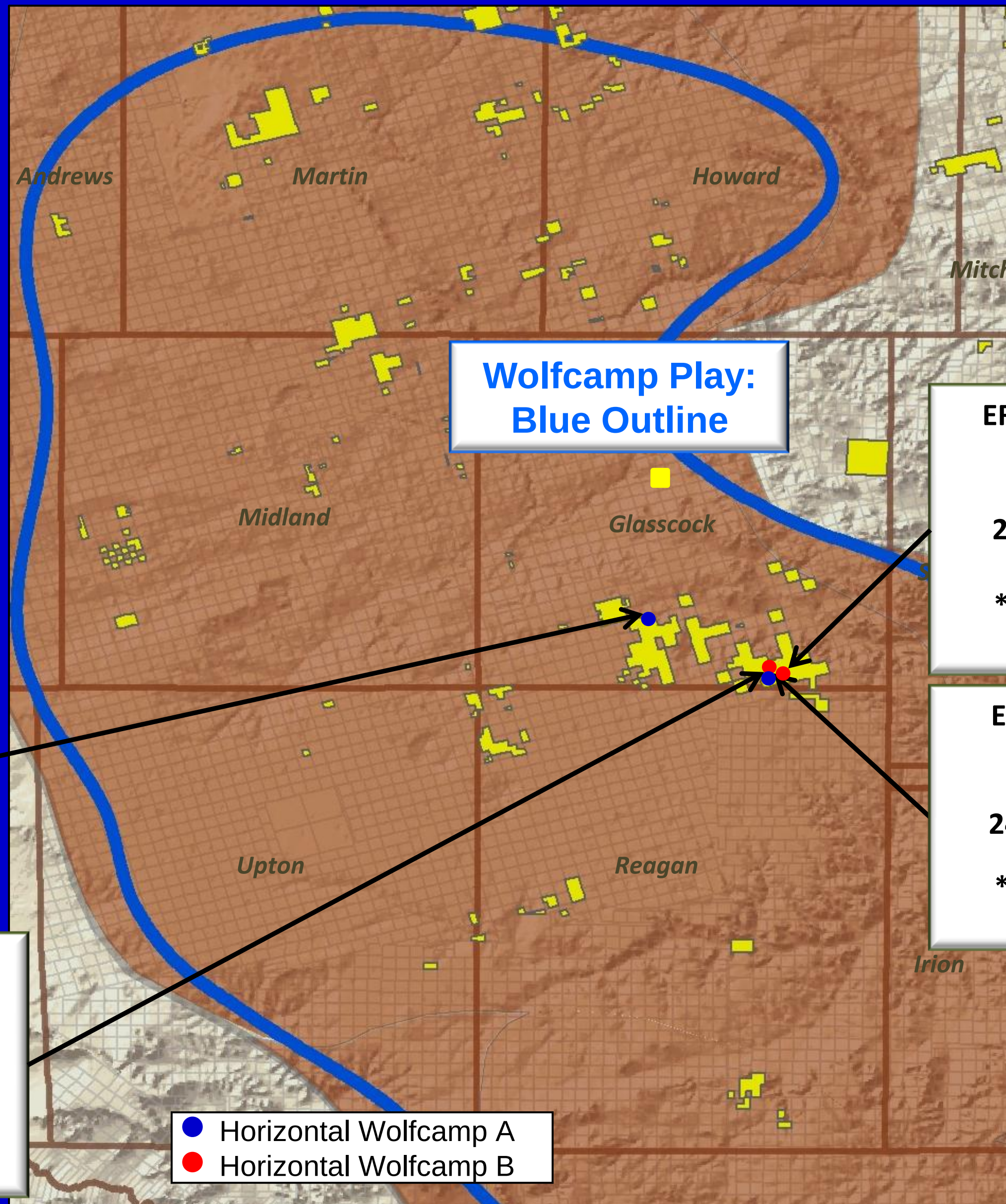
The Petrophysical Model

The Petrophysical Model must be rooted in the rock, fit within the geologic framework, and be vetted against the production



Midland Basin Exploratory Drilling Program

South Glasscock Wolfcamp A & B Results



ERC Daniel SN 10-3 #101H
Wolfcamp A
8,150' lateral
24 Hour Peak Rate: (3 Phase)
707 BOEPD (89% Oil)
20 Day Peak Rate: (3 Phase)
561 BOEPD (86% Oil)

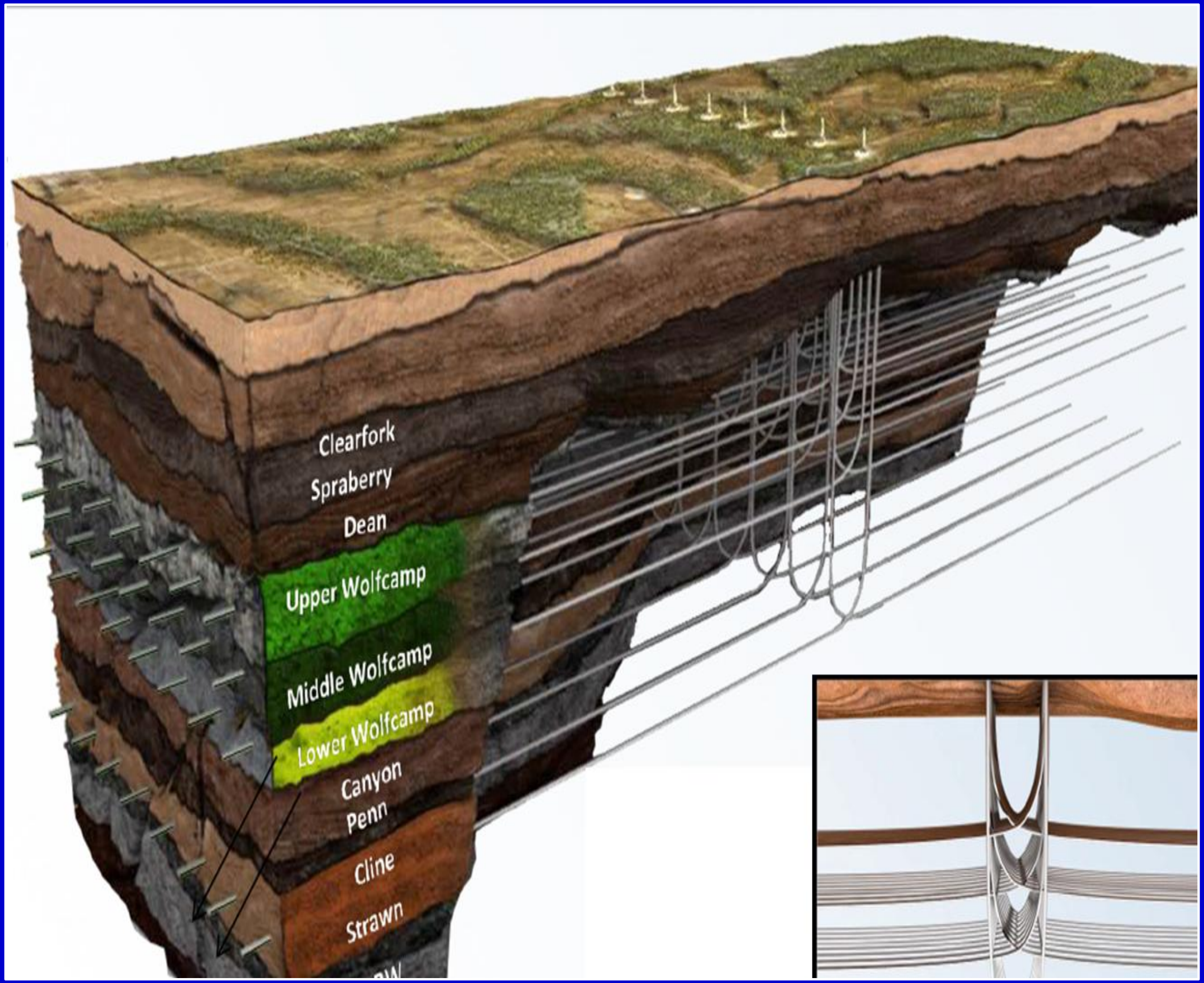
ERC San Saba NS 37-48 #205H
Wolfcamp B
7,300' lateral
24 Hour Peak Rate: (3 Phase)
1,387 BOEPD (80%)
***Peak 30 Day Avg: (3 Phase)**
1,264 BOEPD (64% Oil)

ERC San Saba NS 37-48 #204H
Wolfcamp B
7,300' lateral
24 Hour Peak Rate (3 Phase)
1,205 BOEPD (79% Oil)
***Peak 30 Day Avg: (3 Phase)**
870 BOEPD (64% Oil)

ERC San Saba NS 3-48 #106H
Wolfcamp A
7,300' lateral
24 Hour Peak Rate: (3 Phase)
921 BOPED (78%)
***Peak 30 Day Avg: (3 Phase)**
876 BOEPD (75% Oil)

ERC Development Plan

Pad Drilling

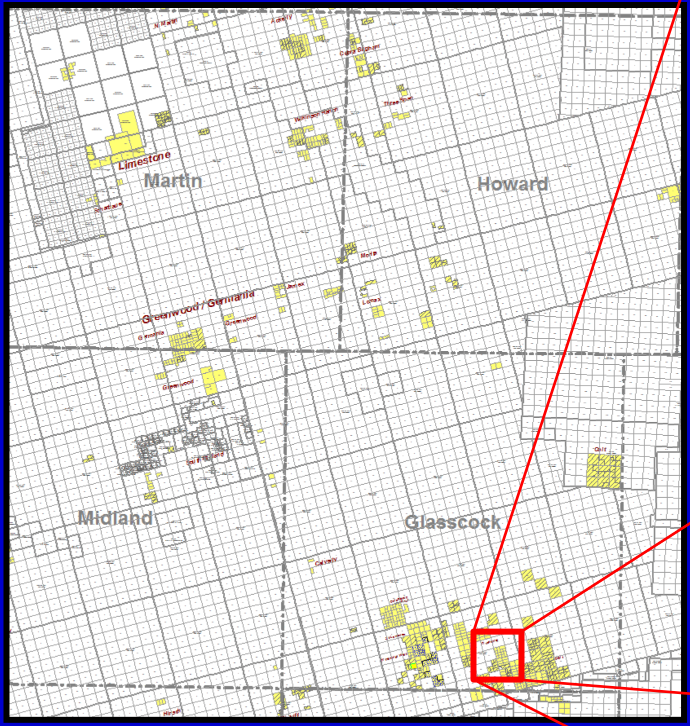


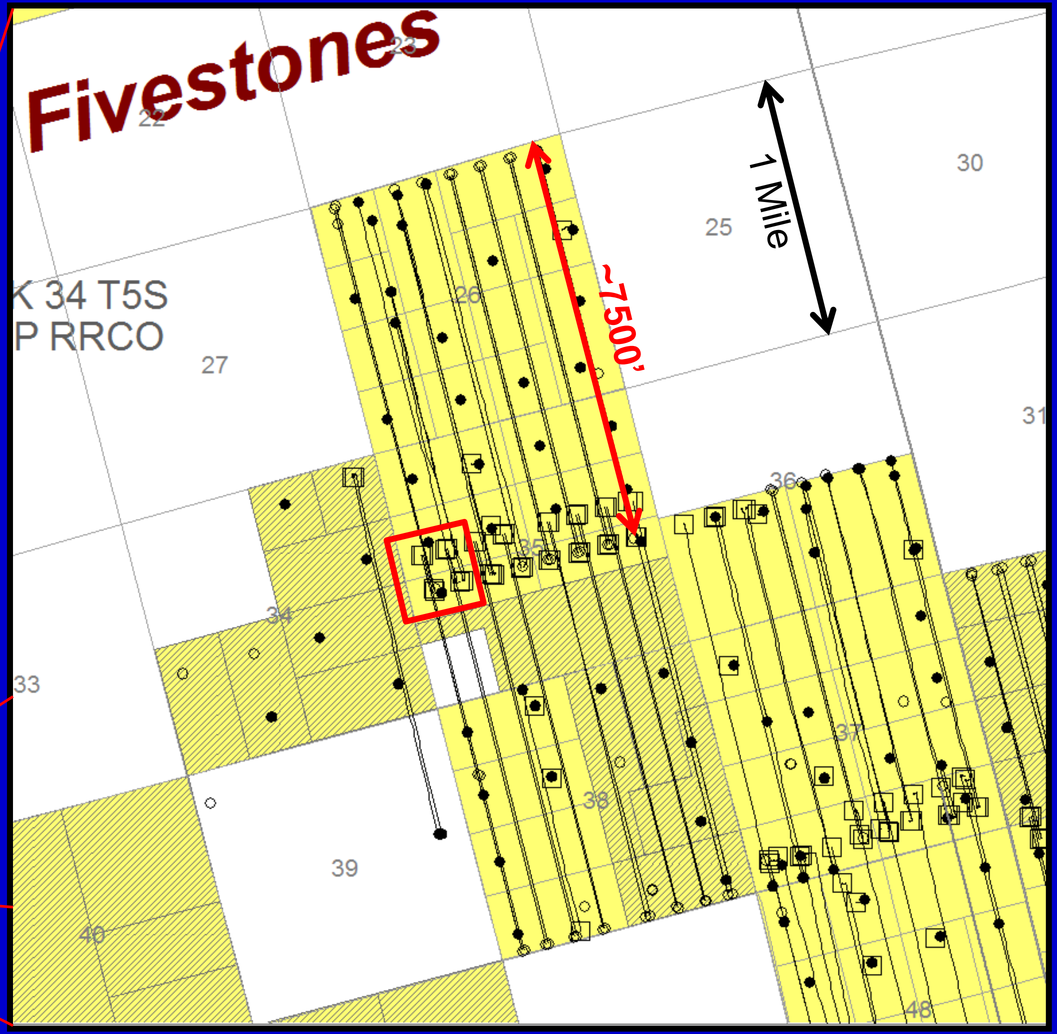
- Minimizes land impacts
- Allows quicker rig moves
- Permits "Zipper" fracing
- More efficient facilities hookup
- Facilitates water recycling

Image source: Laredo Petroleum

Development Pattern

Maximizing the Resource

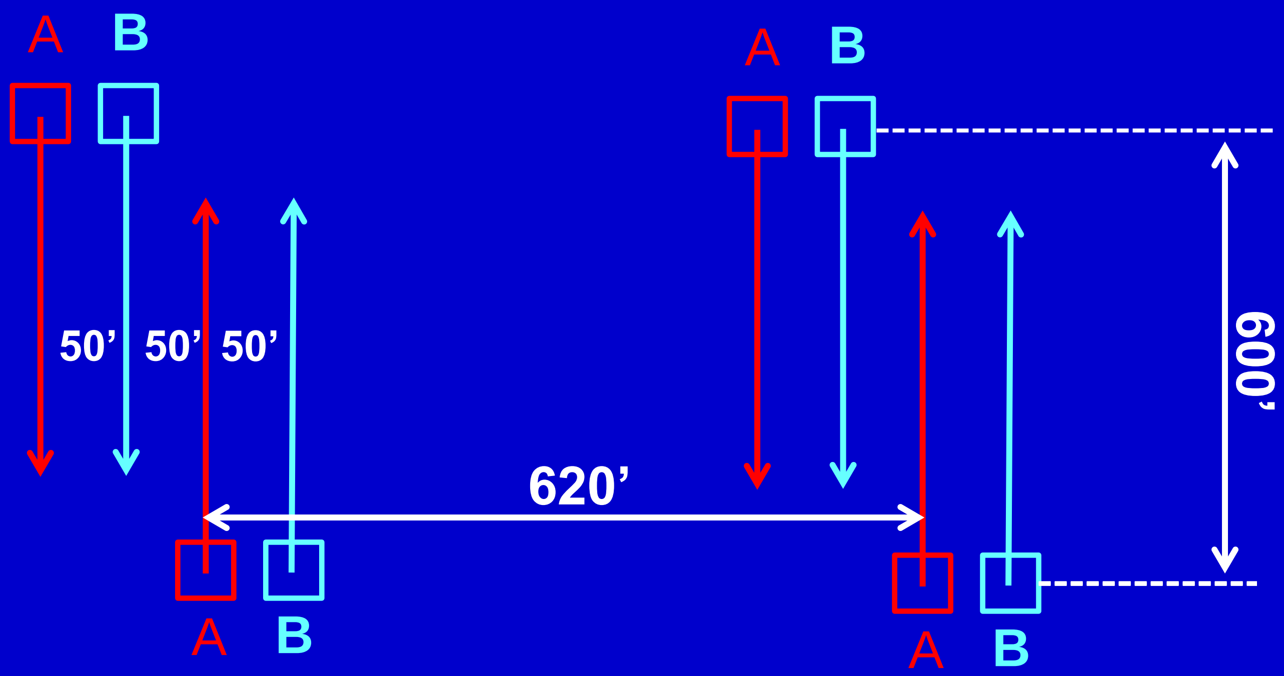




Development Pattern

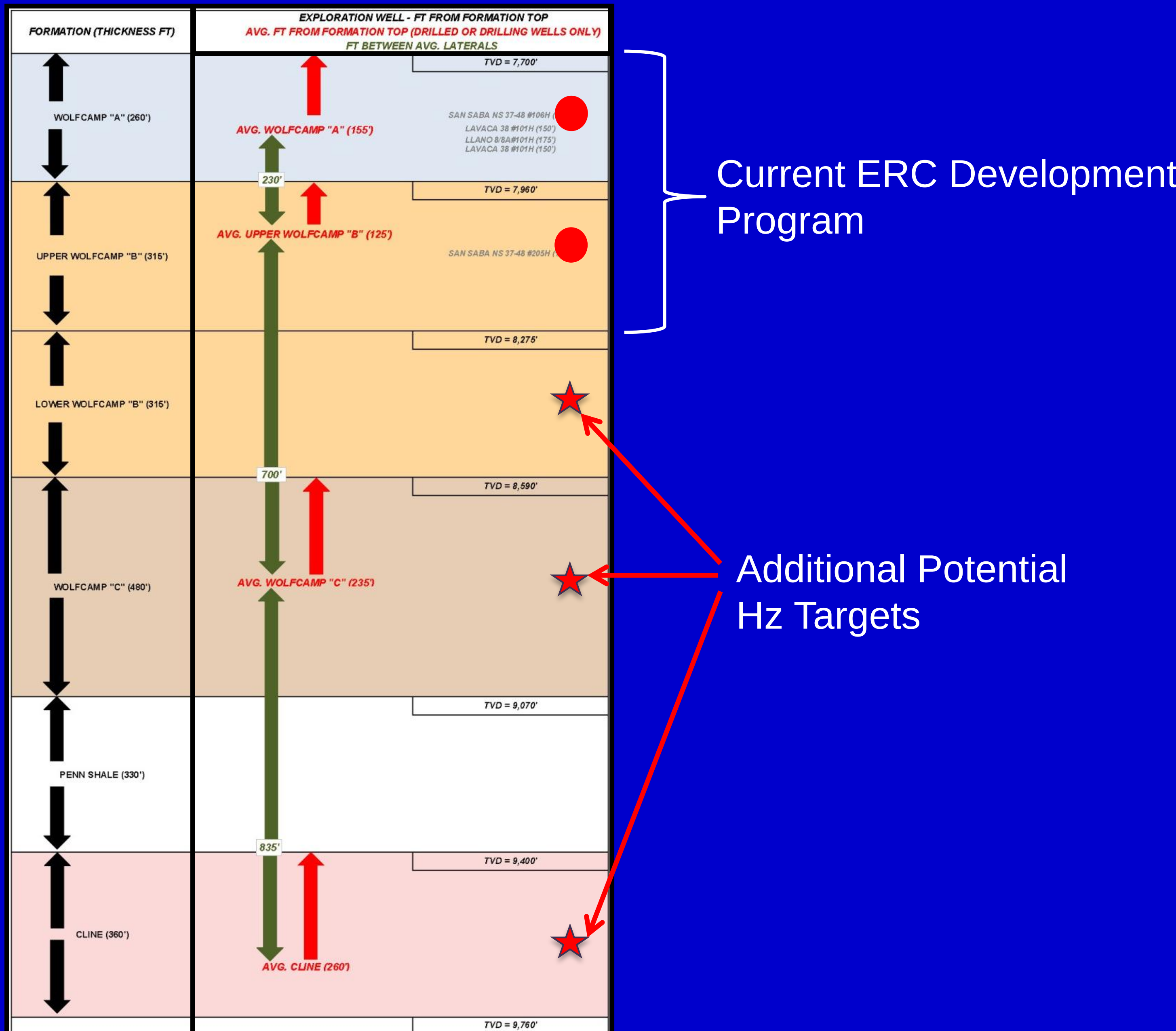
Current inter-well spacing

N to S and S to N crossing wells

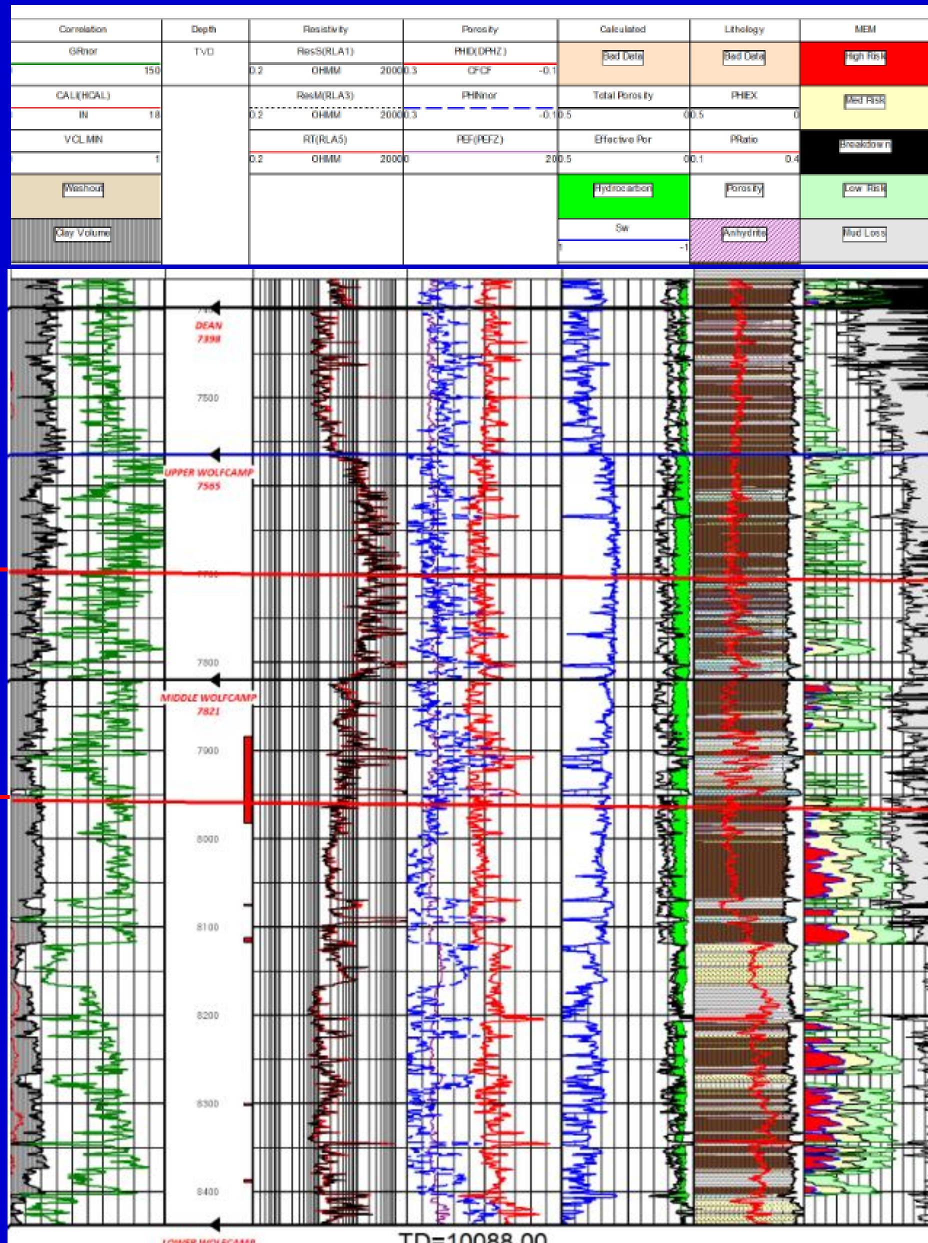


Lateral Targets

S Midland Basin Lateral Schematic



ERC
LAVACA 38A 2
County=GLASSCOCK
KB = 2733.00



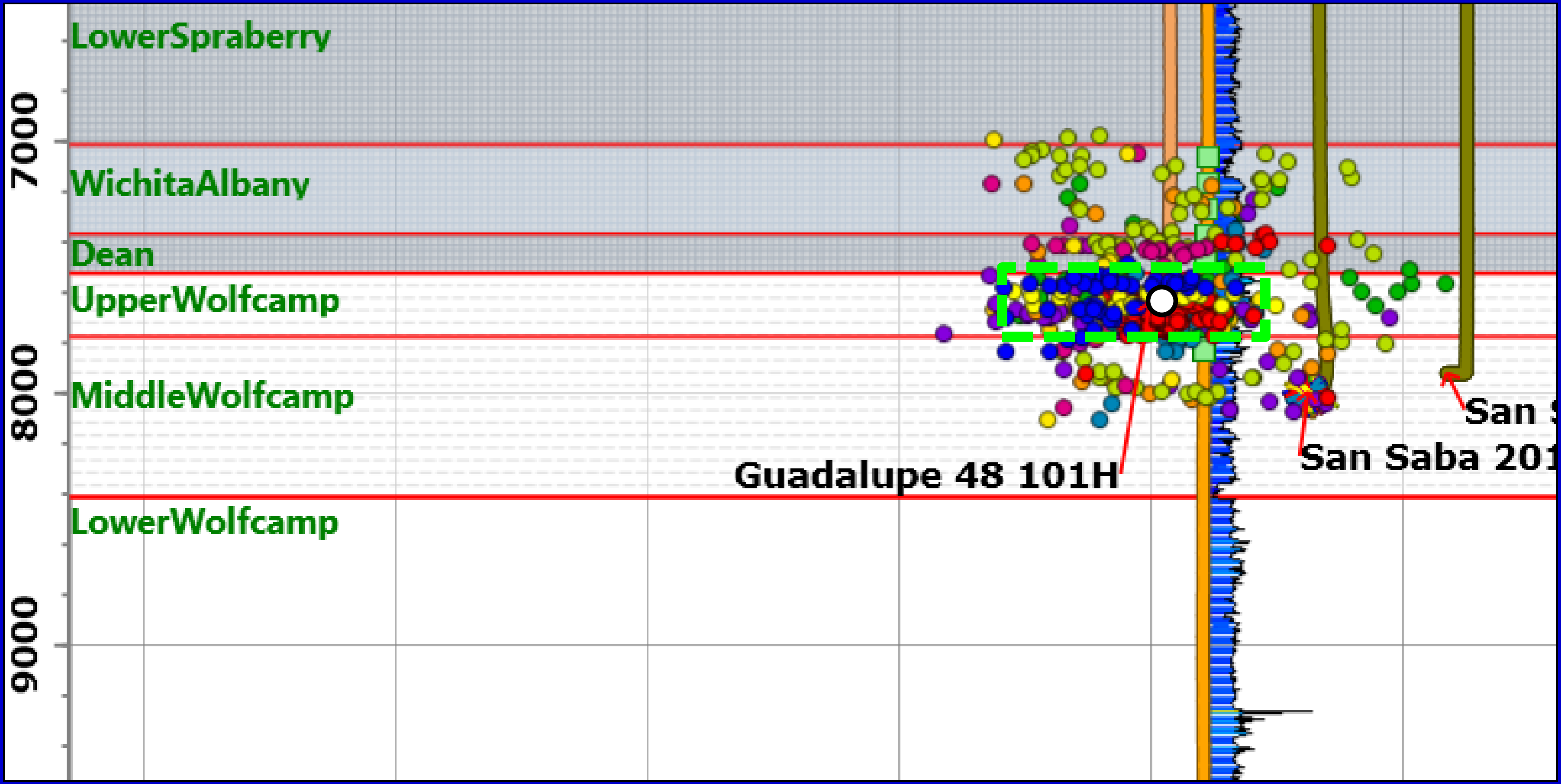
~250’

WC A Target

WC B Target

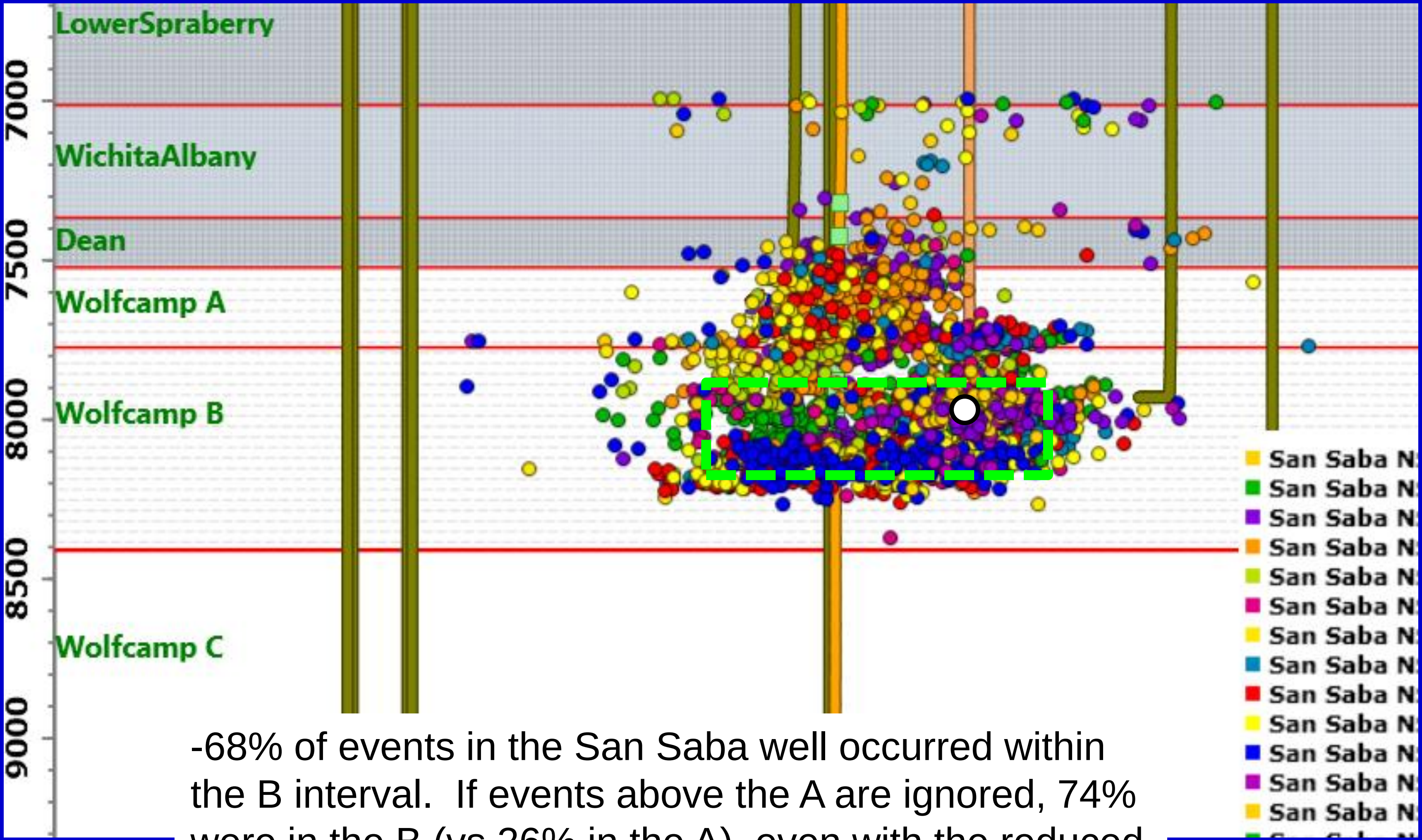
Is 250’ vertical separation too close for stacked laterals?

WC A - Guadalupe 48 #101H Gun-barrel view



-67% of events in the Guadalupe well occurred within the A interval. If events above the A are ignored, 87% were in the A (vs 13% in the B).
-High-density area of events in the A is 250’ high, almost 1000’ wide.

WC B - San Saba NS 204H Gun-barrel view



-68% of events in the San Saba well occurred within the B interval. If events above the A are ignored, 74% were in the B (vs 26% in the A), even with the reduced pressure in the adjacent existing A fracture network.
-Highest density area of events (green rectangle) in the B is 300' high, almost 1000' wide.

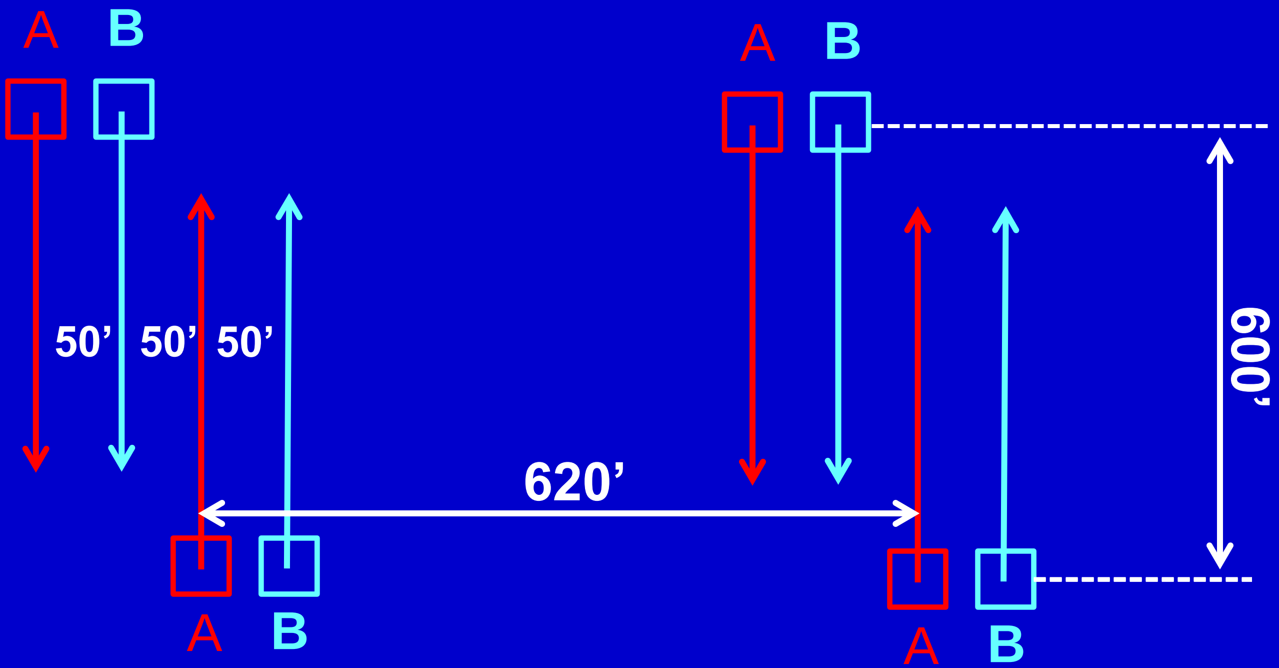
So do the stacked wells communicate?

During the fracture stimulation: Yes.

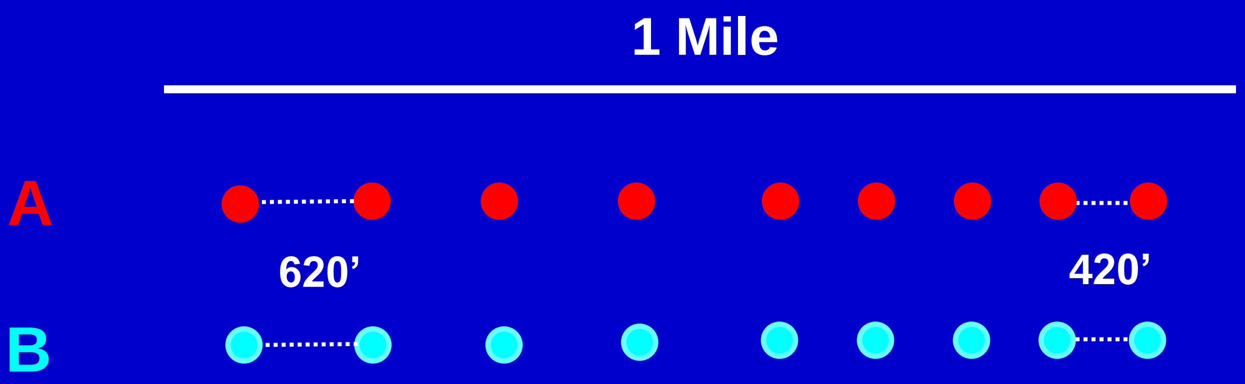
But, flowback and production characteristics suggest…..not much.

Spacing: How close is close enough?

Currently about 620’



One way to find out:
Spacing test

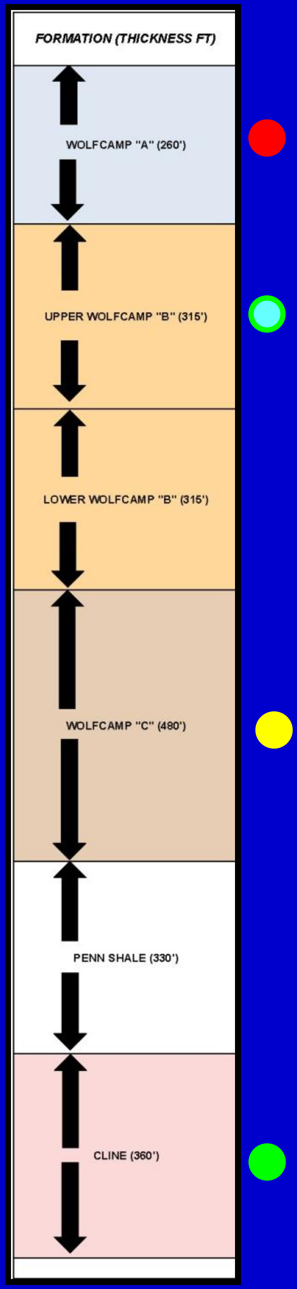


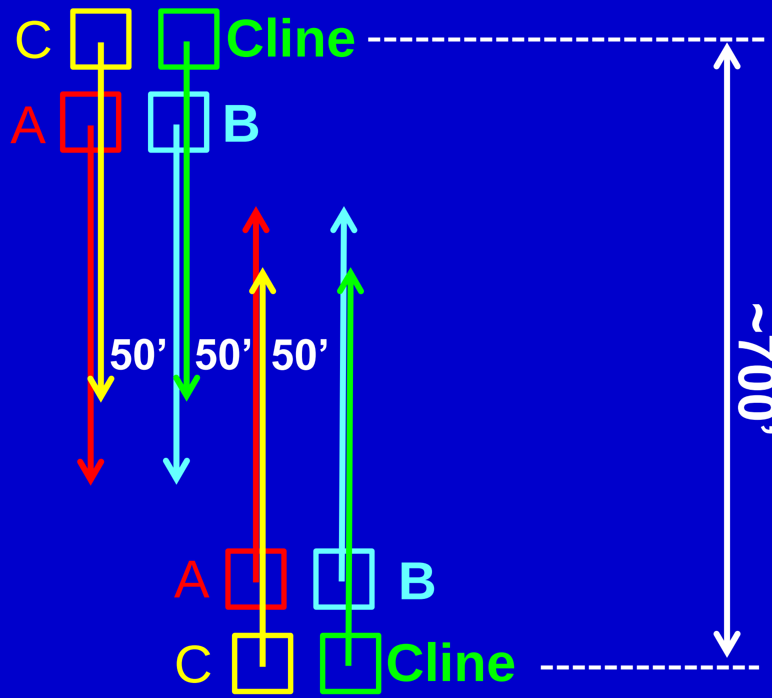
Two sets side by side, all parameters (length, stimulation, landing) the same except spacing

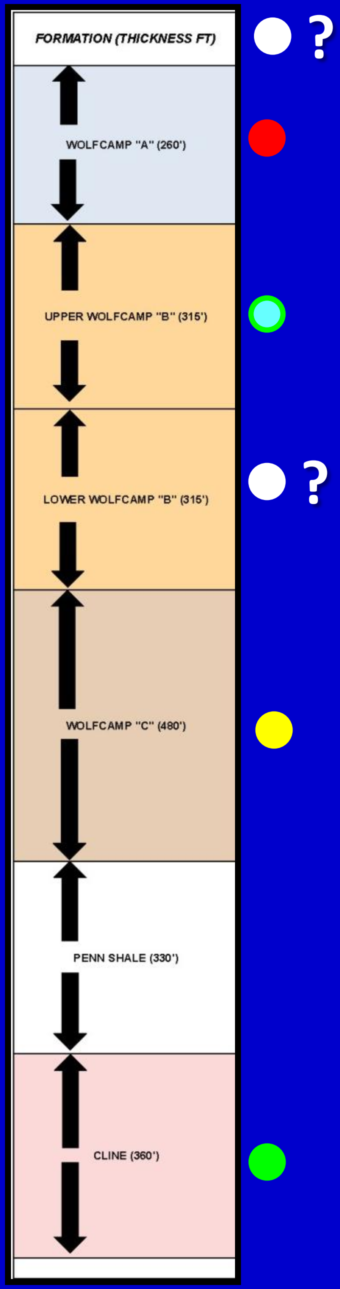
Development Pattern:
The Next Step

More Pad Drilling

What's the best arrangement?







How many total horizons?

More to be tested.

Potentially 6+ horizons per pad,
8 pads across a section, 48+ wells per section

It’s going to get crowded out there

(but only on the drilling pads)

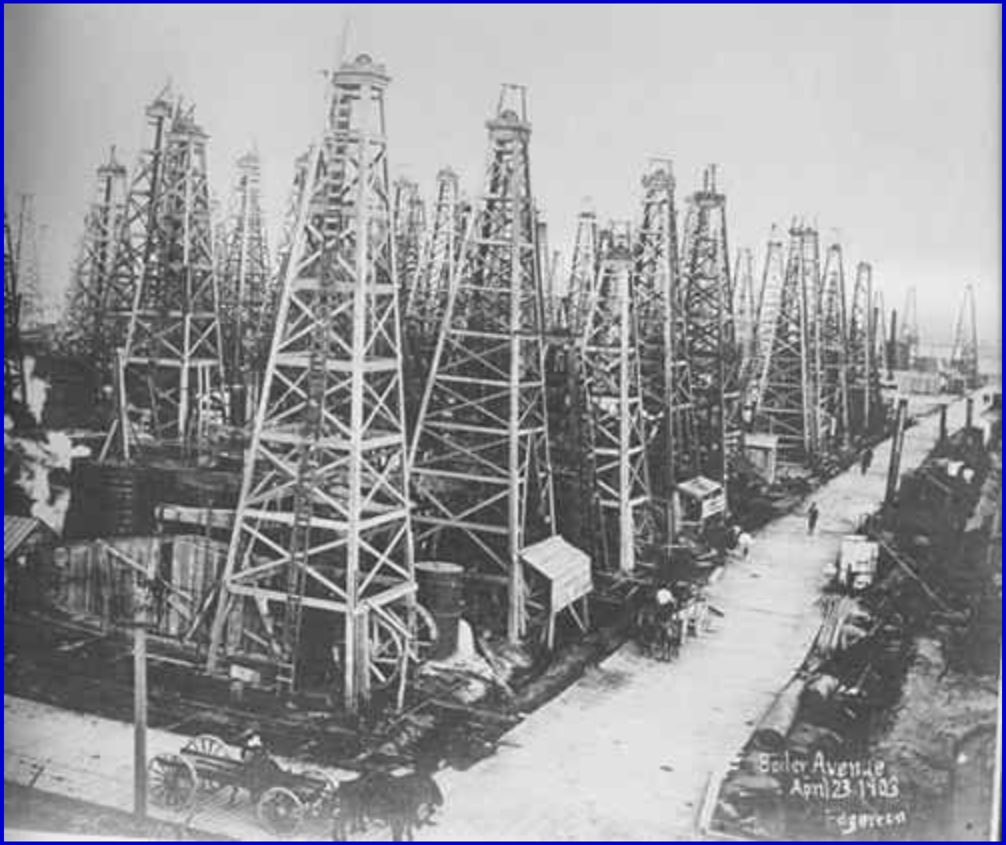


Photo from the American Petroleum Institute, via priweb.com

Questions?