# Cana Woodford Shale Play, Anadarko Basin: The Effects of Mudrock Lithologies and Mechanical Stratigraphy on Completion and Production

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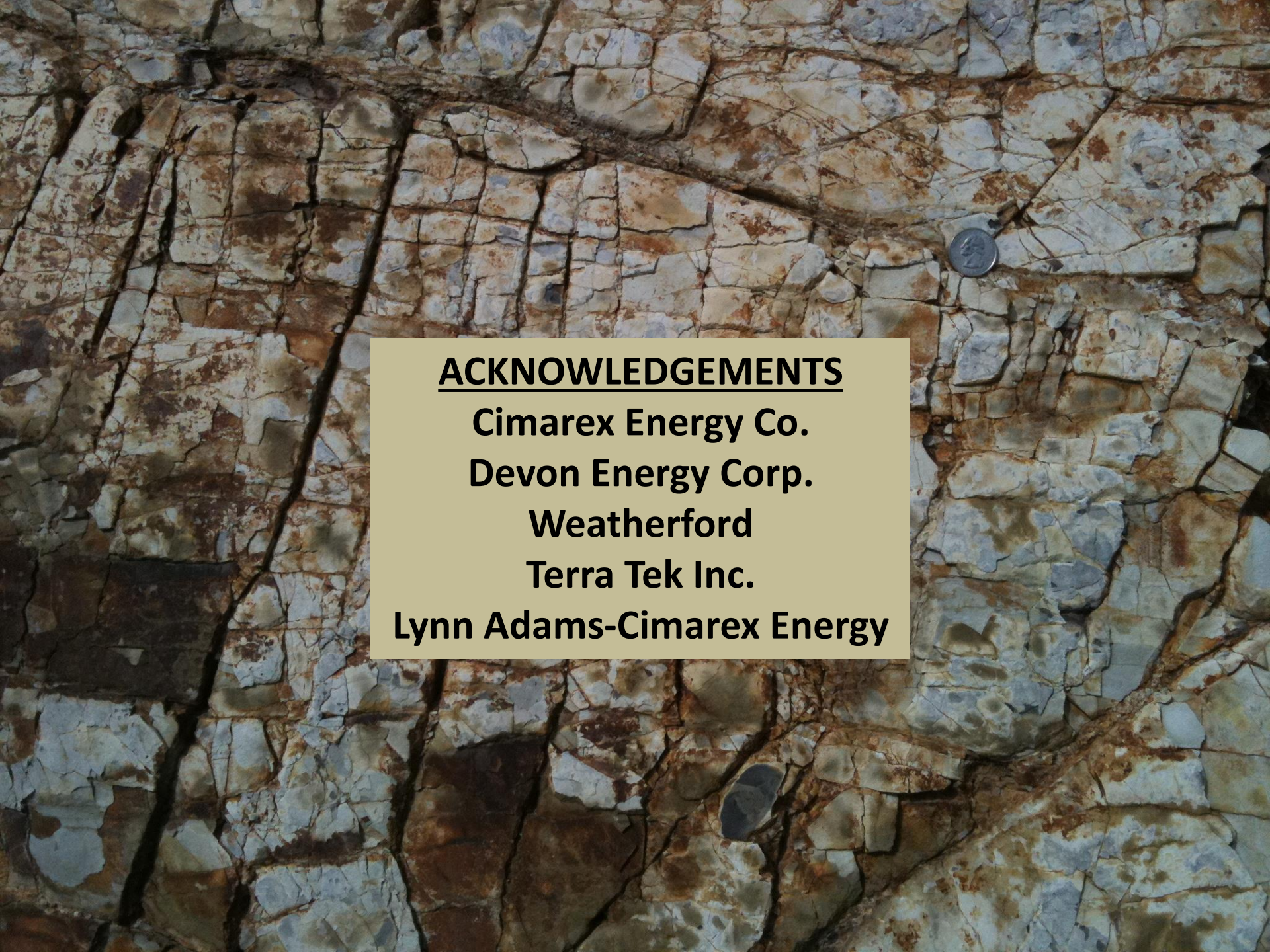
**Cimarex Energy Co., Tulsa, OK**

2013 OK Shale Gas and Oil
November 20, 2013 Norman, OK




**ACKNOWLEDGEMENTS**

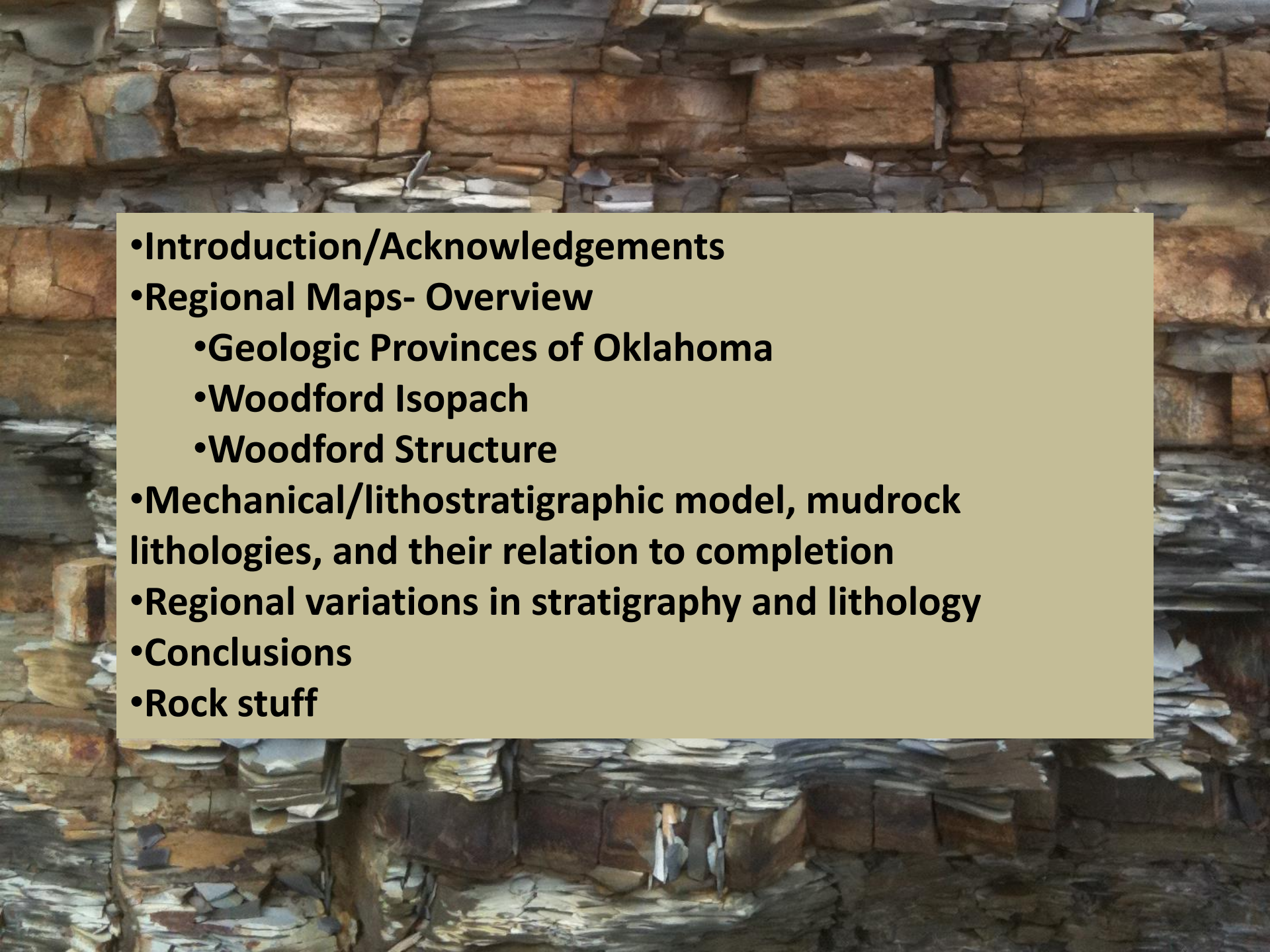
**Cimarex Energy Co.**

**Devon Energy Corp.**

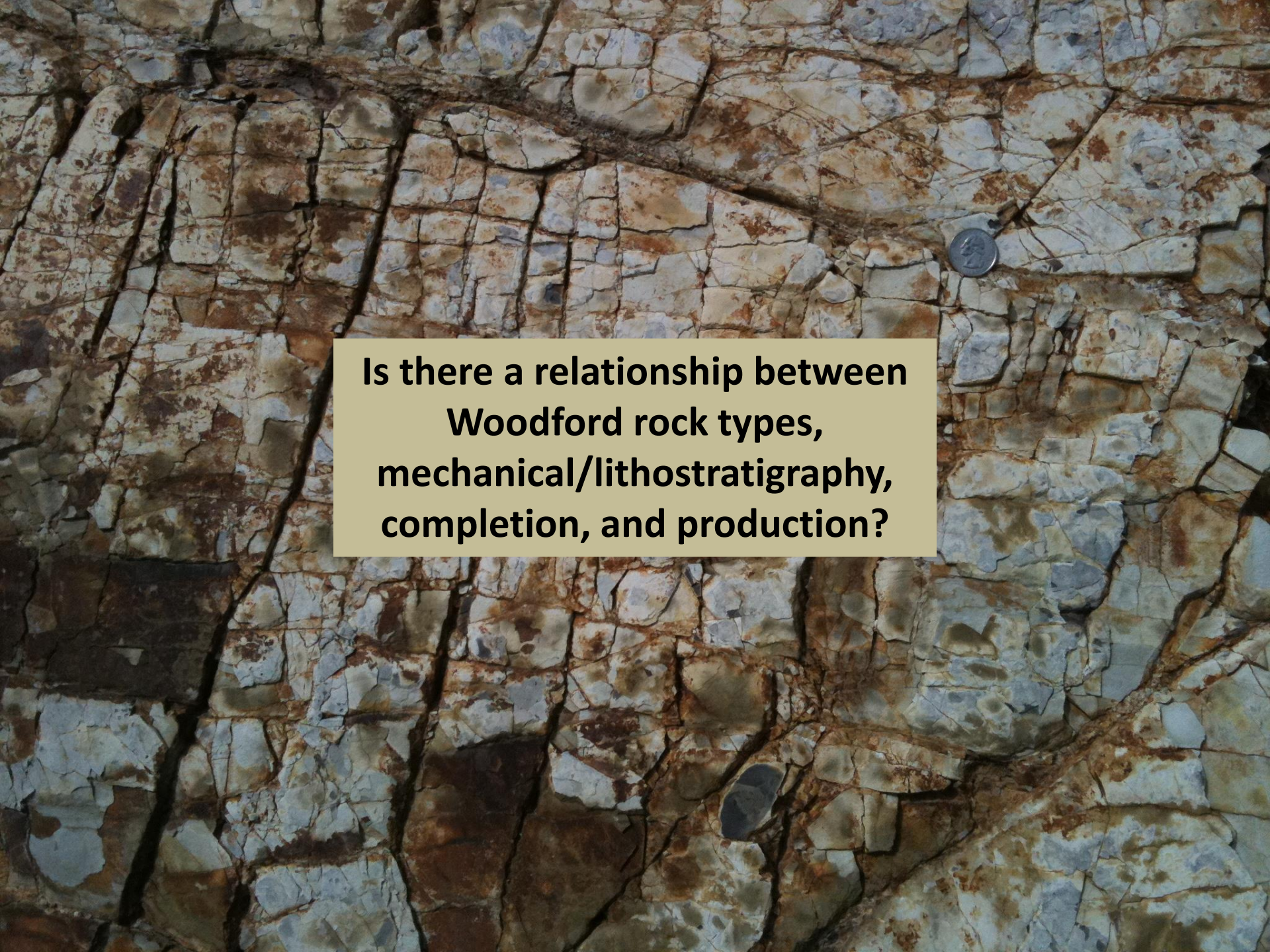
**Weatherford**

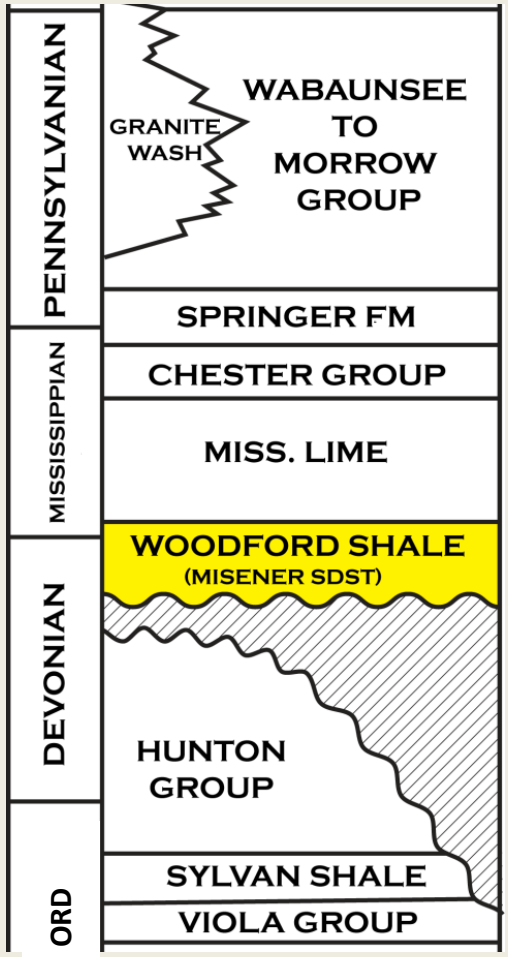
**Terra Tek Inc.**

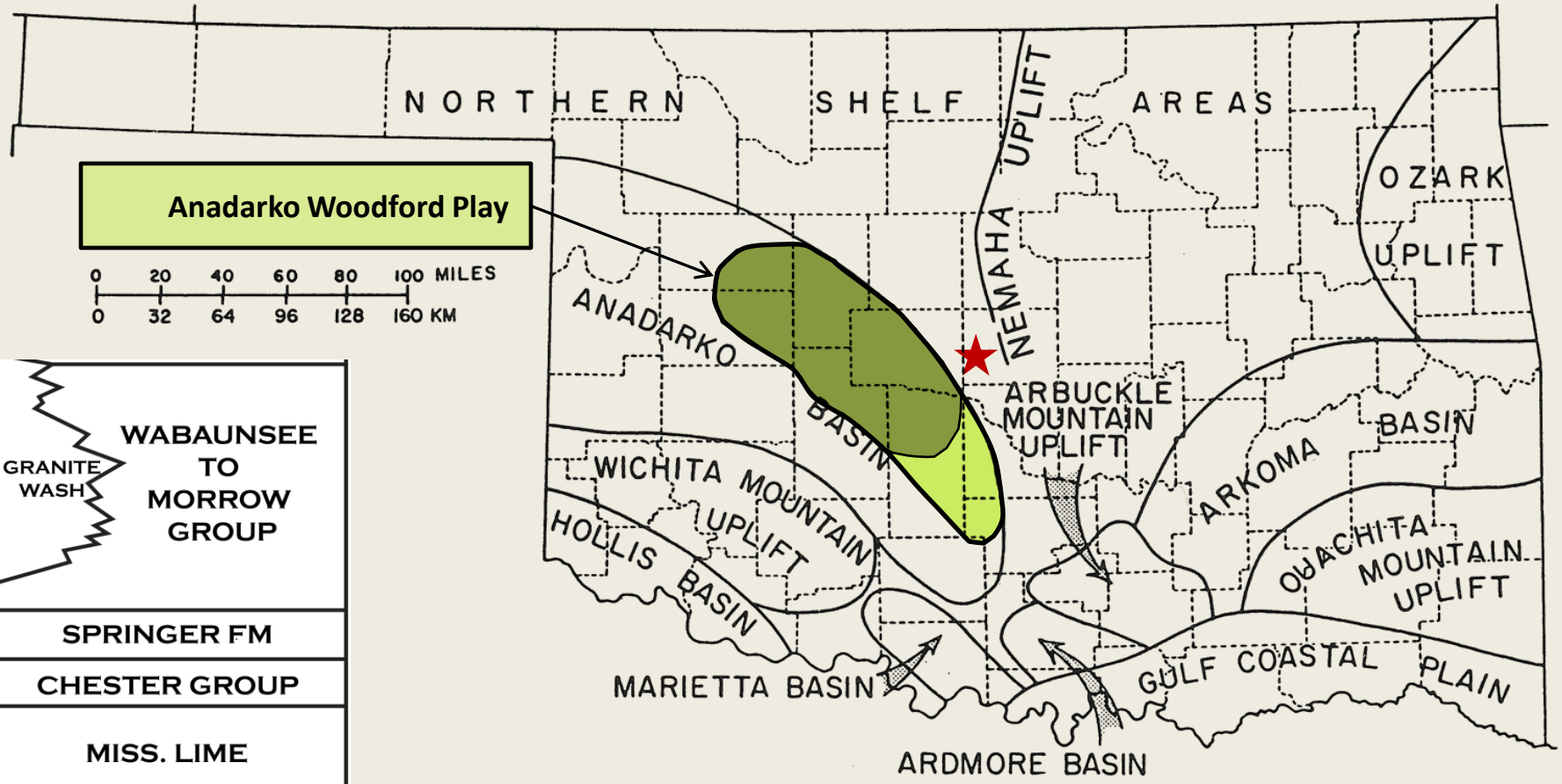
**Lynn Adams-Cimarex Energy**



- Introduction/Acknowledgements
- Regional Maps- Overview
  - Geologic Provinces of Oklahoma
  - Woodford Isopach
  - Woodford Structure
- Mechanical/lithostratigraphic model, mudrock lithologies, and their relation to completion
- Regional variations in stratigraphy and lithology
- Conclusions
- Rock stuff


Is there a relationship between Woodford rock types, mechanical/lithostratigraphy, completion, and production?



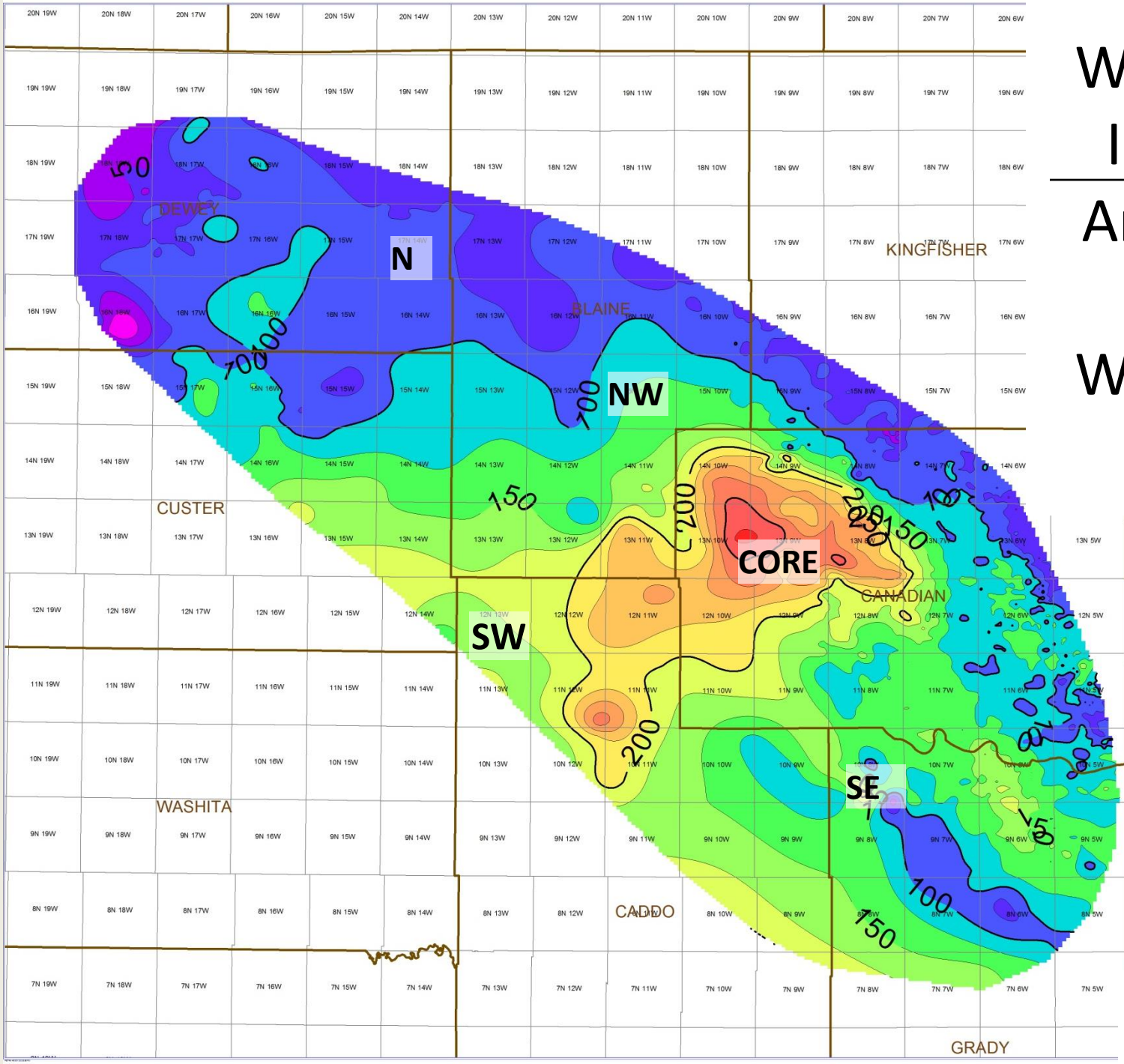




# STRAT COLUMN AND MAJOR GEOLOGIC PROVINCES OF OKLAHOMA

*After Johnson et al (2000)

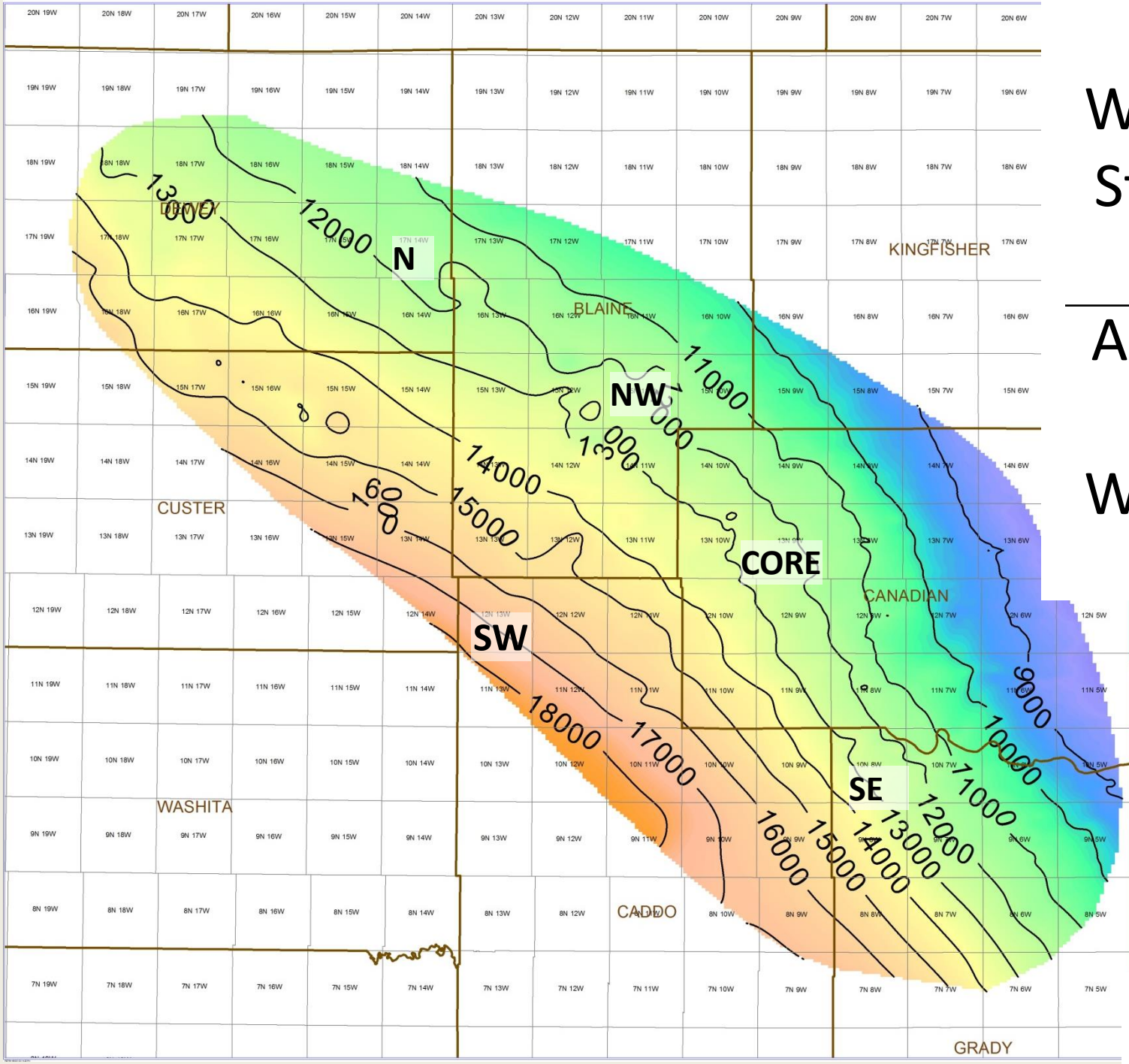
# Woodford Isopach

## Anadarko Basin Woodford Play



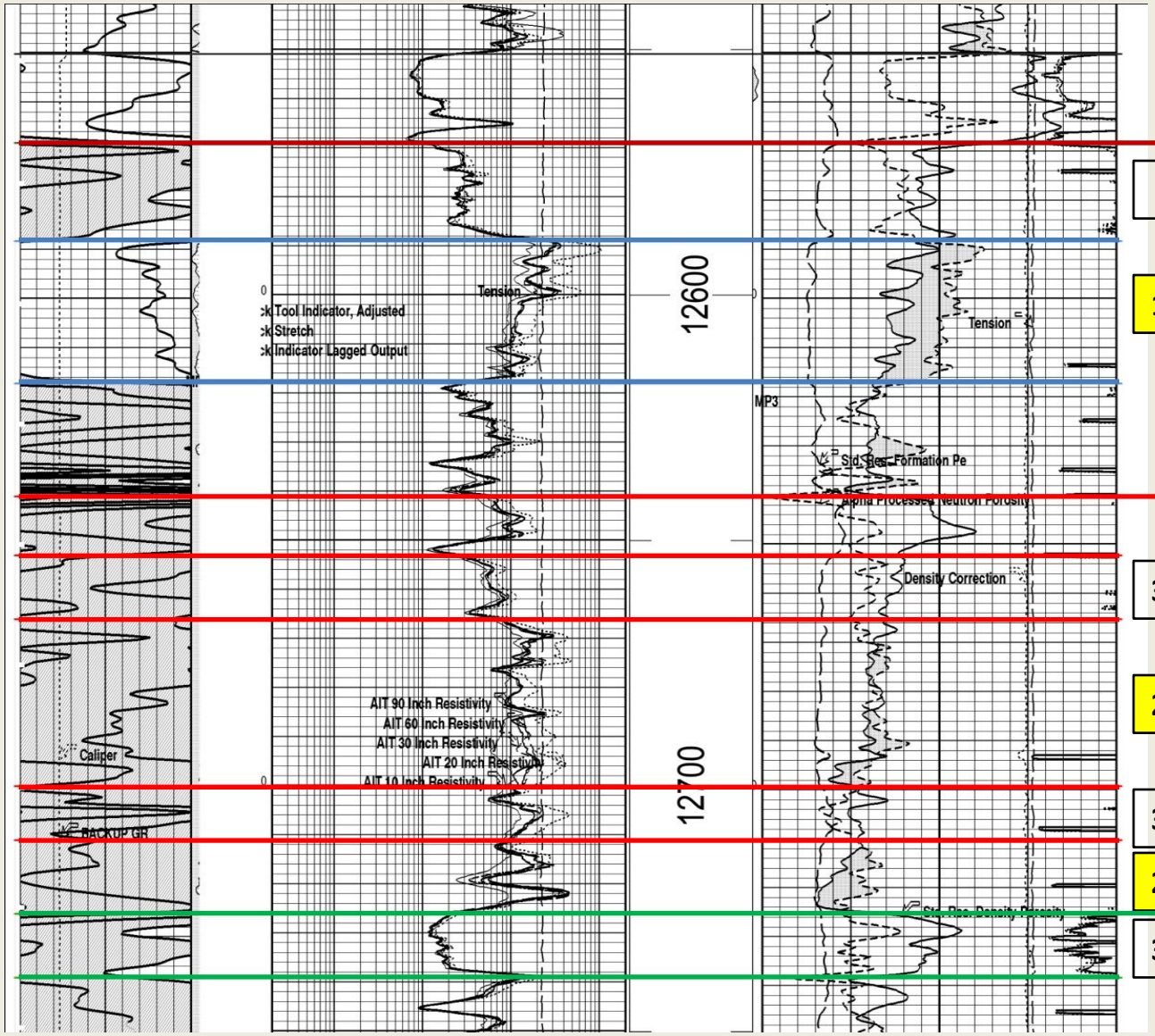
# Top Woodford Structure (MD)

## Anadarko Basin Woodford Play




CIMAREX

# Type Log from Core Area Showing Lithostratigraphy and % Clay for Middle & Upper Woodford



# Woodford Rock Types
# Anadarko Basin Woodford Play

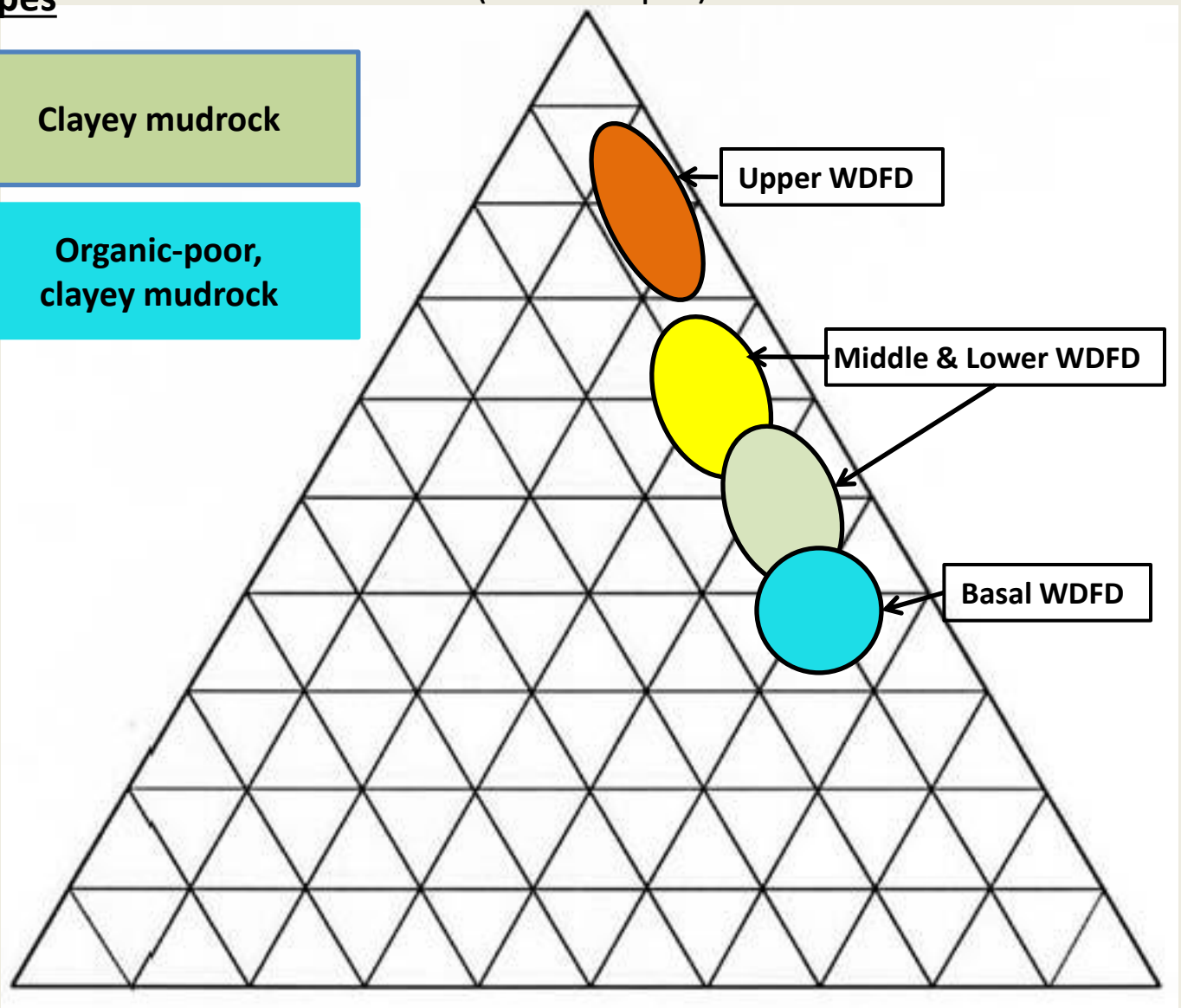
| ROCK TYPE | % QUARTZ | % CLAY | % TOC | % GAS-FILLED POROSITY | PRv | Brittleness Index* |
|---|---|---|---|---|---|---|
| Siliceous mudrock | 75.2 | 14.5 | 4.86 | 5.4 | 0.155 | 0.75 |
| Clayey, siliceous mudrock | 54.8 | 27.4 | 6.43 | 6.8 | 0.164 | 0.55 |
| Clayey mudrock | 40.6 | 38 | 5.97 | 5.6 | 0.192 | 0.41 |
| Organic-poor, clayey mudrock | 27.3 | 52.4 | 0.6 | 1.8 | 0.25 | 0.27 |

*B.I.=Quartz/Qtz+Carbonates+Clay

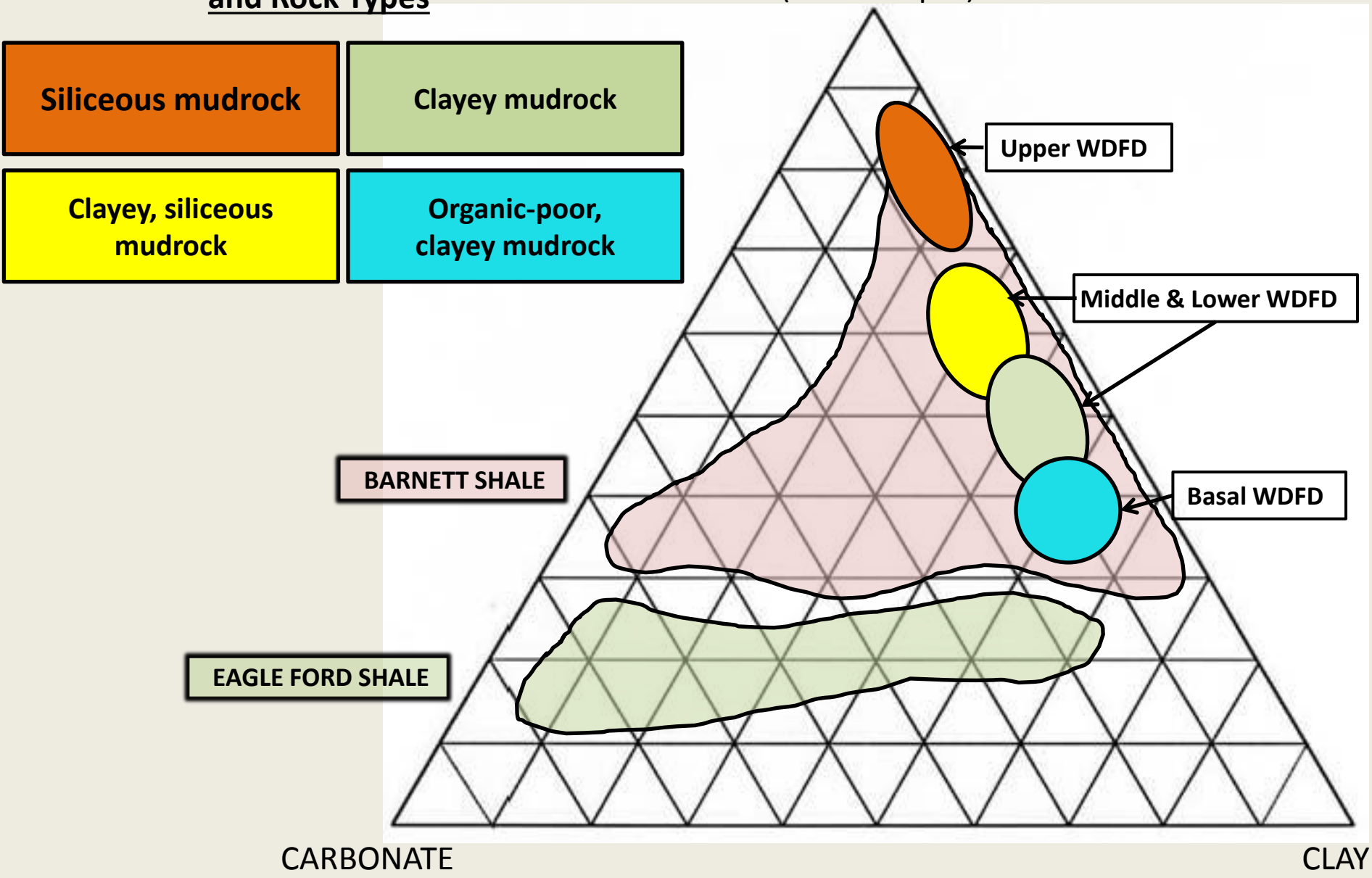
(Sondergeld et. al., 2010)

## Anadarko Woodford Mineralogy (XRD) and Rock Types

| | |
|---|---|
| **Siliceous mudrock** | **Clayey mudrock** |
| **Clayey, siliceous mudrock** | **Organic-poor, clayey mudrock** |



## Anadarko Woodford Mineralogy (XRD) and Rock Types



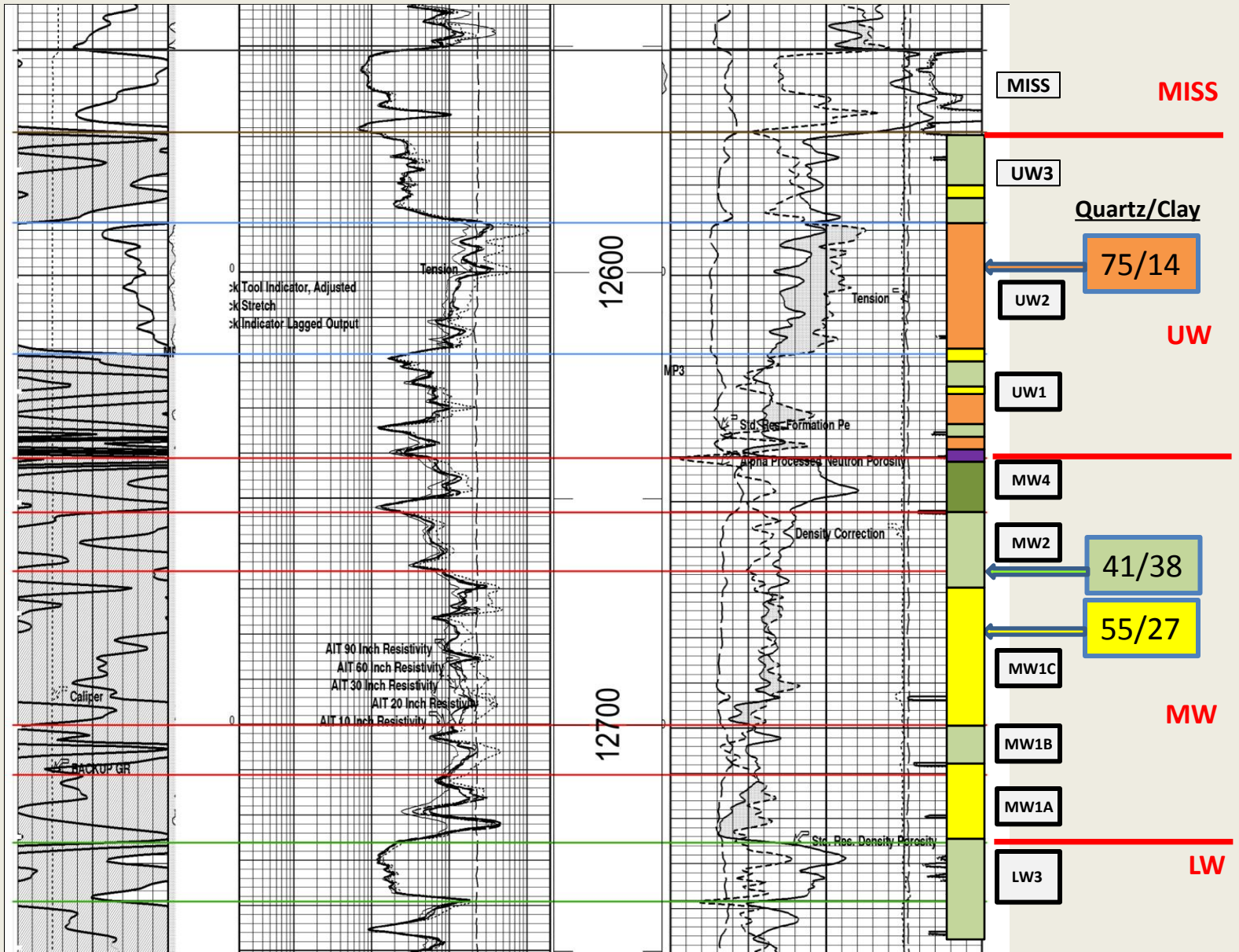

Barnett and Eagle Ford Mineralogy from Q. R. Passey Et. Al. 2010

# Middle and Upper Woodford Lithostratigraphy, Anadarko Woodford Play – Core Area

**Siliceous mudrock**

**Clayey, siliceous mudrock**

**Clayey mudrock**

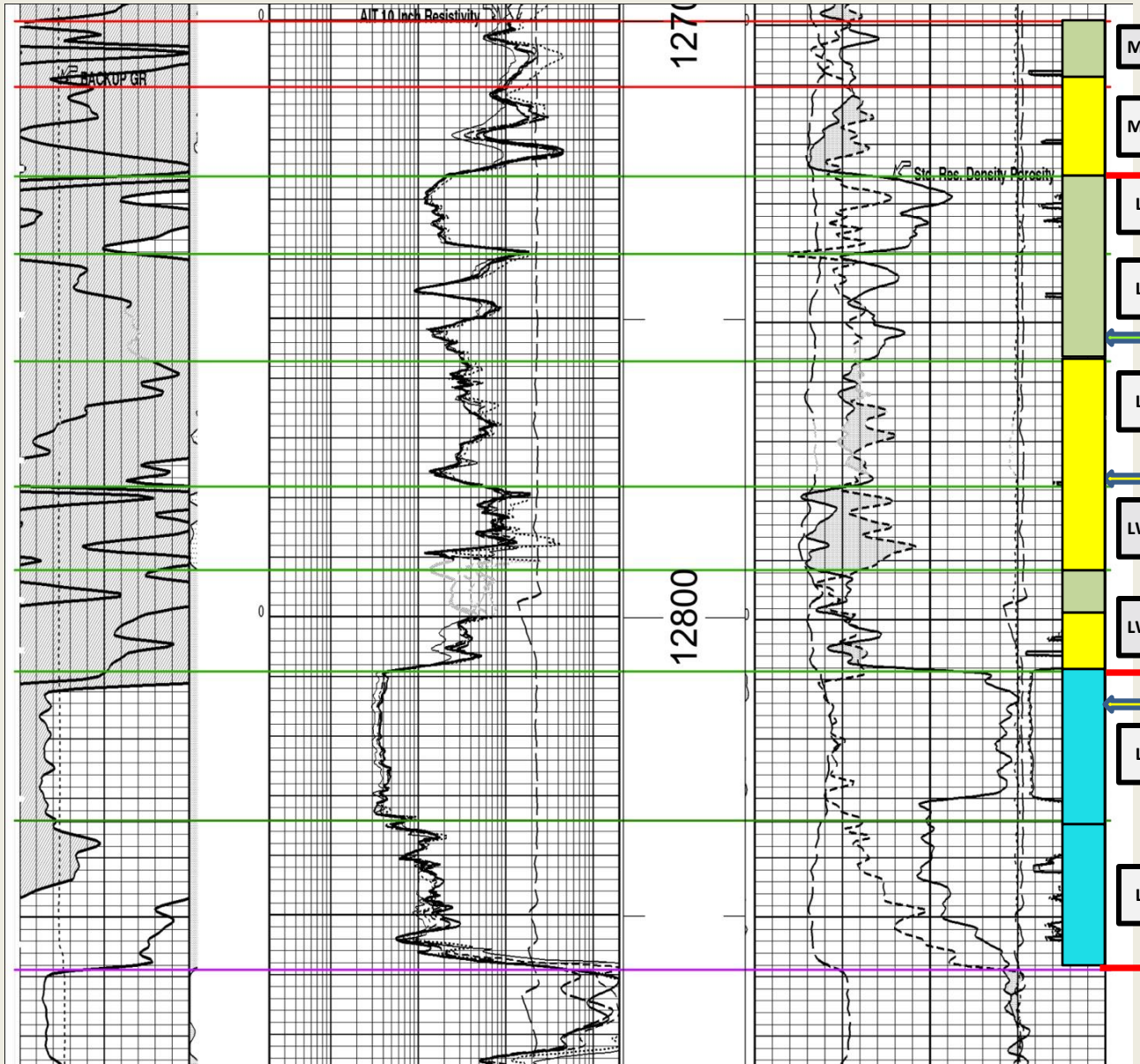


# Basal, Lower, & Middle Woodford Lithostratigraphy, Anadarko Woodford Play – Core Area

**Clayey, siliceous mudrock**

**Clayey mudrock**

**Organic-poor clayey mudrock**



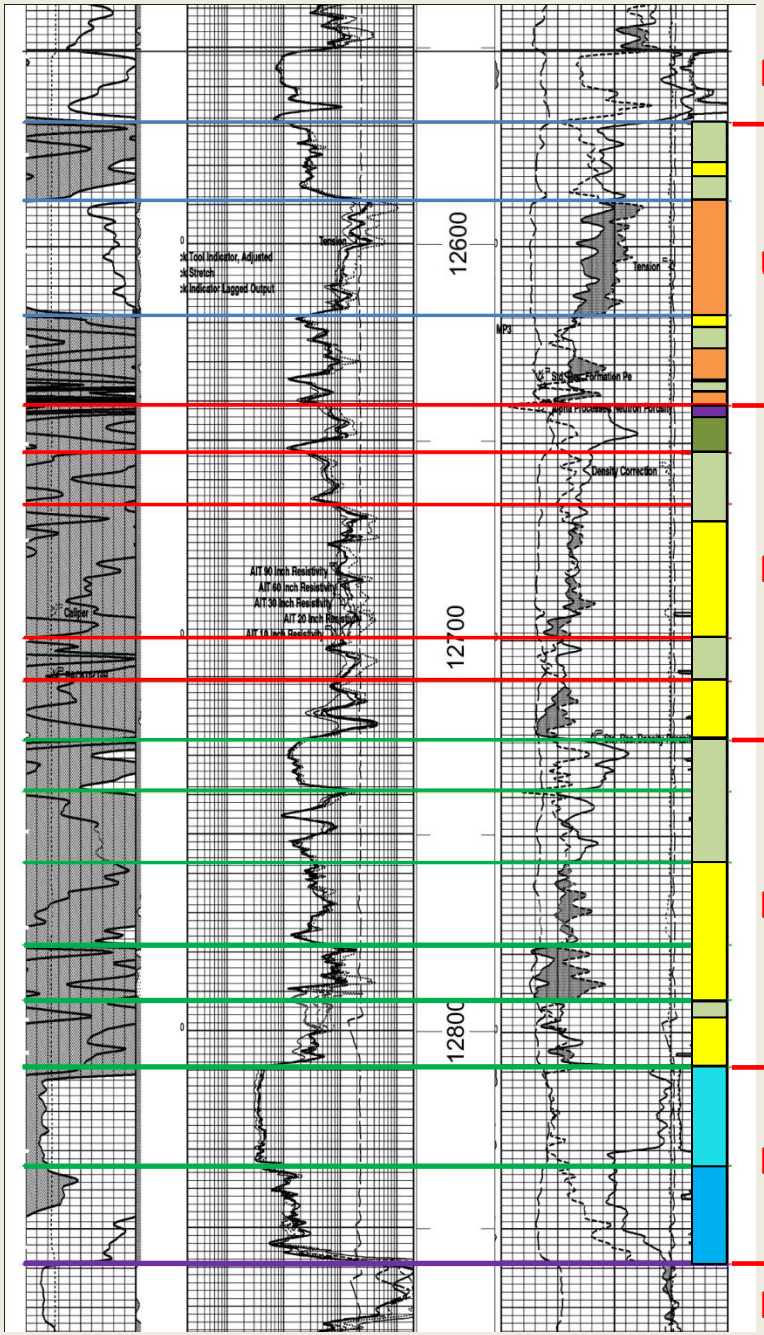
# Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous mudrock

Clayey, siliceous mudrock

Clayey mudrock

Organic-poor clayey mudrock




MISS

UW

MW

LW

BW

Hntn

WDFD Thk. 290’

CIMAREX

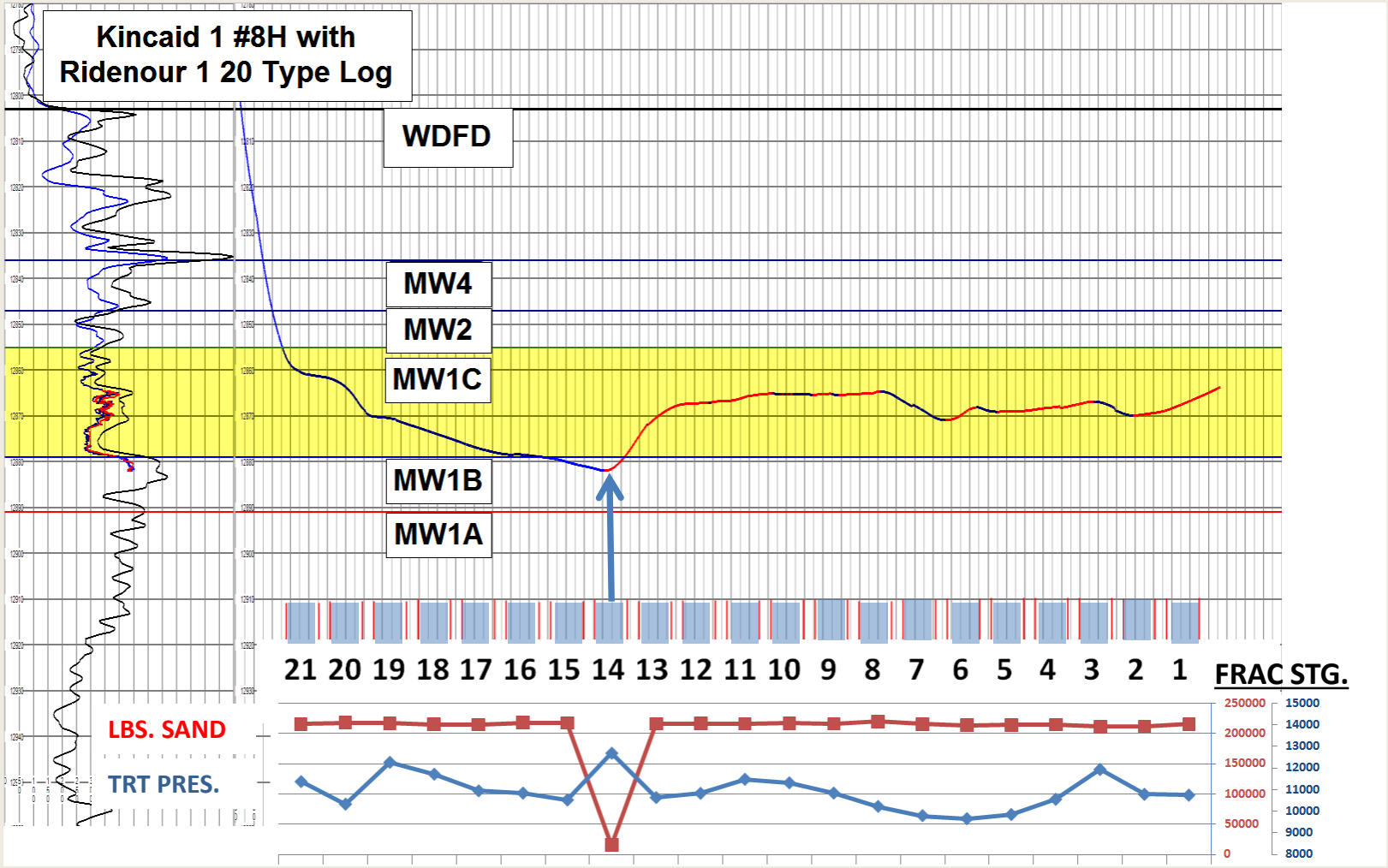
| Frac' Success and Woodford Rock Types | | | |
|---|---|---|---|
| ROCK TYPE | % QUARTZ | % CLAY | % SUCCESS |
| Siliceous mudrock | 75.2 | 14.5 | 100 |
| Clayey, siliceous mudrock | 54.8 | 27.4 | 86 |
| Clayey mudrock | 40.6 | 38 | 53 |

Successful frac' defined as one in which >75% of planned proppant amount was placed.

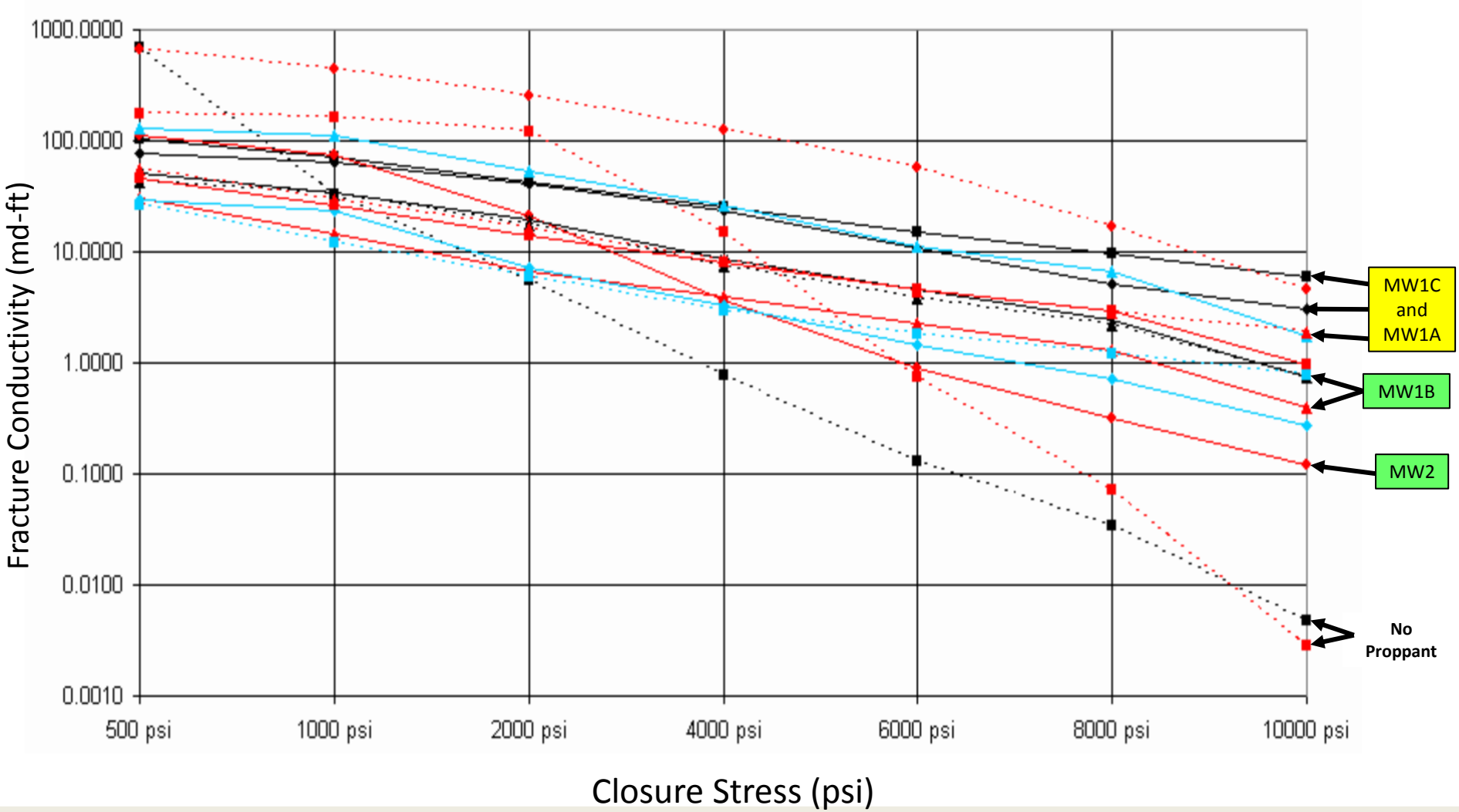
| Frac' Success and Woodford Rock Types | | | | | |
|---|---|---|---|---|---|
| ROCK TYPE | % QUARTZ | % CLAY | % DOLOMITE | % Success, Pre-HF | % Success, w/ HF |
| Siliceous mudrock | 75.2 | 14.5 | 2.8 | 100 | 100 |
| Clayey, siliceous mudrock | 54.8 | 27.4 | 3.6 | 86 | 94 |
| Clayey mudrock | 40.6 | 38 | 5.0 | 53 | 80 |

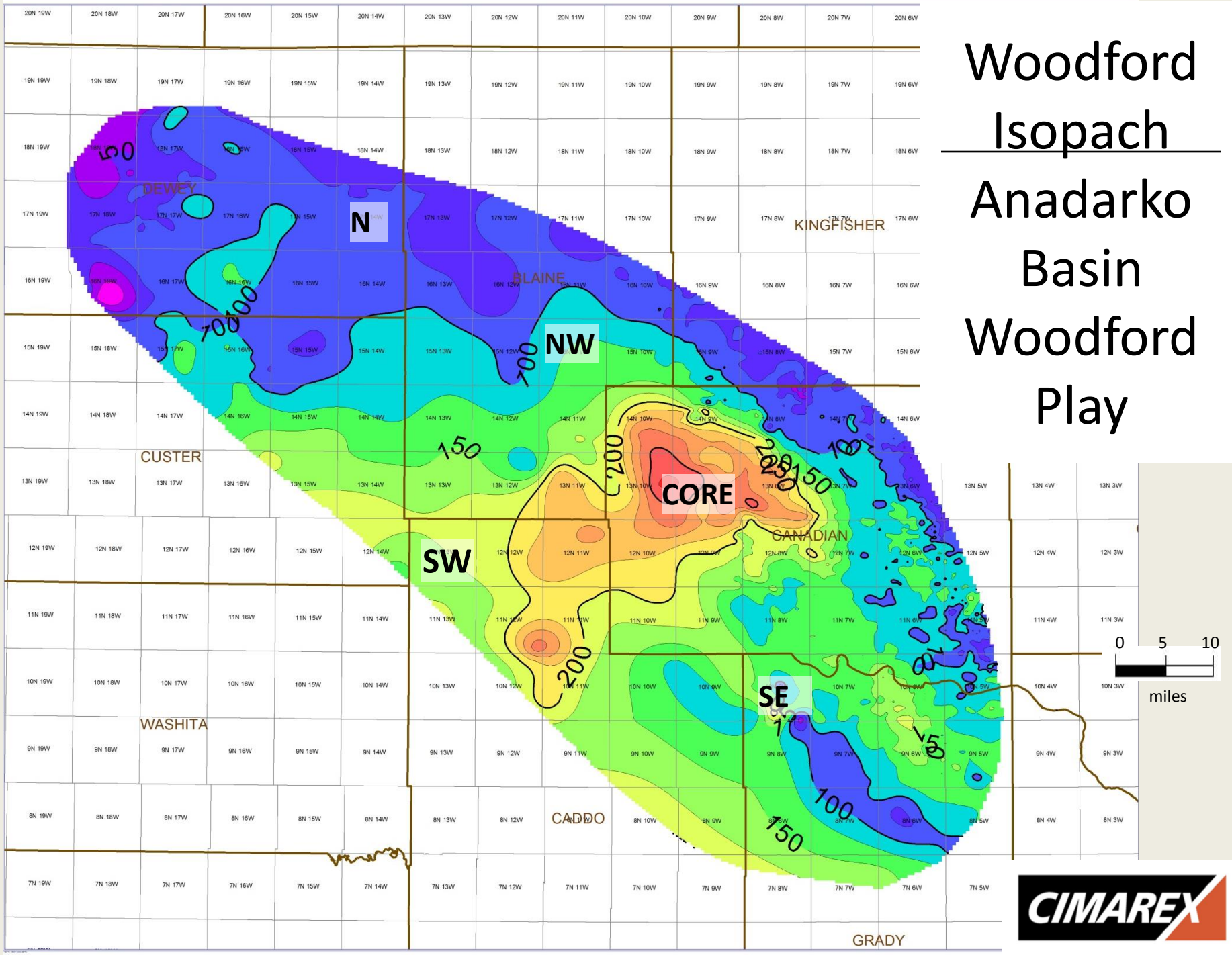
Successful frac' defined as one in which >75% of planned proppant amount was placed.
Table drawn from 906 frac stages.

# Well Path Showing Woodford Lithostratigraphy and Lateral Placement

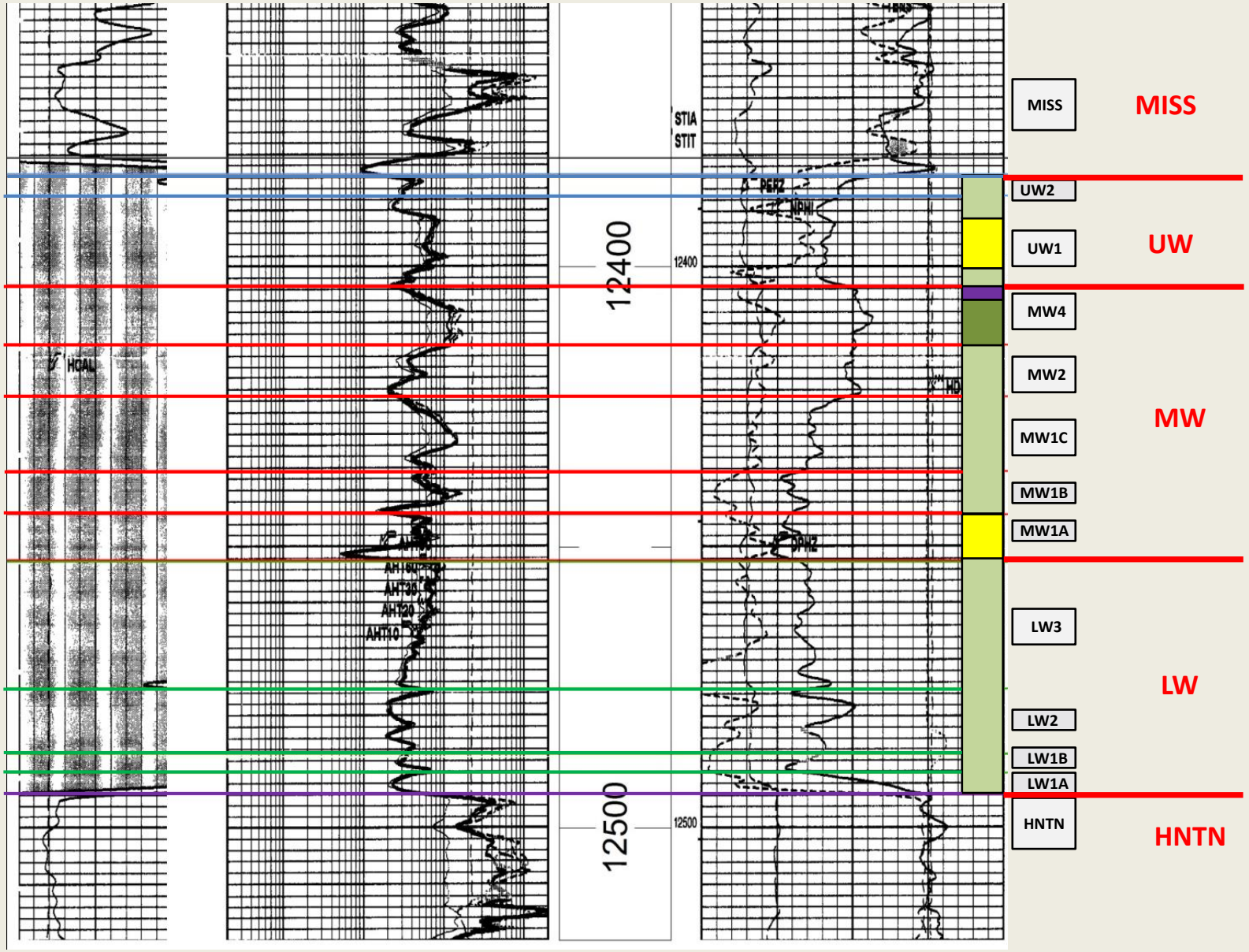


# Fracture Conductivity versus increasing Closure Stress – 40/70 PRC Proppant




Woodford
Isopach
Anadarko
Basin
Woodford
Play
N
NW
SW
CORE
SE
DEWEY
BLAINE
KINGFISHER
CUSTER
CANADIAN
WASHITA
CADDO
GRADY
50
100
150
200
0
5
10
miles
CIMAREX

# Woodford Lithostratigraphy Anadarko Basin
# Woodford Play - SE Area



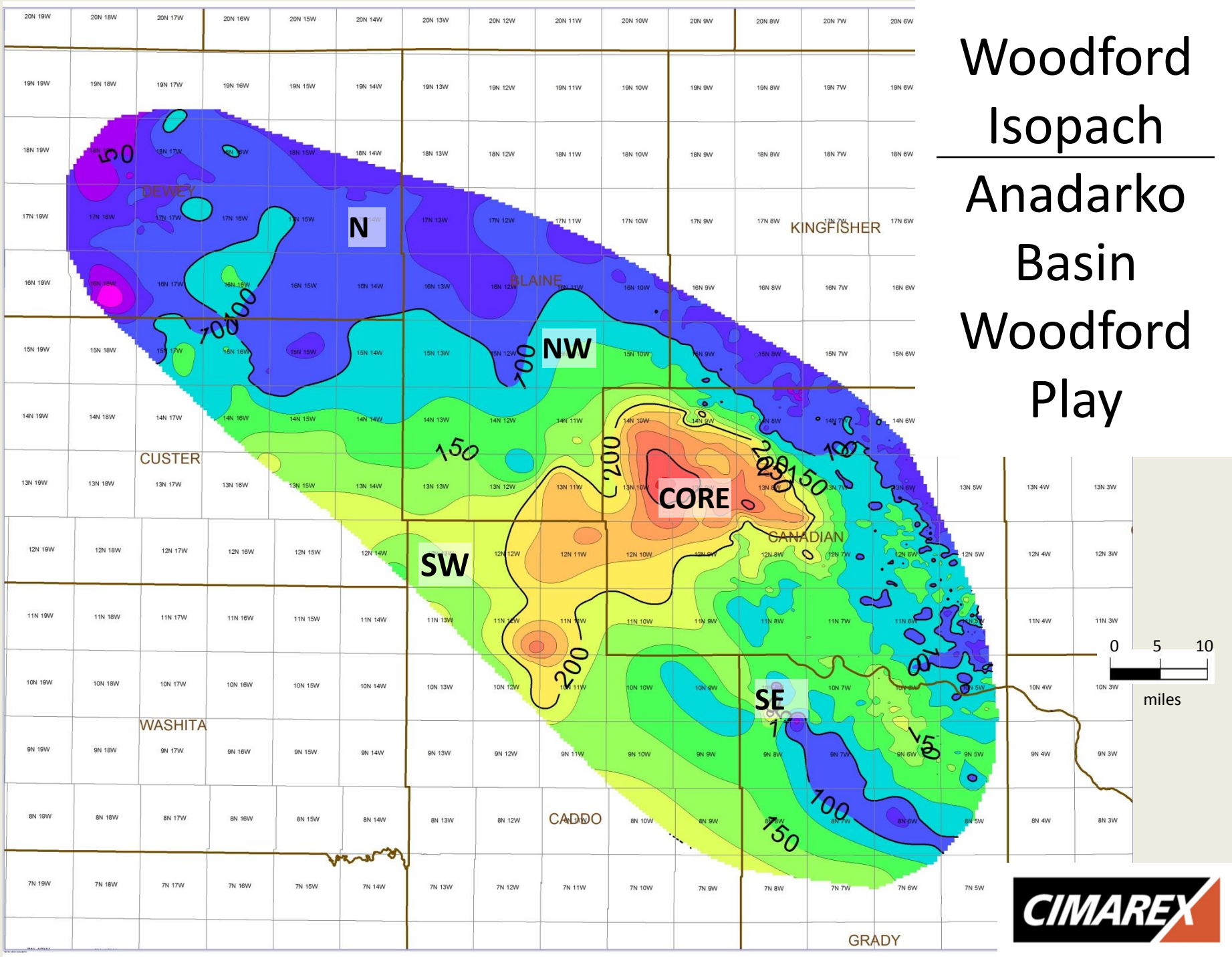

**Clayey, siliceous mudrock**

**Clayey mudrock**

**WDFD Thk. 110’**

# Woodford Isopach

## Anadarko Basin Woodford Play



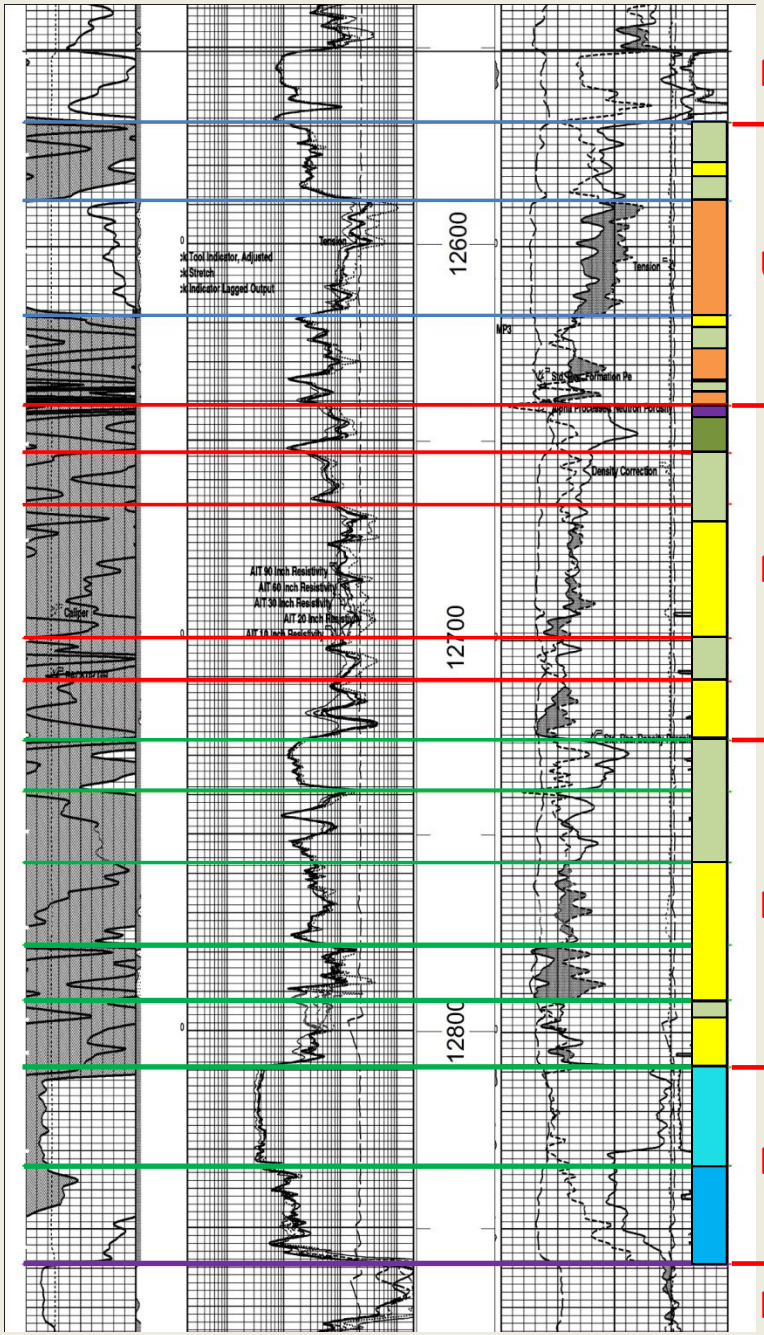
# Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous mudrock

Clayey, siliceous mudrock

Clayey mudrock

Organic-poor clayey mudrock




MISS

UW

MW

LW

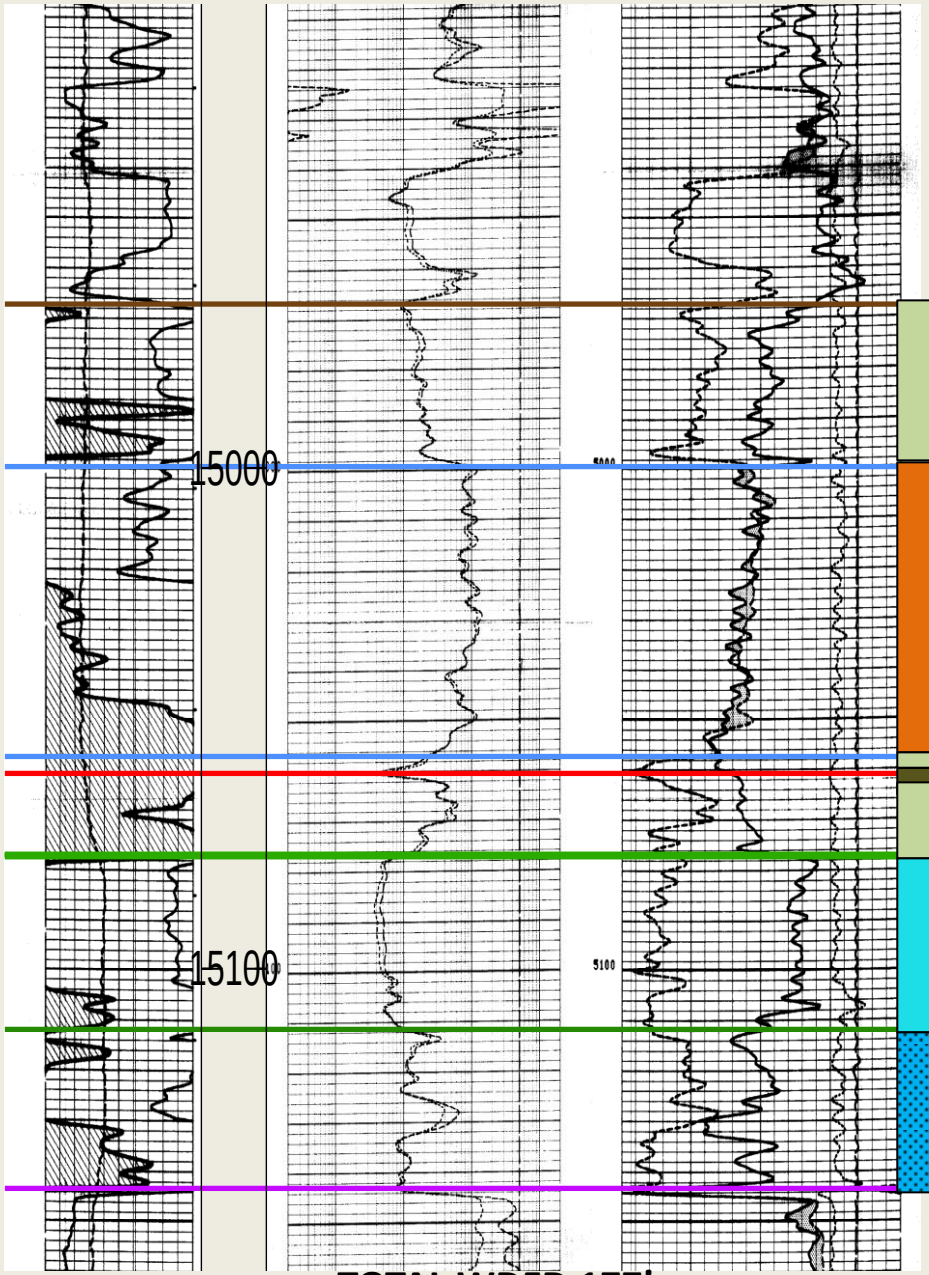
BW

Hntn

WDFD Thk. 290’

CIMAREX

# SW AREA




Siliceous mudrock

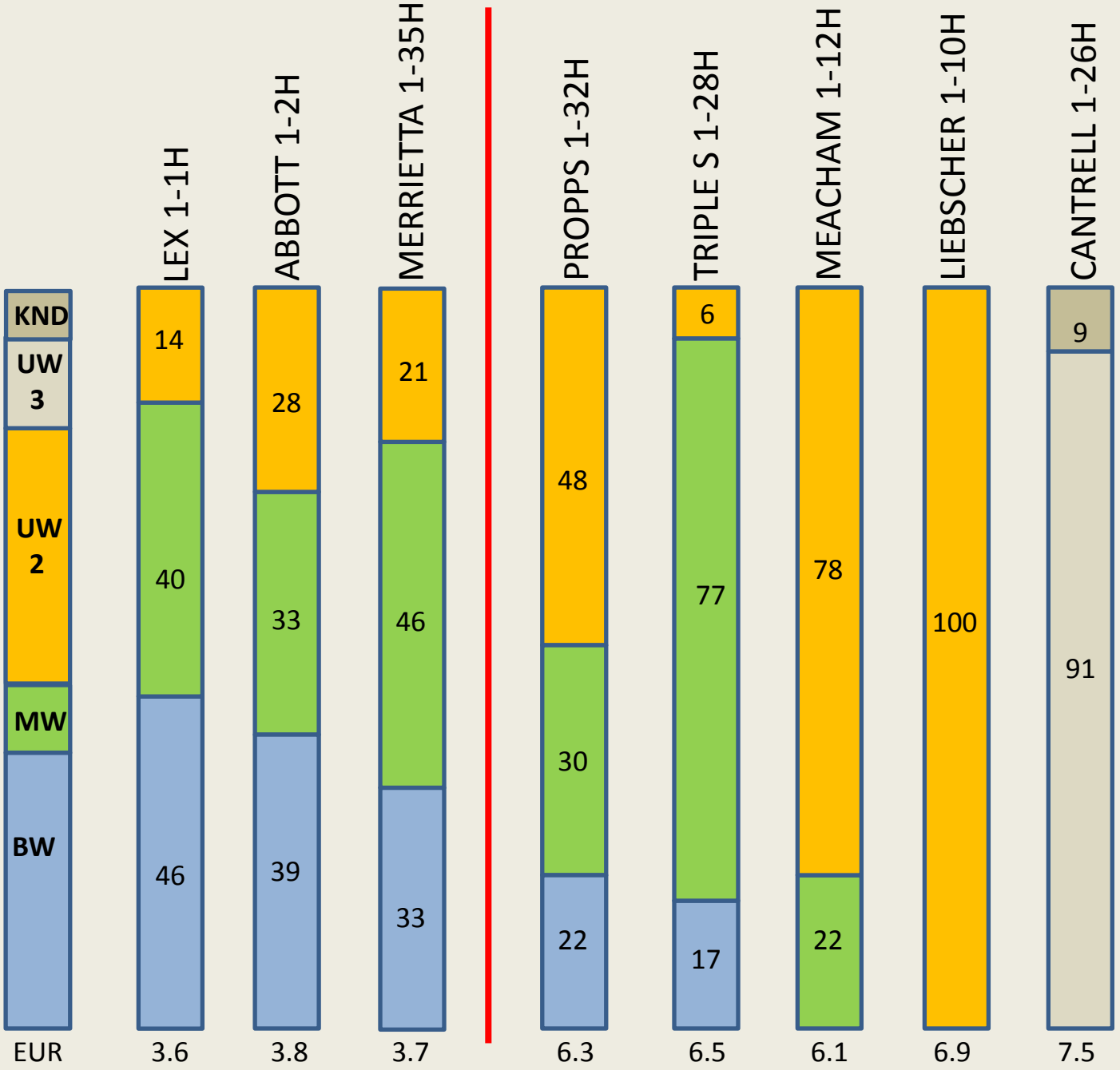
Organic-poor, clayey mudrock

Clayey mudrock

TOTAL WDFD 177’

WDFD minus BW 111’

# Lateral Placement and EUR- CANA SW



# CONCLUSIONS:

Seven mudrock lithologies are defined, primarily on mineral content and percent TOC, and a mechanical/lithostratigraphic model is established for the central part of the Anadarko Woodford Play.

Core and frac' data indicate that quartz-rich mudrocks and clay-rich mudrocks have distinctively different mechanical properties. Clay-rich mudrocks commonly treat at higher pressures and proppant placement can be challenging.

Embedment studies demonstrate lower fracture conductivity in more clay-rich lithologies compared to those observed in more silica-rich rock.

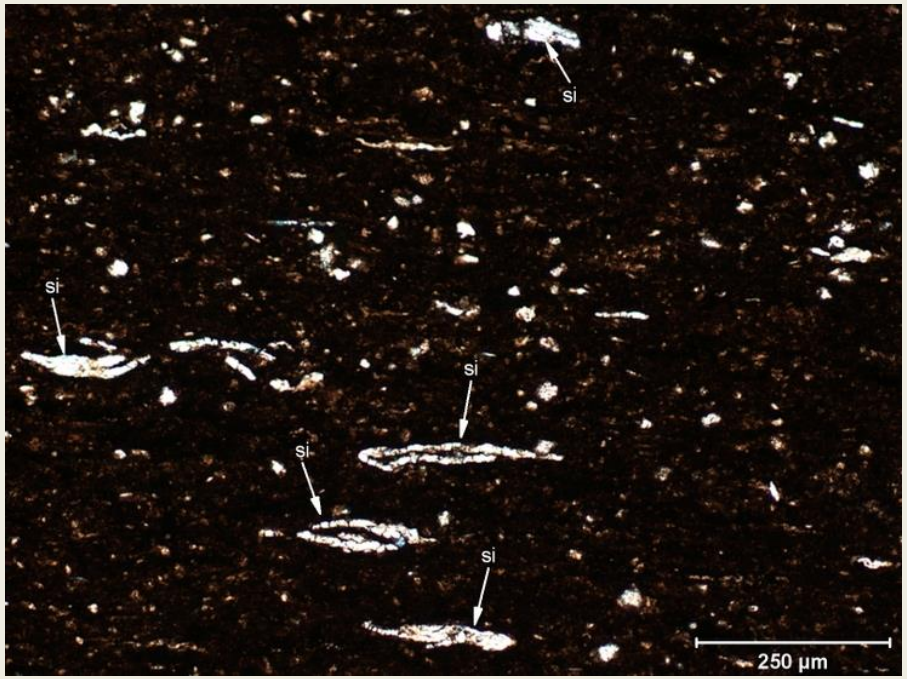
Regional work shows that in the SE Cana area decreased Woodford thickness and an overall increase in percent of clay-rich lithologies is associated with decreased well performance.

In the SW Cana area a relationship appears to exist between lateral placement and EURs.

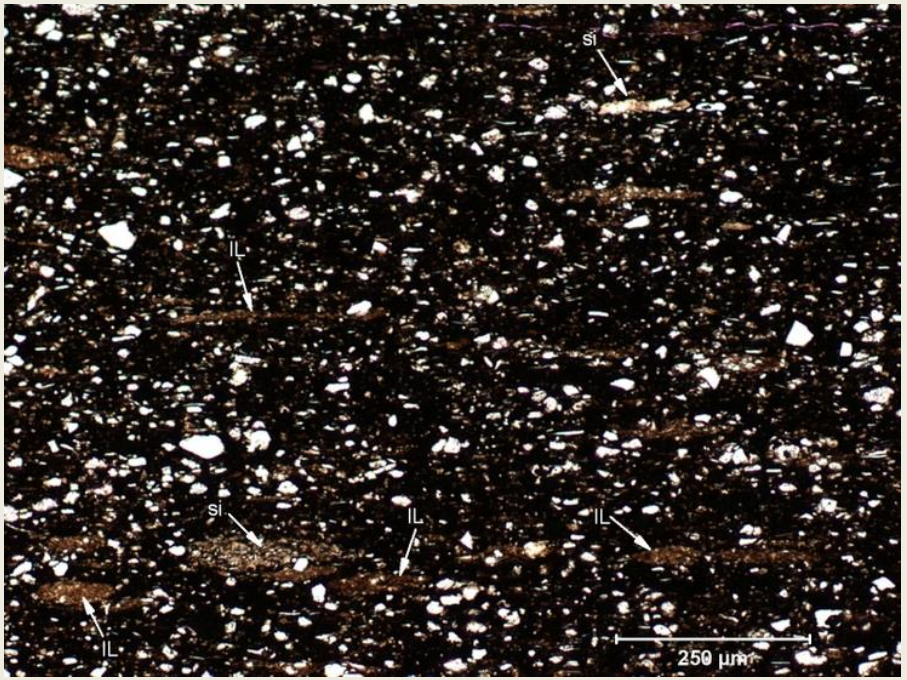
An important part of any Woodford completion program should be the discussion of lateral placement.


Rock Stuff

# Thin Section Photomicrographs of Woodford Rock Types



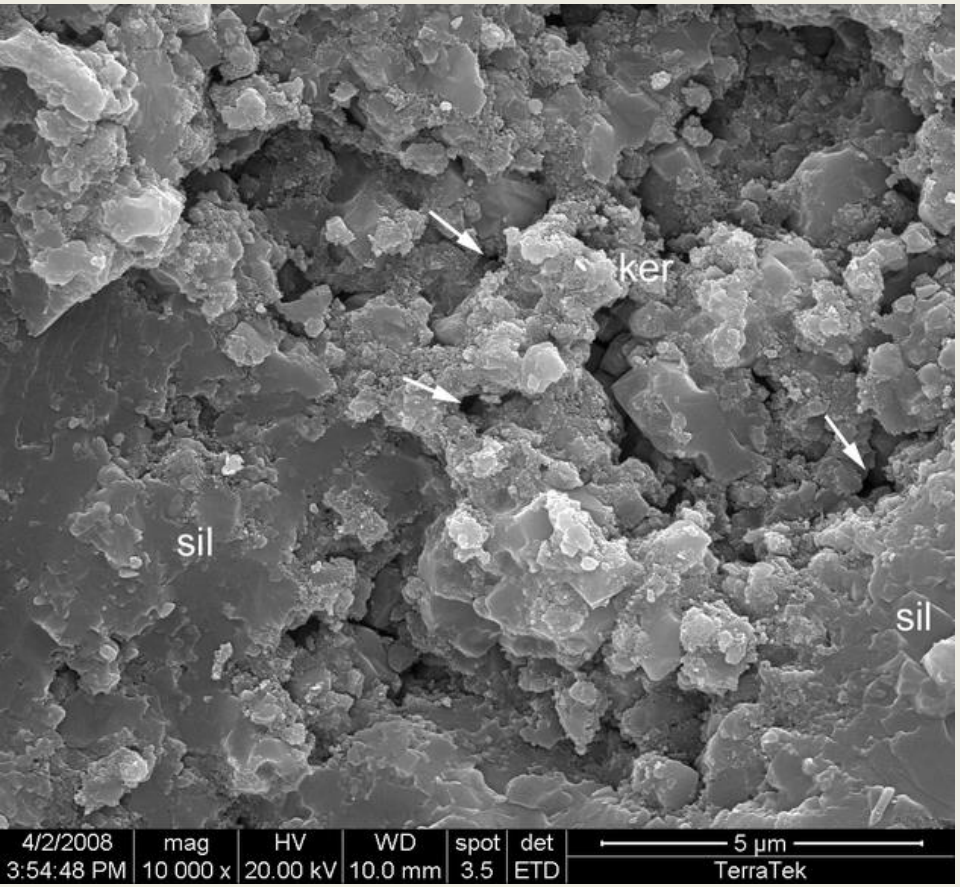

**UW1 sample showing silicified Tasmanites; sample is 64% quartz and 21% clay. Siliceous mudrock lithology.**



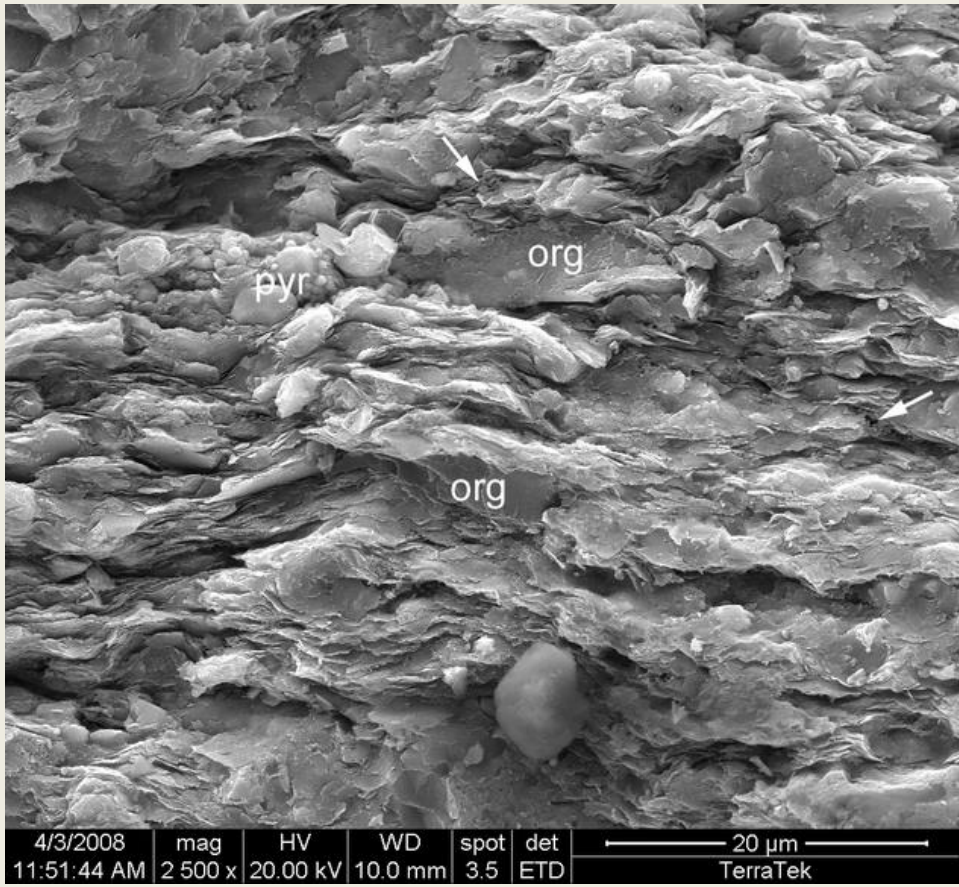

**MW1B sample showing detrital silt; sample is 34% quartz and 38% clay. Clayey mudrock lithology.**

CIMAREX

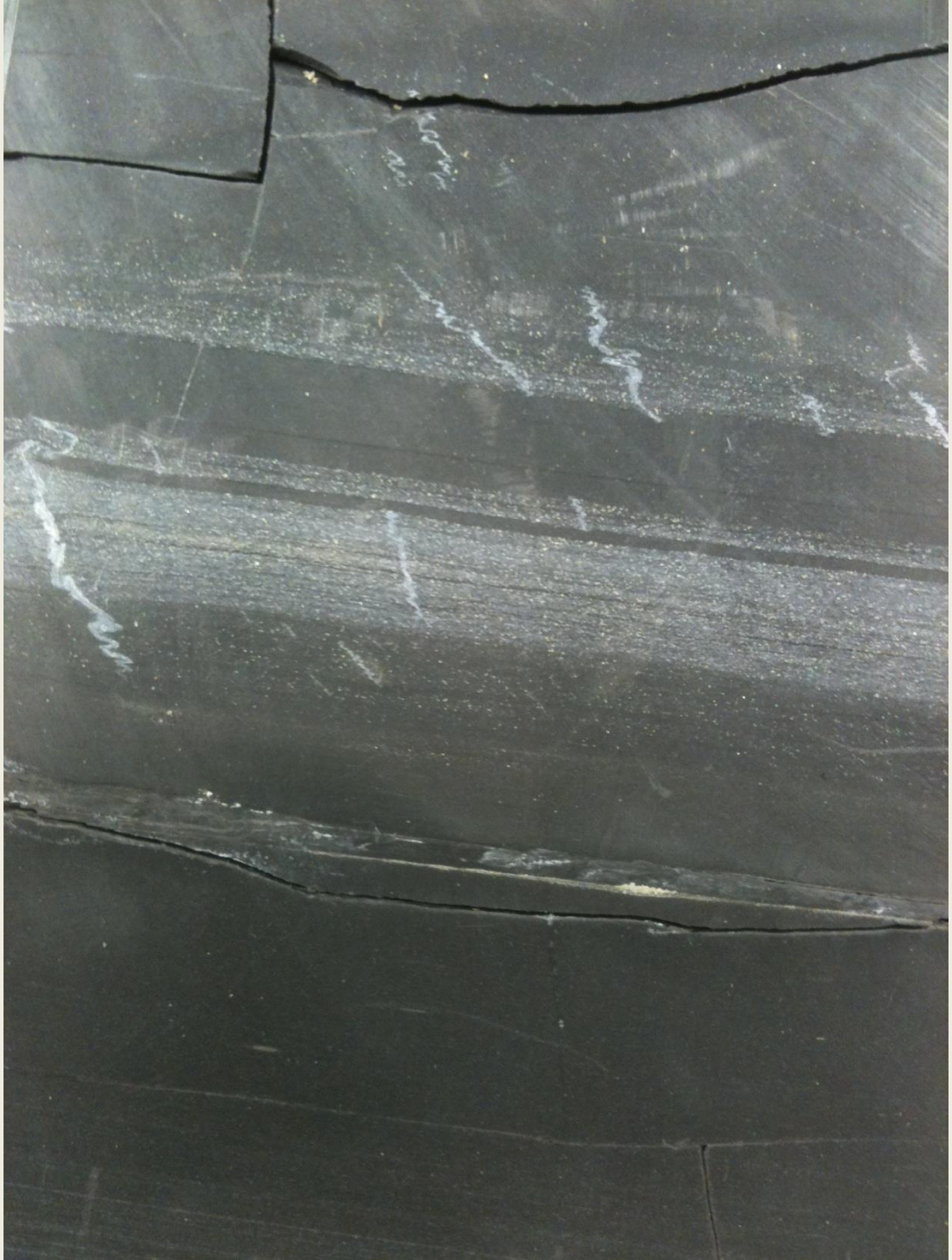
# SEM Photomicrographs of Woodford Microfabrics




**UW2 sample showing microcrystalline silica with intercrystalline porosity; sample is 76% quartz and 18% clay. Siliceous mudrock lithology.**




**MW4 sample showing parallel alignment of illite clay; sample is 26% quartz and 44% clay. Clayey mudrock lithology.**

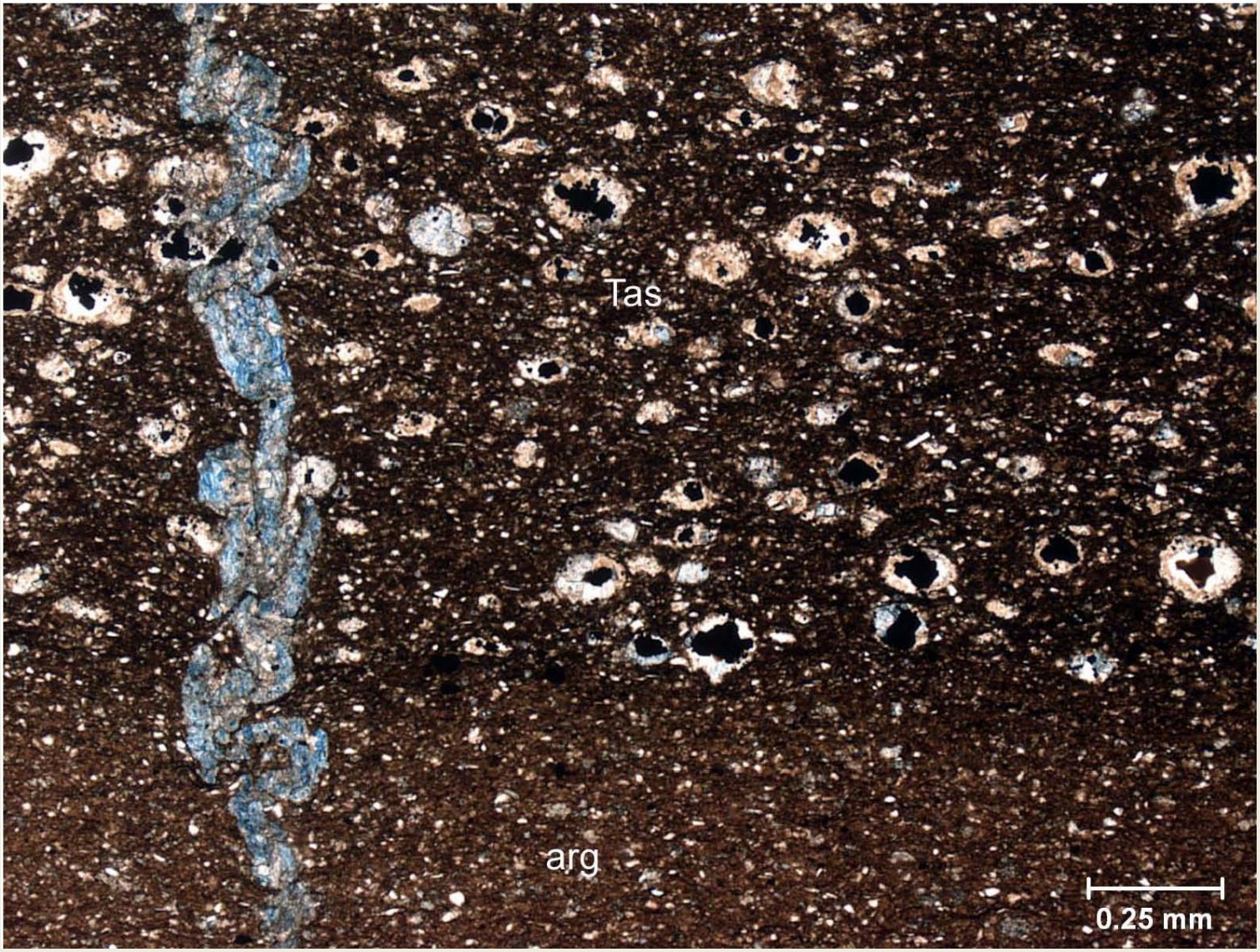


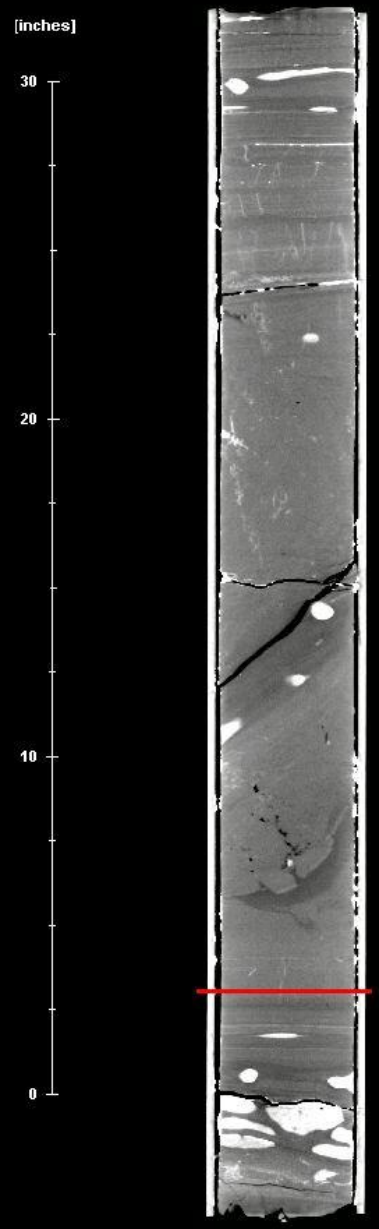
**Bed-limited dolomite-cemented fractures in thin silicic layers**

**Siliceous mudrock lithology**

CIMAREX

# Silicic laminae with dolomite-cemented fracture
# Siliceous mudrock lithology






16214.00 Feet

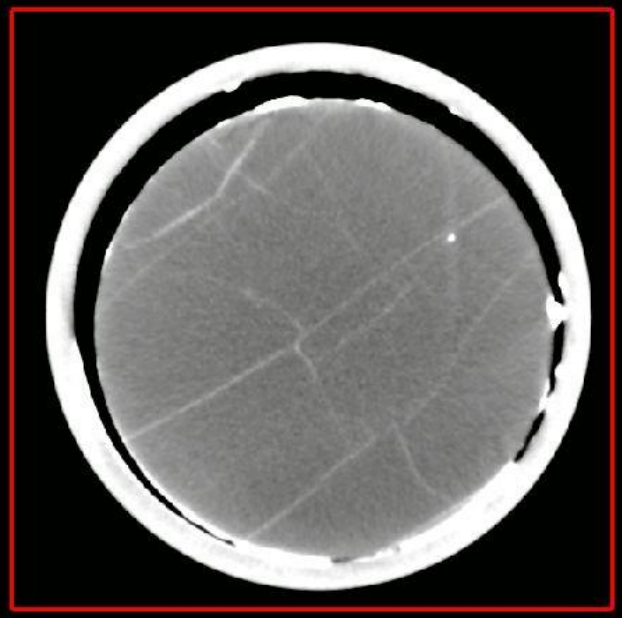
16217.00

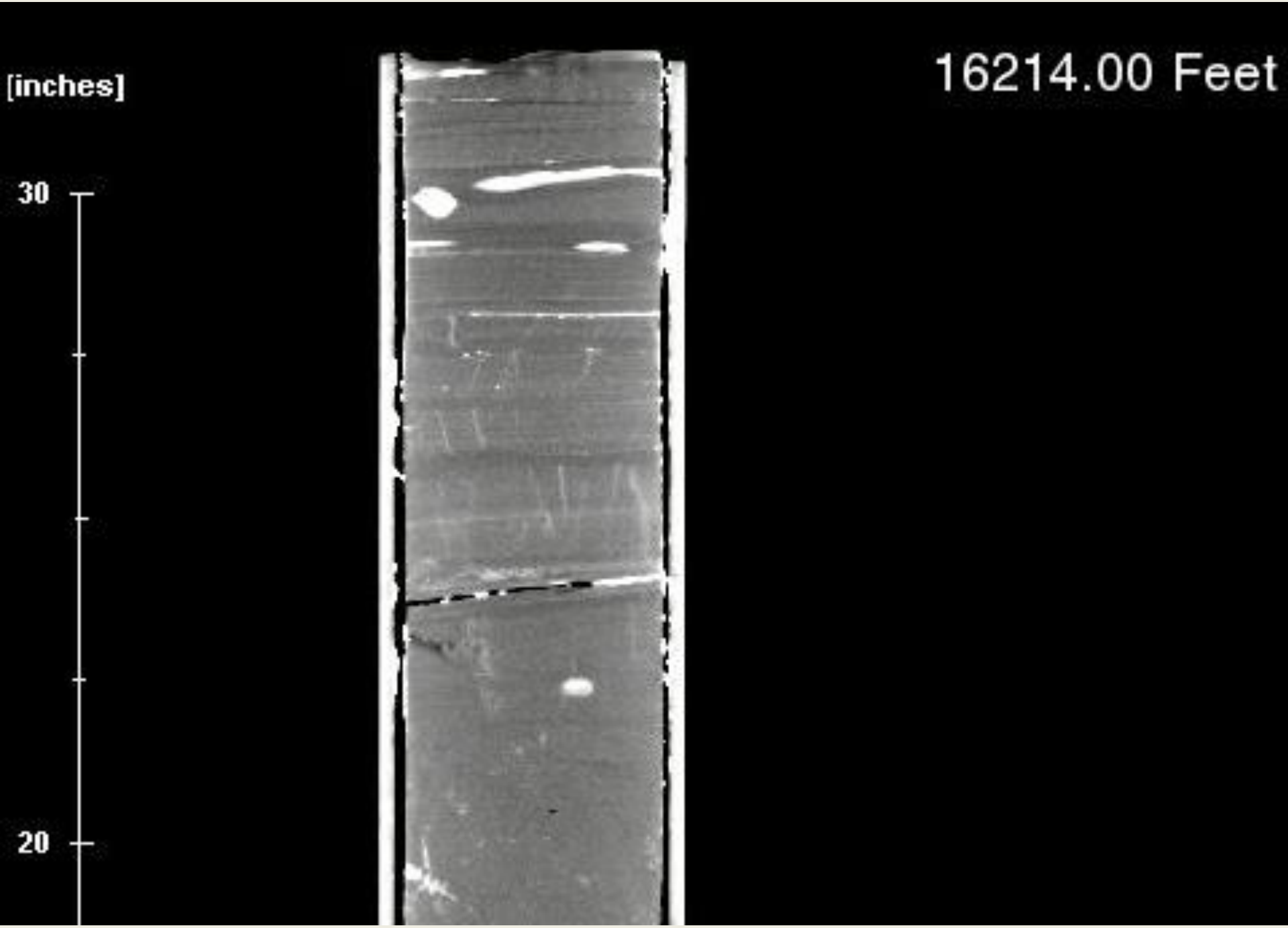
Weatherford LABORATORIES

Cimarex Energy Company
Flanigin 1-20H
Woodford Shale

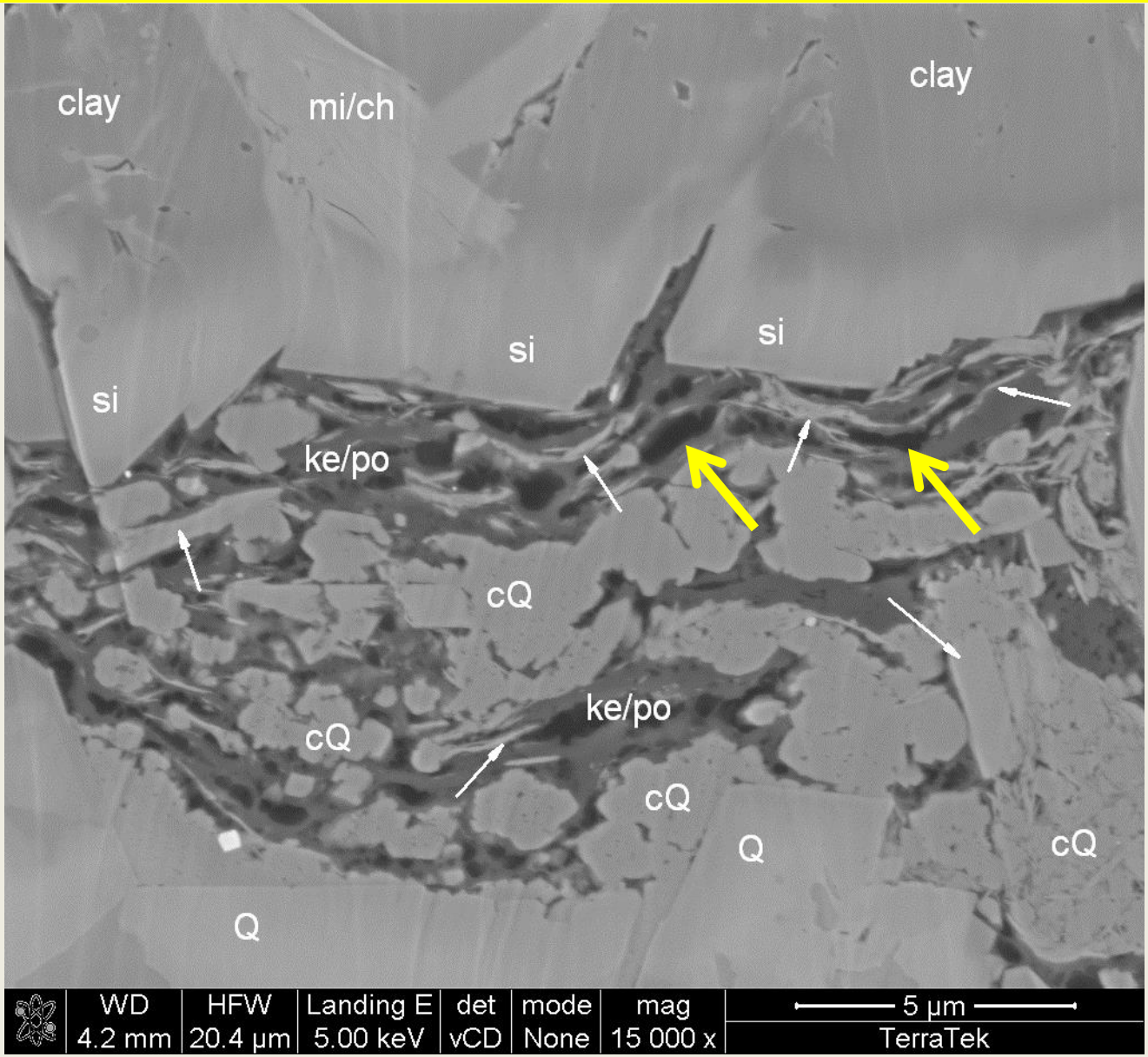
Caddo County, OK, USA

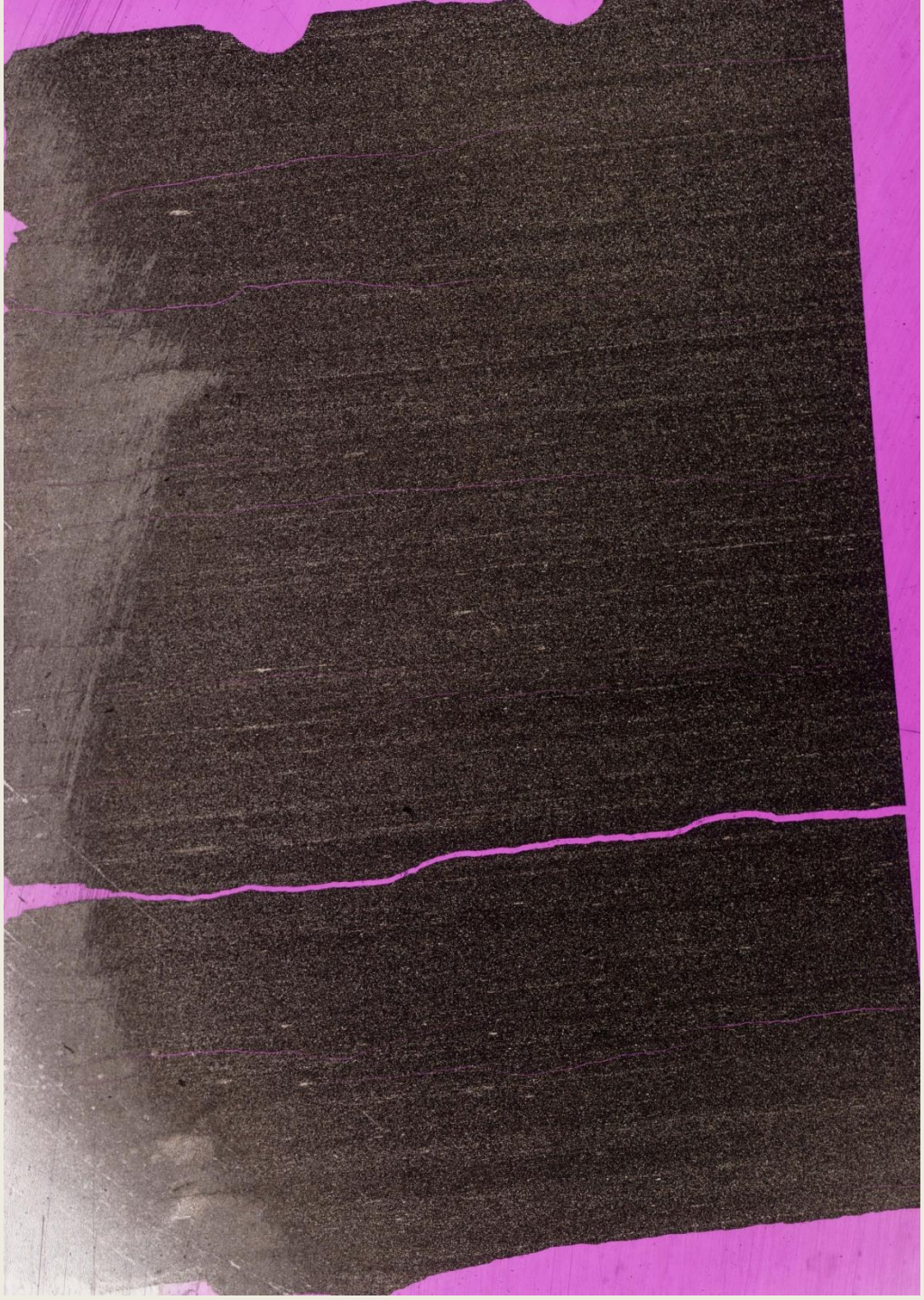
HH-50217





[inches]
30
20
16214.00 Feet

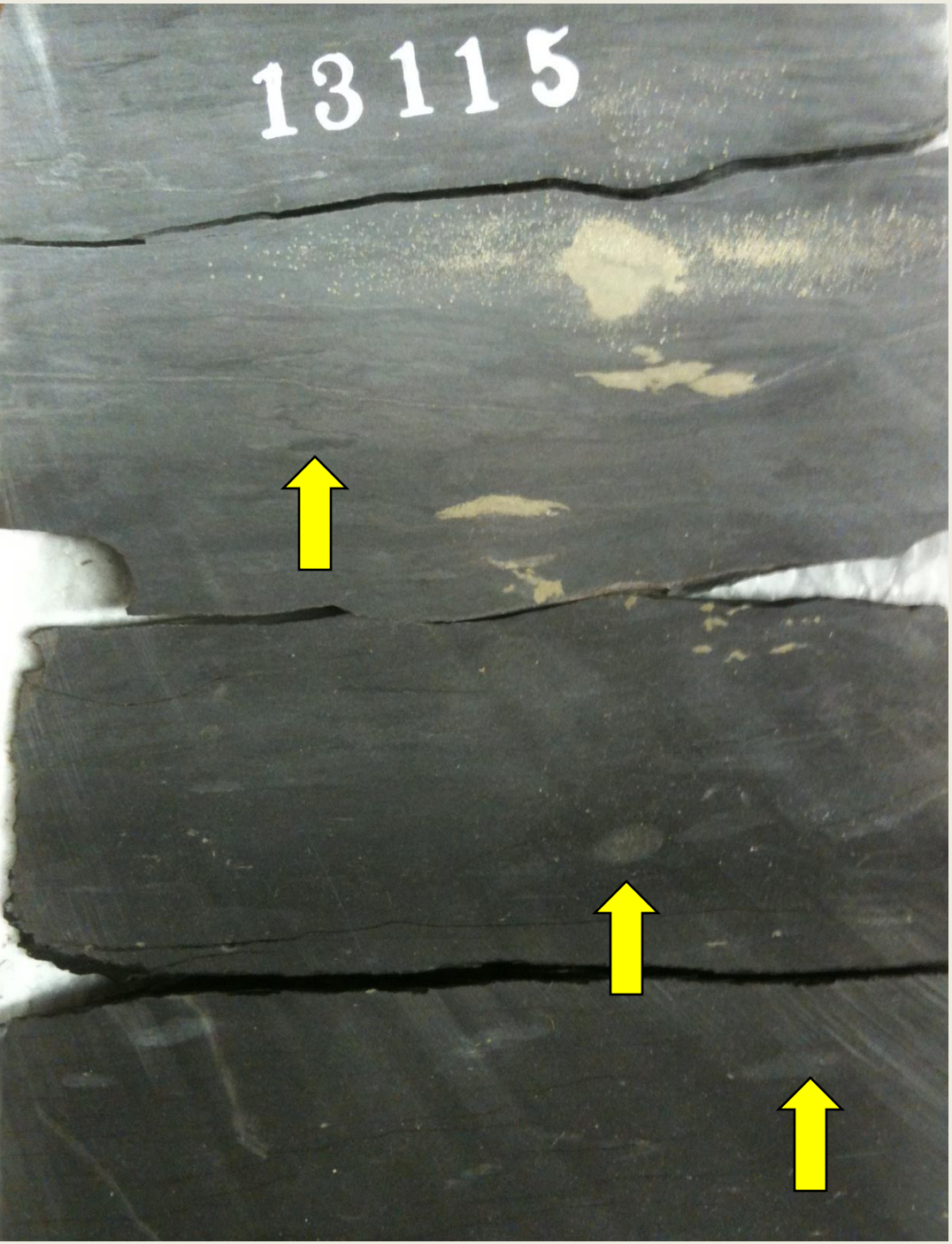
# Porosity in organic laminae
# Clayey siliceous mudrock



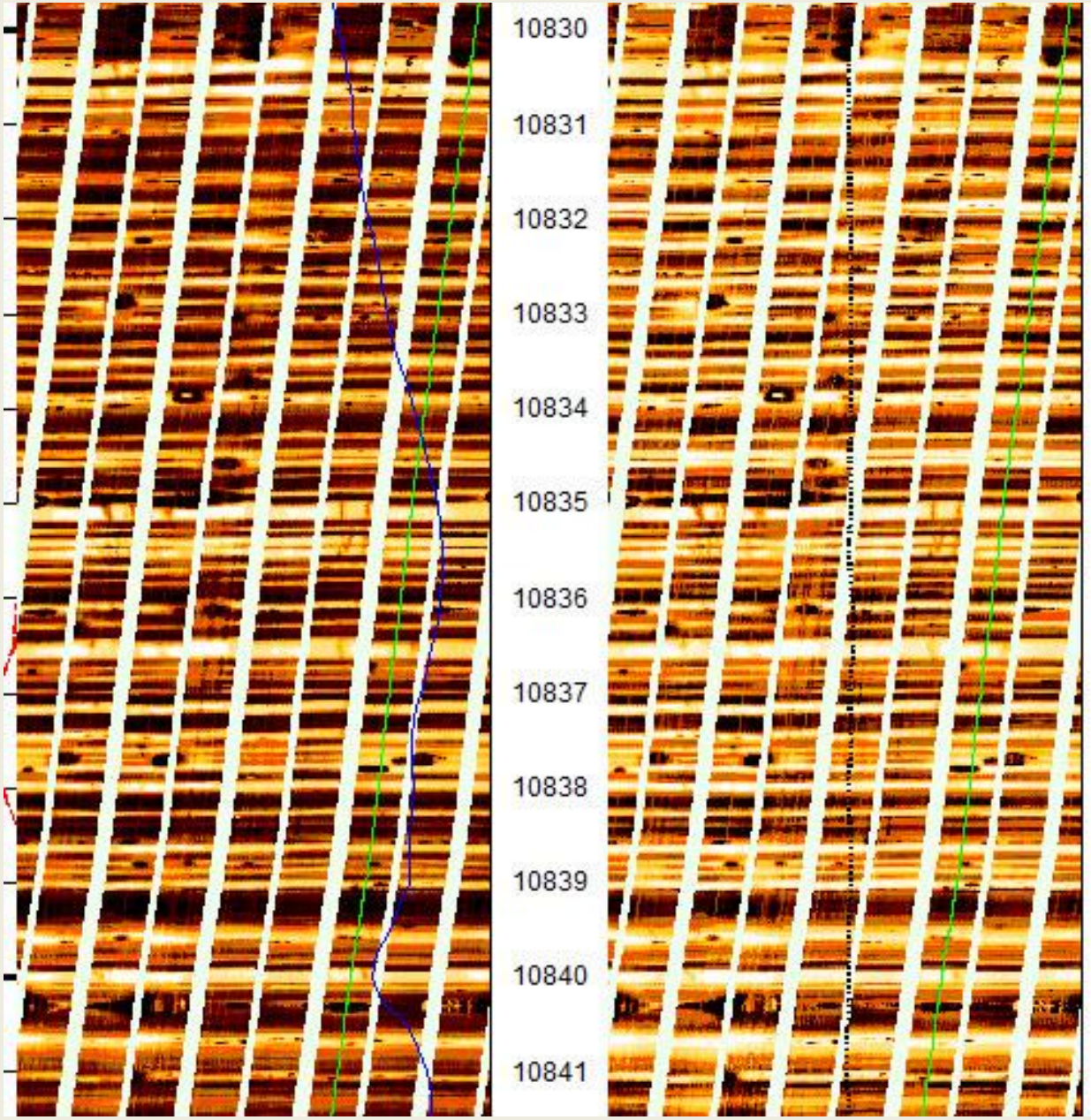


# Parallel lamination in Clayey mudrock lithofacies

CIMAREX

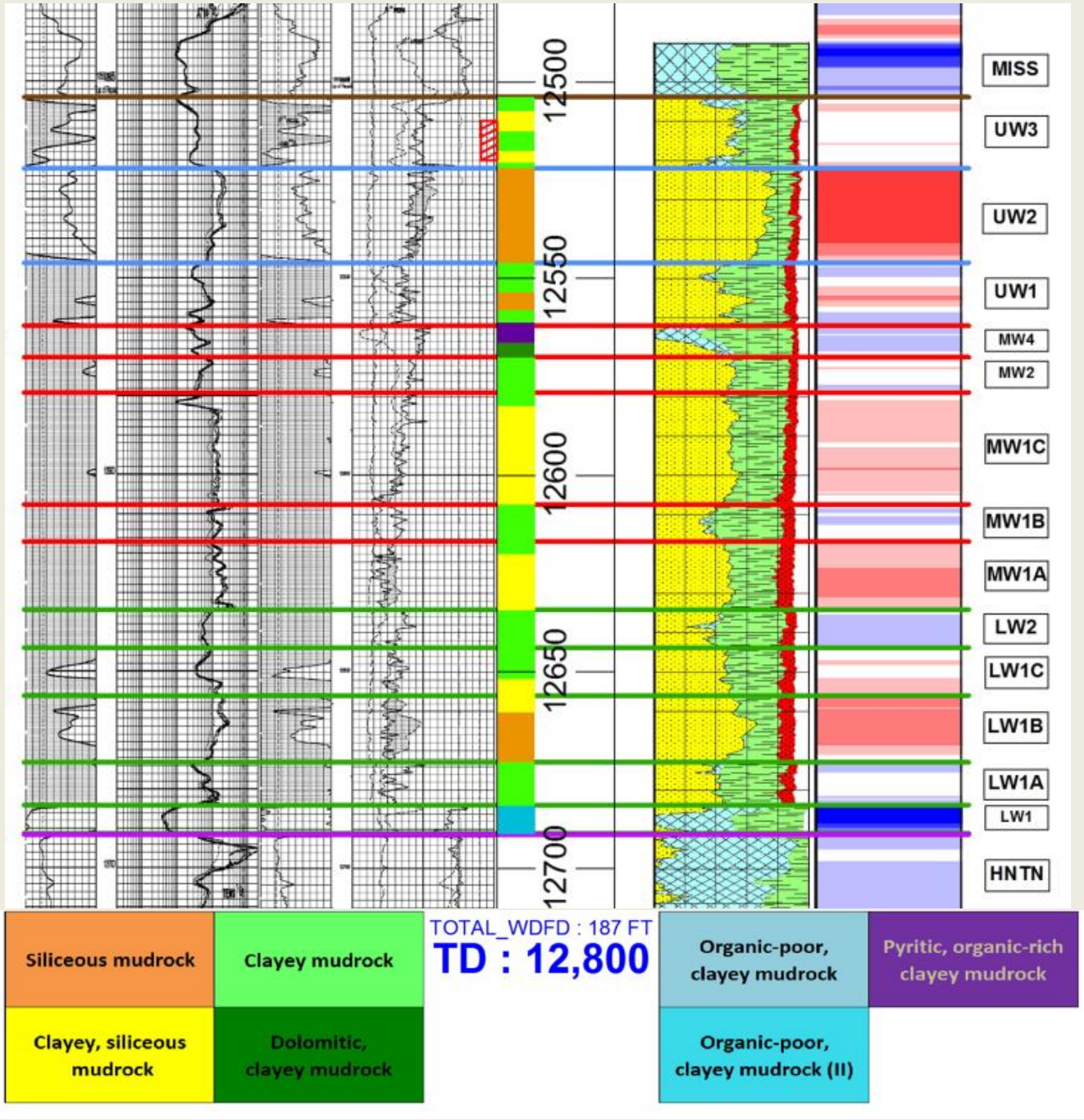



**Bioturbated bed**
**Clayey mudrock lithofacies**

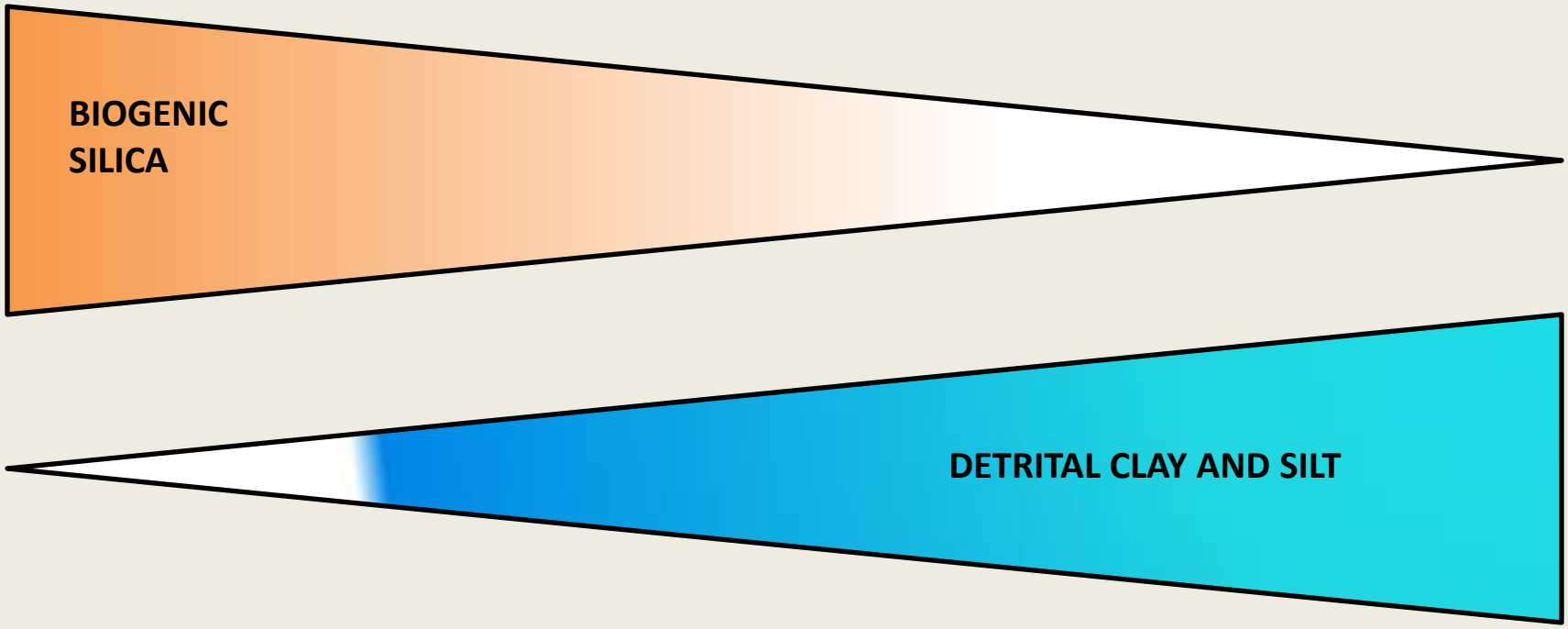



# Image Log of Thin-Bedded Upper Woodford

# Woodford Lithostratigraphy With Sonic Scanner Data



# Woodford Lithofacies





**Distal (?)**

**Proximal (?)**

**“GOOD” MECHANICAL PROPERTIES**

**“POOR” MECHANICAL PROPERTIES**

# An Incomplete List of Things That Could Impact Cana Woodford Production

## The Rocks

- Thickness
- Brittleness
- Porosity/Perm
- Natural Fractures
- Maturity

## The Completion

- Lateral Length
- Amount & Type Proppant
- Amount & Type Fluid
- Number Stages
- Cluster Spacing
- Pump Rate
- Lateral Configuration
- Lateral Placement

Siliceous mudrock

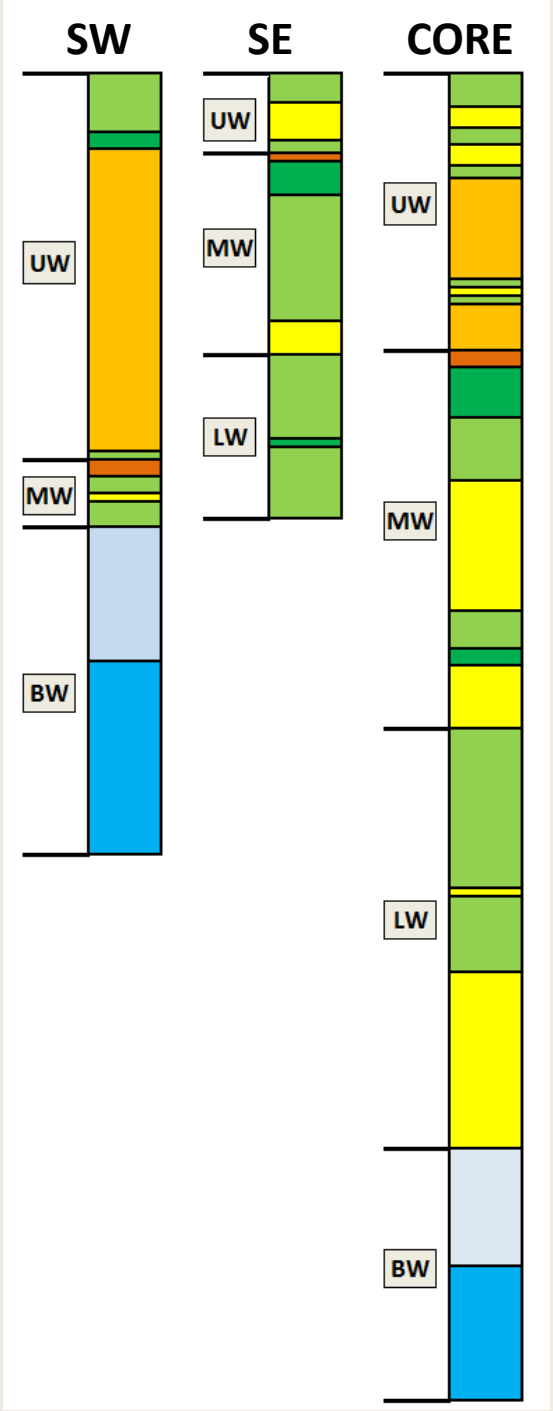
Clayey, siliceous mudrock

Clayey mudrock

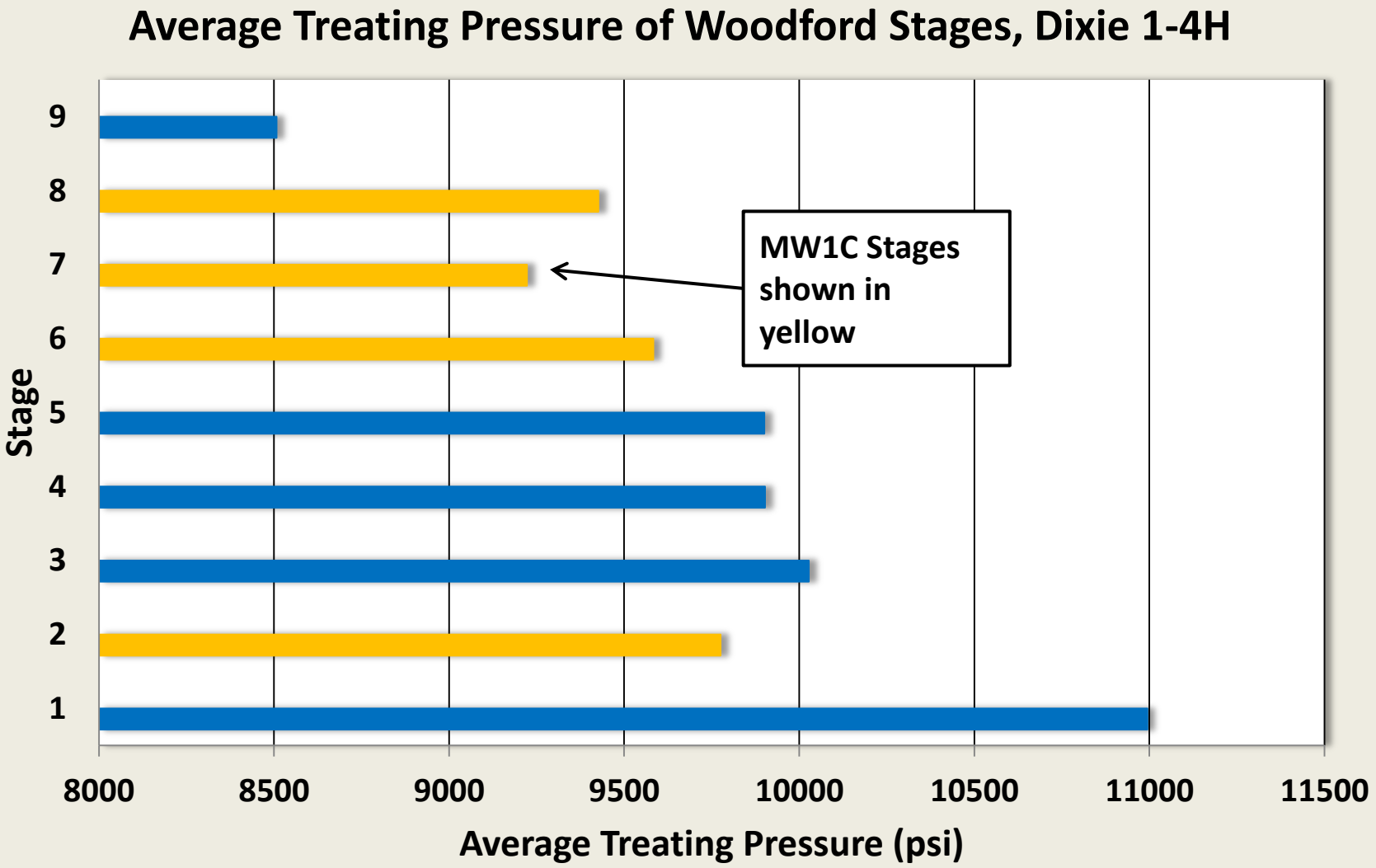
Dolomitic, Clayey mudrock

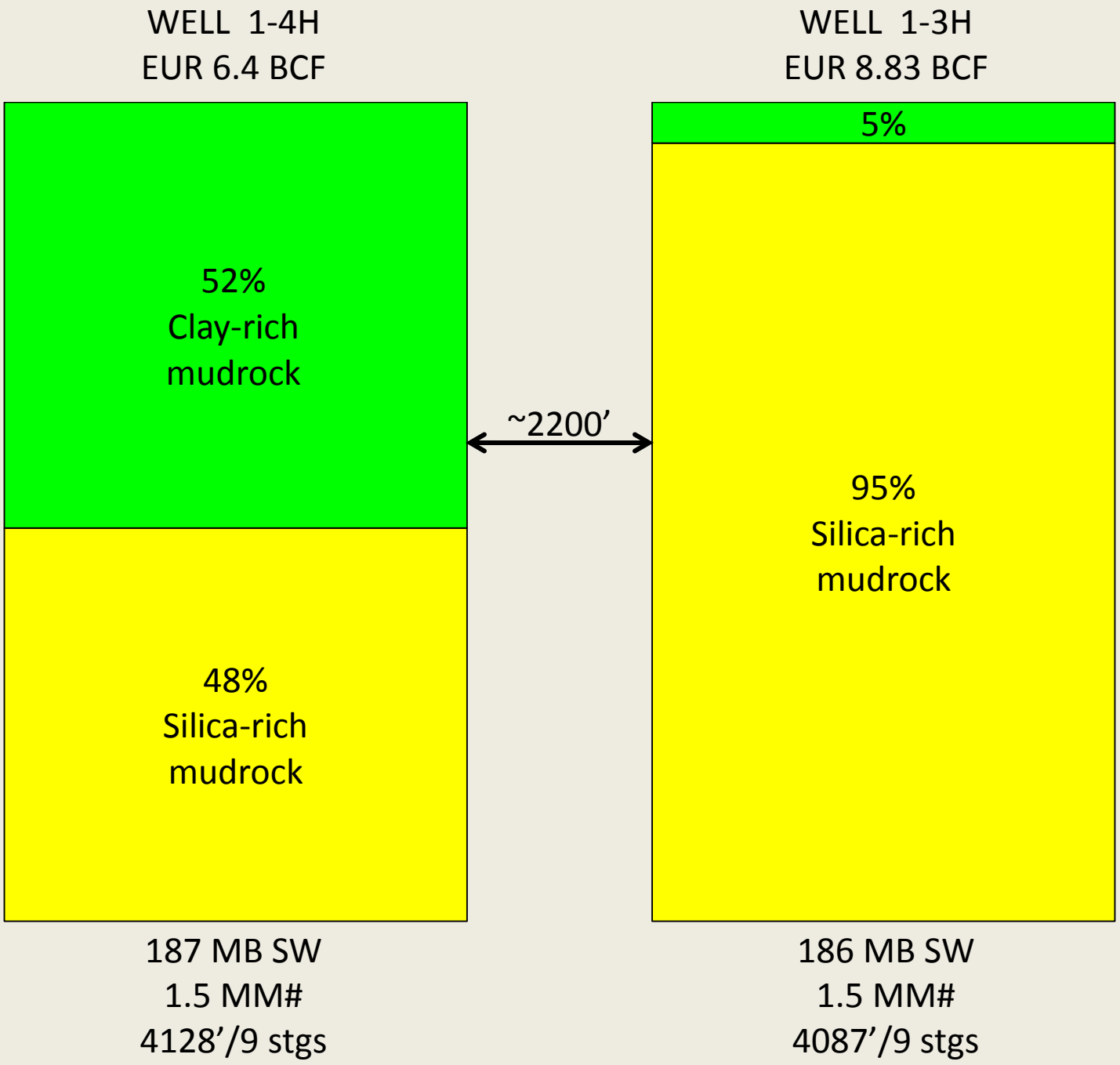
Organic-poor clayey mudrock

Organic-poor clayey mudrock II



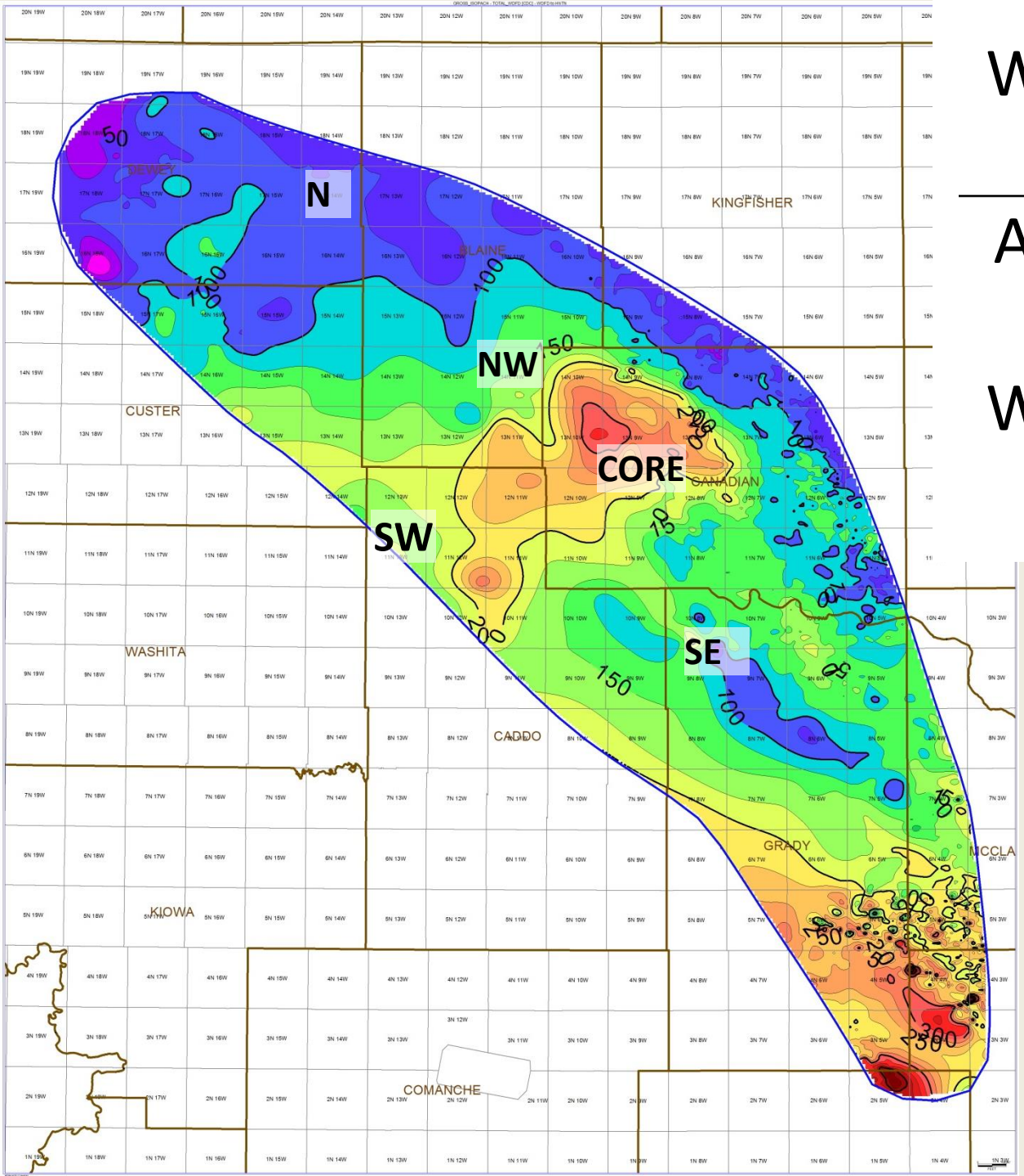

Regional Stratigraphic Variability Anadarko Woodford Play


Average Treating Pressure of Woodford Stages, Dixie 1-4H
Stage
9
8
7
6
5
4
3
2
1
MW1C Stages shown in yellow
8000
8500
9000
9500
10000
10500
11000
11500
Average Treating Pressure (psi)


WELL 1-4H
EUR 6.4 BCF
WELL 1-3H
EUR 8.83 BCF
5%
52%
Clay-rich
mudrock
~2200'
95%
Silica-rich
mudrock
48%
Silica-rich
mudrock
187 MB SW
1.5 MM#
4128'/9 stgs
186 MB SW
1.5 MM#
4087'/9 stgs

# Woodford Isopach

## Anadarko Basin Woodford Play




0 5 10

miles

CIMAREX