# The Geological Reservoir Characterization and Assessment of Reservoir Deliverability for Unconventional Reservoir Targets In the Hereford Field Area, Weld County, Colorado

Chad Taylor
MSc Geology Student
Anticipated - August 2023

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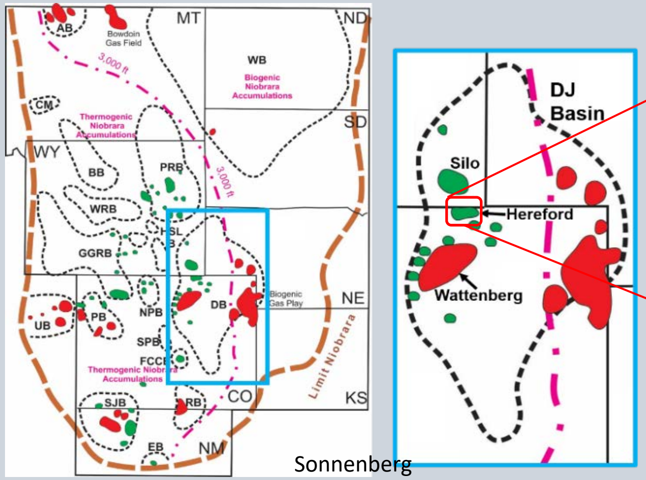
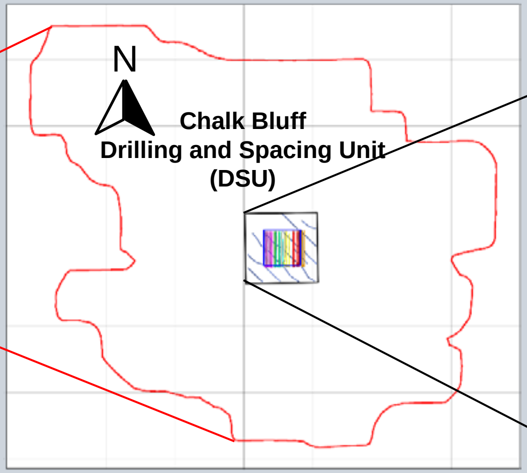
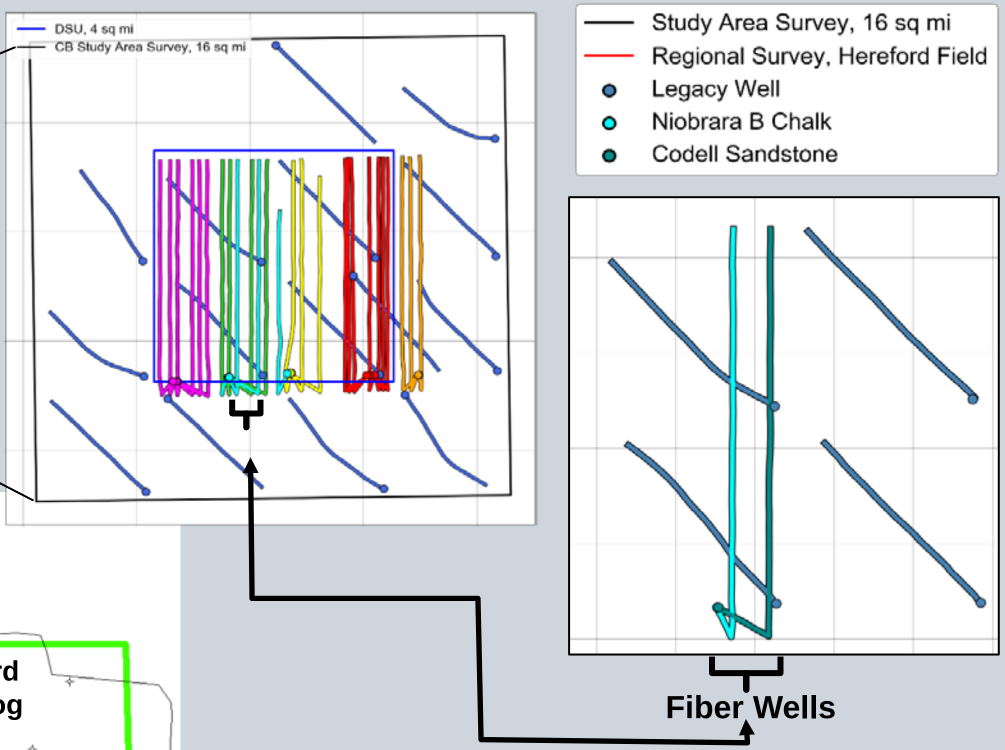
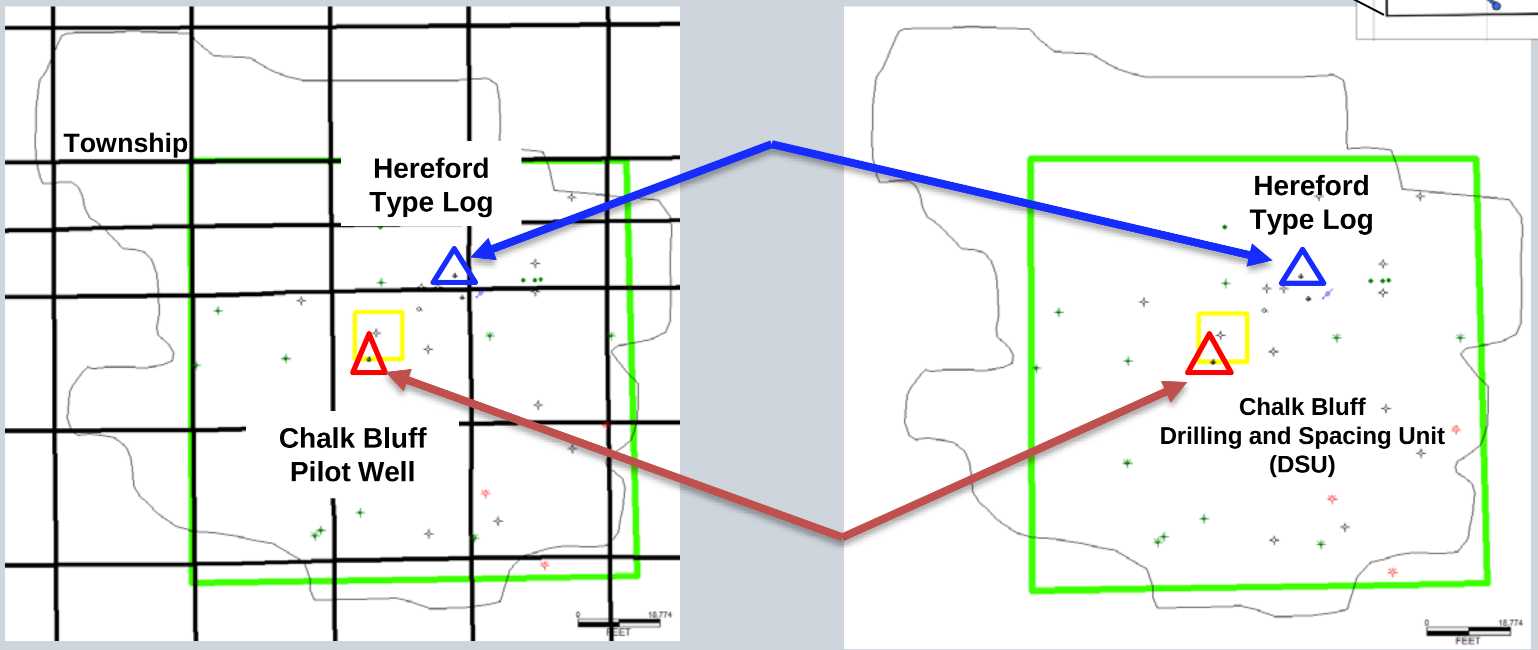
MUDTOC

# Hereford Study - Data Overview



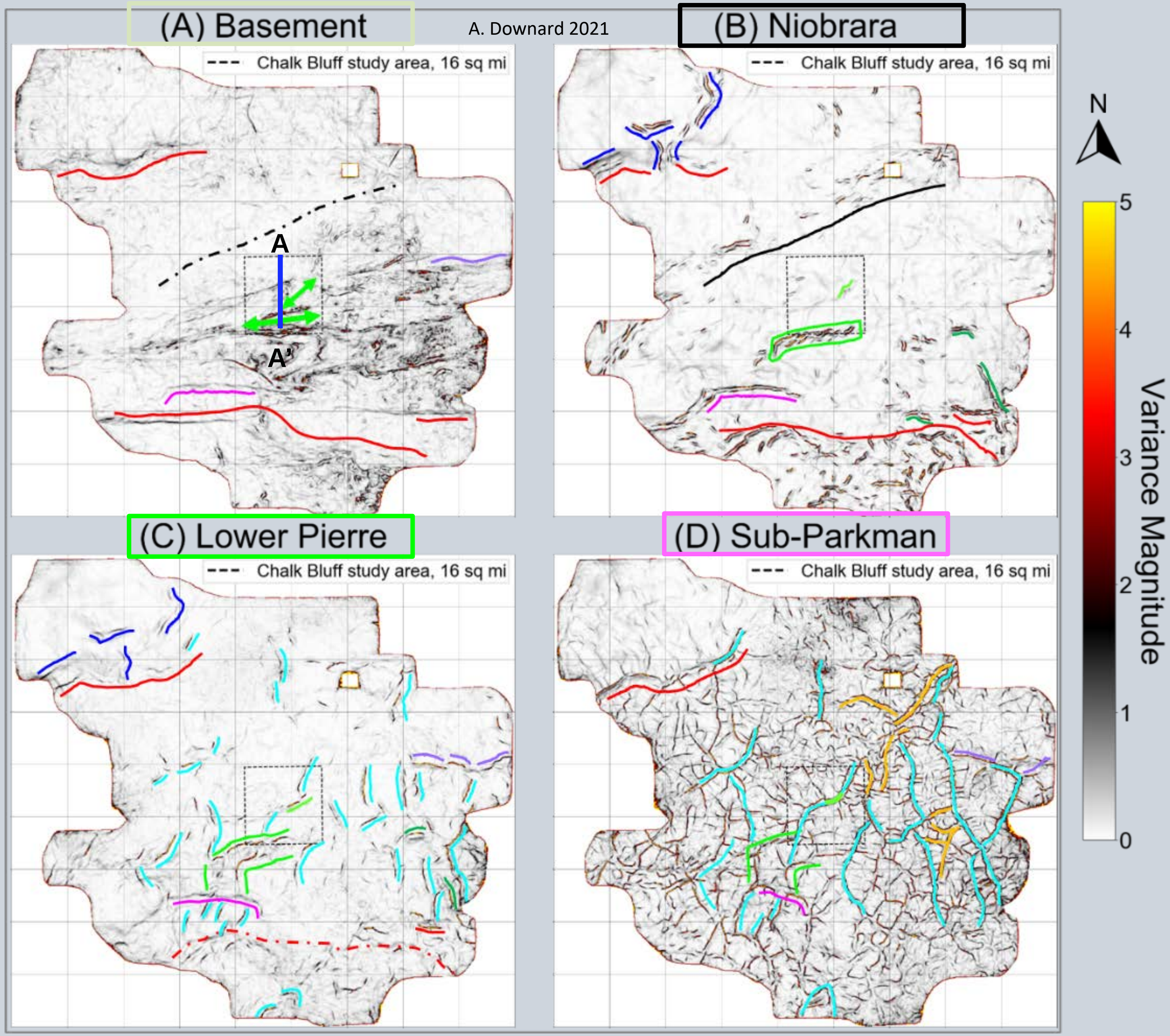



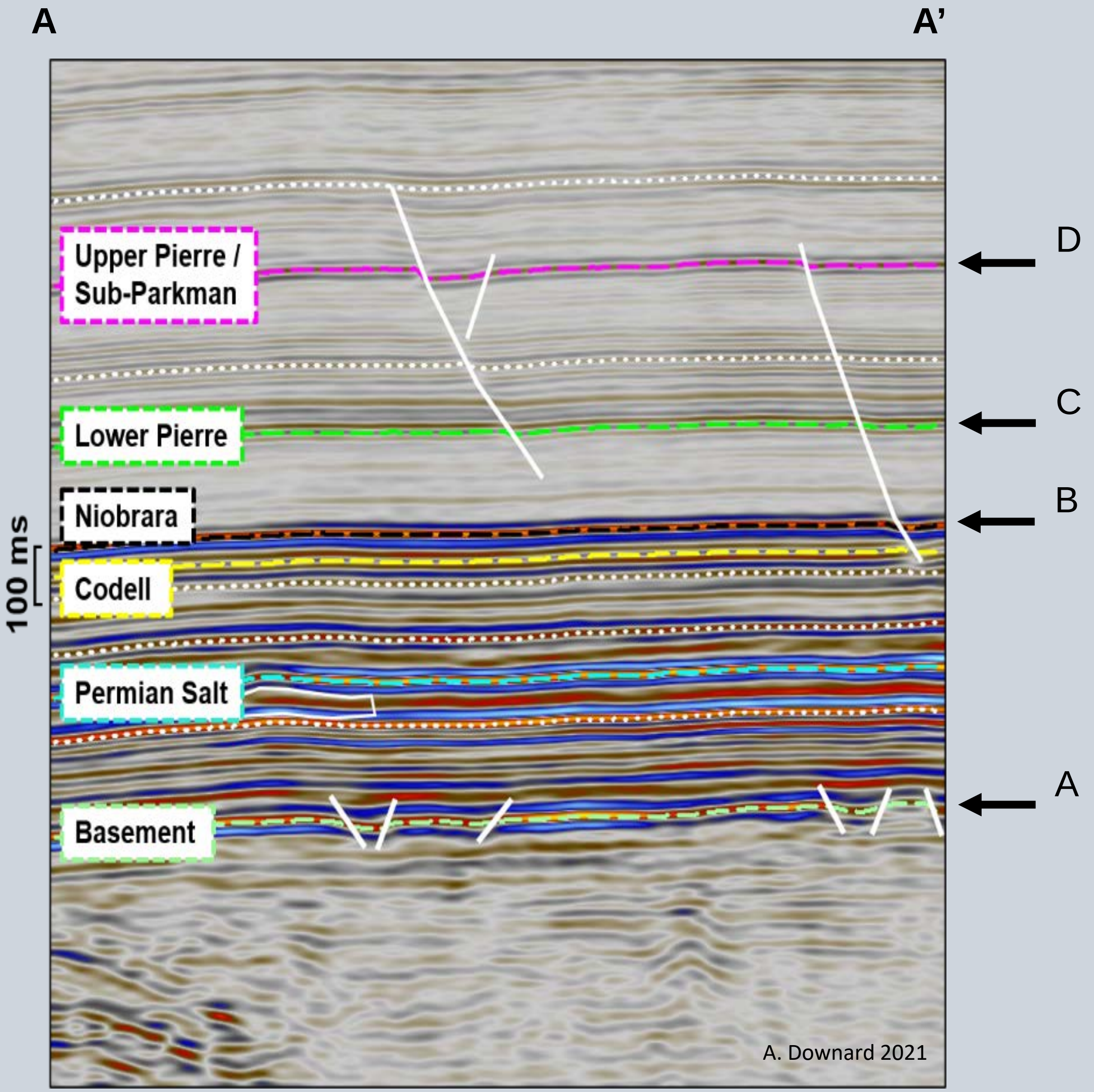




**Hereford / Chalk Bluff Study**
**Vertical Well Data Distribution**

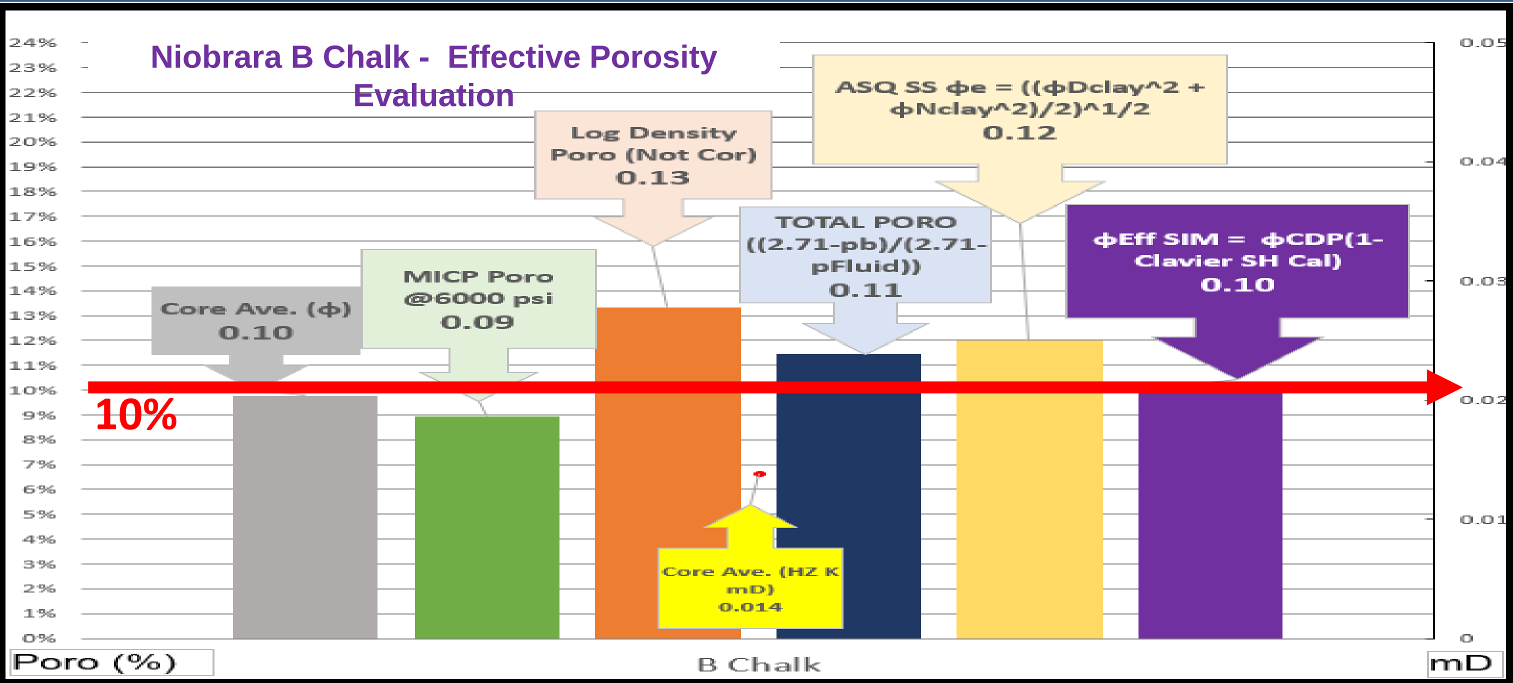
# Structural Context



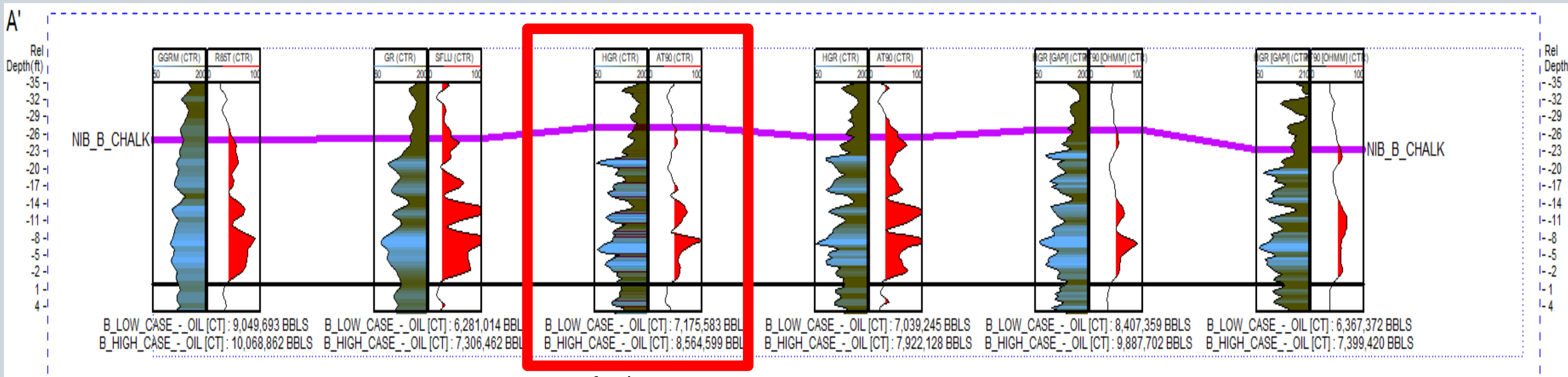
# Hereford - Niobrara B Chalk

## Petrophysical Reservoir Quality

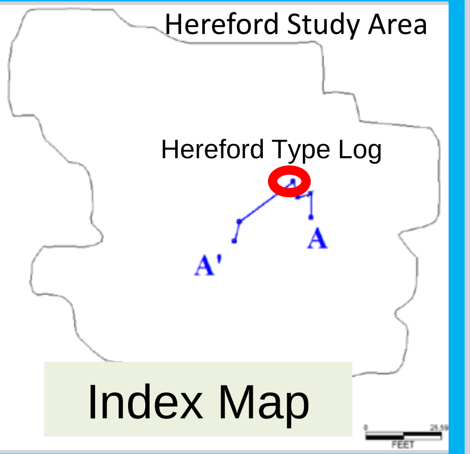



### Hereford - Niobrara B Chalk Statistics

- Niobrara B thickness ranges from 20 to 56 ft
- Average Gross Thickness = 36 ft
- B Chalk net resistivity (> or = 20 Ohm m) can range from 0 to 43 ft with an average of 25 ft within the study area
- 10 % porosity average (crush core and corrected well log)
- Highest calcite content of all Niobrara Chalk benches
- < 10% Clay Content
- Lower organic content (3% , TOC on average) in comparison to the bounding marl units
- Contains many fracture types (open, closed, and faults)



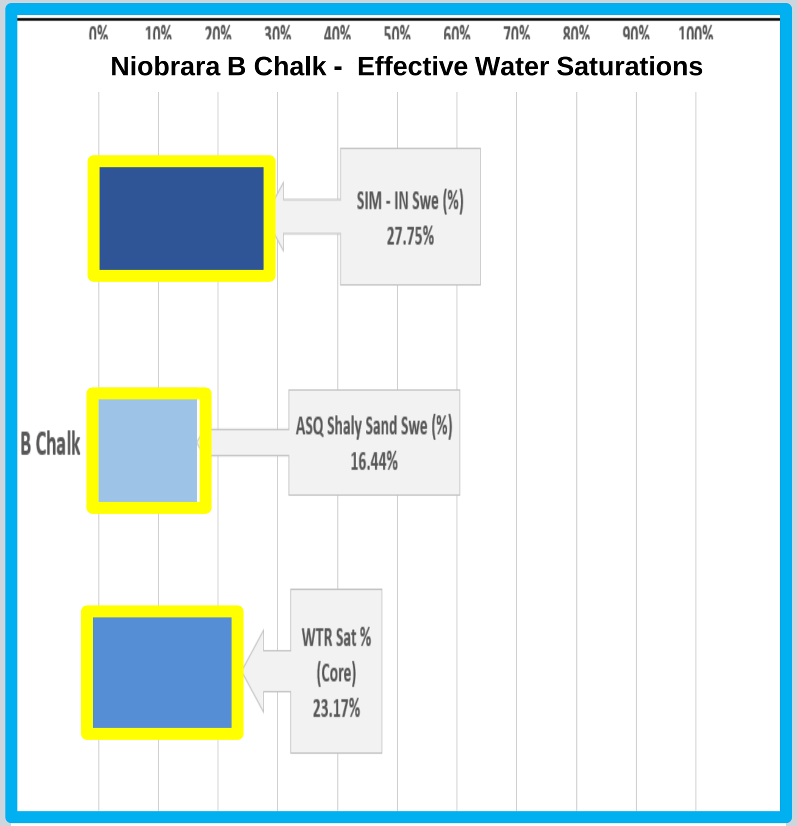

Hereford Type Log

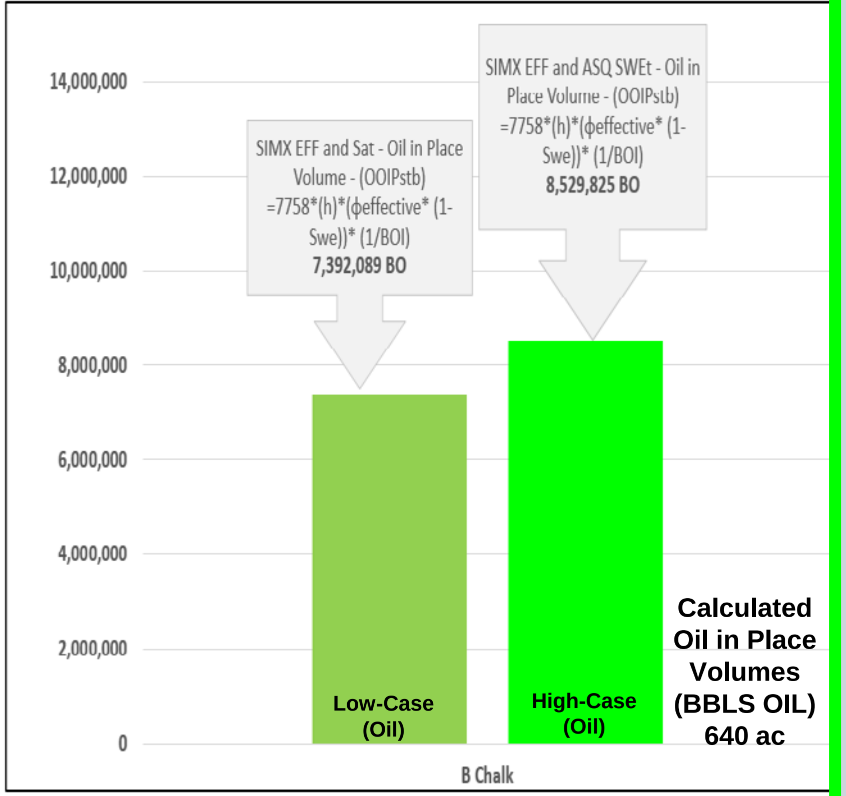


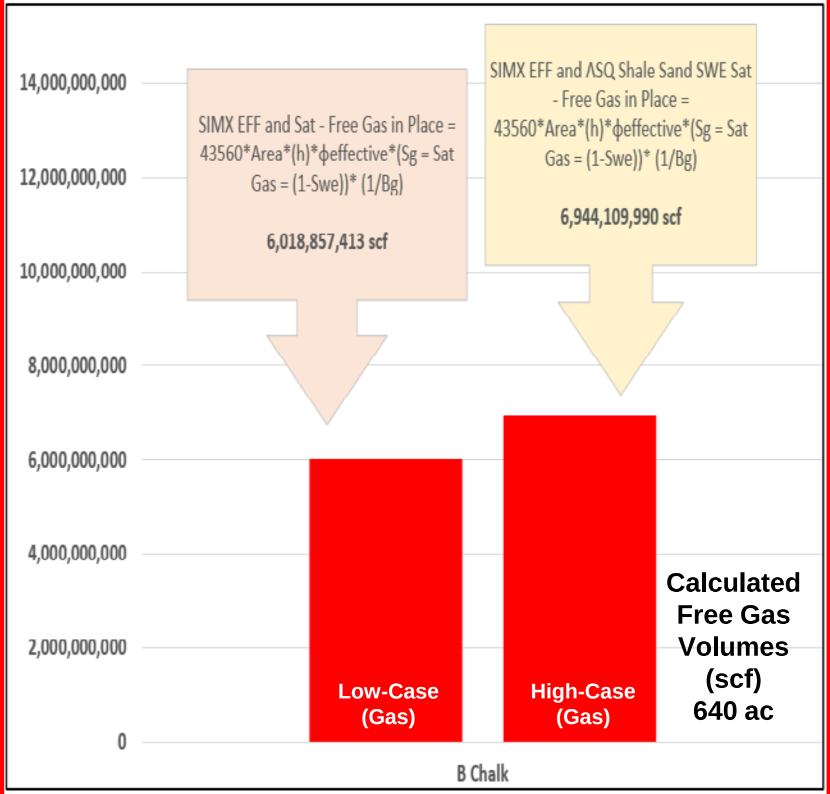

Index Map

# Hereford - Niobrara B Chalk

## Reserves




B Chalk – Average In-Place Reservoir Volumes (Est 640ac) :

Gas (High Case): **6.9 BCF** (Low Case): **6 BCF**

Oil (High Case): **8.5 MMBO** (Low Case): **7.4 MMBO**

# Hereford – Niobrara B Chalk

## Reservoir Quality – Pore Scale

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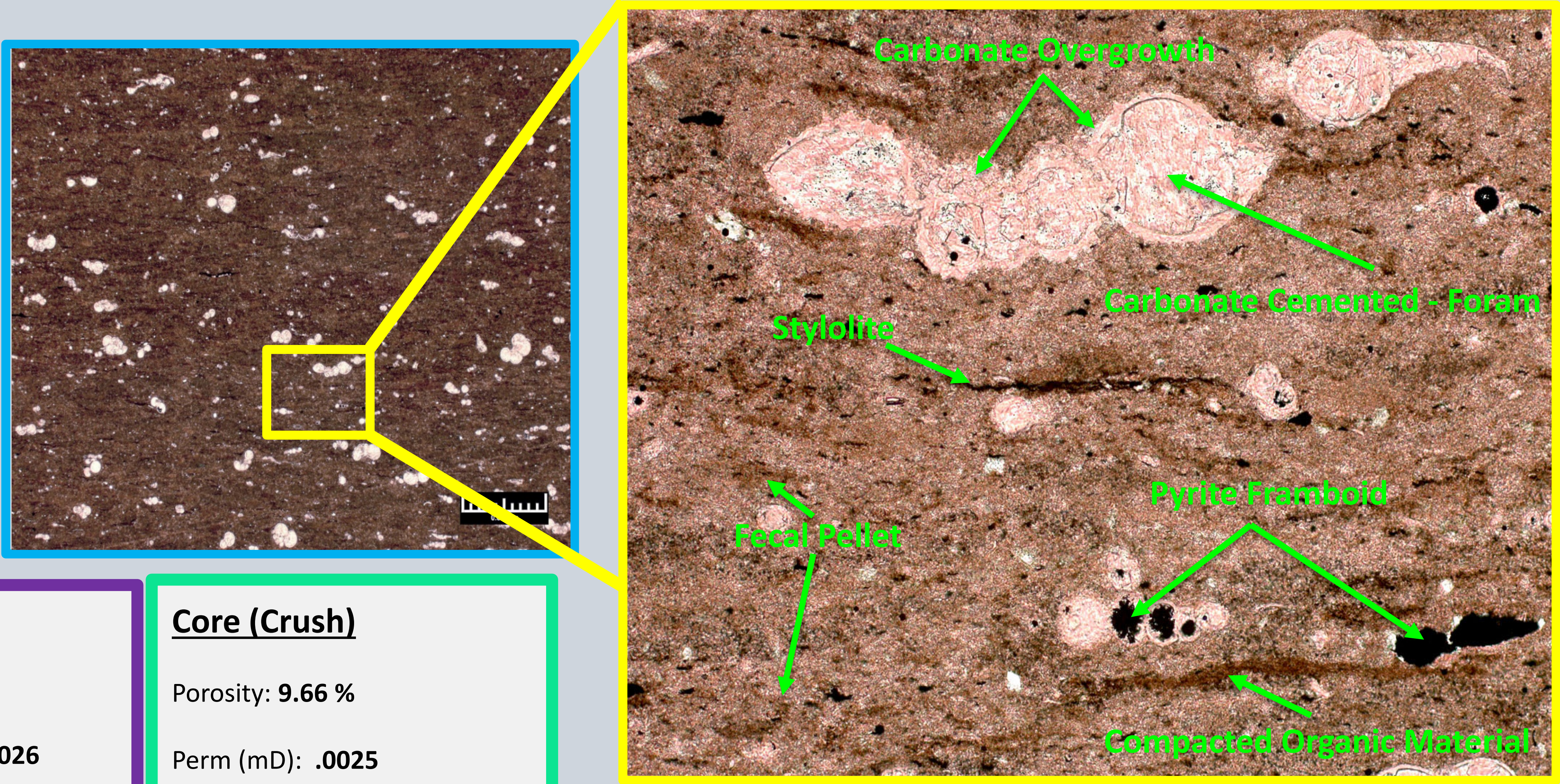
**XRD (wt.%)**

| | |
|---|---|
| Calcite: | **96.12** |
| Dolomite: | **0.07** |
| Siderite: | **0.02** |
| Fluorapatite: | **0.17** |
| Quartz: | **2.29** |
| K-Spar: | **0.00** |
| Pyrite: | **0.08** |
| Total Clays: | **1.24** |
| Marcasite: | **0.03** |
| Illite: | **0.06** |
| Kaolinite: | **1.07** |
| Chlorite: | **0.11** |




**MICP @ 6000 psi**

Porosity: **10.5%**

Pore Throat Radius (µm): **.026**

Perm (mD): **.00856**

**Core (Crush)**

Porosity: **9.66 %**

Perm (mD): **.0025**

Sat: 43% Oil, 47% Gas, 10% WTR

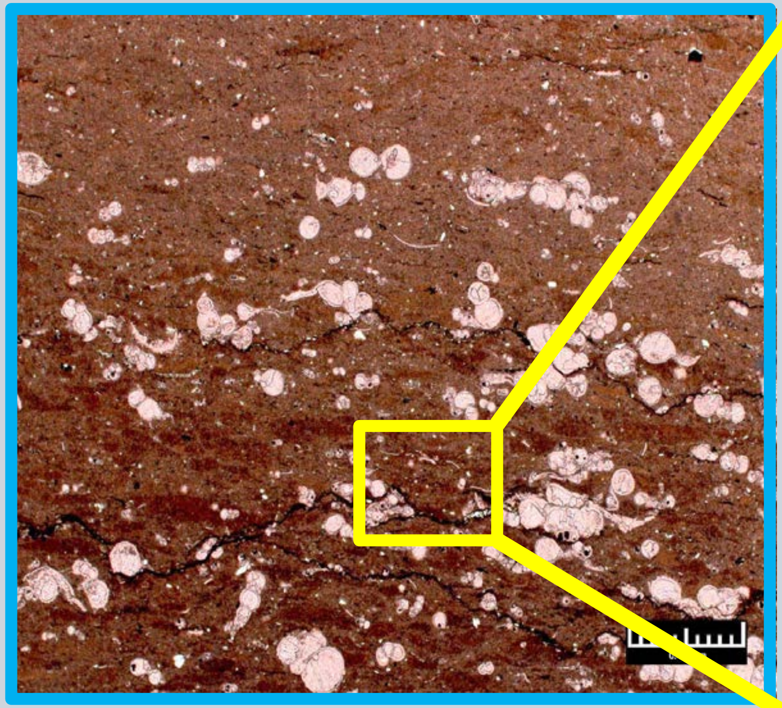
7413

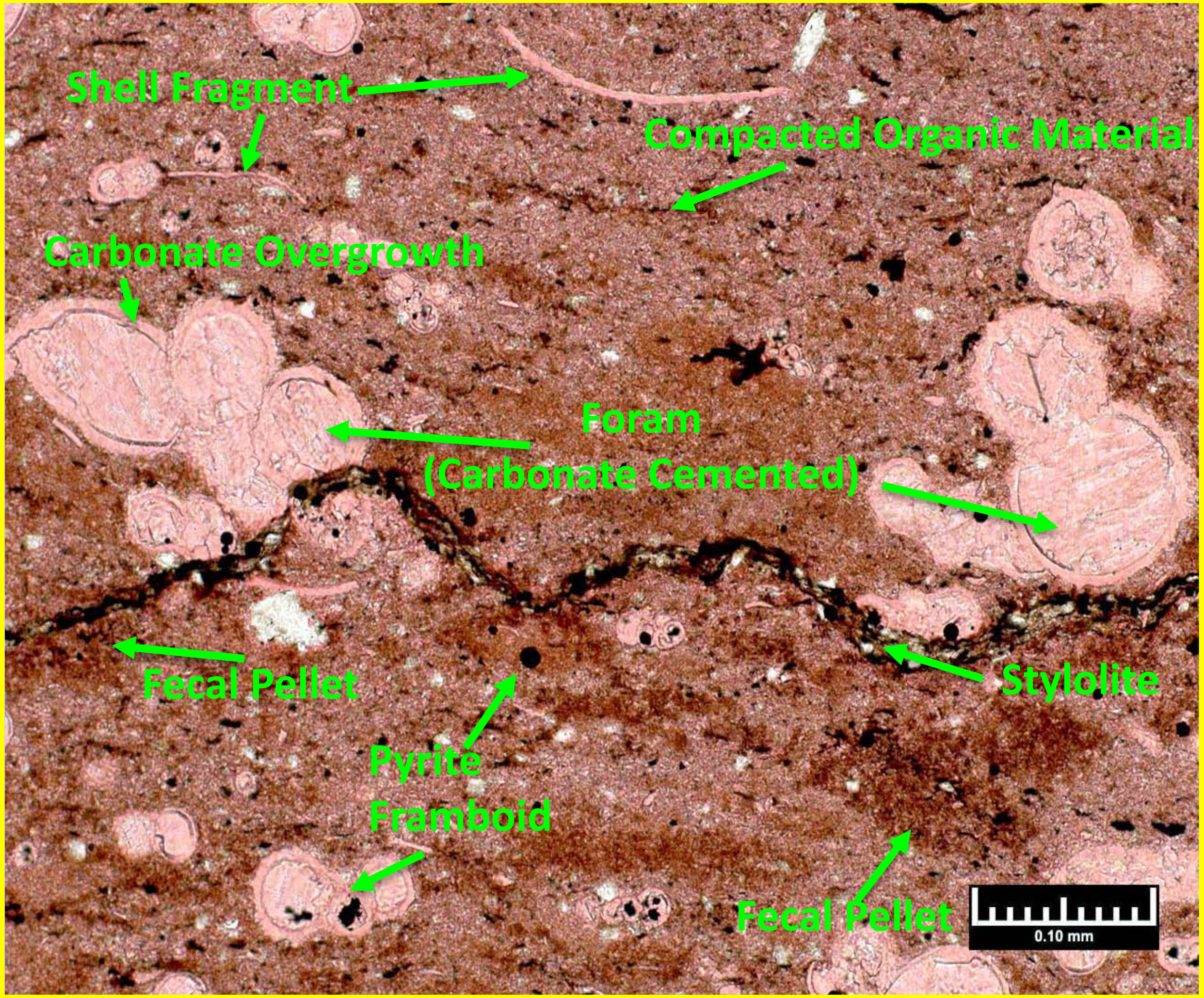
# Hereford – Niobrara B Chalk

## Reservoir Quality – Pore Scale

**XRD (wt.%)**

| | |
|---|---|
| Calcite: | **80.00** |
| Dolomite: | **0.00** |
| Siderite: | **0.00** |
| Fluorapatite: | **NR** |
| Quartz: | **4.00** |
| K-Spar: | **1.00** |
| Pyrite: | **2.00** |
| Total Clays: | **11.00** |
| Marcasite: | **NR** |
| Illite: | **6.00** |
| Kaolinite: | **1.00** |
| Chlorite: | **0.00** |






**MICP @ 6000 psi**

Porosity: **8.2%**

Pore Throat Radius (µm): **.02**

Perm (mD): **.00315**

**Core (Crush)**

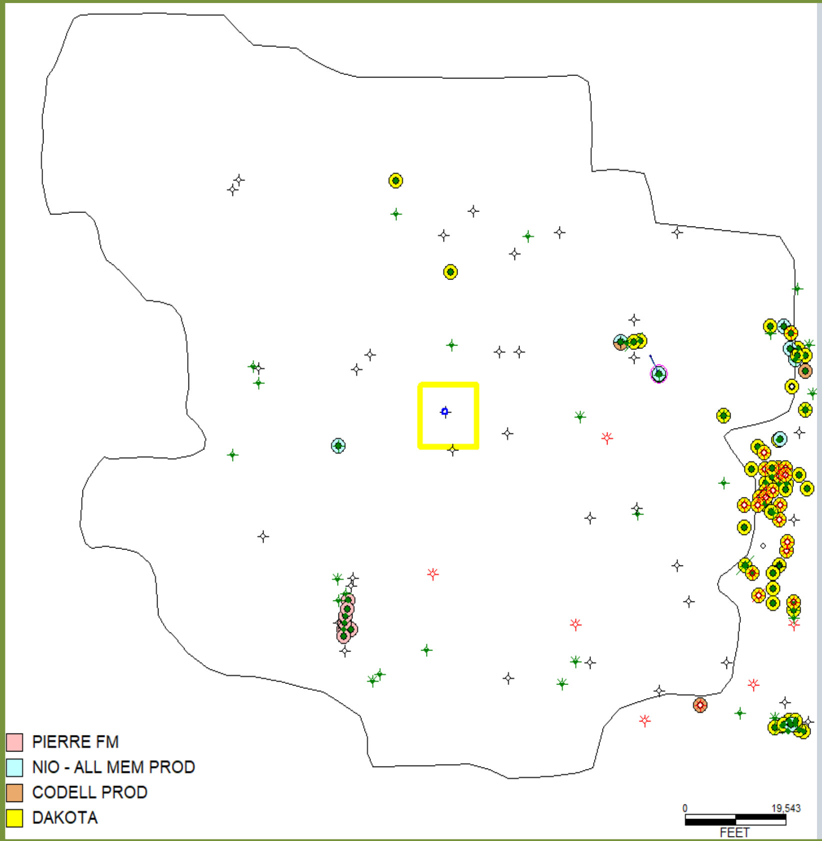
Porosity: **10 %**

Perm (mD): **.0033**

Sat: 30% Oil, 32% Gas, 38% WTR

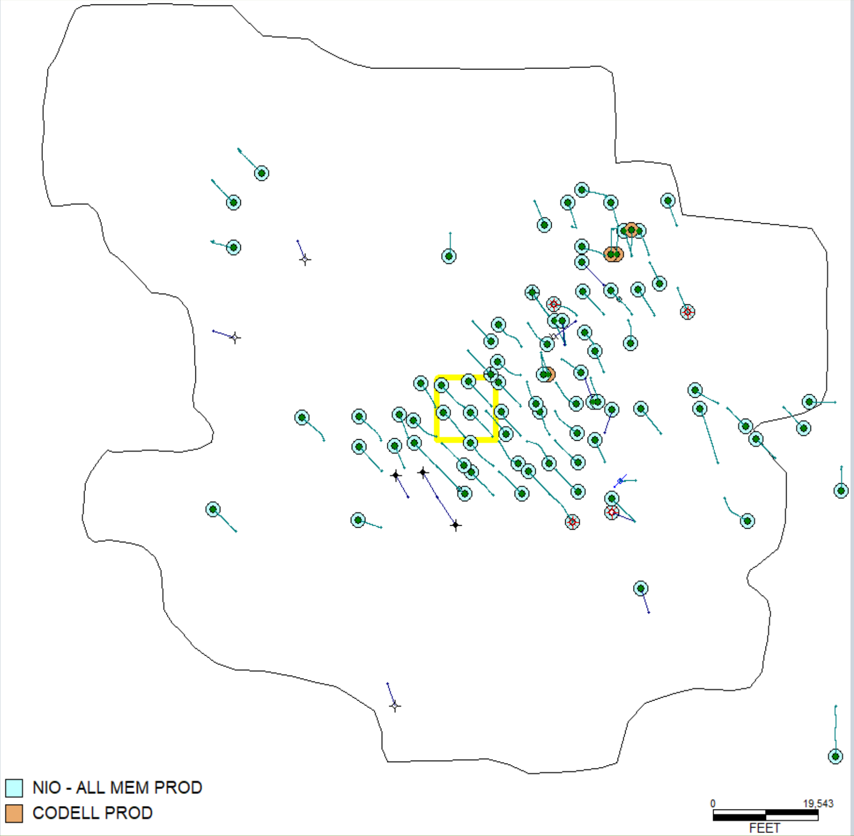
@ 7317

# Unconventional Production Evolution

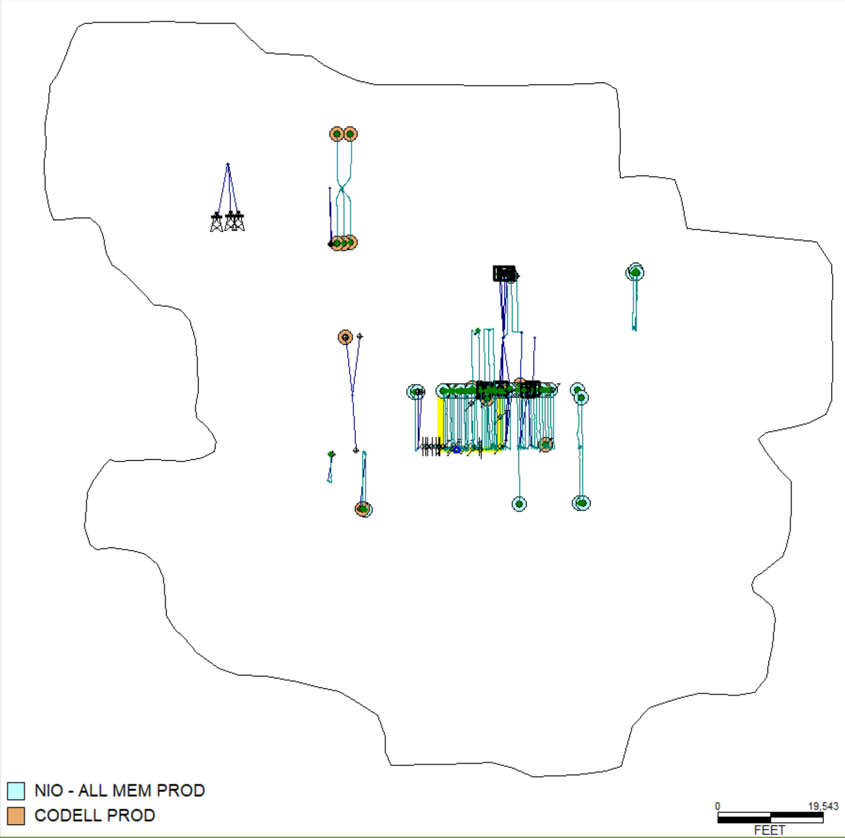



Existing Conventional Wells

*(Pre 2009)*



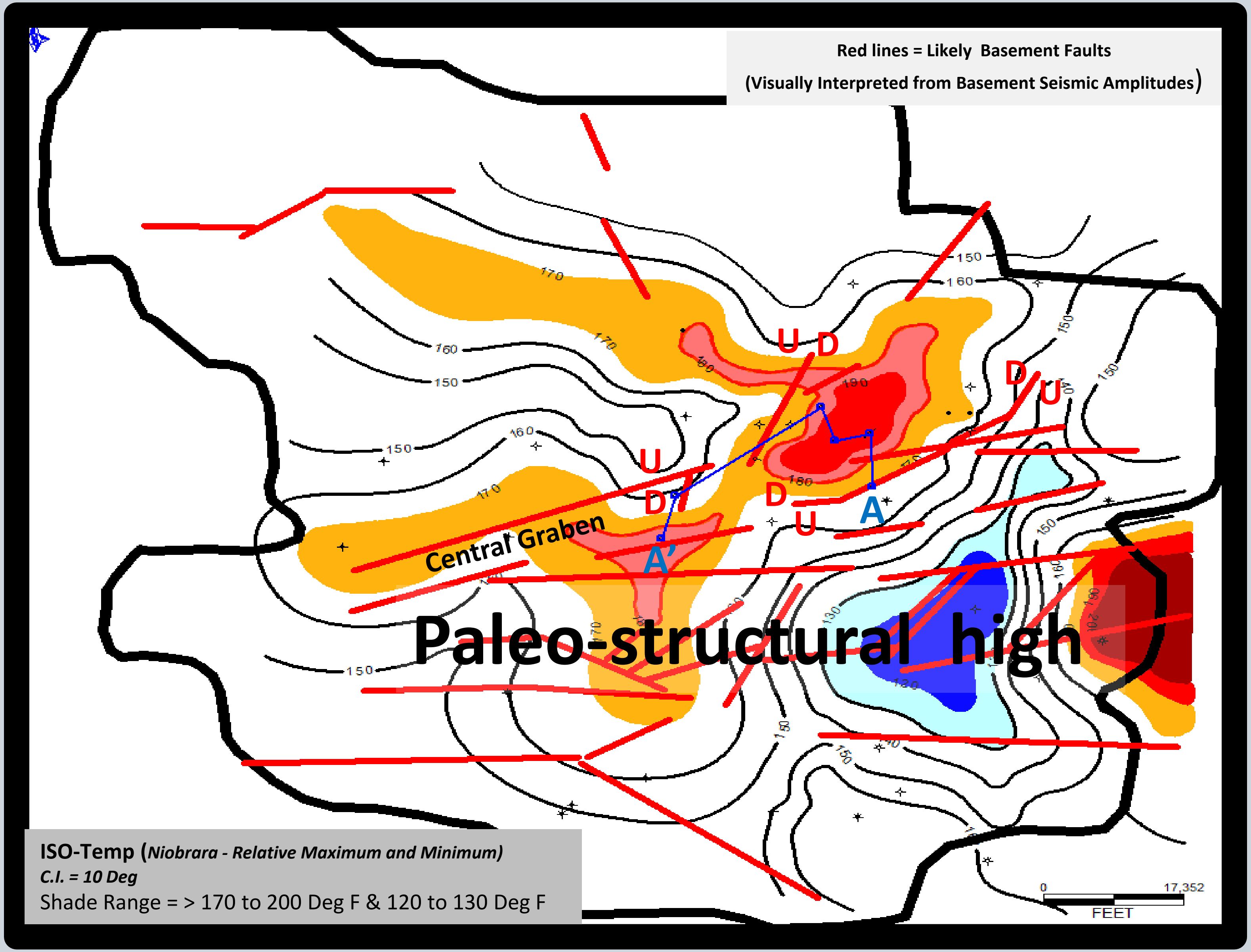

1st Generation Unconventional Wells
EOG
Uncemented Liner – Sliding Sleeve Completions (SRL)
*(2009 - 2015)*




2nd & 3rd Generation Unconventional Wells
Fifth Creek & HighPoint Resources
Cemented CSG w/ Plug & Perf Completions (SRL and XRL)
*(2015 - 2021)*

# Hereford Niobrara B Chalk

## Unconventional Reservoir Quality

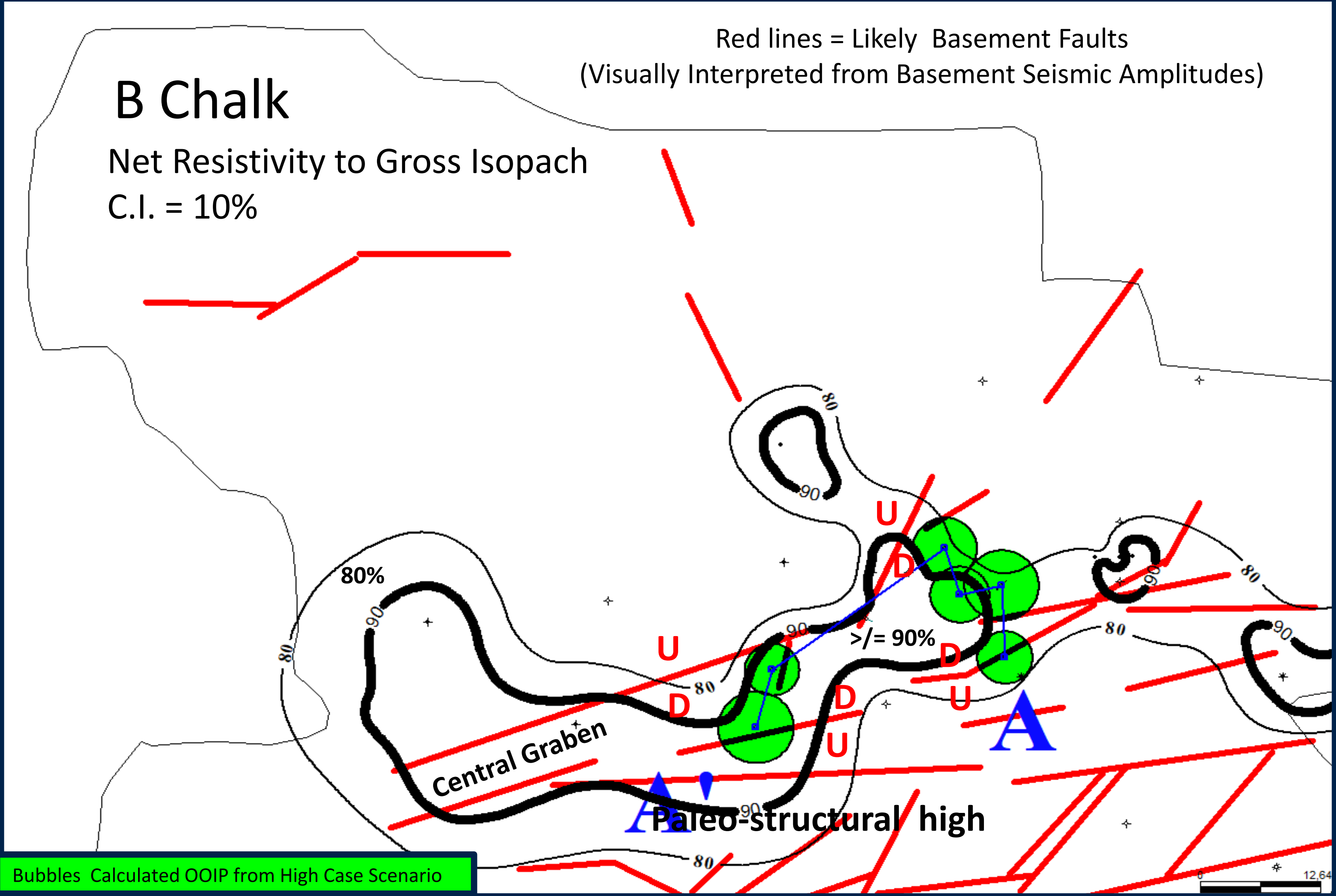



### Paleostructure / Temperature Relationships

- Hereford consists of a large positive paleostructure that bounds the field's southern boarder
- The field contains a main central graben trending NE-SW, defining the heart of the productive Hereford field
- Two distinct fracture systems: NE-SW orientated sheer system and a E-W orientated extensional system
- Well log derived temperature gradients suggest the primary formation temperature anomaly exists exclusively with the confines of the field's central graben
- Tmax values throughout the field show poor correlation to formation temperatures suggesting the potential for earlier heat emplacement, preceding the field's ultimate Niobrara Tmax timing

# Hereford Niobrara B Chalk

## Unconventional Reservoir Quality




Bubbles Calculated OOIP from High Case Scenario

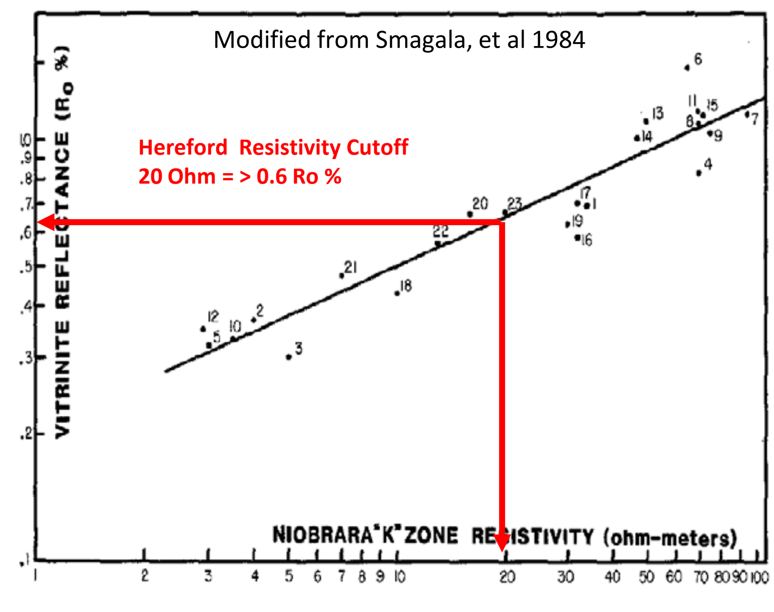


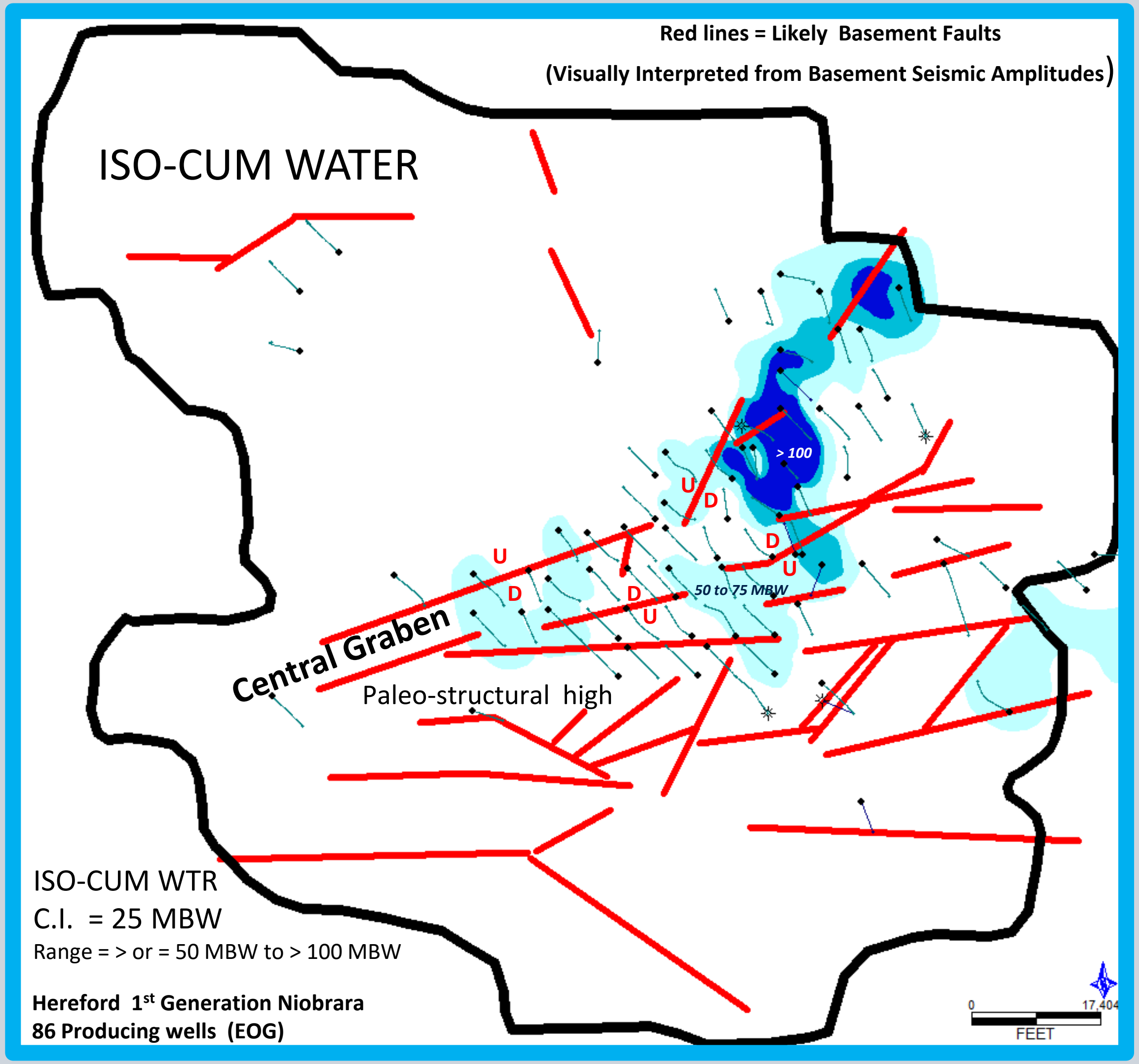

Figure 9. Niobrara vitrinite reflectance versus "K" zone resistivity, Denver basin.

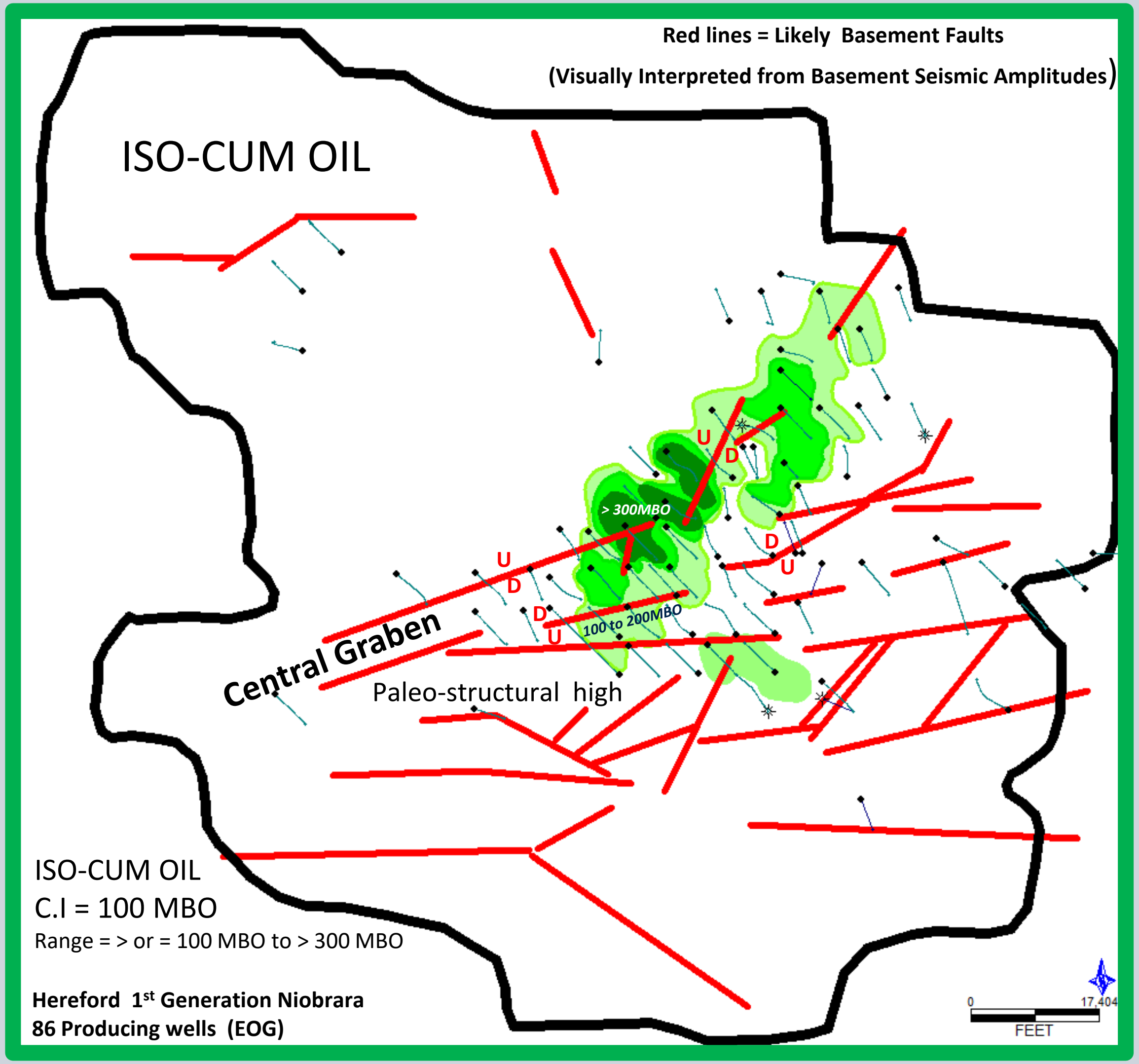
% Formation Net Res. to Gross Formation

Niobrara Net Res.
Cutoff = (>/=) 20 Ohm RT 80

# Hereford Reservoir Delivery

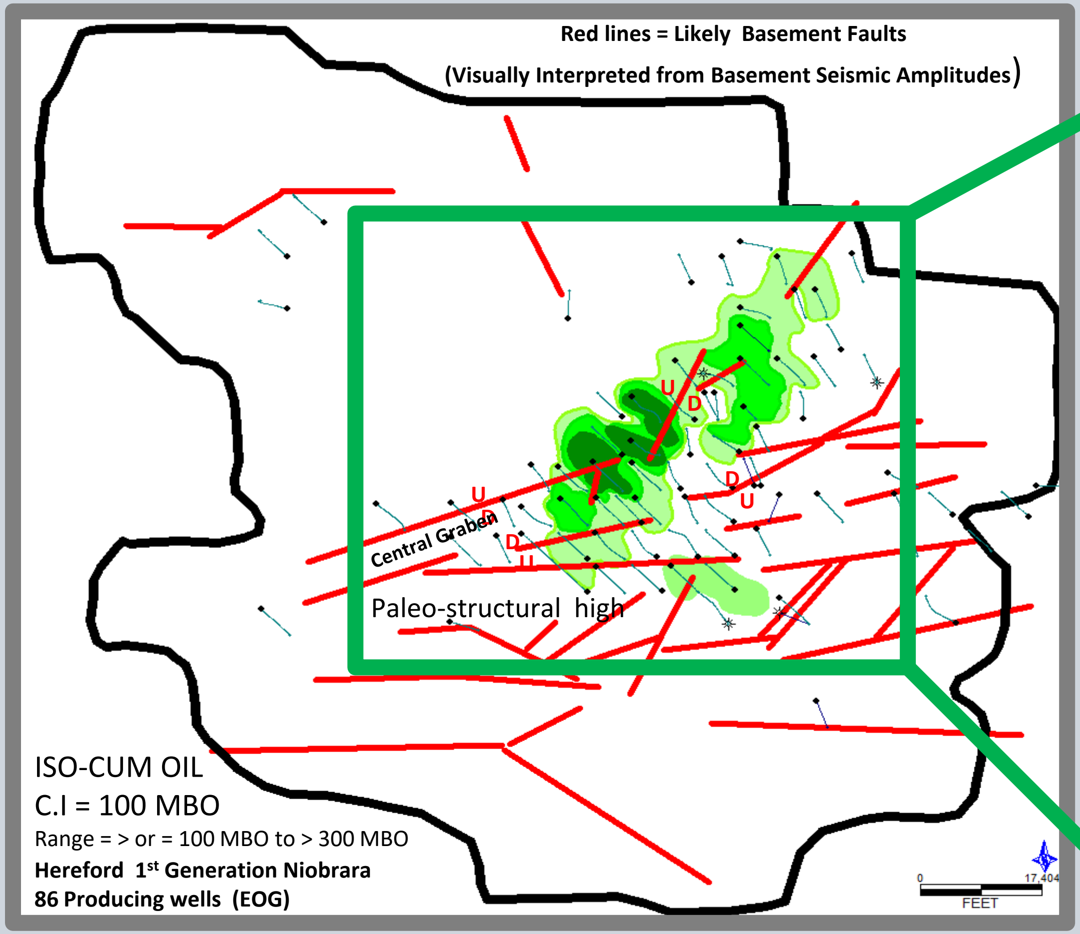
## 1st Generation Well Performance

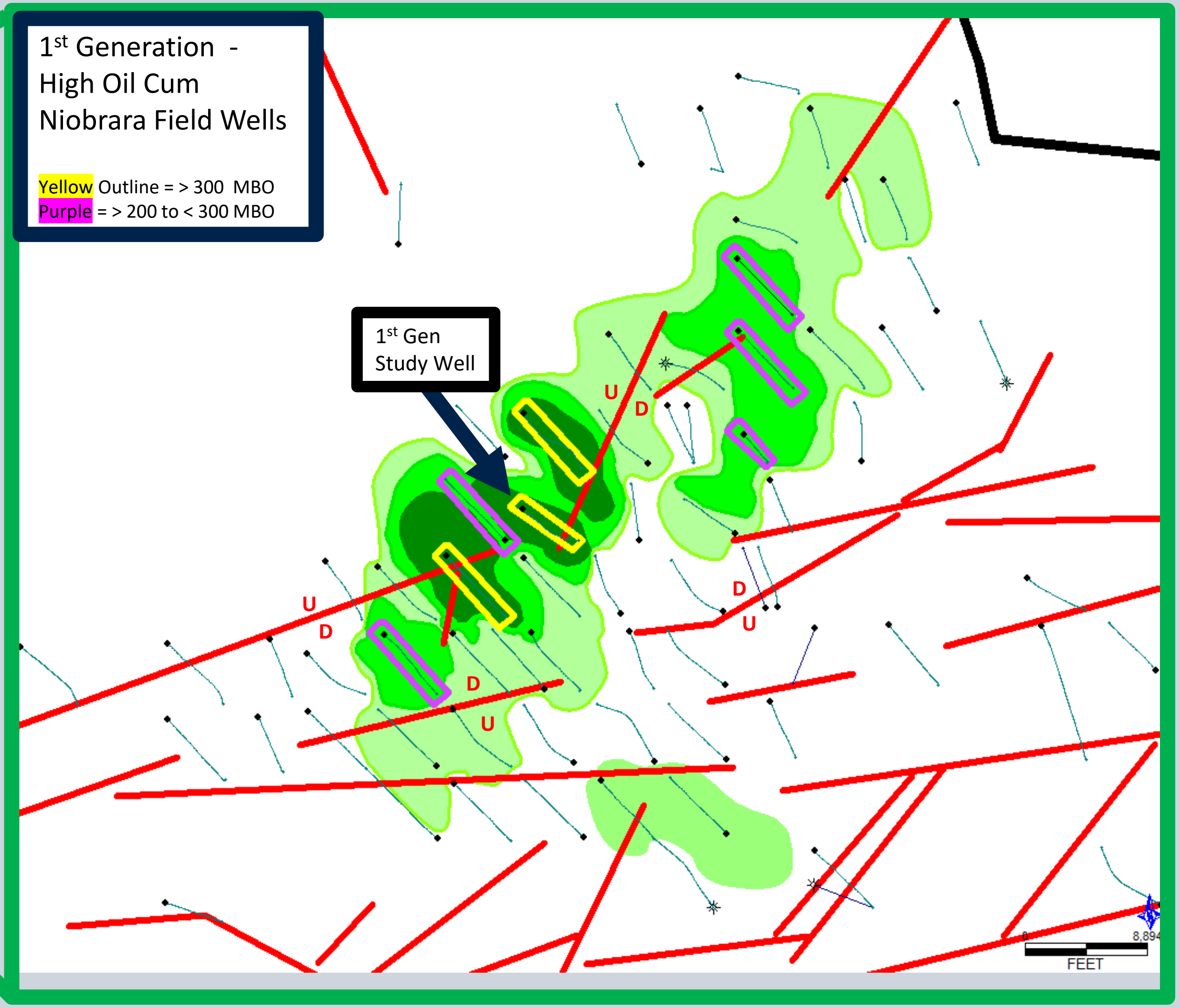


# Hereford Reservoir Delivery

## 1st Generation Well Performance




## Hereford 1st Gen Niobrara Well Production Highlights

3 wells (> 300MBO) = 1,010,683 BO Cum Production

6 wells (200 to 300 MBO) = 1,240,127 BO Cum Production

* *8 out of 86 total producing wells = 30% of the total field's Niobrara production*

# Hereford - Niobrara Reservoir Delivery

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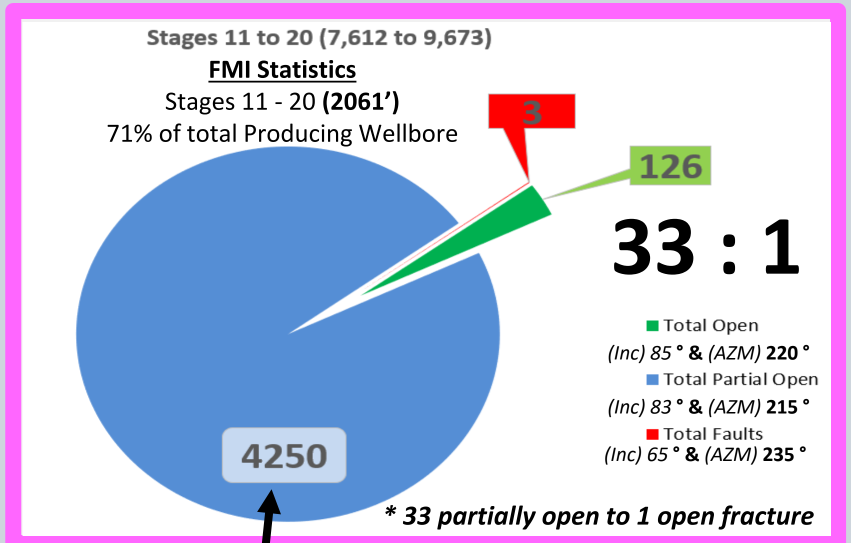
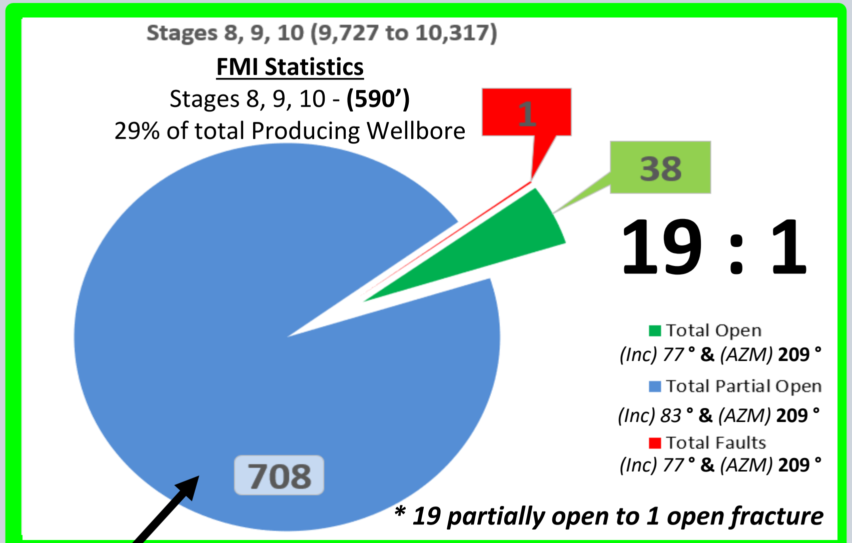
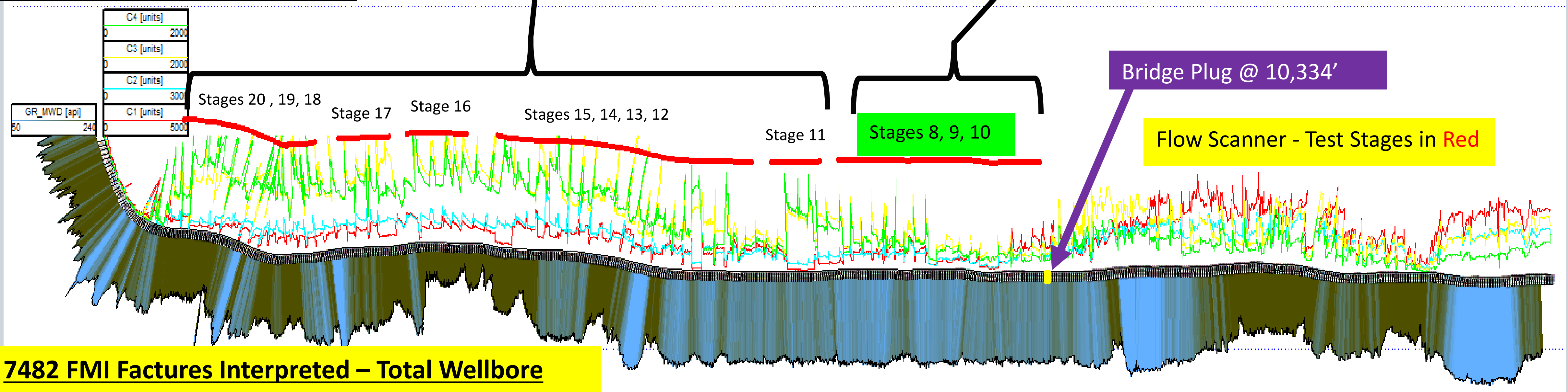
EOG 1st Generation Niobrara
Study Well Date: 7/3/2010
IPF: 622 BO + 407 MCF & 110 BW
Oil Gravity: 35.3
Cum: 334 MMBO + 525 MMCF

Schlumberger Flow Scanner Test

Stages: **8, 9,10** (9,727 – 10,317MD)
**335** BOPD – Pre-IP well test
**~80%** of the lateral production

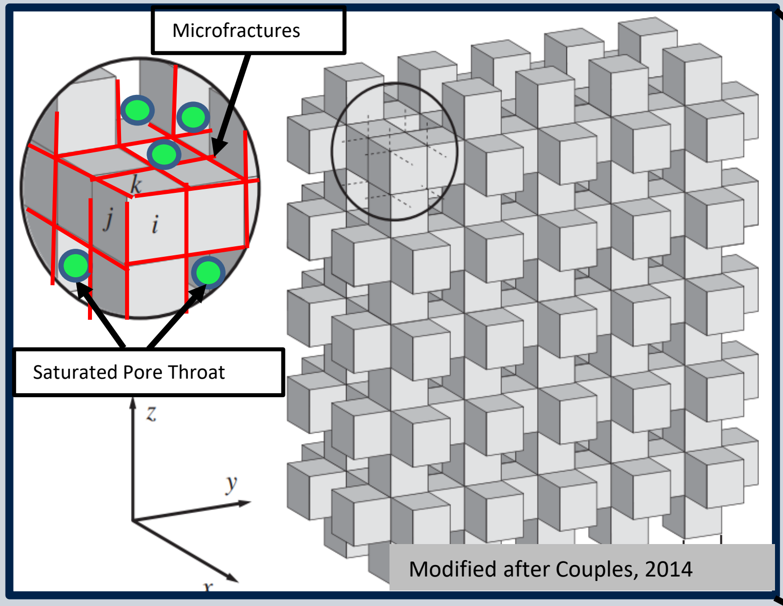


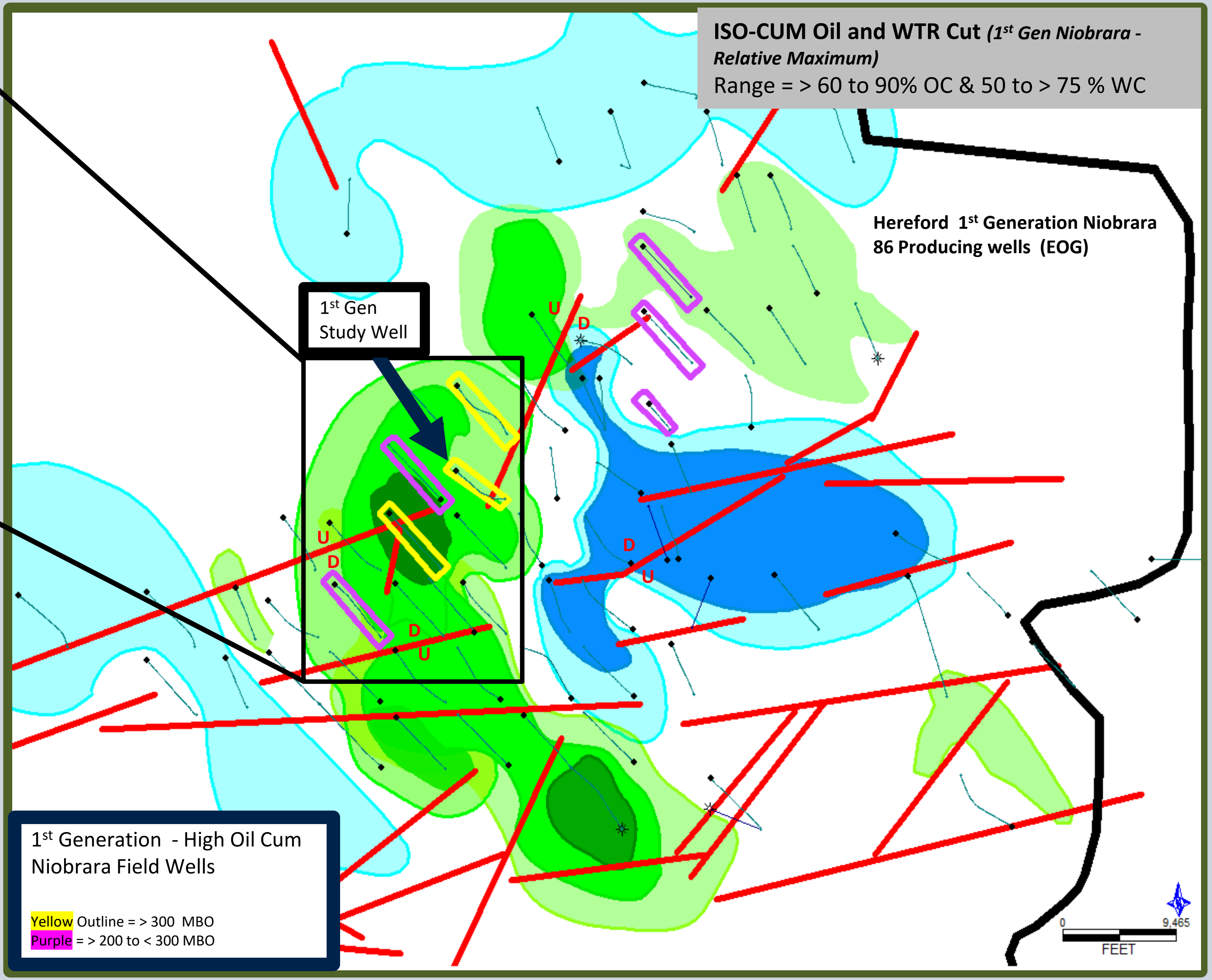



# Hereford Reservoir Delivery

## 1st Generation – Niobrara Well Performance




***Niobrara B Chalk - Dual Porosity Model (Idealized)***




## Niobrara – "Damage Zone Reservoir"

- ✓ Fracture apertures intersect a controlling frequency of matrix pore-throats
- ✓ Fracture network within the damage zone's have likely been enhanced due the micro hydraulic fracture generated by the expansion and expulsion of hydrocarbons during kerogen transformation
- ✓ Data suggest the relative permeability and capillary forces differ greatly withing damage zone matrix vs the intact chalk matrix
- ✓ Damage zones facilitate conventional reservoir dynamics in the Hereford Niobrara Formation
- ✓ Systematic pressure depletion in the connected damage zones have reduced relative permeability, and potentially Niobrara's subsequent field recovery factor

# Conclusions

## Niobrara Reservoir Deliverability

**Niobrara B Chalk**

- *Structurally-controlled*
  - Fracture controlled by Hereford's primary NE – SW shear faults
  - Dual-porosity, with overprinting fracture dominance within the connected basement faults damage zone
  - Graben-centered, formation temperature anomaly likely connected to underlying structural complexity and hydrocarbon generation

- **Damage Zone Reservoirs (DZR)** *Characterization and Deliverability*
  - Contained primary NE – SW shear fault's fracture halo
  - Fracture frequency likely enhanced by hydraulicly generated fractures during the conversion of kerogen confined within the chalk and marl matrix
  - Fracture apertures largely control pore throat fluid-flow and relative permeability
  - Reduced bubble point and subsequent relative permeability reduction facilitated by volumetric depletion during legacy fluid production
  - 1$^{st}$ Generation cumulative oil cut distribution appears reactive to paleo-structure, suggesting high reservoir connectivity and conventional style oil migration within the **DZR**
  - Relatively high GOR = lower bubble-point pressure and breakout and structural buoyancy contrast

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