Preliminary Geological Overview of the Chalk Bluff Area: Reservoir Characteristics and Production Evolution

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Presentation Outline

- Personal Research Outline / Planned Geological Workflow
- Denver Basin Geological Overview
- Chalk Bluff / Hereford Field Introduction
- Project Data Distribution
- RCP Chalk Bluff - Geological Team Integration
- Stratigraphy and Reservoir Statistical Overview
- Hereford Field - Historical Production Development
- Base Rock Quality / Reservoir Performance Modeling
- Conclusions (Preliminary)

Sonnenberg 2011

Personal Research Outline and Planned Geological Workflow

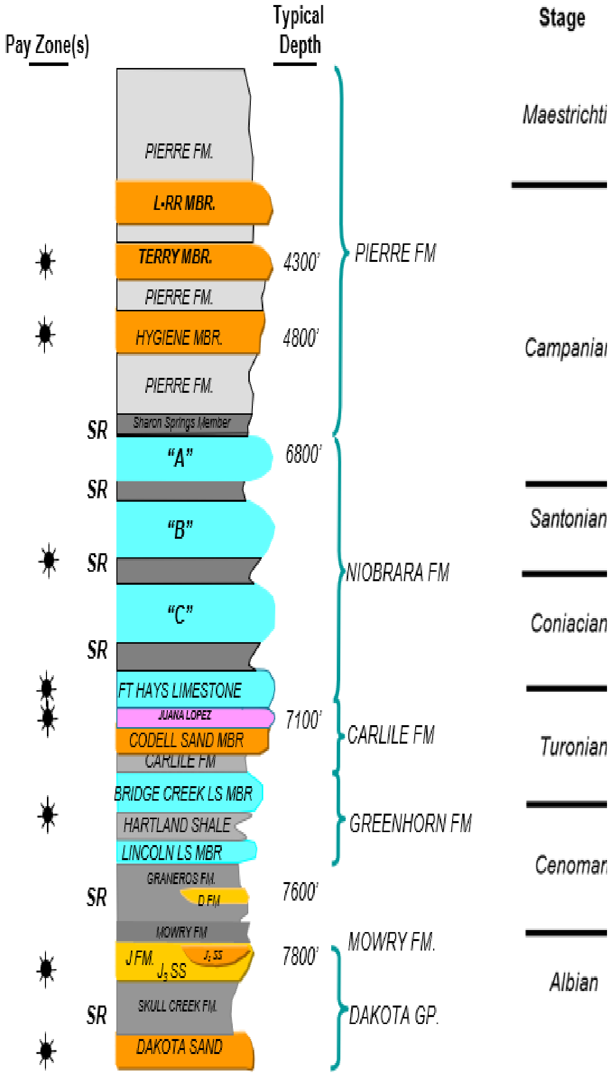
- Phase I:
  - Construct Regional Reservoir Characterization and Performance Model
    - Well performance (legacy and latest generation) evaluation and mapping
    - Rock quality and petroleum system mapping (continual)
    - Supply geological support and interpreted data / observations to the RCP - Chalk Bluff team

- Phase II:
  - Integration of the Chalk Bluff - High-Resolution Geological Data to Enhance Model Precision
    - Reconcile geological controls on reservoir performance
    - Incorporate geologically calibrated seismic interpretations developed by geophysicists within the RCP Chalk Bluff team

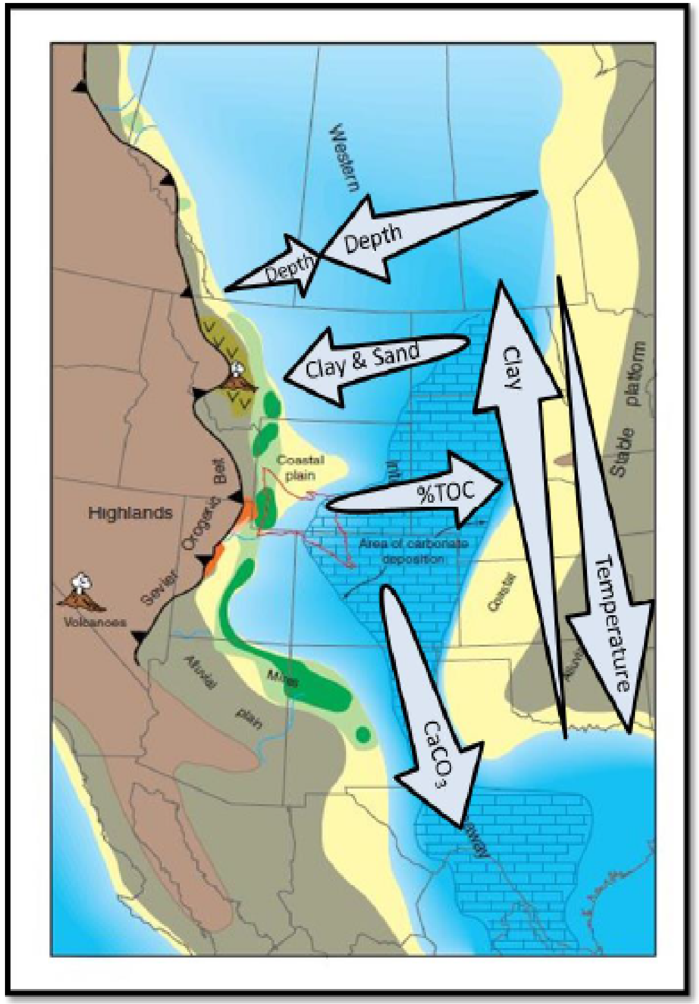
- Phase III:
  - Chalk Bluff Project Team Recommendations / Research Observations: Fracture and Fault Characterization, Reservoir Optimization and Enhancement Planning

Denver Basin Overview

- Formed during a transgressive event that connected the Artic Ocean to the Gulf of Mexico
- Foreland Basin active from the Paleozoic Era
- Water rich in nutrients and $CaCO_3$ mixed throughout the transgressive Western Cretaceous Interior Seaway
- Volcanic Input (Siliciclastic) from the NW
- NW trending faulting (Precambrian) & NE trending shear zones – *reactivation from Paleozoic to Cretaceous*
- The Niobrara and Codell formations deposition occurred within the Western Cretaceous Interior Seaway
- Niobrara Deposition = Late Cretaceous (81 to 89 Ma)
- Codell Deposition = Late Cretaceous (89.8 Ma)



Sonnenberg



Modified from Roberts and Kirschbaum (1995) and Longman et al. (1998)

Figure 1.6: Image displaying the Cretaceous Western Interior Seaway and depositional patterns seen by Longman et al. in the 1998 study.

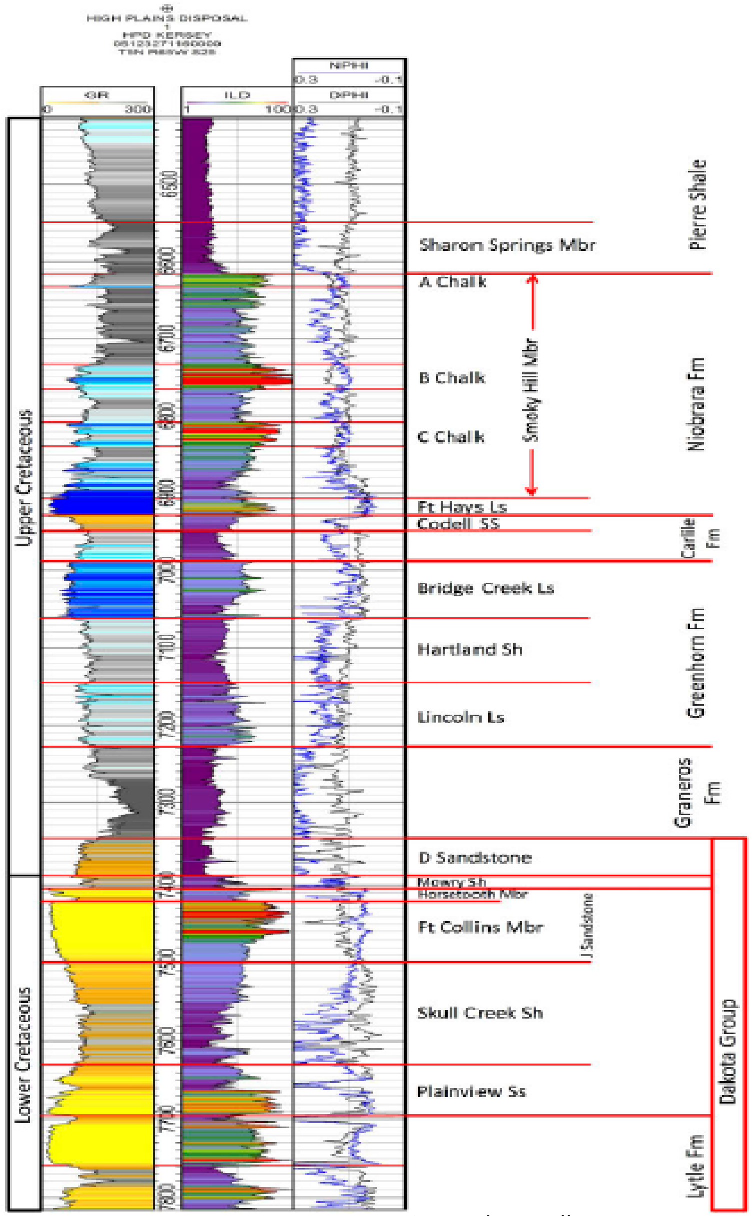
Denver Basin Stratigraphy

Major Unconventional Petroleum Systems / Reservoirs

- **Niobrara Formation** (Santonian - Turonian Age)
  - Sequences of Chalk (> $CaCO_3$) (Regressive) and Intervening Organic-rich Marls (Transgressive)
  - Composed of Planktonic Foraminifera, Coccoliths, Fecal Pellets, Oyster Shell Fragments, Quartz, Silt, and Clay
  - TOC Range: 1 to 8%
  - Thermally Mature throughout the Basin
  - Low Permeabilities and can be Extensively Fractured

- **Codell Sandstone** (Turonian Age)
  - Marine Shelf Sand - Deposited as a part of the Frontier Pro-Delta growing from the West
  - Lithofacies consist of Fine-grained Sand, Silt, and Clay (Authigenic & Detrital)
  - Niobrara charged – "Carrier Bed Reservoir" (Sonnenberg)

Figure 7. DJ Basin Type Log



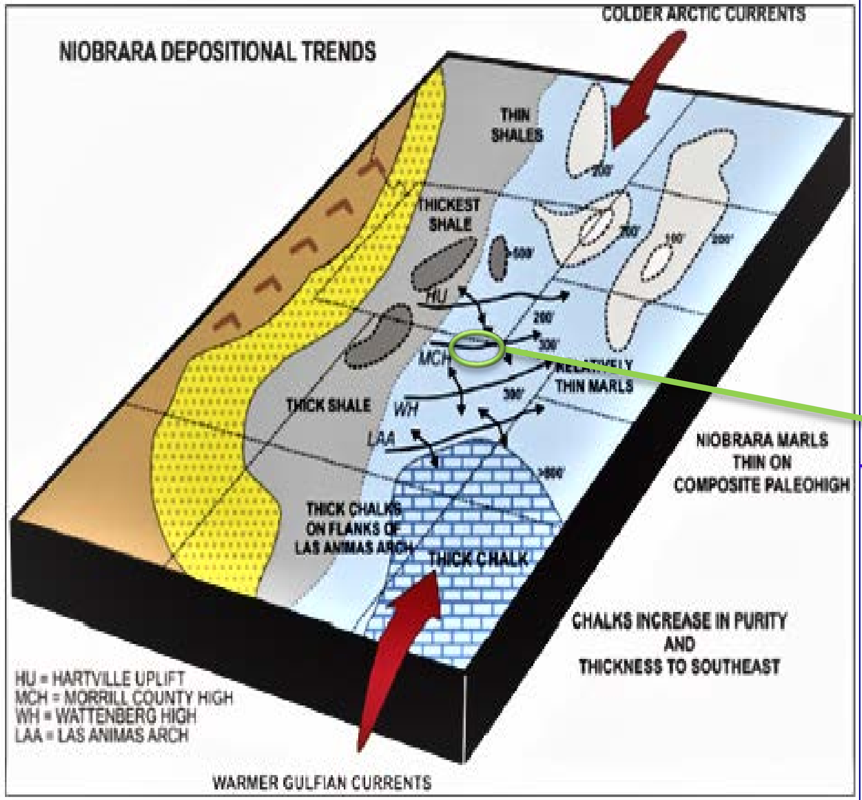
Mine and Cumella, 2014

Hereford Field Area

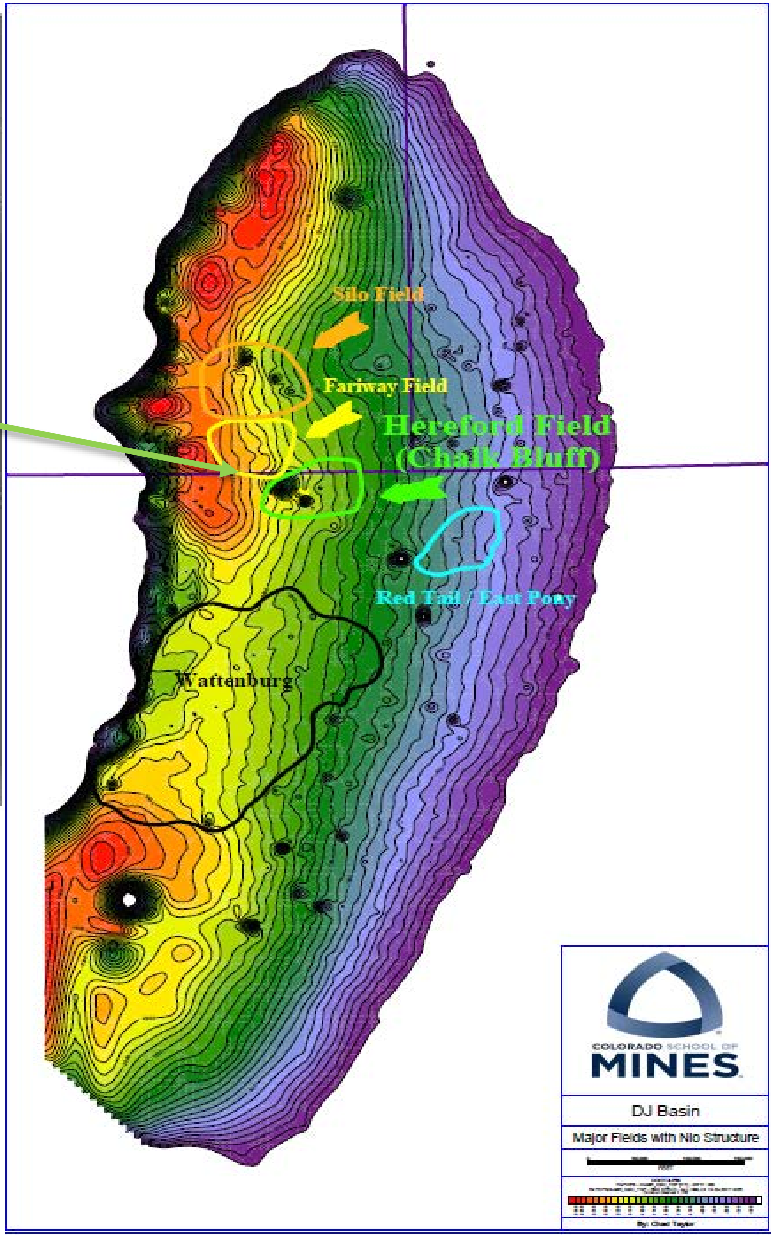
Hereford Field

Northern Weld County, Colorado

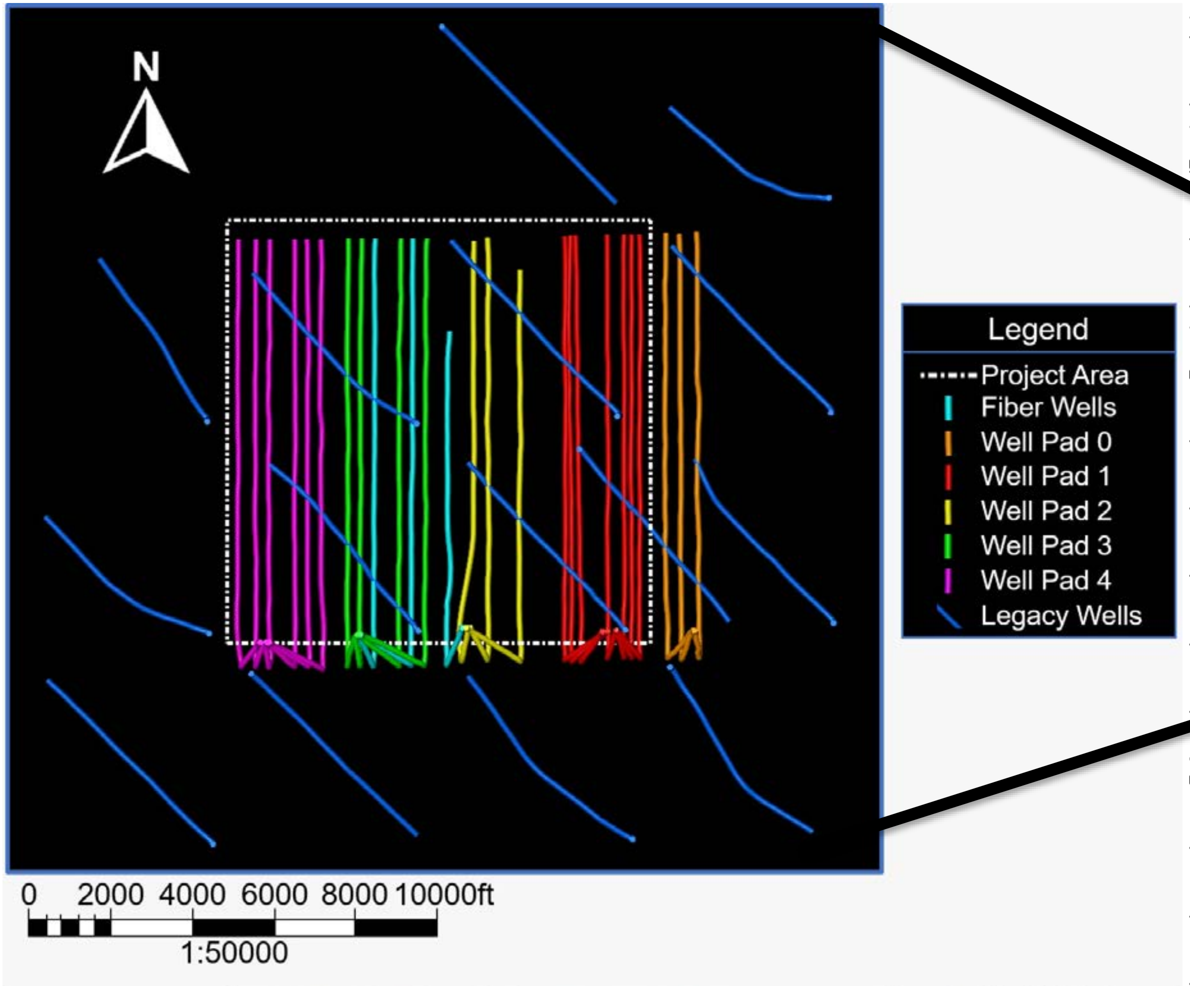
- Productivity Controls
  - Associated Thermal Anomaly
  - Downdip to Deep Paleobathometry
  - Regional Paleostructure
    - Morrill County High
- Primary Unconventional Reservoirs
  - Niobrara B Chalk
  - Codell Sandstone
- Secondary Targets
  - Niobrara B1 Chalk
  - Niobrara C Marl / “M” Zone
- Field Significance
  - DJ Basin horizontal Niobrara play kicked off in the Hereford Field with the drilling of the EOG Jake 2-01H well (555 bop/d IP90) in 2009
  - > 3.5 BBOE OOIP - *HighPoint Estimate

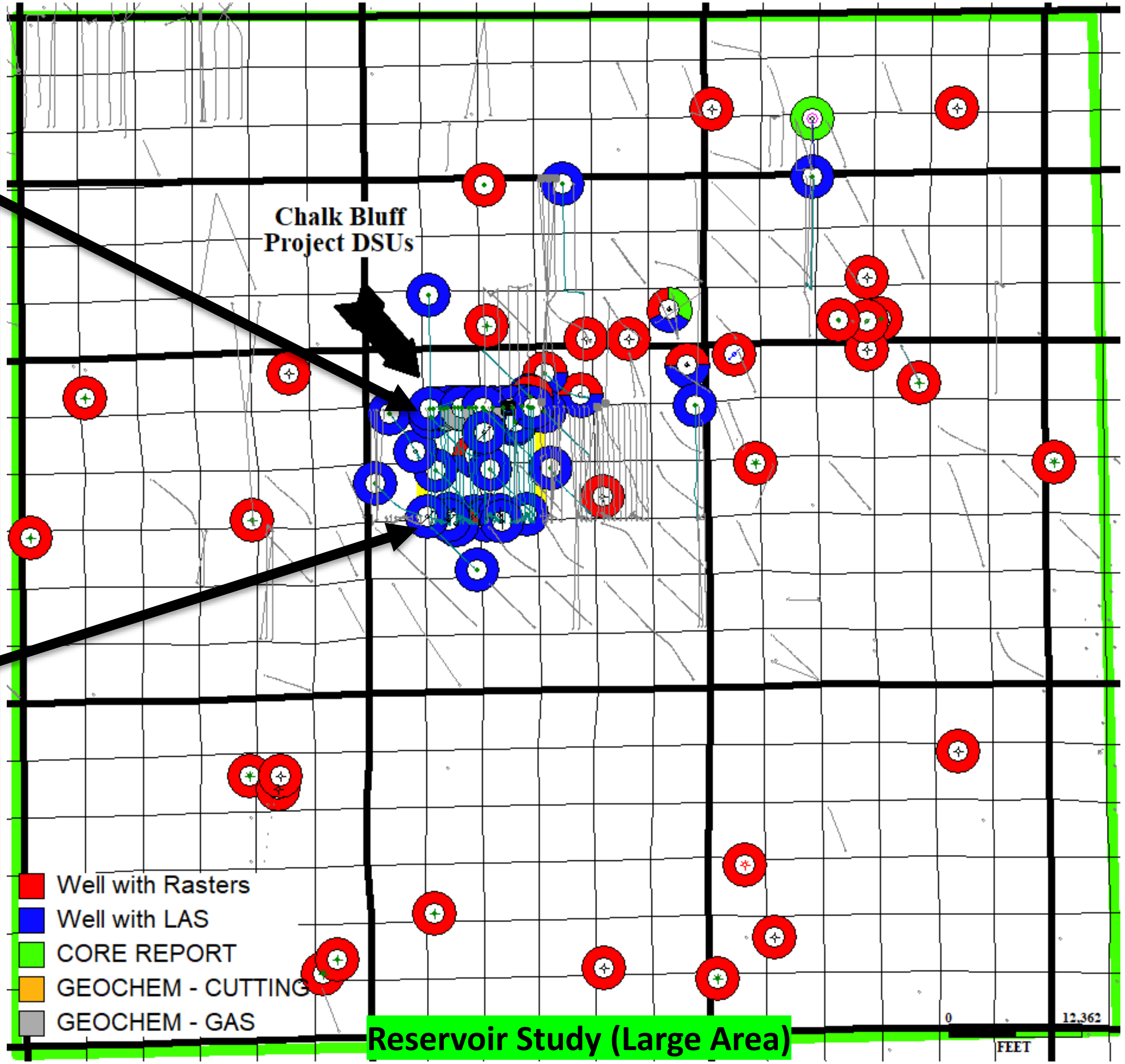


(modified from Longman et al., 1998

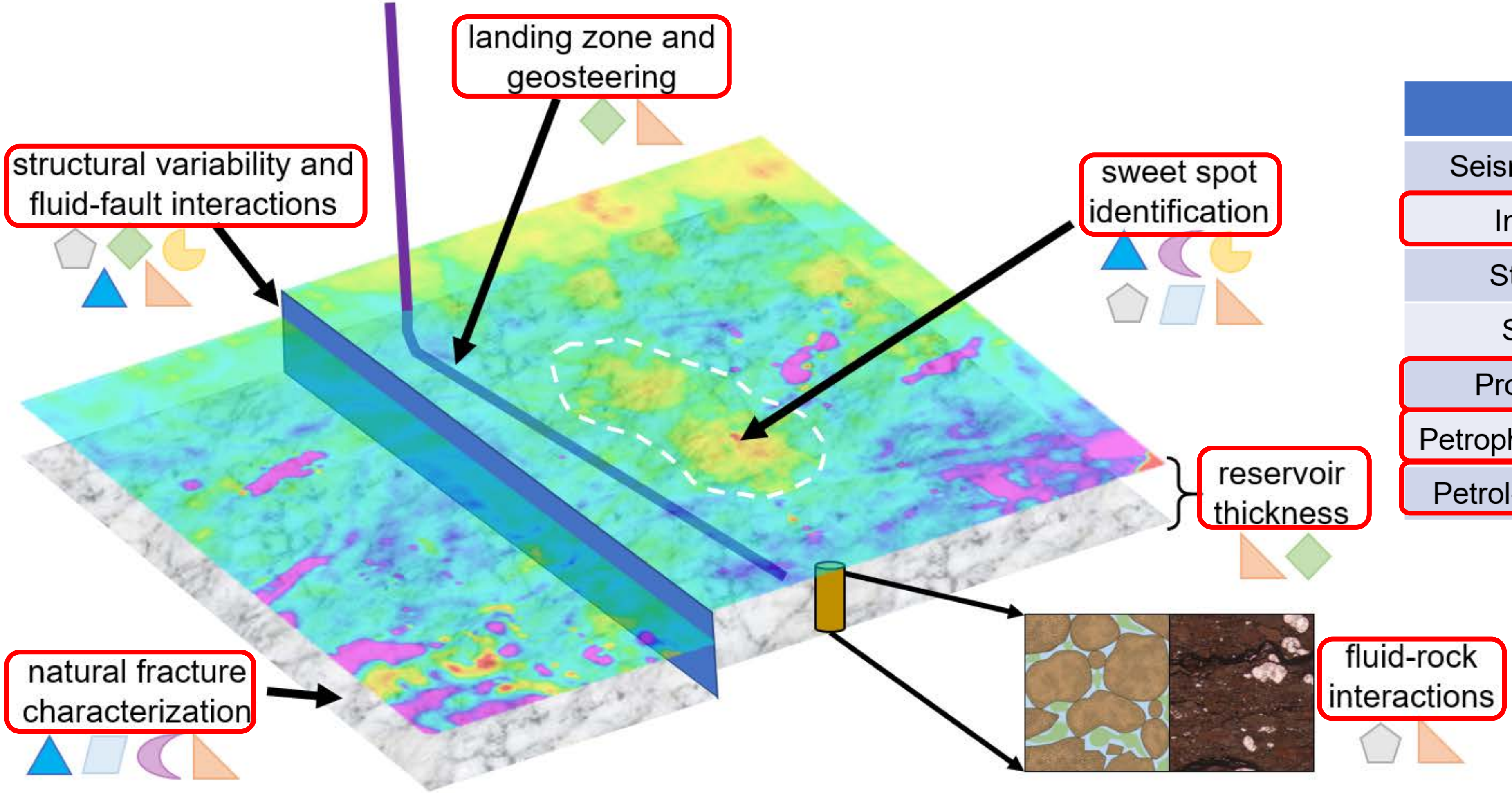


Study Data Distribution





Characterizing Geologic Heterogeneity



Method	Symbol
Seismic attribute analysis	▲
Image log analysis	▱
Structural modeling	◆
Seismic inversion	☾
Production evaluation	◔
Petrophysical characterization	◺
Petroleum systems analysis	⬠

Hereford Stratigraphy & Reservoir Overview

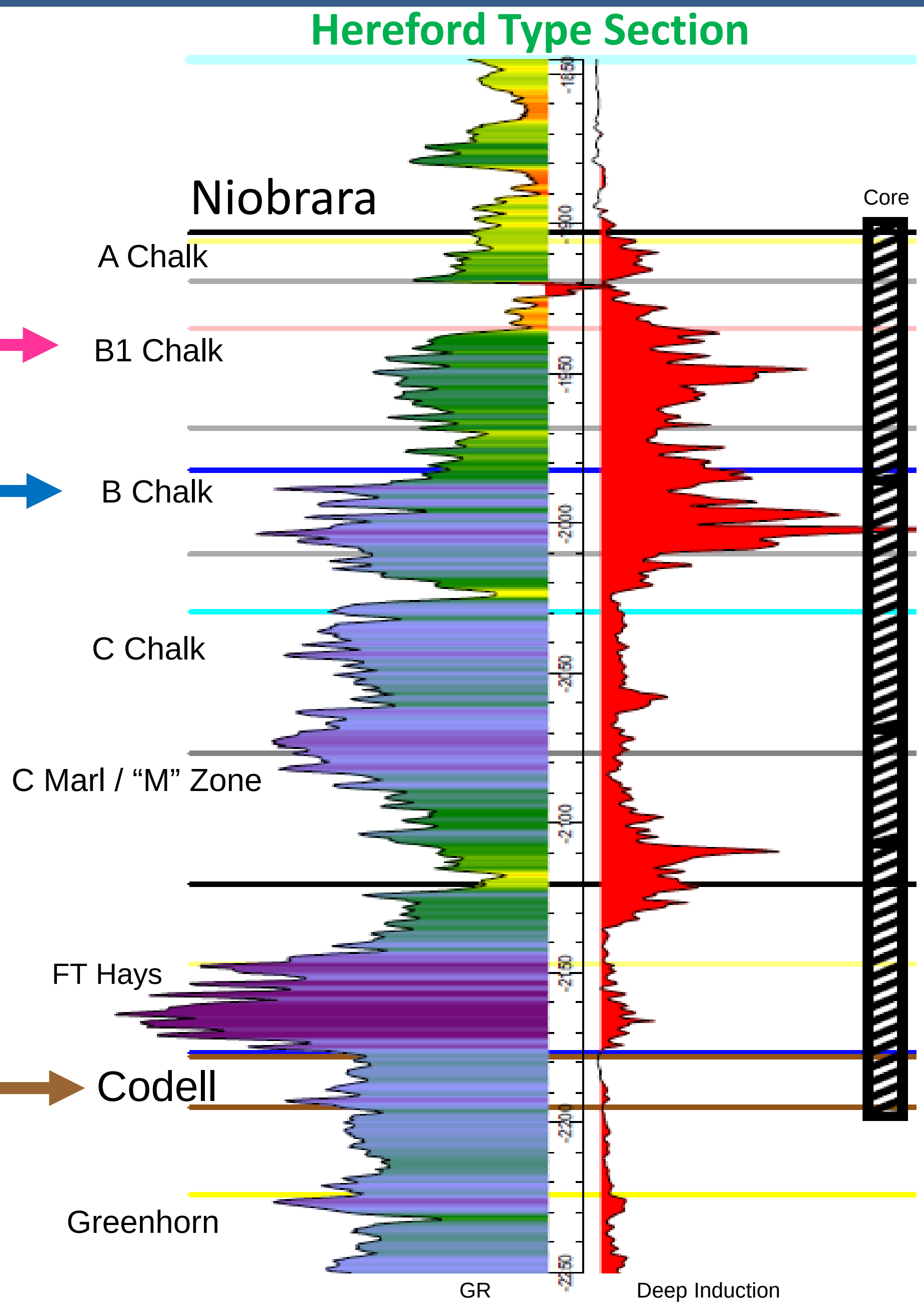
Model Statistics (As of 11-1-20)

B1 Chalk
- Avg Thickness: 29’
- Range (8 to 52’)
- > / = 20 ohm/m (DIL): 0 - 34’ (14’ Ave)

B Chalk
- Avg Thickness: 36’
- Range (20 to 56’)
- > / = 20 ohm/m (DIL): 0 to 43’ (25’ Ave)

C Marl
- Avg Thickness: 45’
- Range (10 to 72’)
- > / = 20 ohm/m (DIL): 0 to 26’ (5’ Ave)

Codell
- Avg Thickness: 16.5’
- Range (<1 to 25”)
- > / = 4 ohm/m (DIL): <2 to >19 (7.4’ Ave)



Hereford Production History T1

Wells Spud Pre 2009

Conventional – Small Completion

Niobrara Production

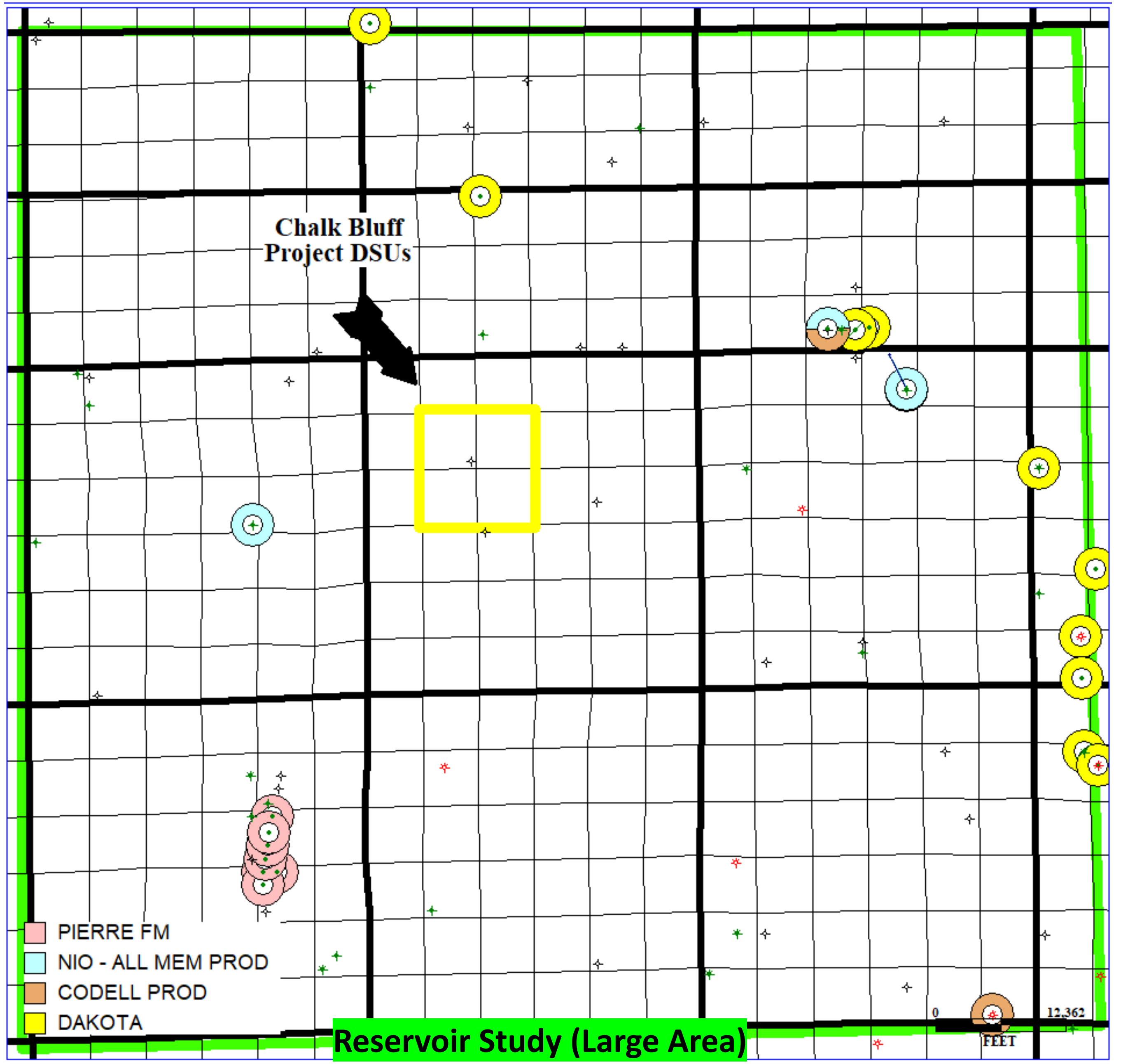
- **Avg / Well Niobrara Production (Cum):** < 6MBO & 1.9 MMCF & 15 MBW
- **Max Cum:** 45 MBO + 6 MMCF & 53 MBW

- **Avg IP:** 34 BOPD + 61 MCF & 13 BWPD (GTY 34 - 35)
- **Max IP Volumes =** 109 BO / 142 MCF / 85 BWPD

Codell Production

- **Avg / Well Codell Production (Cum):** 2.6 MBO & 2 MMCF & 960 BW
- **Max Cum:** 4.5 MBO + 6 MMCF & 1.6 MBW

- **Avg IP:** 26 BOPD + 23 MCF & 0 BWPD (GTY NR)
- **Max IP Volumes =** 47 BO / 23 MCF / 0 BWPD



Production History T2

Wells Spud 2009 to 2014

(SRL) Uncemented Laterals – Sliding Sleeve Completions

Niobrara Production

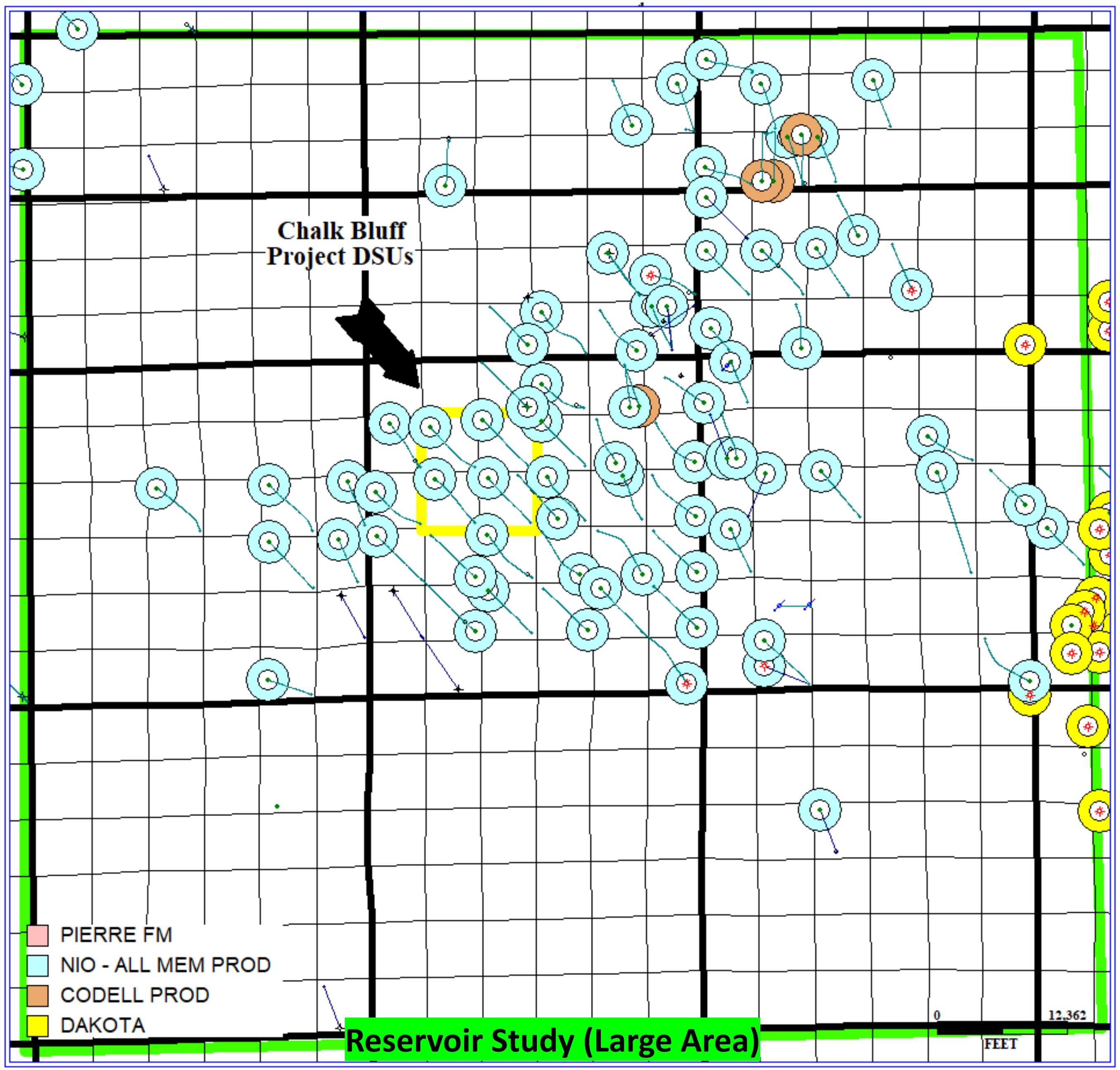
- **Avg / Well Niobrara Production (Cum):** 76 MBO & 119 MMCF & 41 MBW
- **Max Cum:** 365 MBO + 525 MMCF & 173 MBW

- **Avg IP:** 287 BOPD + 136 MCF & 233 BWPD (GTY 34 - 35)
- **Max IP Volumes** = 1605 BO / 816 MCF / 2556 BWPD

Codell Production

- **Avg / Well Codell Production (Cum):** 29 MBO & 31 MMCF & 23 MBW
- **Max Cum:** 75 MBO + 79 MMCF & 52 MBW

- **Avg IP:** 178 BOPD + 120 MCF & 154 BWPD (GTY NR)
- **Max IP Volumes =** 298 BO / 196 MCF / 299 BWPD)



Production History T3

Wells Spud 2015 to Present

(SRL & XRL) Plug and Pref - Cemented Laterals

Niobrara Production

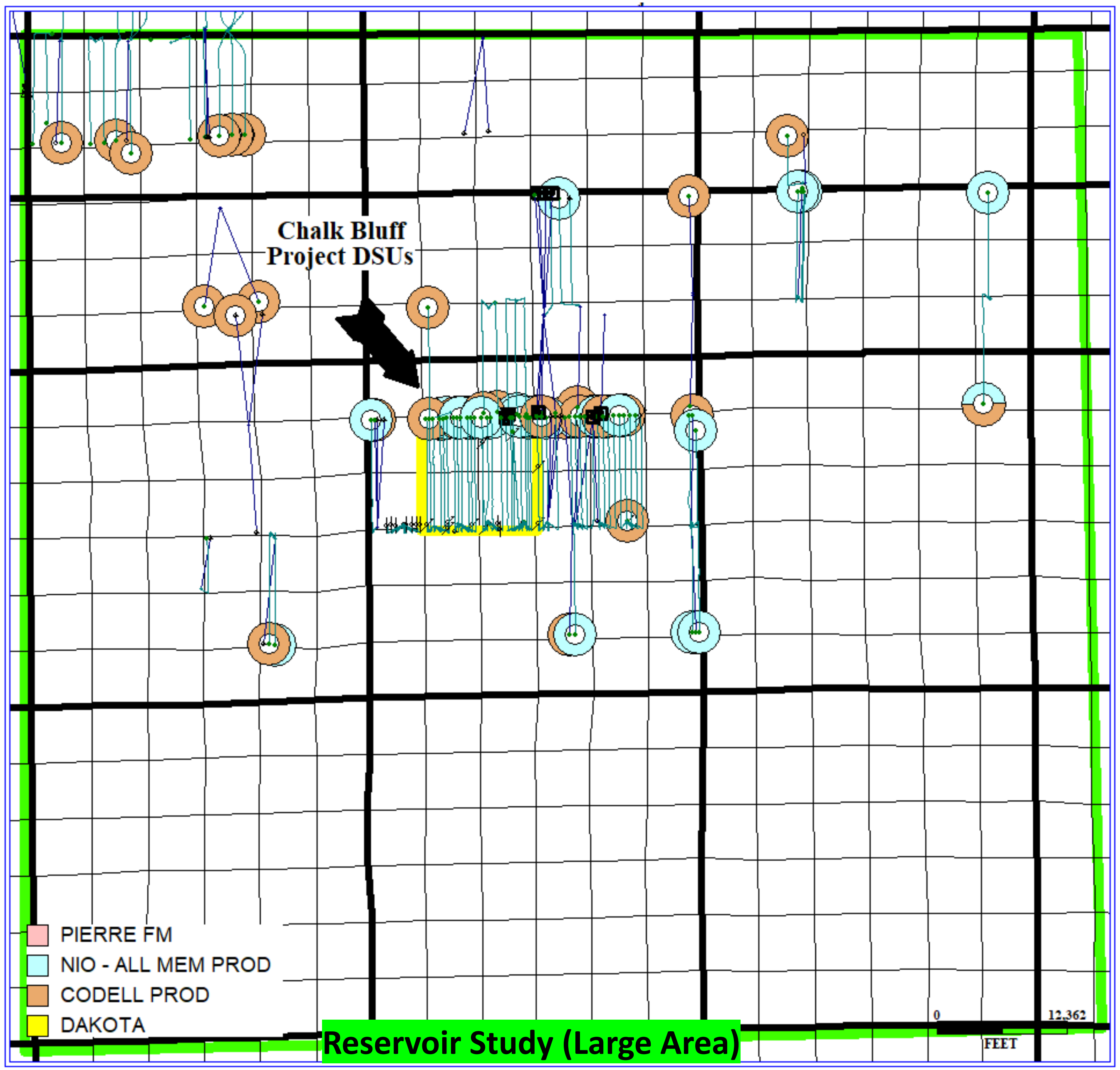
(*5 Years or less production history – SRL & XRL)

- **Avg / Well Niobrara Production (Cum):** 82 MBO & 138 MMCF & 31 MBW
- **Max Cum:** 201 MBO + 405 MMCF & 230 MBW
- **Avg IP:** Variable testing periods

Codell Production

(*5 Years or less production history – SRL & XRL)

- **Avg / Well Codell Production (Cum):** 93 MBO & 101 MMCF & 117 MBW
- **Max Cum:** 252 MBO + 285 MMCF & 280 MBW
- **Avg IP:** Variable testing periods



Hereford - Total Cumulative Production

ALL WELLS

Niobrara Production
(Since 1984 (Public Data)

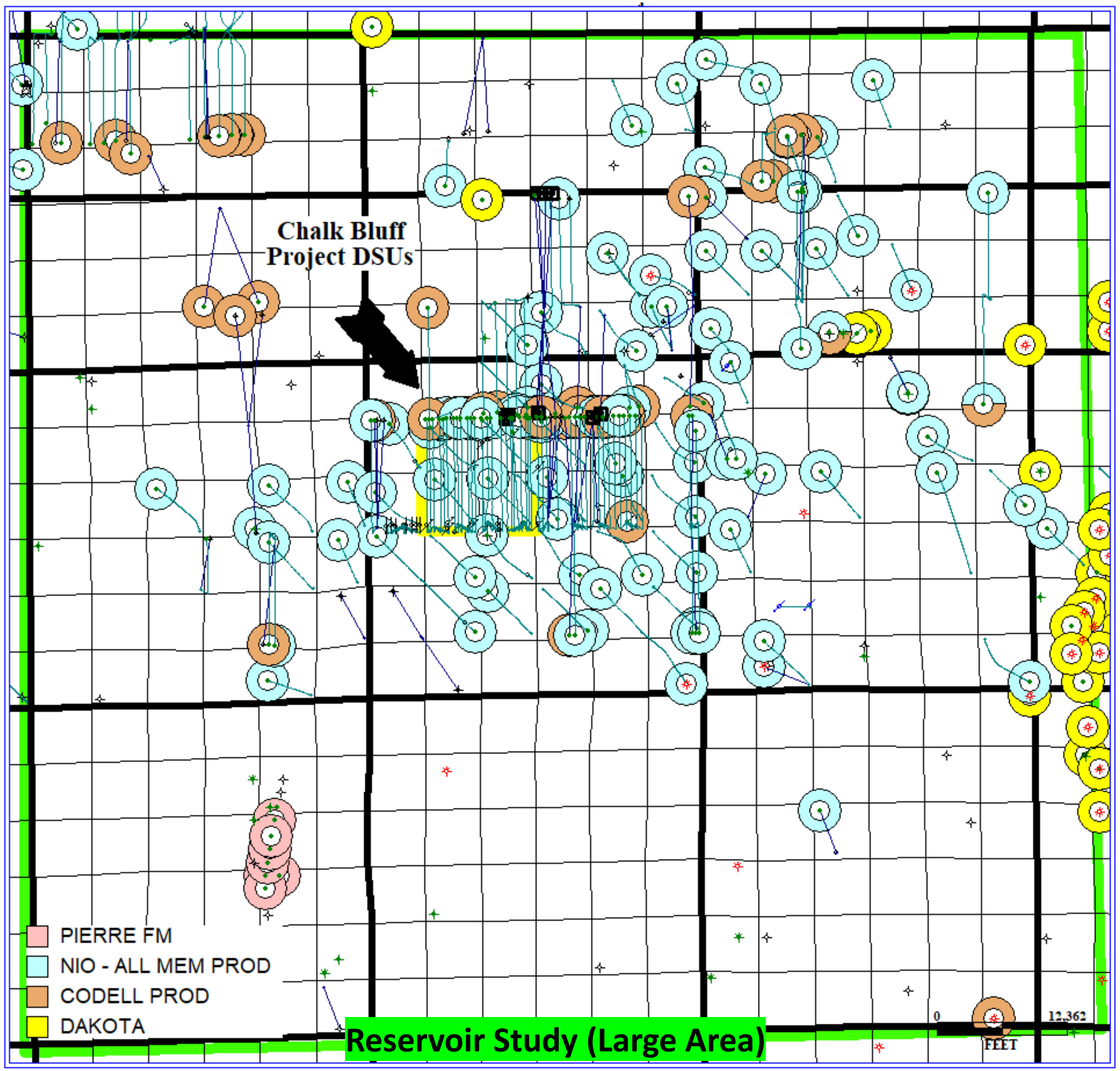
Field Niobrara Production (Cum):
9.1 MMBO & 14 BCF & 7.5 MMBW

Codell Production
(Since 1984 (Public Data)

Field Codell Production (Cum):
4.2 MMBO & 4.6 BCF & 5.2 MMBW

Commingled Cumulative Field Recovery:
- 13.3 MMBO / 18.6 BCF / 12.7 MMBW

Water / Oil = .95 BW to 1 BO
Cum GOR = 1398 SCF to 1 BO



Rock Quality Modeling

Niobrara B Chalk Isopach (Gross)

- Preliminary Base Layer in the B Chalk Reservoir Model
- Additional Net Pay Layers will Provide Enhanced Refinement and Calibration. (In progress)

COLORADO SCHOOL OF MINES

RCP - Chalk Bluff

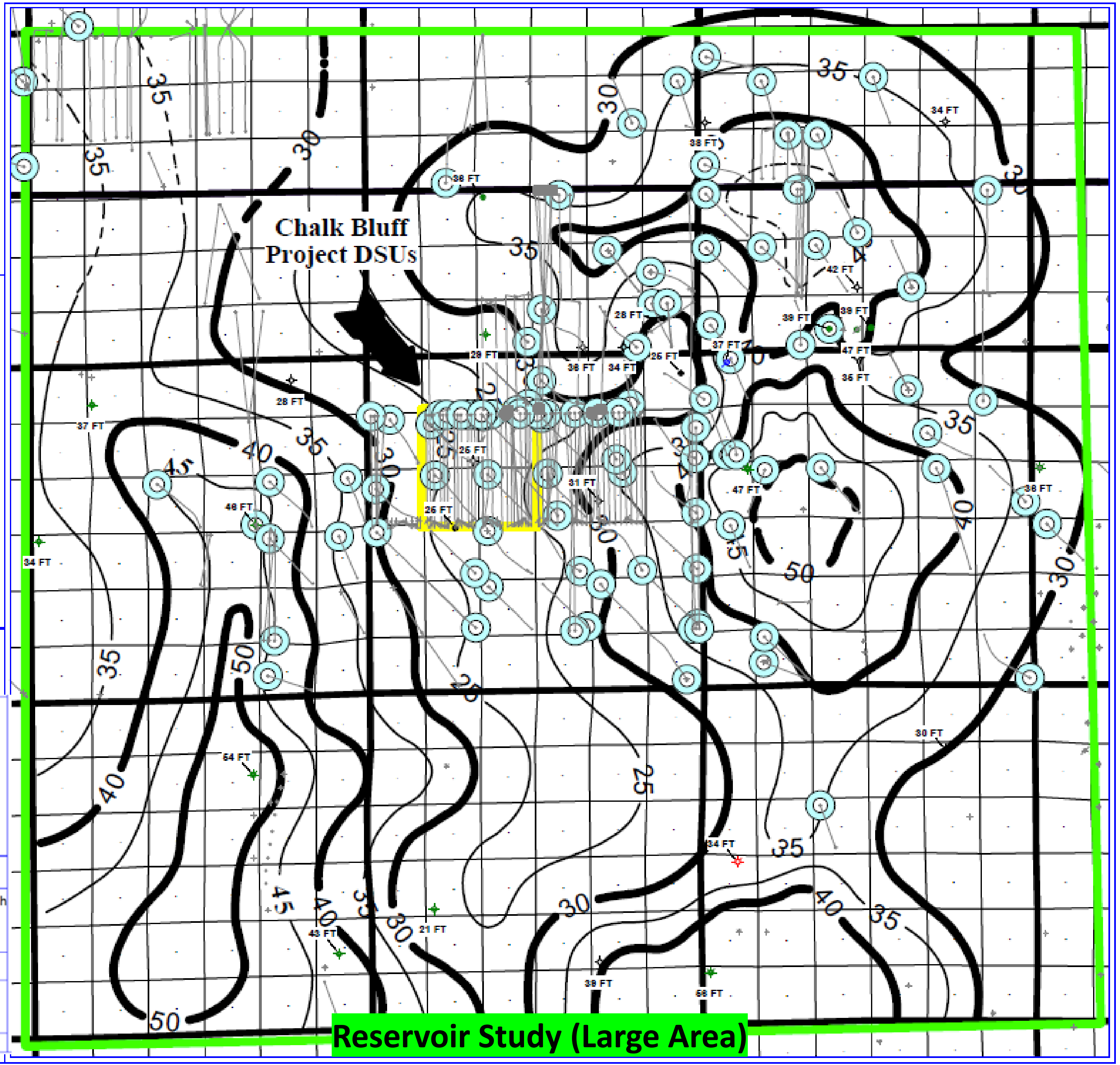
Niobrara Chalk B - Gross Isopach

Niobrara Production Highlighted

Large Area

C.I. = 5'
Isopach Values Posted
All Wells Shown
Wells with values shown in full size

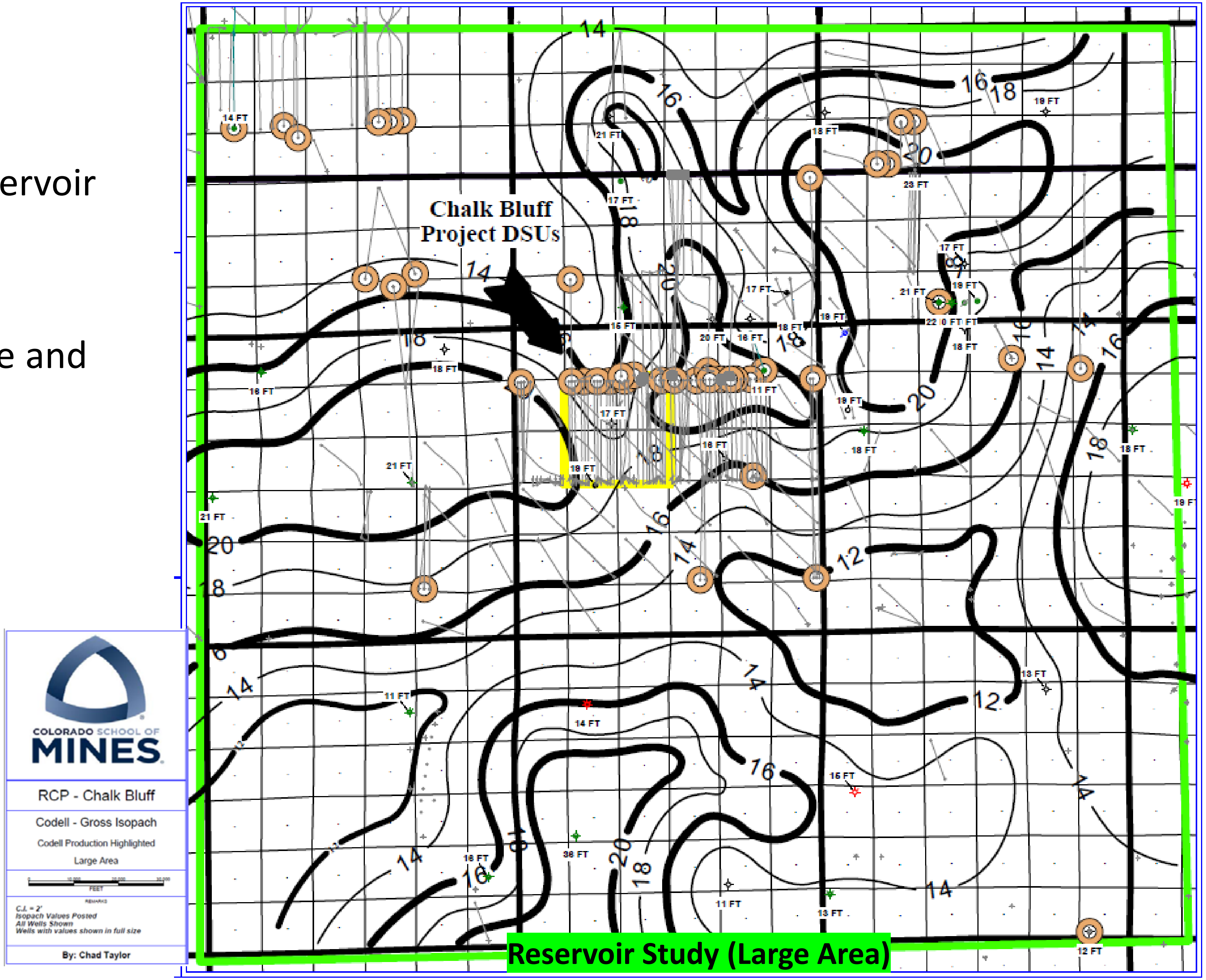
By: Chad Taylor



Rock Quality Modeling

Codell Isopach (Gross)

- Preliminary Base Layer in the Codell Reservoir Model
- Early Clues to the Reservoir Architecture and Underlying Paleostructure

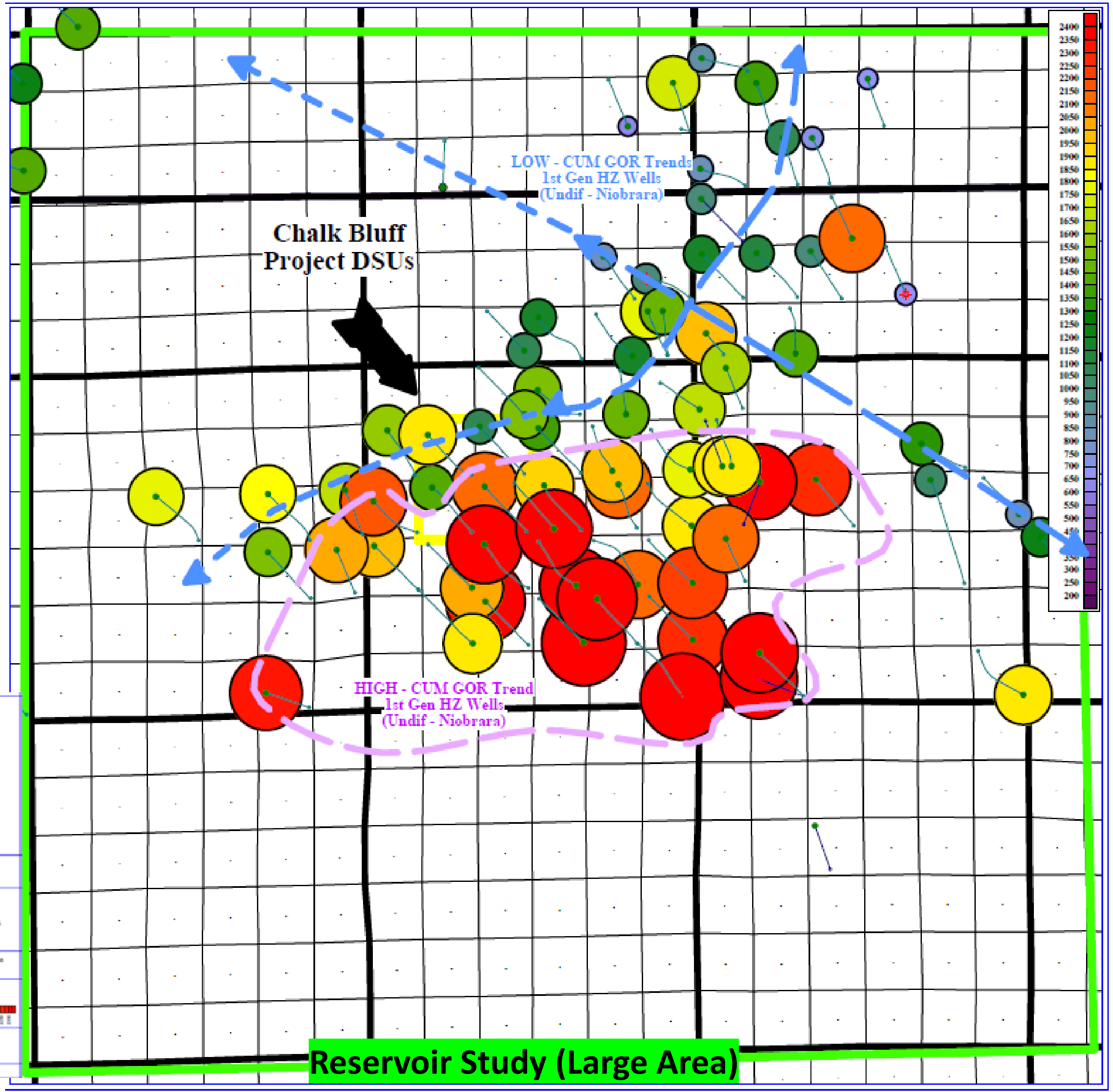


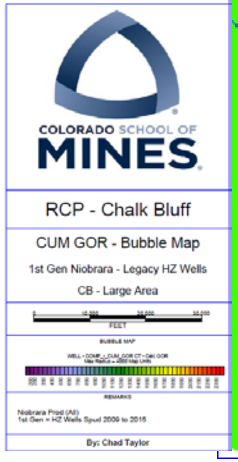
Reservoir Performance Modeling

Legacy HZ Niobrara Cumulative GOR Bubble Map

(Wells Spud 2009 to 2015)

- GOR Trends Highlights Potential Reservoir Compartmentalization & Heterogeneity in the B Chalk
- Geological Controls on Reservoir Bubble Point Evolution
- High GOR = High Confinement (Matrix production)
- Low GOR = Low Confinement (Fracture production)





Preliminary Conclusions

- Performance variations observed in every phase of field development suggests rock properties alone do not solely define reservoir sweet spots
- Variations in fluid properties (GOR, Oil Gravity, etc.) and existing geochemistry studies suggest reservoir production is heavily enhanced by fractures (multi-phase)
- Reservoir heterogeneity and geochemical compartmentalization implies a complicated oil charge evolution and variable wettability system
- The Codell may have more reserve predictability, and be less pressure depleted
- More to come

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