A Vintage Well Perspective on Basin Model Production Prediction within the Niobrara Formation, Southern Powder River Basin, Wyoming*

Matthew M. Morton[1]

[1]Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD, USA (matthew.morton@halliburton.com)

Abstract

The Late Cretaceous Niobrara formation is a steadily emerging unconventional resource play within the greater Rocky Mountain foreland province. A substantial amount of research and operational effort has been directed towards understanding the complexity of the Niobrara in the Denver-Julesburg (DJ) basin. While sharing the same shallow seaway depositional environment as the DJ basin, but with an alternative Laramide-style deformation sequence of events and diagenetic alteration, the Powder River basin stands valiantly as a viable resource play for the Niobrara. This is especially true for the deeper, geochemically mature southern portion (Converse and Niobrara Counties) of the Powder River basin. As a completely self-sourced reservoir, the Niobrara formation makes up a cohesive petroleum system, free from the effects of any external geology. The alternating brittle, chalk-rich reservoir intervals and associated ductile, marl-rich source rock intervals lead to a predictable hydrocarbon migration system. Such migration information plays a critical role in optimized well placement and hydraulic stimulation planning, ultimately leading to enhanced production. It was therefore of paramount importance that a complete visualization of the brittleness behavior, trends, and patterns be actualized. A basin model was created in order to statistically interpolate such patterns and trends inherent within the subsurface environment. The approach to such an endeavor had one objective in mind - use free, publicly available well data. The gamma ray (GR) log curve provided the much needed information pertaining to the "purity" of the chalk-rich reservoir intervals. Within the confines of the Niobrara, lower GR units indicated increasingly "pure", and hence, more brittle reservoir rocks conducive to natural hydrocarbon migration and fracturing. In order to test such results, this information pertaining to the optimal "sweet spot" well placement was compared to present-day and historical petroleum production. The results prove that if the basin modeler continually ties the model back to a clearly defined objective central to the history of the rocks, the limitation of data availability may be ultimately ignored.

References Cited

ESRI, 2015, ArcGIS Desktop: Release 10.3.1, Redlands, California: Environmental Systems Research Institute.

Kauffman, E.G., 1977, Geological and biological overview, Western Interior Cretaceous basin: Mountain Geologist, v. 14, p. 75-99.

Longman, M.W., B.A. Luneau, and S.M. Landon, 1998, Nature and distribution of Niobrara lithologies in the Cretaceous Western Interior Seaway of the Rocky Mountain region: The Mountain Geologist, v. 35/4, p. 137-170.

Wyoming Oil and Gas Conservation Commission (WOGCC), 2015, Wyoming oil and gas conservation commission: The State of Wyoming eGovernment Website, Cheyenne, Wyoming, Geophysical well log data retrieved from: http://wogcc.state.wy.us/.

Theme 7: Exploration and Production Applications of Basin Modeling

A Vintage Well Perspective on Basin Model Production Prediction Within the Niobrara Formation, Southern Powder River Basin, Wyoming
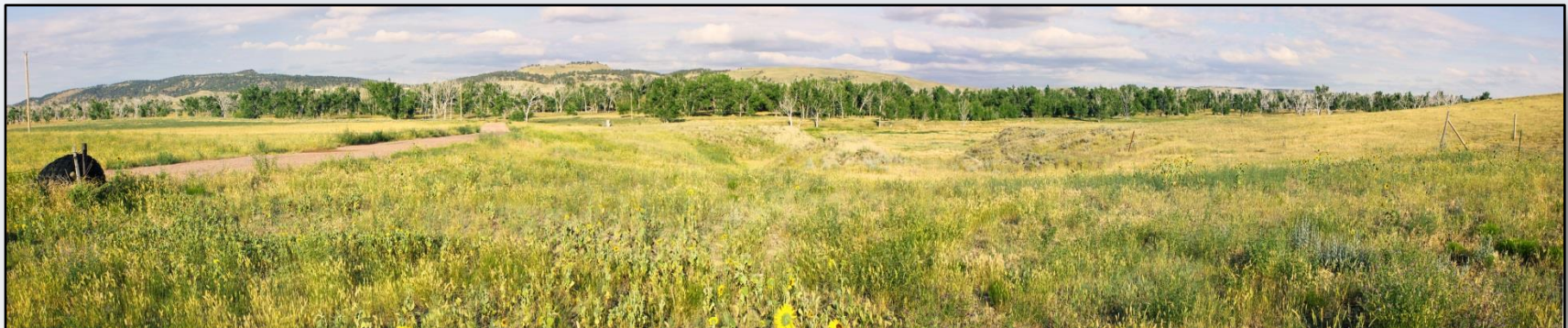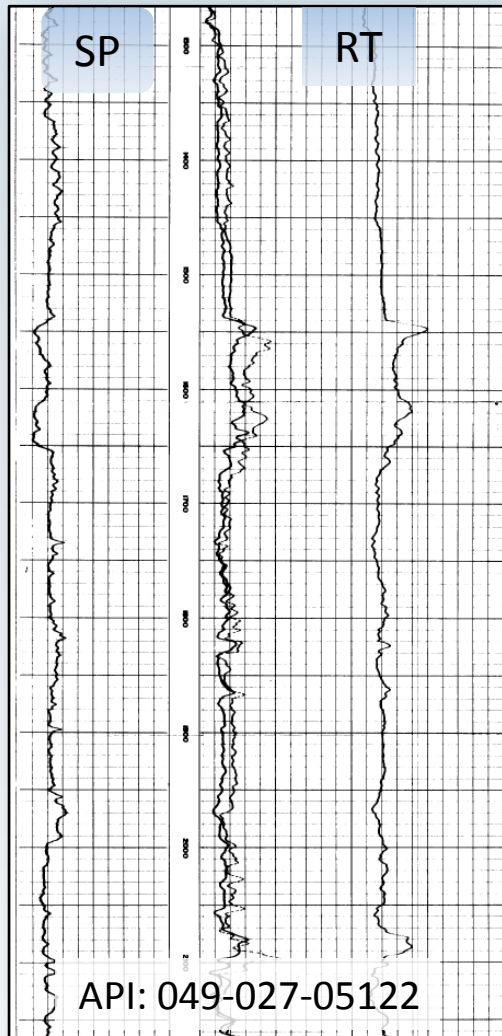
Matthew M. Morton

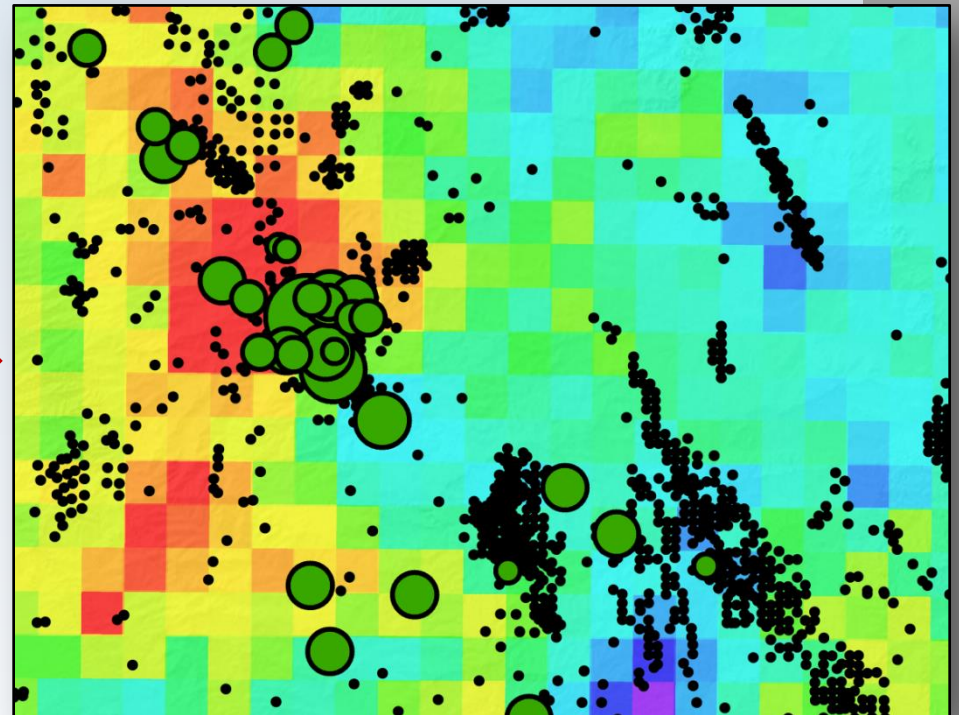Photo Location: Old Woman Anticline, Niobrara County, Wyoming

Objective – Explore vintage data to identify a relationship between fracture porosity and hydrocarbon production

Vintage Well Log (1949)

SP

RT

API: 049-027-05122

(Accessed from WOGCC, 2015)

Geomodel

Niobrara Fm. Oil Production

1. Initial Condition: There exists a boundless repository of vintage data available from a variety of easily accessible sources.
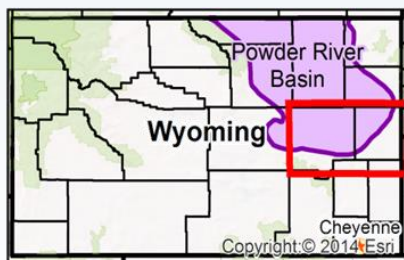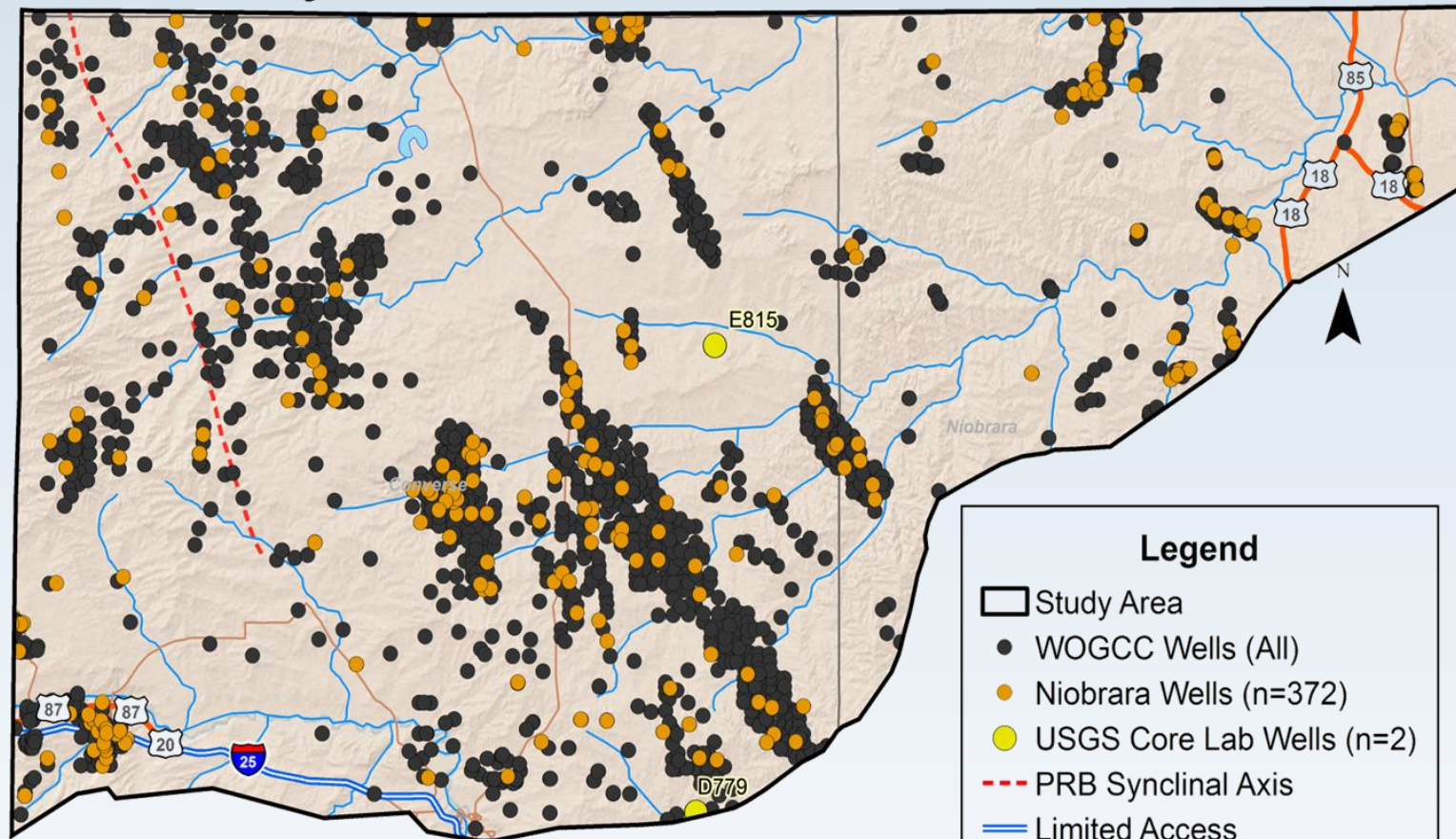
2. Barrier: In some cases, the reliability and quality of vintage data can be questionable.

3. Question: How can the complications of vintage data be overcome to explore relationships between fracture porosity and hydrocarbon production?
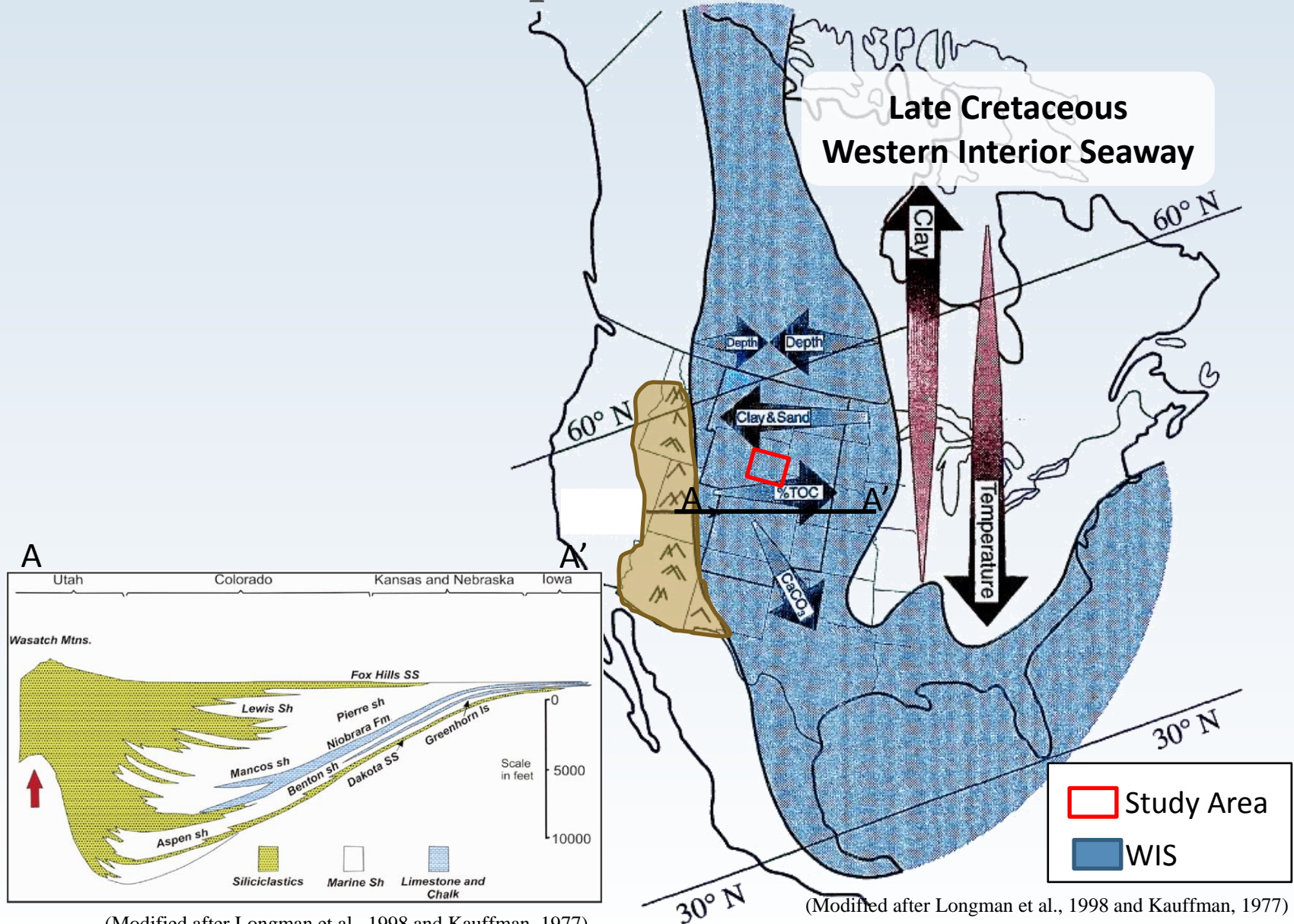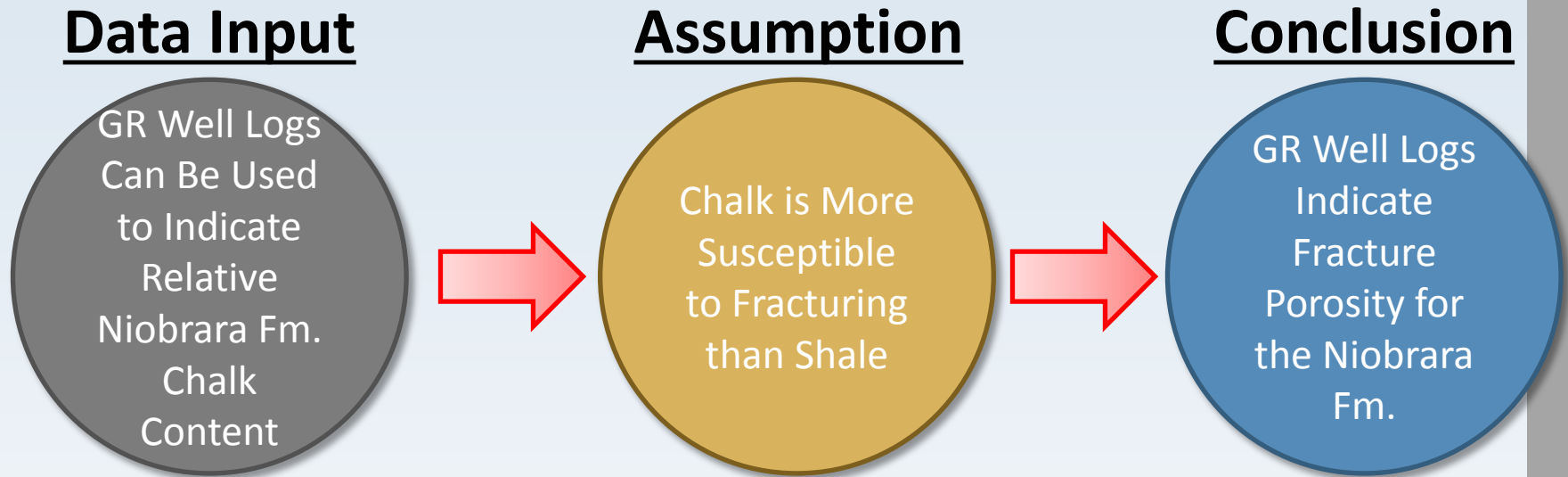
Study Area - Southern Powder River Basin, WY

Niobrara Fm. Depositional Environment

Late Cretaceous
Western Interior Seaway

Study Area

WIS

(Modified after Longman et al., 1998 and Kauffman, 1977)

(Modified after Longman et al., 1998 and Kauffman, 1977)

Workflow

Data Input

GR Well Logs Can Be Used to Indicate Relative Niobrara Fm. Chalk Content

Assumption

Chalk is More Susceptible to Fracturing than Shale

Conclusion

GR Well Logs Indicate Fracture Porosity for the Niobrara Fm.

- **Well Logs Used to Indicate Fracture Porosity:**
  - Gamma Ray (GR)
  - Resistivity (RT)
  - Porosity (NPHI)

Data Integration

1-12 J T Federal
API: 049-009-21924

Gamma Ray (0-200 gAPI)

10,300ft

160 gAPI

10,400ft

95 gAPI

10,500ft

(Accessed from WOGCC, 2015)

Core D779

**Middle Marl
(Marl B)**

4x

3 mm

Core D779

**Lower Middle Chalk
(Chalk B)**

4x

3 mm

Structural Top of the Niobrara Fm.

-1500ft

E815

D779

Legend

☐ Study Area
● WOGCC Wells (All)
● Niobrara Wells (n=372)
● USGS Core Lab Wells (n=2)
--- PRB Synclinal Axis

Niobrara (Top)
Elevation (ft)

| 500 |
| 0.00 |
| -500 |
| -1000 |
| -1500 |
| -2000 |
| -2500 |
| -3000 |
| -3500 |
| -4000 |
| -4500 |

N

Powder River Basin
Wyoming
Cheyenne
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0 5 10 20 30 Miles

References:
(ESRI, 2011)

Coordinate System: NAD83, UTM Zone 13N
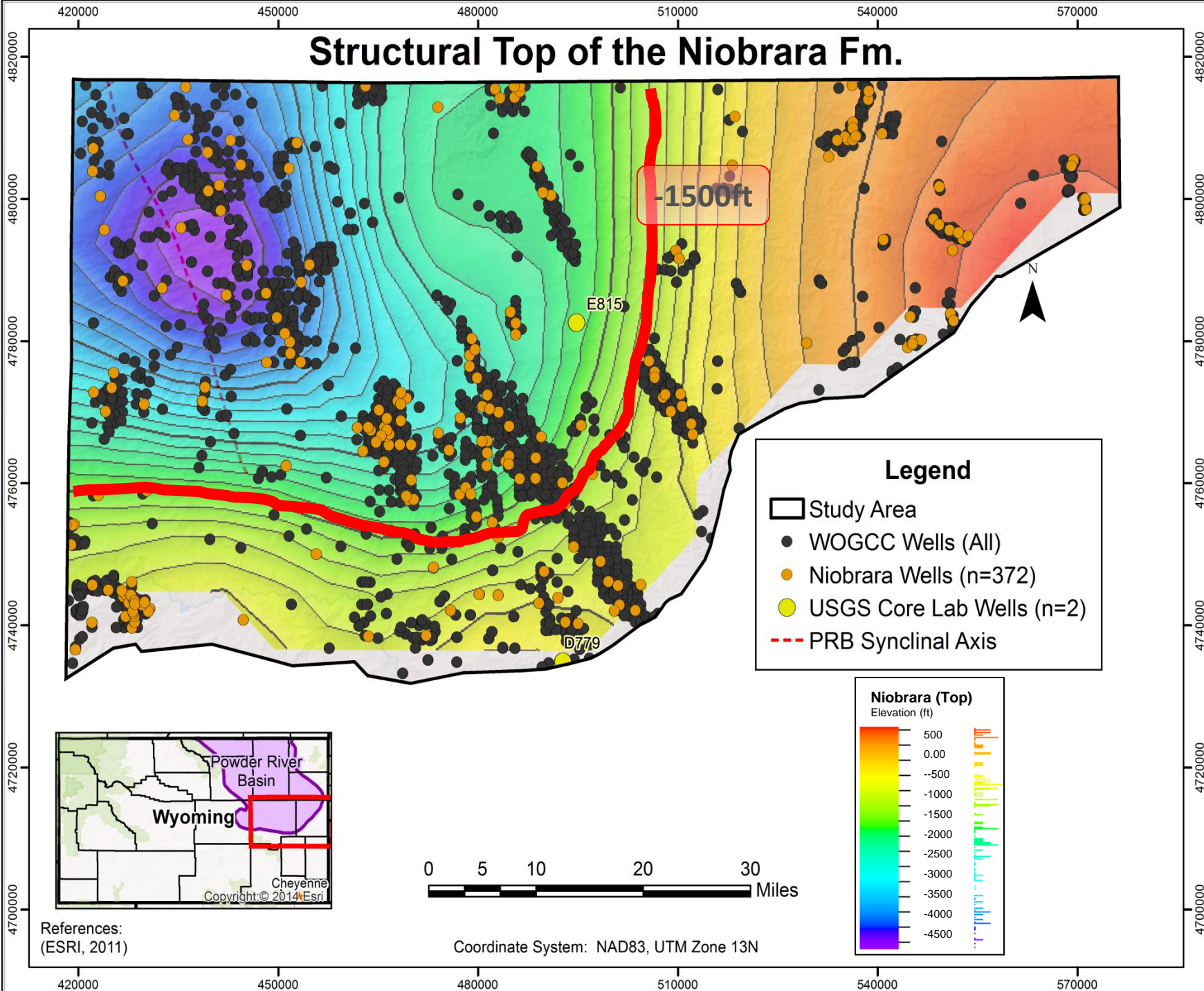
Input Parameters

- **<u>Well Data Overview</u>**
  - 372 wells used for re-picking tops
  - 72 wells digitized for geomodel
  - 52 wells with Niobrara Fm. production information
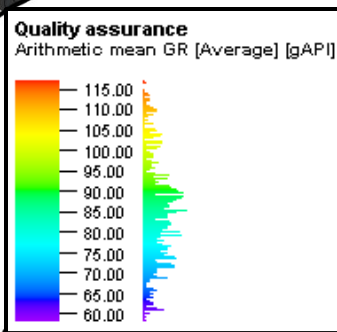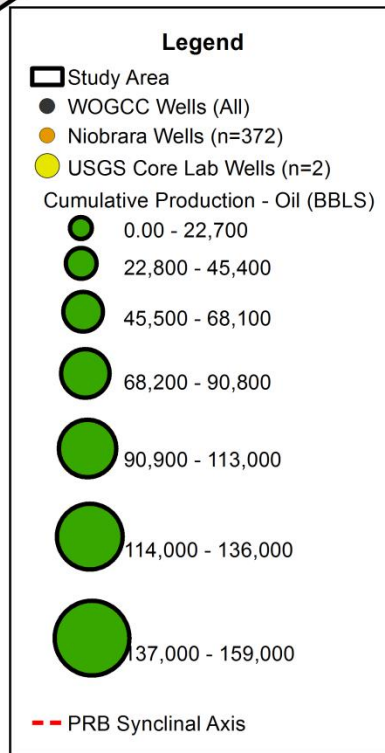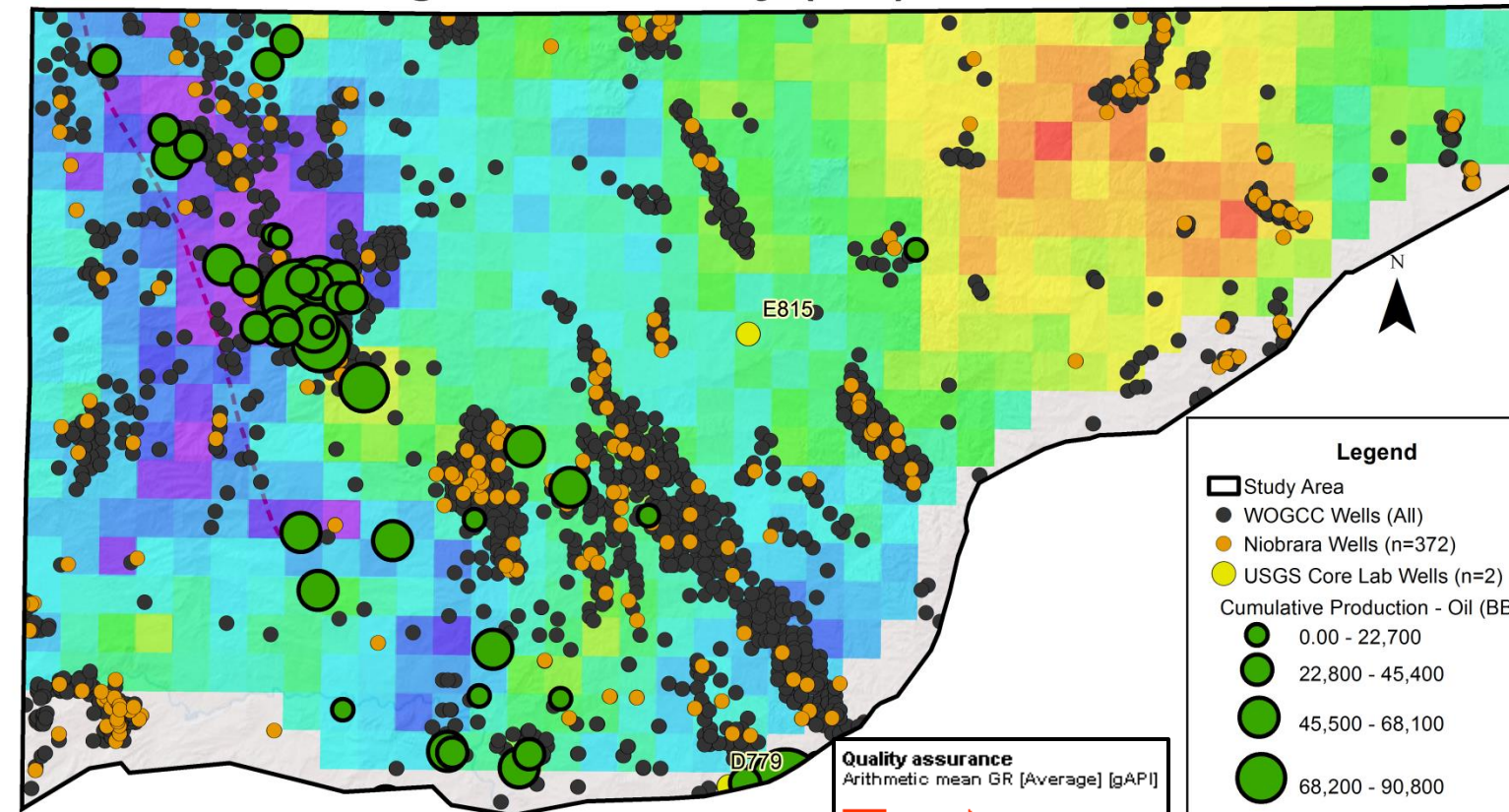 - 2 wells with USGS Core Lab information (D779 and E815)
- **<u>Geomodel Input Parameters</u>**
  - Grid cell size chosen based on average well spacing
    - 13,000 ft (x) by 13,000 ft (y)
    - Grid height (z) based on Chalk/Marl A, B, C, and D thicknesses
  - Explored data relationships (e.g., variogram analysis, cross-plots, etc.)
  - Sequential Gaussian Simulation
  - Arithmetic mean of 100 realizations (for property models)
  - Sum of each normalized property model used for final production score

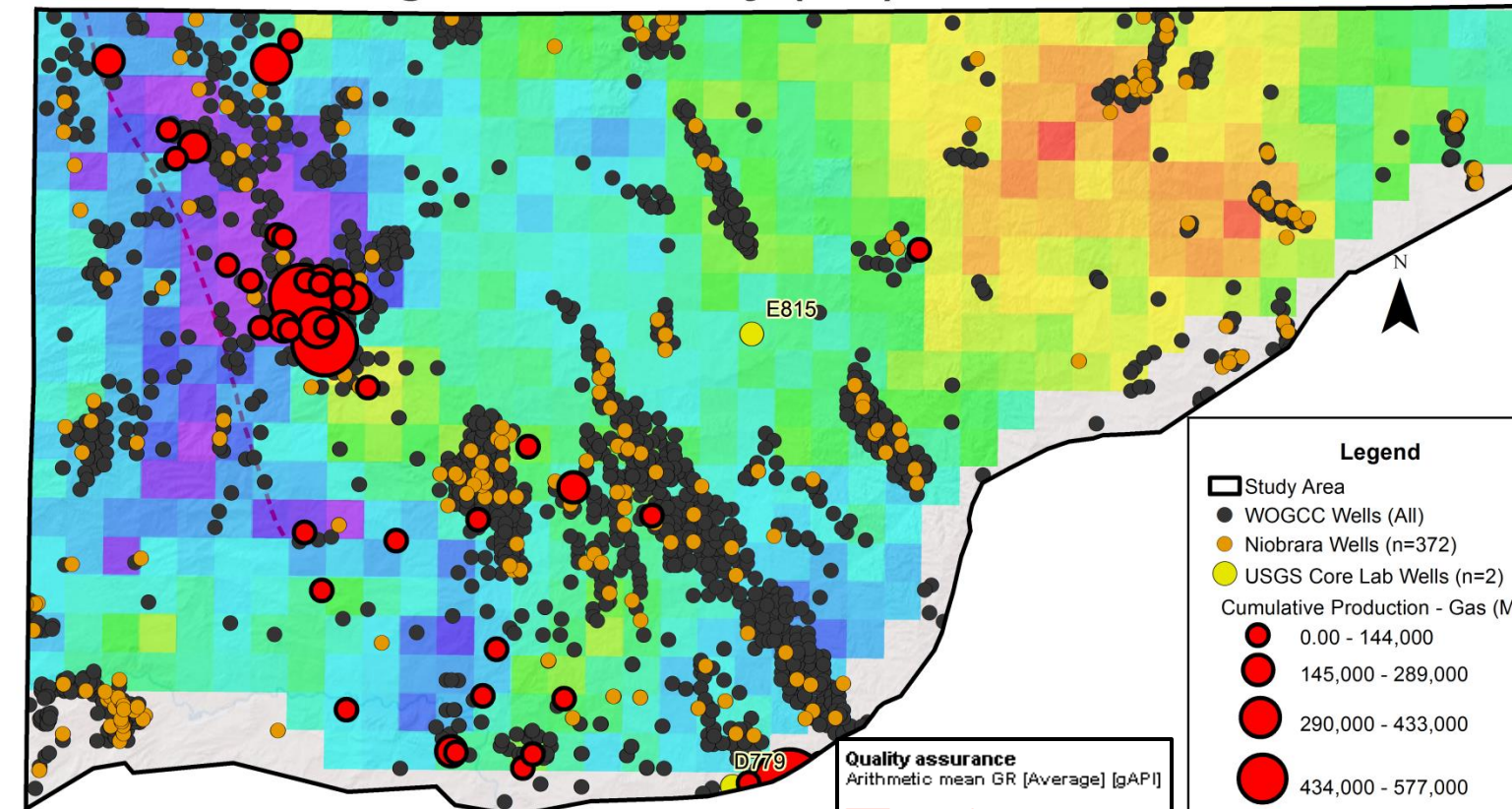# Cross-Plot – Modeled GR vs. Modeled RT vs. Production Score

Lower Production Score

Higher Production Score

$R^2 = -0.90$

$y = -1.7x + 110$

Gamma Ray (gAPI)

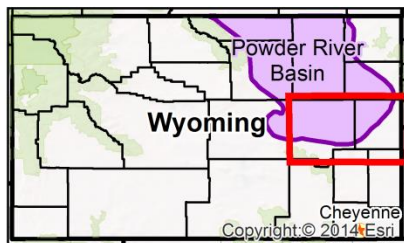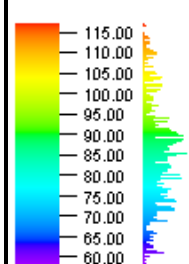Resistivity (ohm.m)
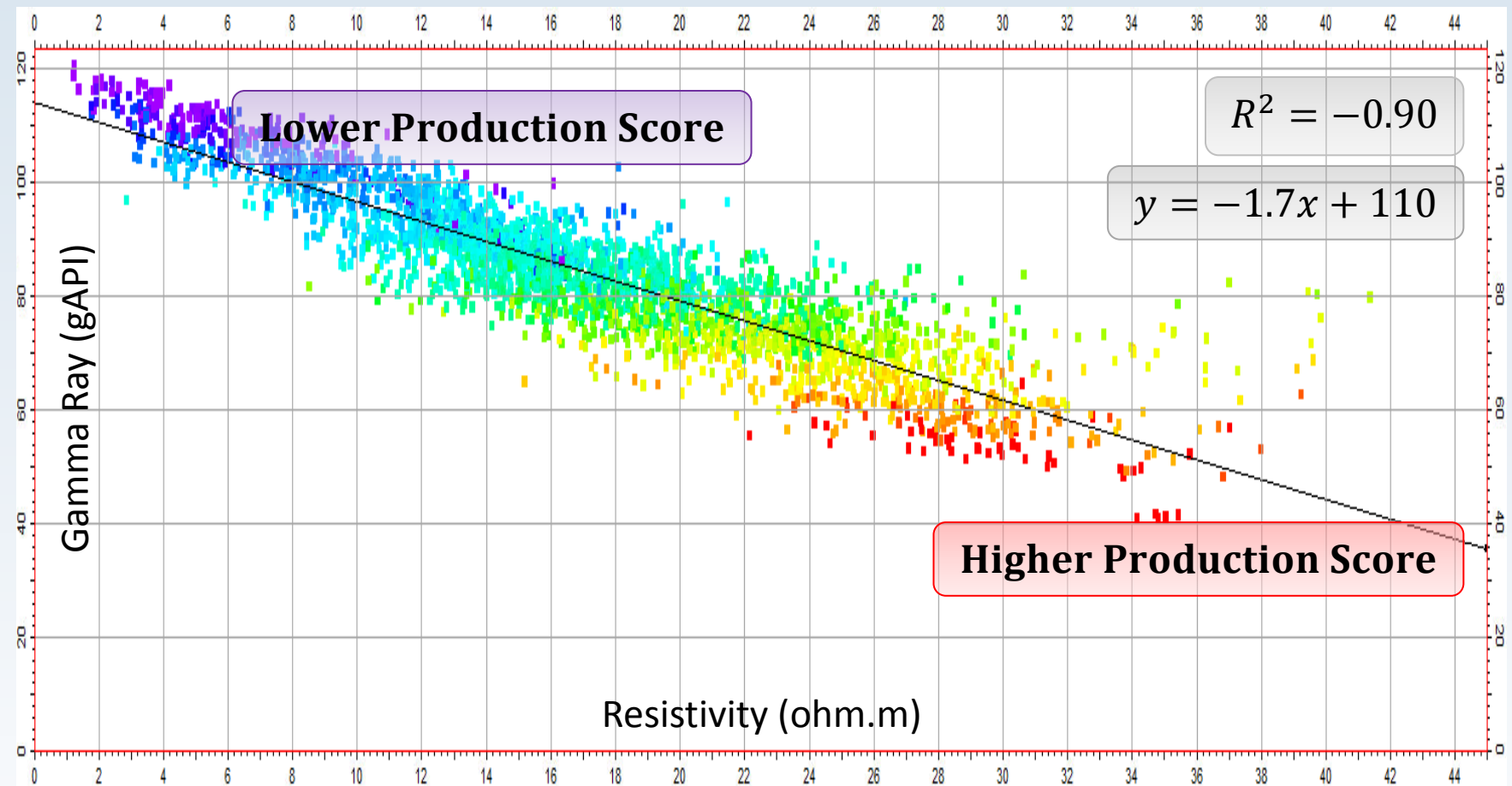
Average Gamma Ray (GR) - Oil Production

Legend

Study Area

WOGCC Wells (All)

Niobrara Wells (n=372)

USGS Core Lab Wells (n=2)

Cumulative Production - Oil (BBLS)

0.00 - 22,700

22,800 - 45,400

45,500 - 68,100

68,200 - 90,800

90,900 - 113,000

114,000 - 136,000

137,000 - 159,000

PRB Synclinal Axis

Quality assurance
Arithmetic mean GR [Average] [gAPI]

115.00
110.00
105.00
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00

E815

D779

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0   5   10   20   30

Miles
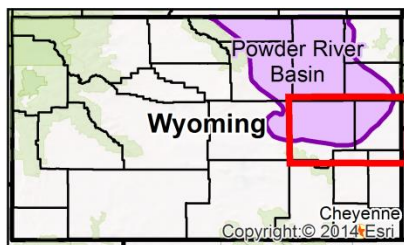
References:
(ESRI, 2011)

Coordinate System: NAD83, UTM Zone 13N

Average Gamma Ray (GR) - Gas Production

Hydrocarbon Production Potential - Niobrara Fm. - Oil

Hydrocarbon Production Potential - Niobrara Fm. - Gas

Legend

- Study Area
- WOGCC Wells (All)
- Niobrara Wells (n=372)
- USGS Core Lab Wells (n=2)

Cumulative Production - Gas (MCF)

- 0.00 - 144,000
- 145,000 - 289,000
- 290,000 - 433,000
- 434,000 - 577,000
- 578,000 - 721,000
- 722,000 - 866,000
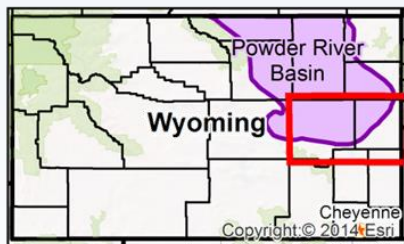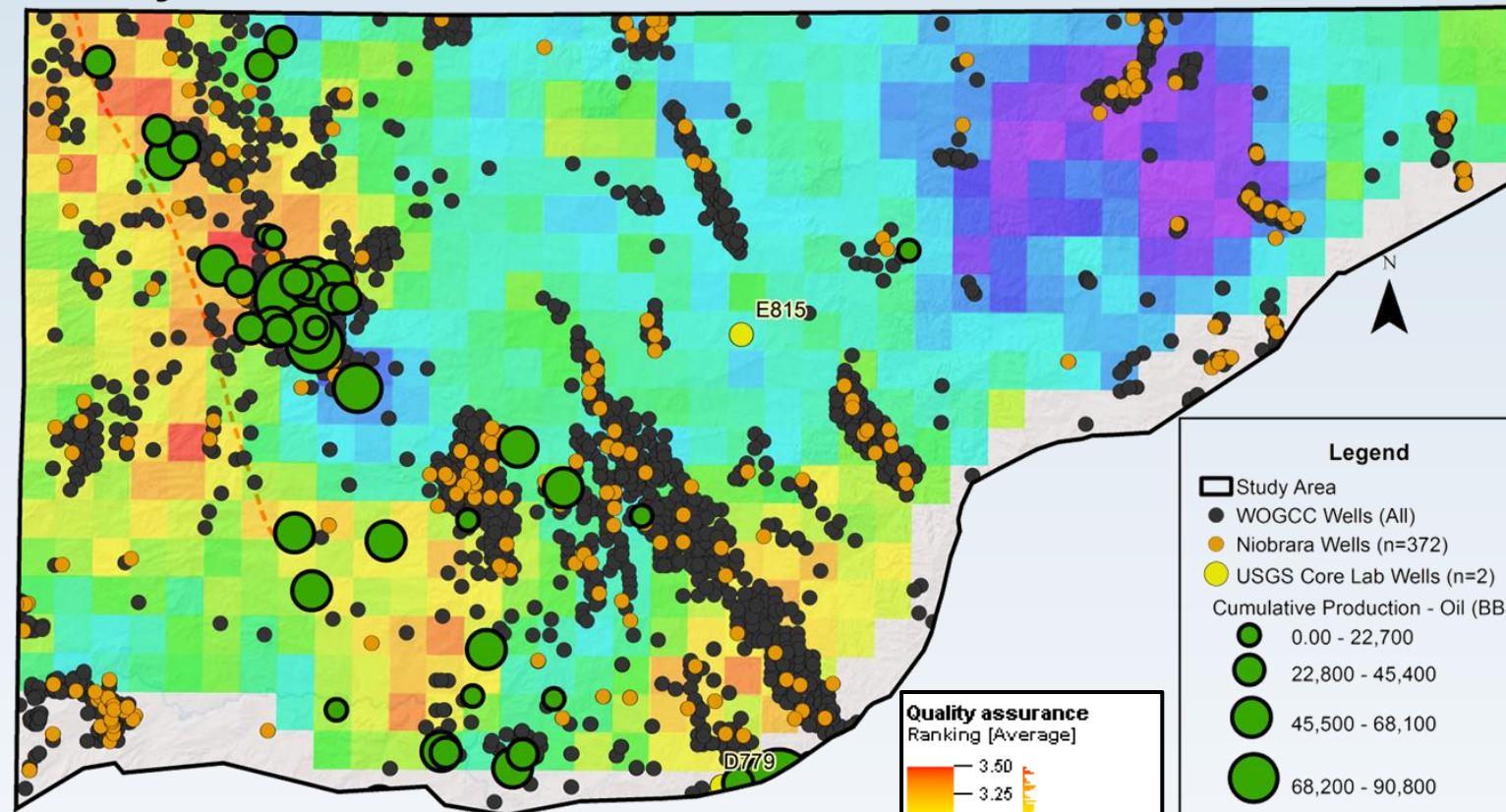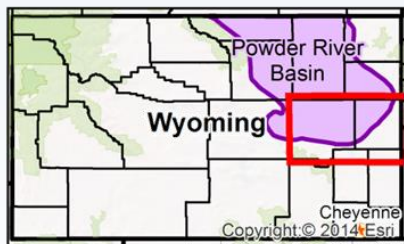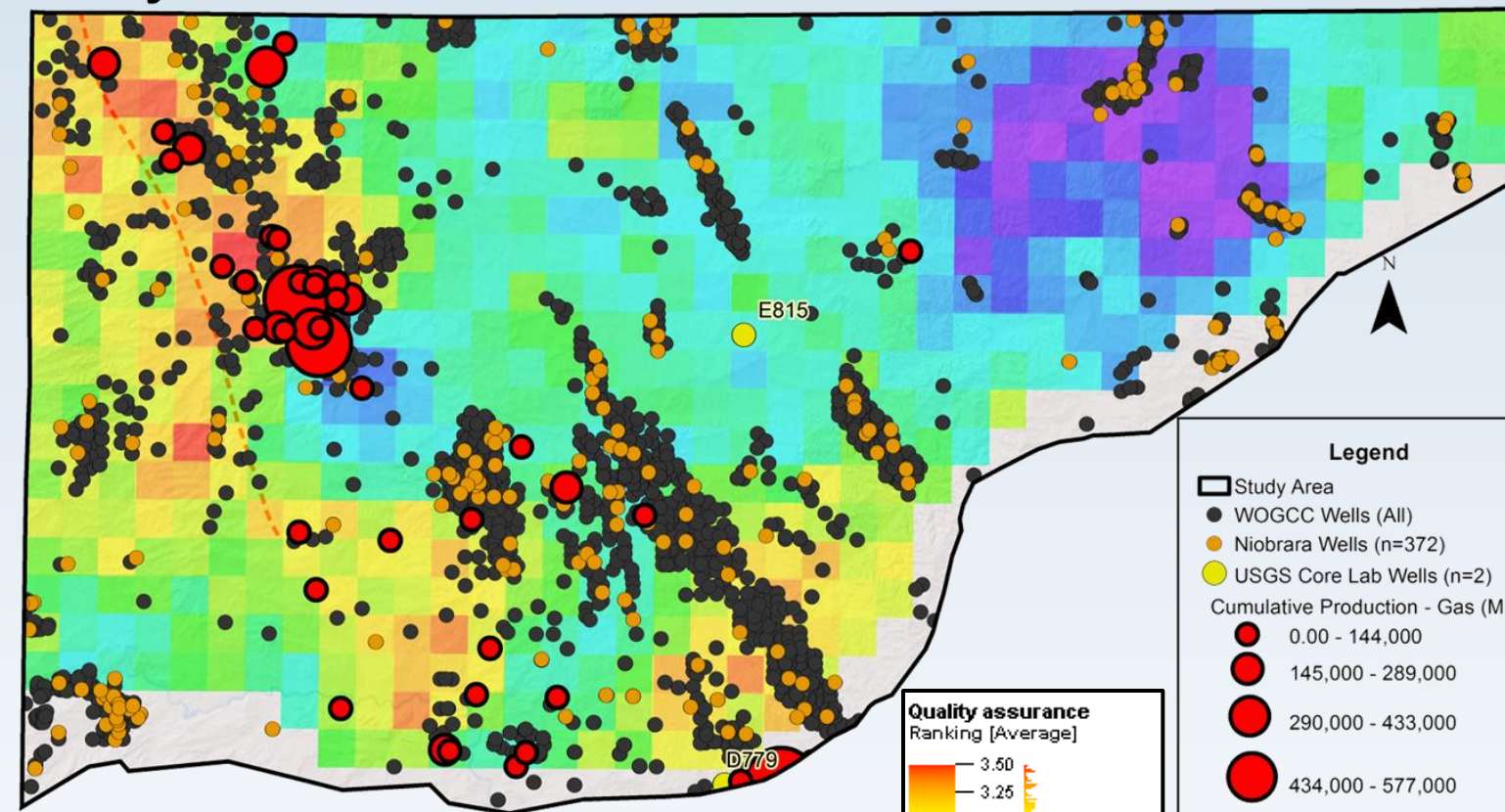- 867,000 - 1,010,000

-- PRB Synclinal Axis

Quality assurance
Ranking [Average]

3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25

E815
D779

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Wyoming
Cheyenne
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References:
(ESRI, 2011)

0   5   10   20   30 Miles

Coordinate System: NAD83, UTM Zone 13N

Conclusions and Implementation

- Vintage data provides numerous avenues to explore potential hydrocarbon production

- Lower GR values indicate relatively higher chalk content

- Fracture porosity leads to hydrocarbon production

- With lease boundaries, ranking of best to worst hydrocarbon potential can be made

Photo Location: Mule Creek Junction, Niobrara County, Wyoming

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- **Dr. Alvis L. Lisenbee**, South Dakota School of Mines and Technology, Rapid City, SD

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- **Halliburton Consulting**

References

- ESRI, 2015, ArcGIS Desktop: Release 10.3.1, Redlands, California: Environmental Systems Research Institute.

- Kauffman, E.G., 1977, Geological and biological overview. Western Interior Cretaceous basin: Mountain Geologist, v. 14, p. 75-99.

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- Wyoming Oil and Gas Conservation Commission (WOGCC), 2015, Wyoming oil and gas conservation commission: The State of Wyoming eGovernment Website, Cheyenne, Wyoming, Geophysical well log data retrieved from: <http://wogcc.state.wy.us/>.