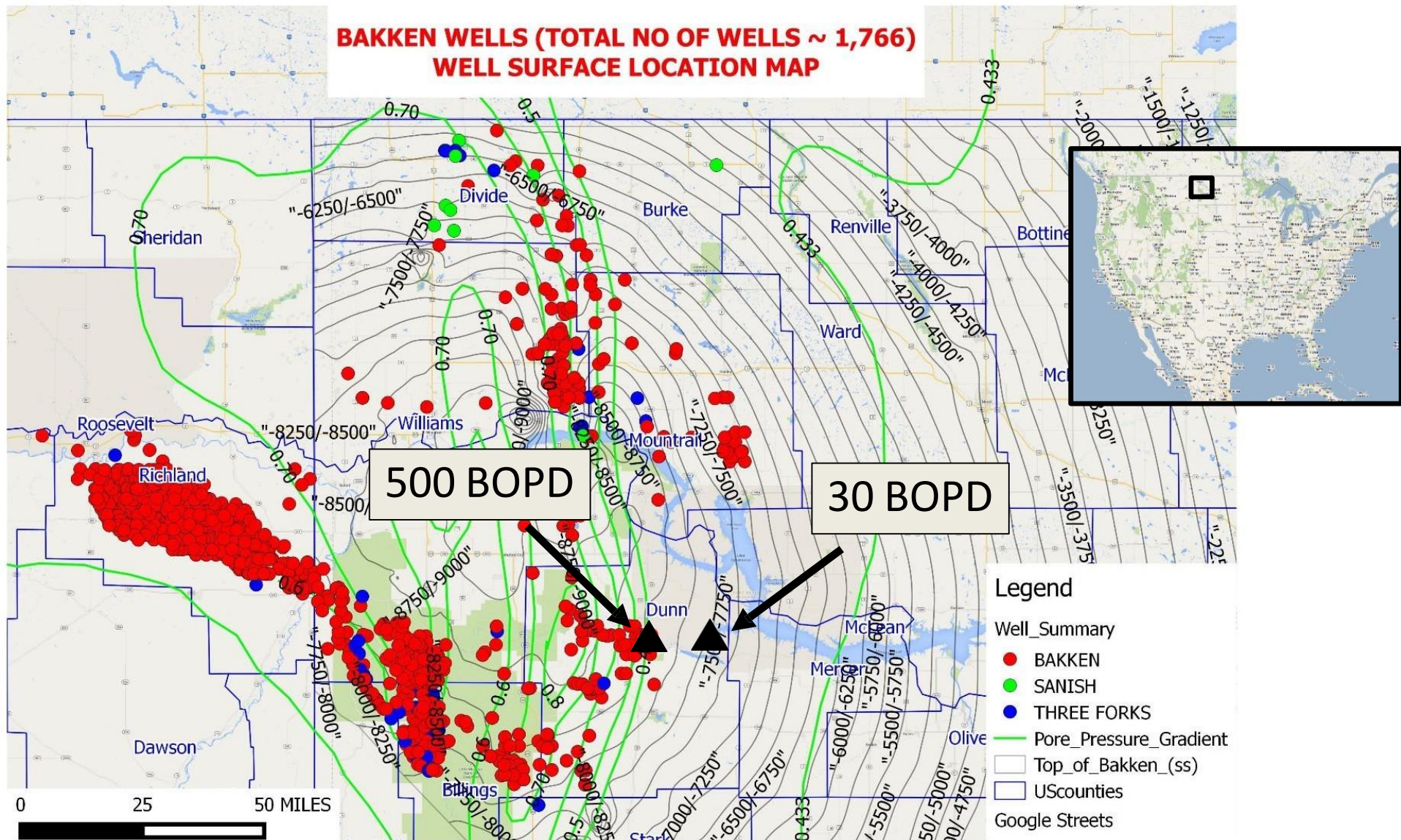


Source Rock Reservoir Characterization Using Geology, Geochemical and Drilling Data

Robert Shelley PE, StrataGen
Amir Mohammadnejad PhD, StrataGen
Stanislav Sheludko, StrataGen



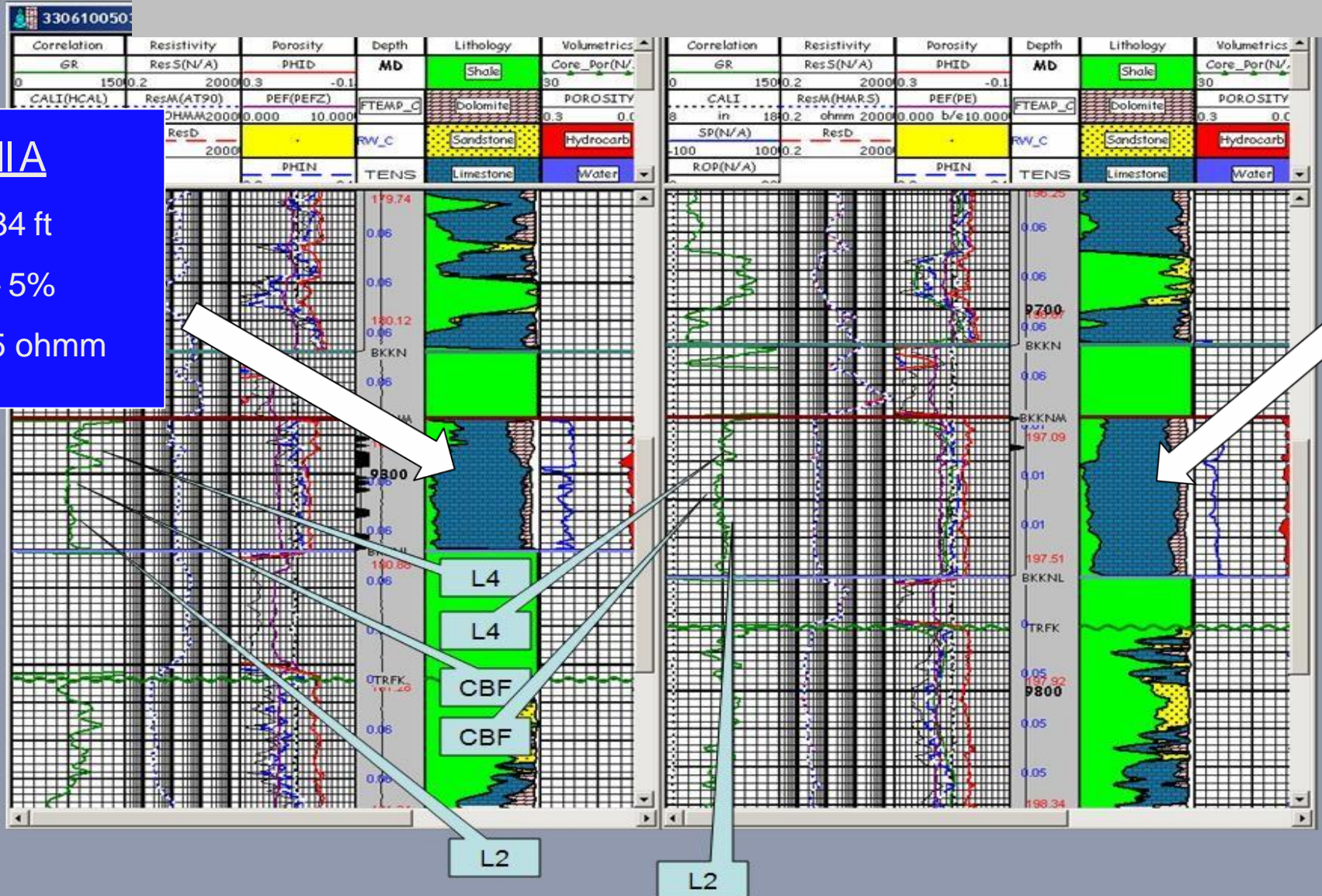
2007 Established Bakken Production



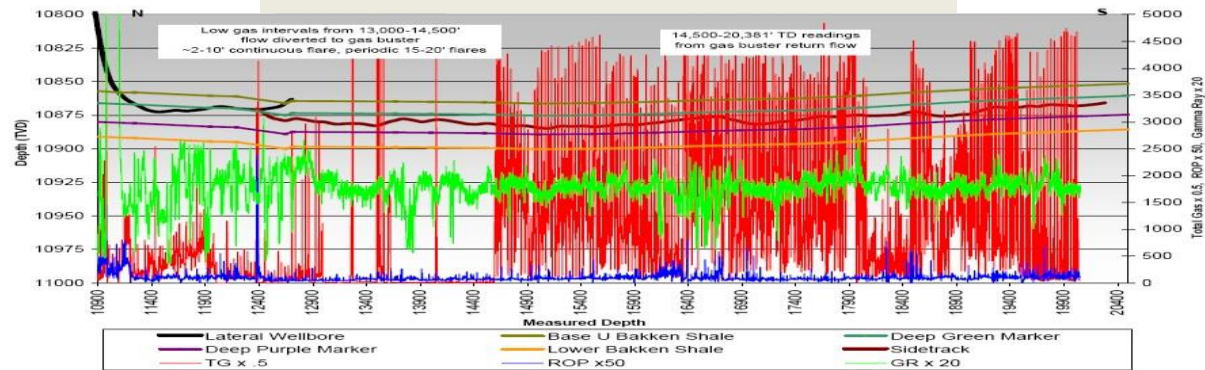
Pilot Well Bore Logs

Well A
 H – 34 ft
 Phi – 5%
 Res – 25 ohmm

Well B
 H – 42 ft
 Phi – 5%
 Res – 10 ohmm



Horizontal Drilling Measurements

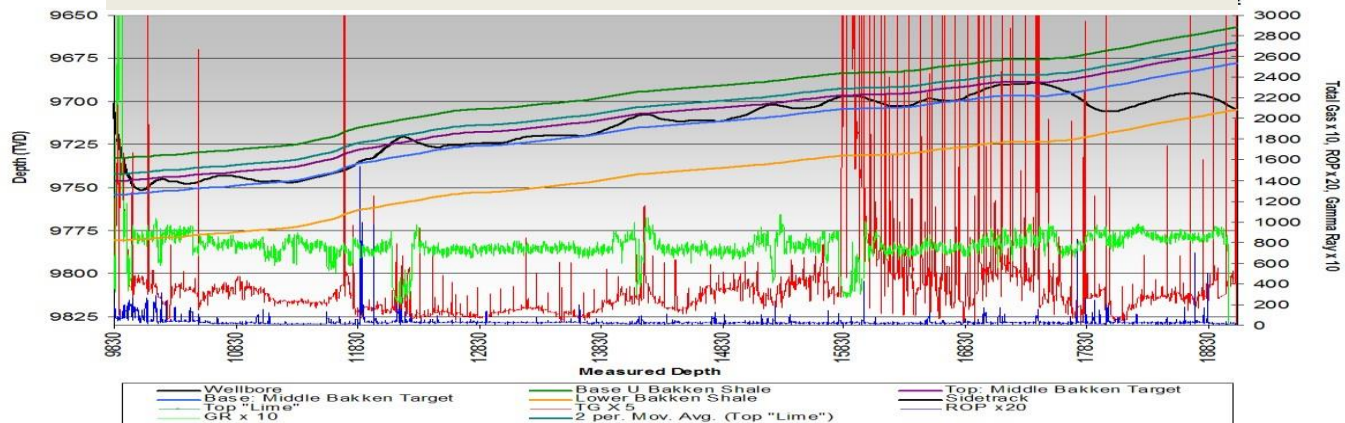


Well A

Avg. TG – 2,018

Avg. Mud Wt. – 11 lb/g

Avg. GR - 88



Well B

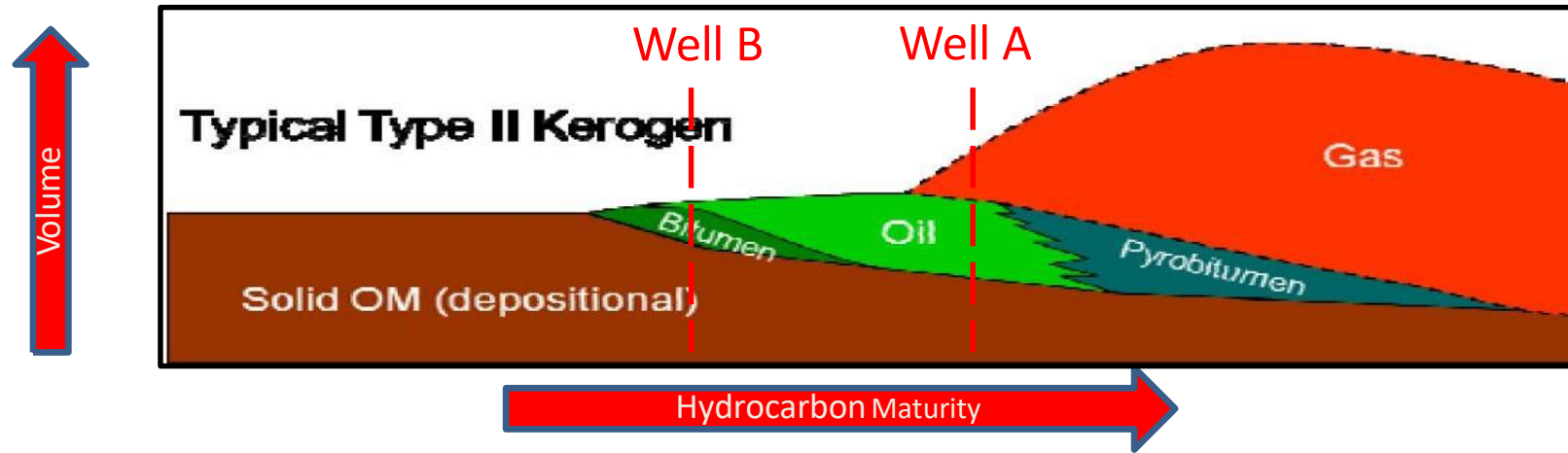
Avg. TG – 38

Avg. Mud Wt. – 9.3 lb/g

Avg. GR - 76

Characterization of Shale Reservoirs

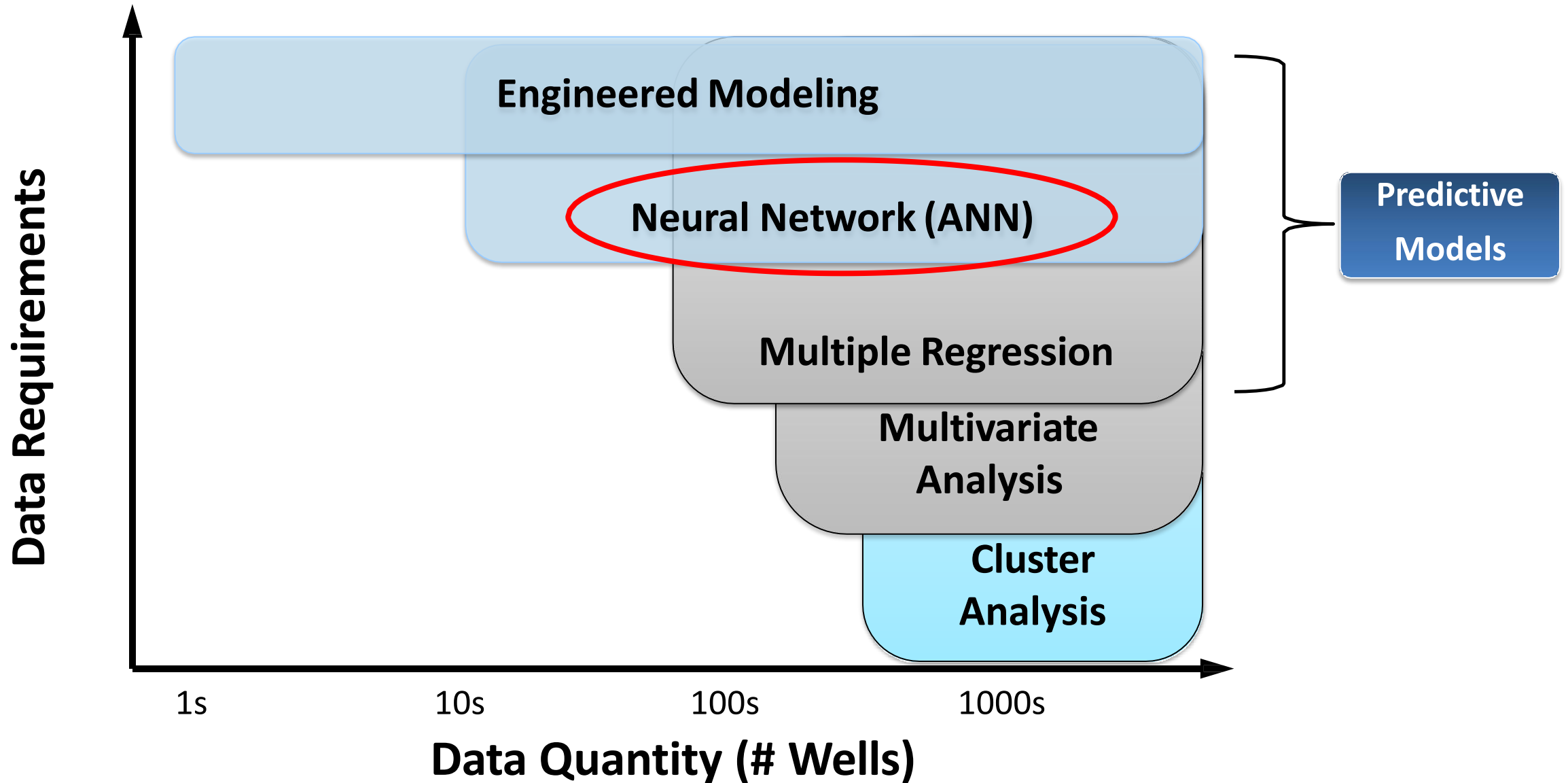
Passey et al, SPE 131350; Bohacs et al IPTC 16676



Horiz. Drilling Measurements

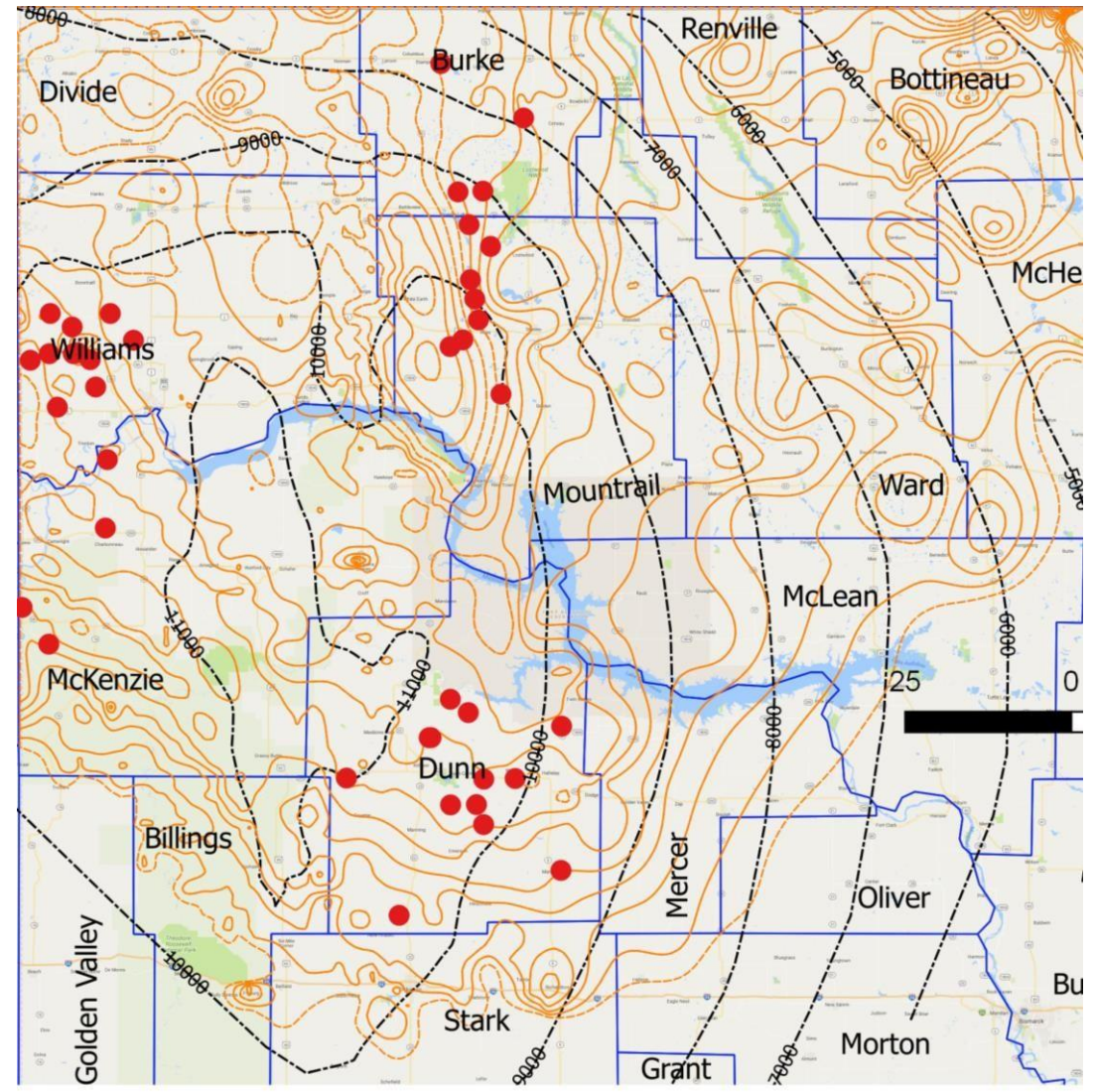
	Well A		Well B
Total Gas Units	2,018	>	38
Mud Wt.	11	>	9.3
Methane Fraction	0.29	<	0.67
Ethane Fraction	0.36	>	0.10
Propane Fraction	0.20	>	0.14
Butane Fraction	0.15	>	0.09
Gamma Ray Count	88	>	76
Bakken TVD	10,840	>	9,714

Well Performance Evaluation & Modeling

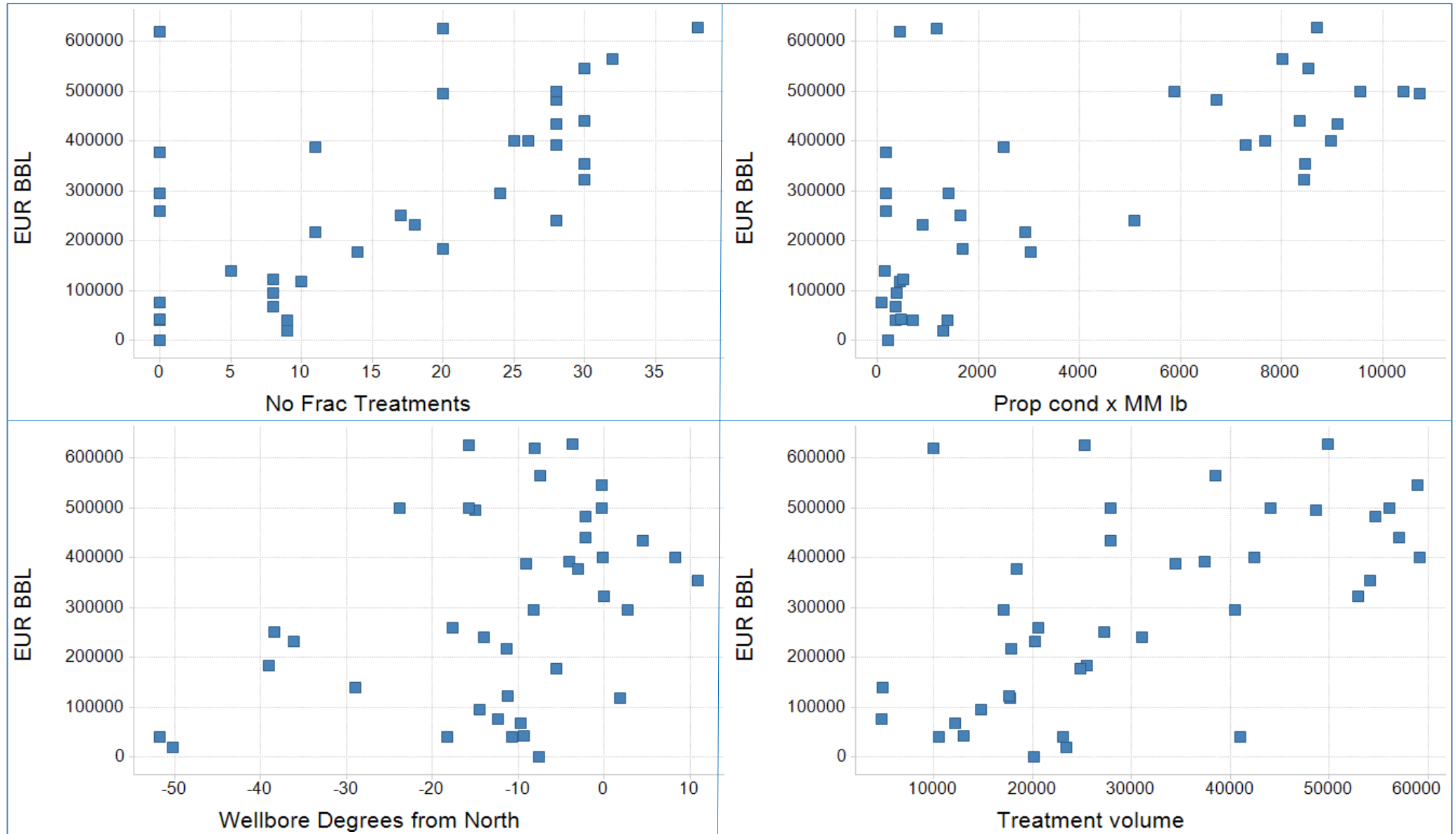


Bakken Well Performance Evaluation Project

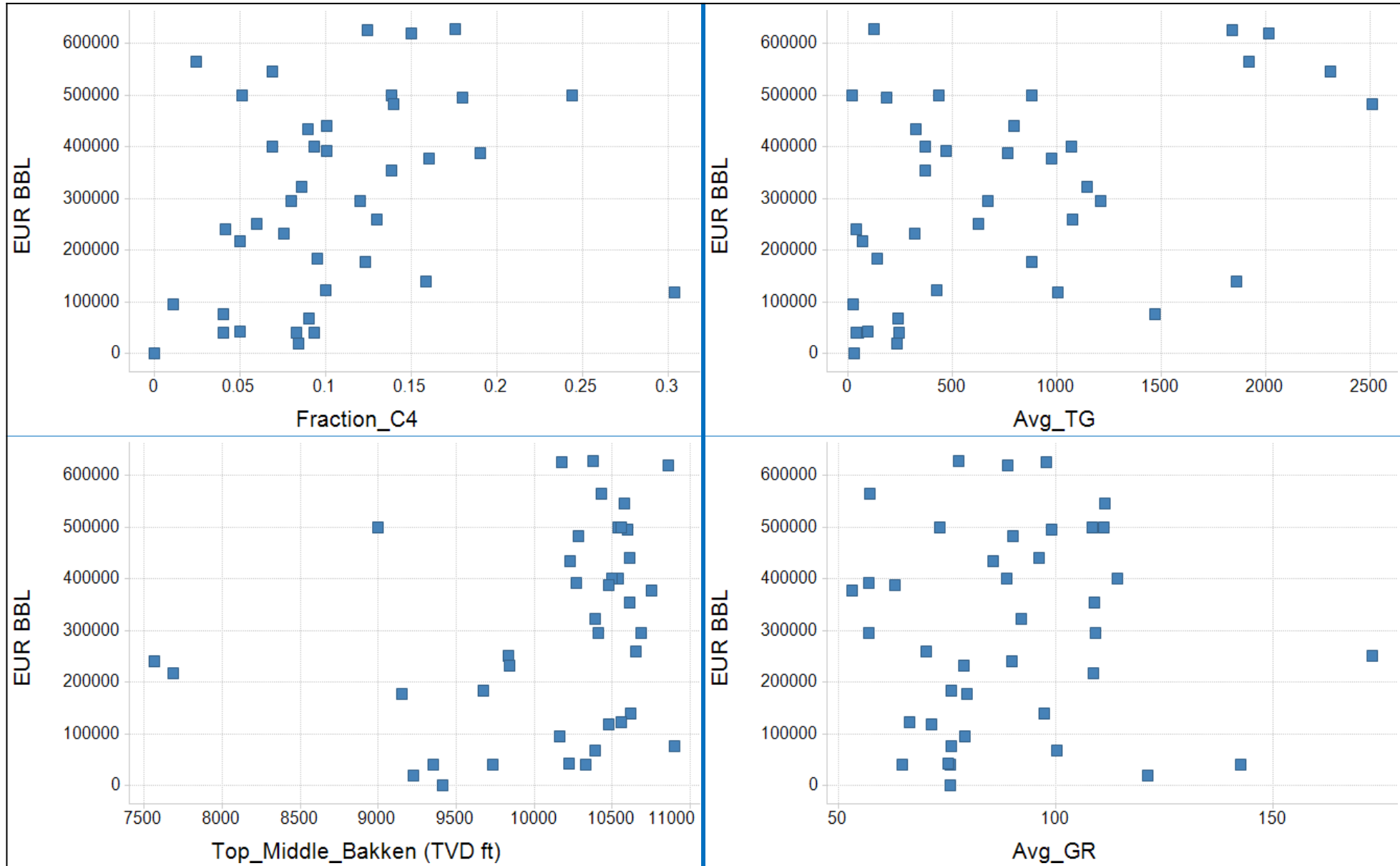
- **1250 well database**
 - **Completion, Frac & Production**
 - **EUR**
- **High graded to 40 wells**
 - **Reduce man-hours & time**
 - **Data quality and completeness**
 - **12 Operators**
 - **Diversity of completion and well productivity**
- **Data base with 80 parameters**
 - **geology, geochemical, drilling, completion, frac & production**



Completion and Frac Data vs EUR



Geology, Geochemical & Drilling Data vs EUR

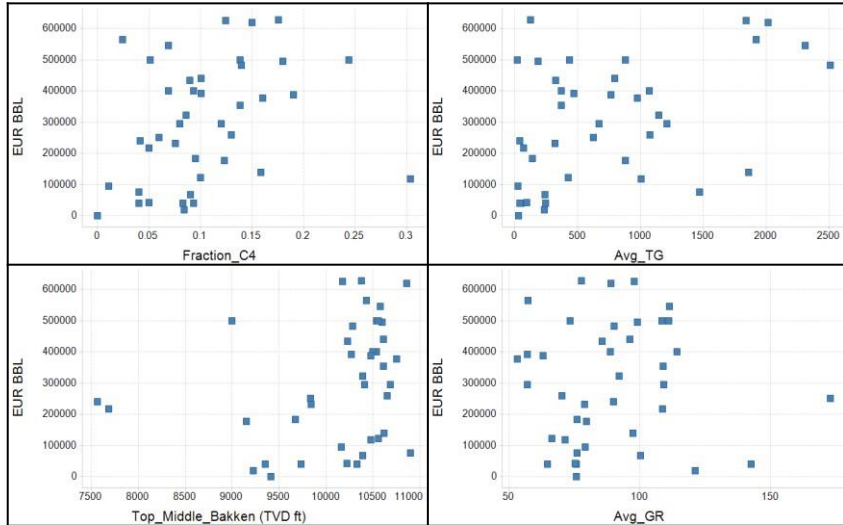


Bakken Neural Network Model Development (ANN)

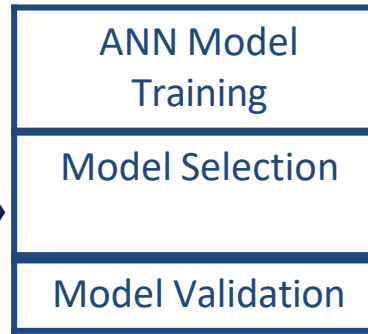
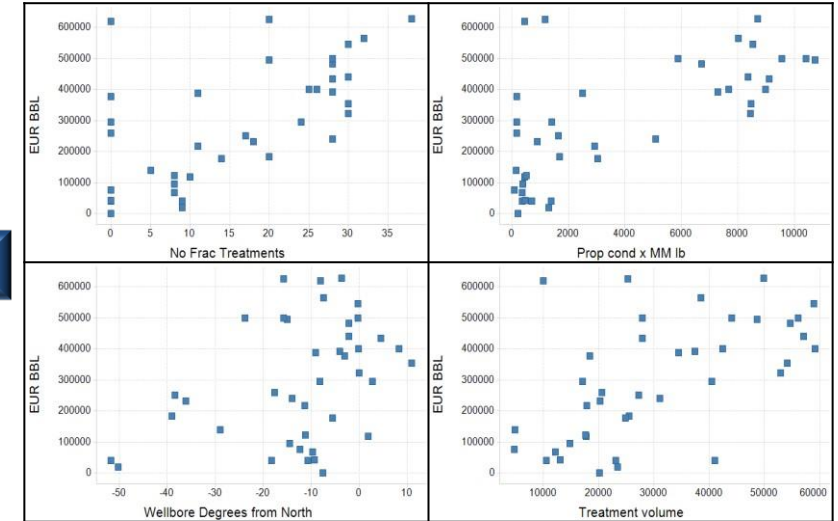
Computers & Geosciences 26 (2000) 941-951

40 Wells – 29 Train, 11 Test

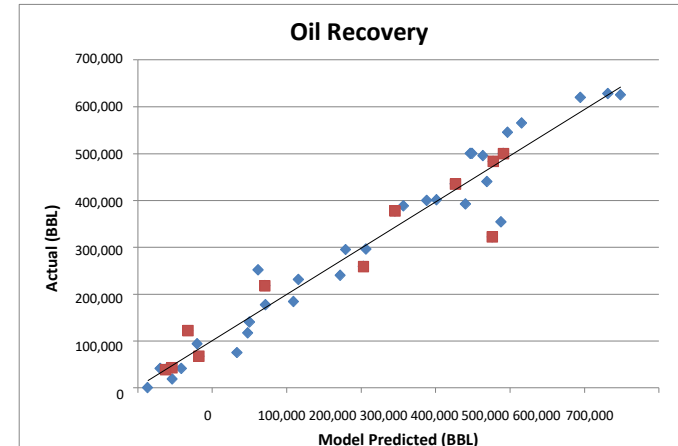
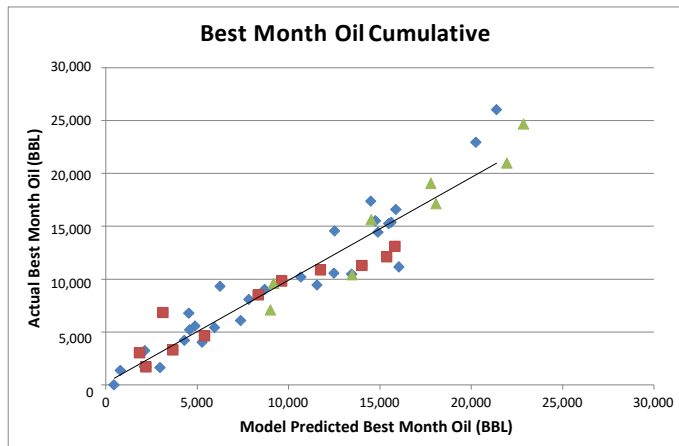
Geology & Drilling



Completion & Frac



Predictive Bakken Model

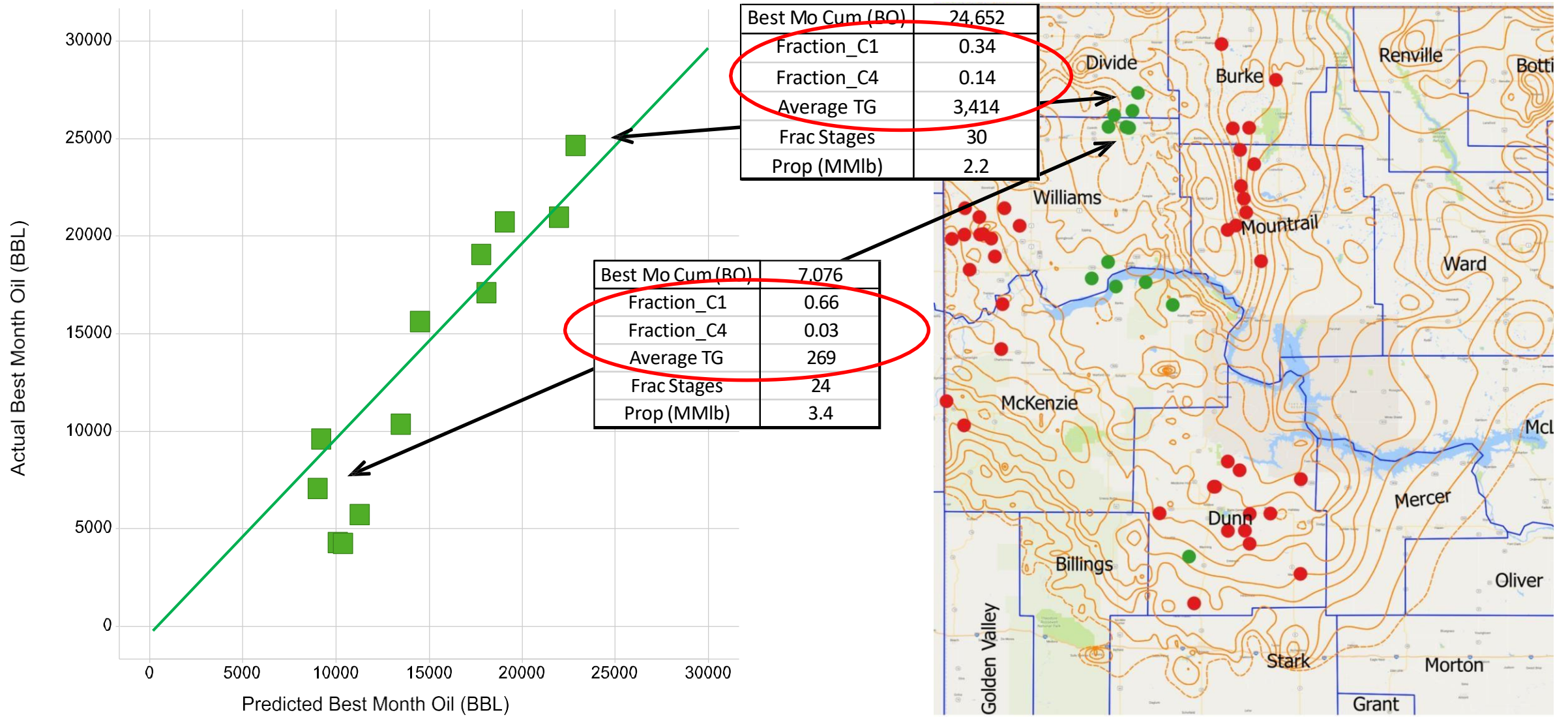


Bakken ANN Model Sensitivities

Parameter	Influence on Best Month Oil	Influence on Oil Recovery
Butane	24.12%	17.70%
No of Fracture Treatment	14.45%	13.25%
Total Gas	6.13%	6.82%
Proppant	3.86%	5.22%
Methane	-3.04%	-3.50%
Staging Method & Perforating	3.92%	1.73%
Treatment Type	2.31%	3.19%
Lateral Length	3.15%	1.05%
Treatment Volume	2.49%	2.03%
Drilling Mud Weight	0.42%	0.48%

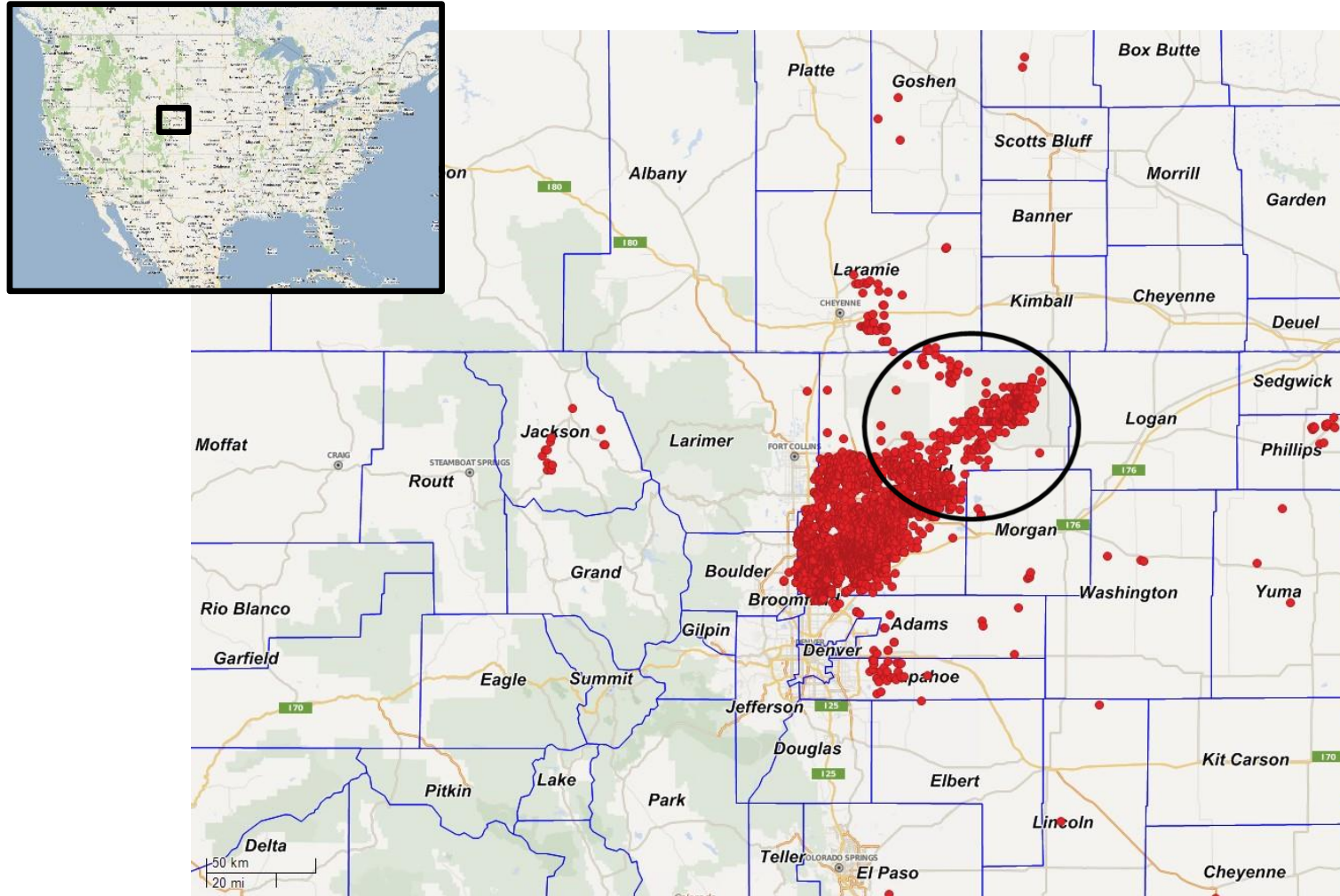
Controllable Completion and Frac Parameters
Non-Controllable Reservoir Related Parameters

New Well Evaluation; Model Predictions vs Actual



Niobrara Well Performance Evaluation Project

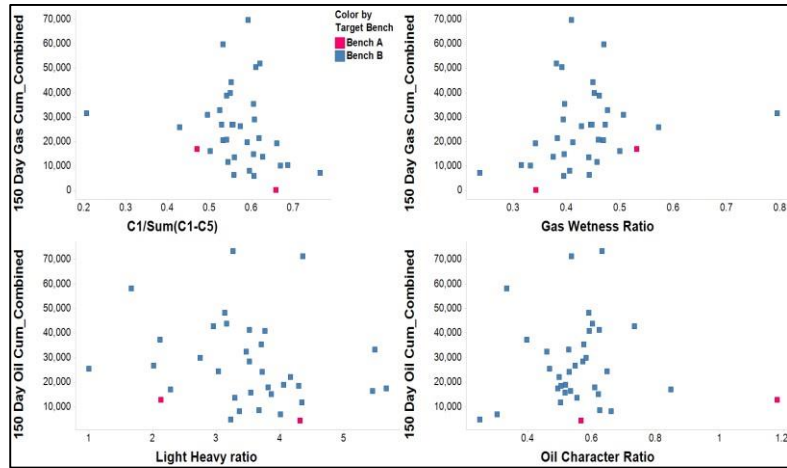
35 Wells Located in Weld County CO



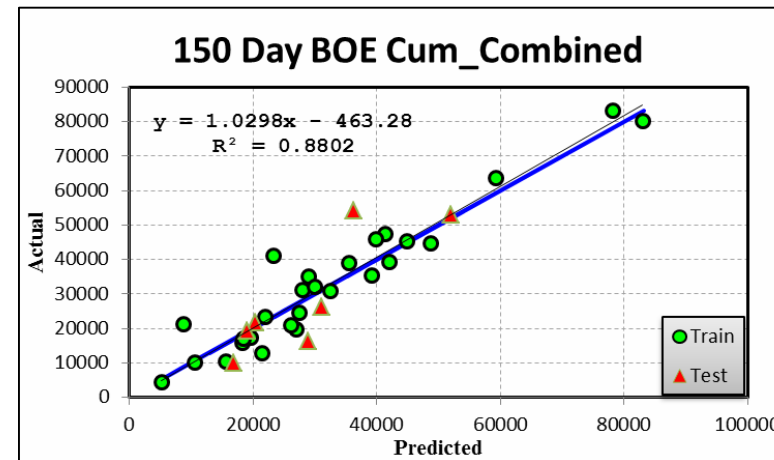
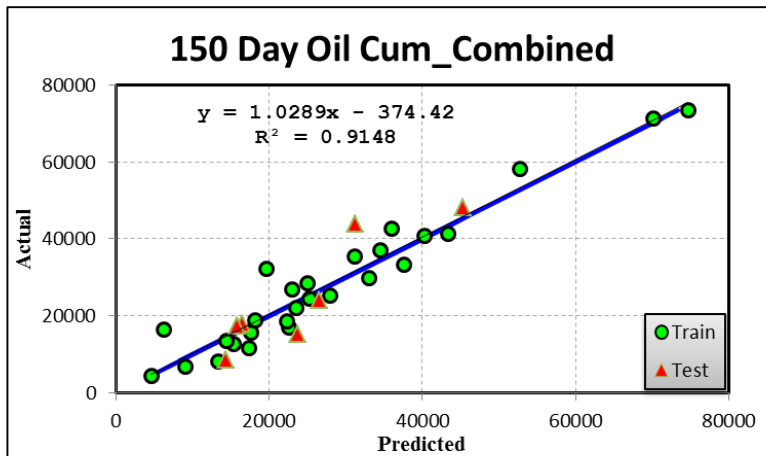
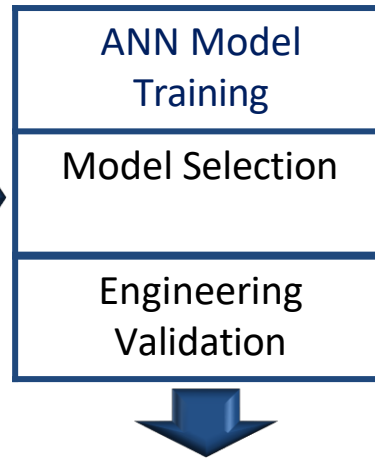
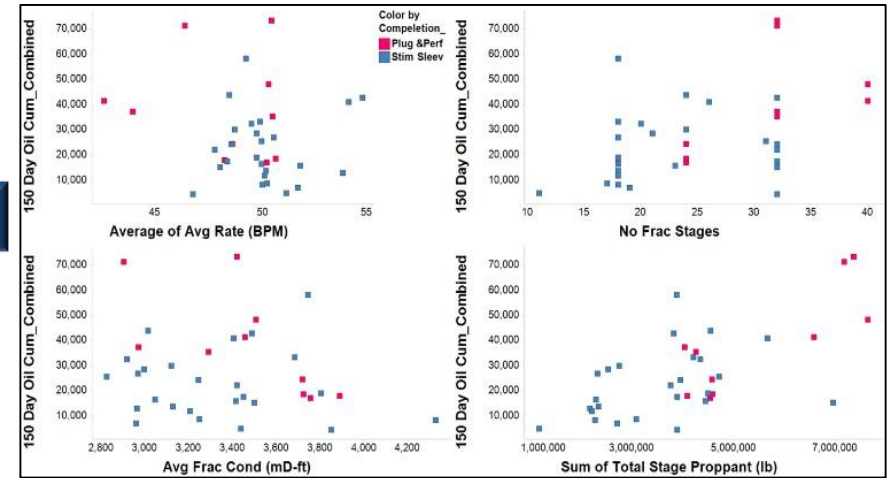
Niobrara ANN Model Development

34 Wells – 27 Train, 7 Test

Geology & Reservoir



Completion & Frac



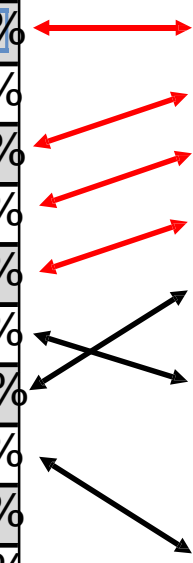
Model Response Comparison

Niobrara ANN Model

Bakken ANN Model

Model Predictor	Influence on 150 day Oil Cumulative
C3+C4	9.9%
Average of GR(API)	-10.3%
NbFrac Stages	8.8%
Avg Tg Normalized	7.5%
Total Proppant	6.9%
Total Fluid	4.4%
Fraction C1	-2.8%
Mud weight	0.8%
Average of Avg Rate (BPM)	1.0%
Max of Avg TVD	-0.3%

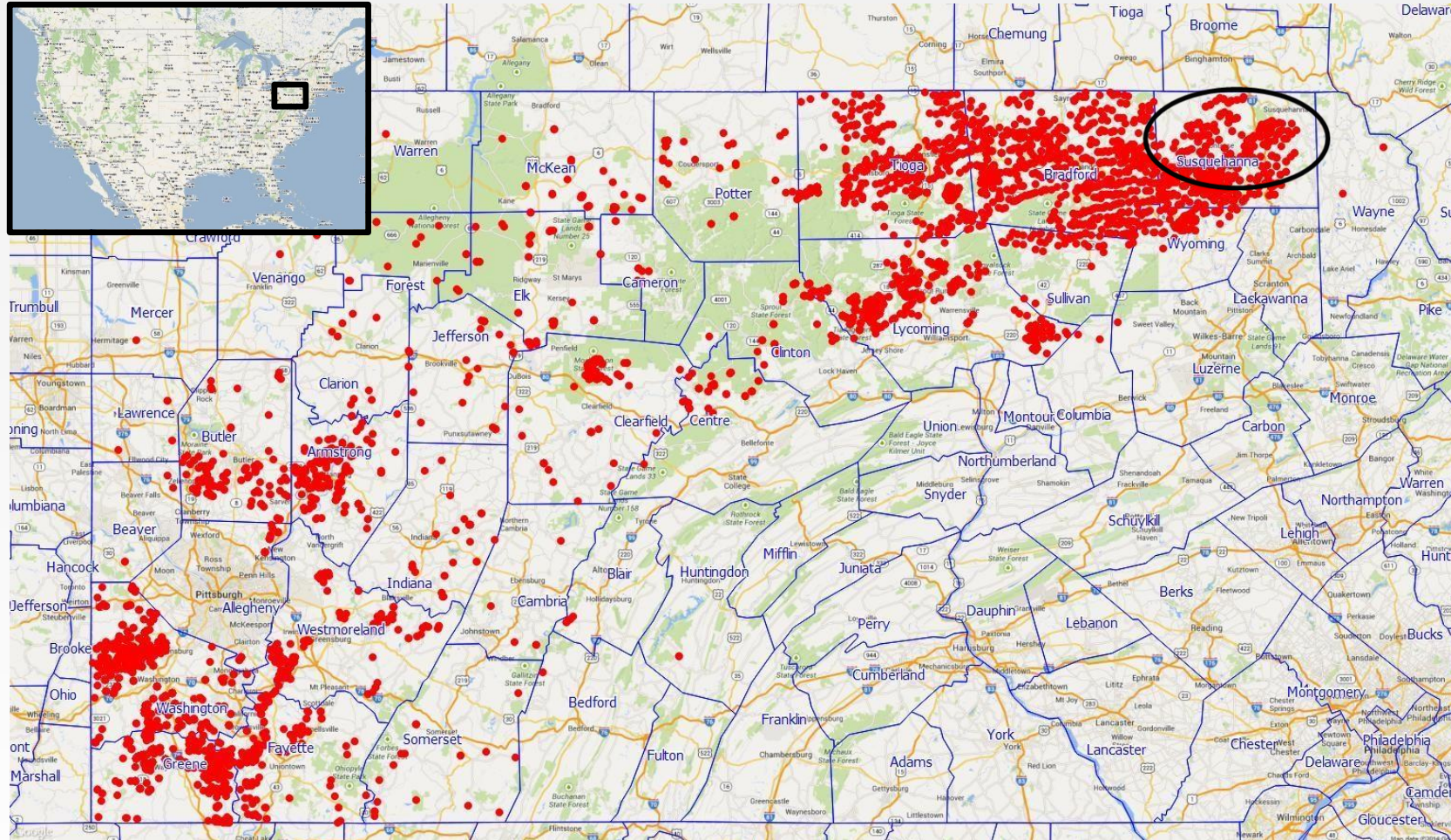
Model Predictor	Influence on Oil Recovery
C4 Fraction	17.70%
No of Fracture Treatment	13.25%
Total Gas	6.82%
Proppant	5.22%
Methane Fraction	-3.50%
Treatment Type	3.19%
Treatment Volume	2.03%
Staging & Perforating	1.73%
Lateral Length	1.05%
Drilling Mud Weight	0.48%



7 of the 10 predictors are the same and have similar responses

Marcellus Well Performance Evaluation Project

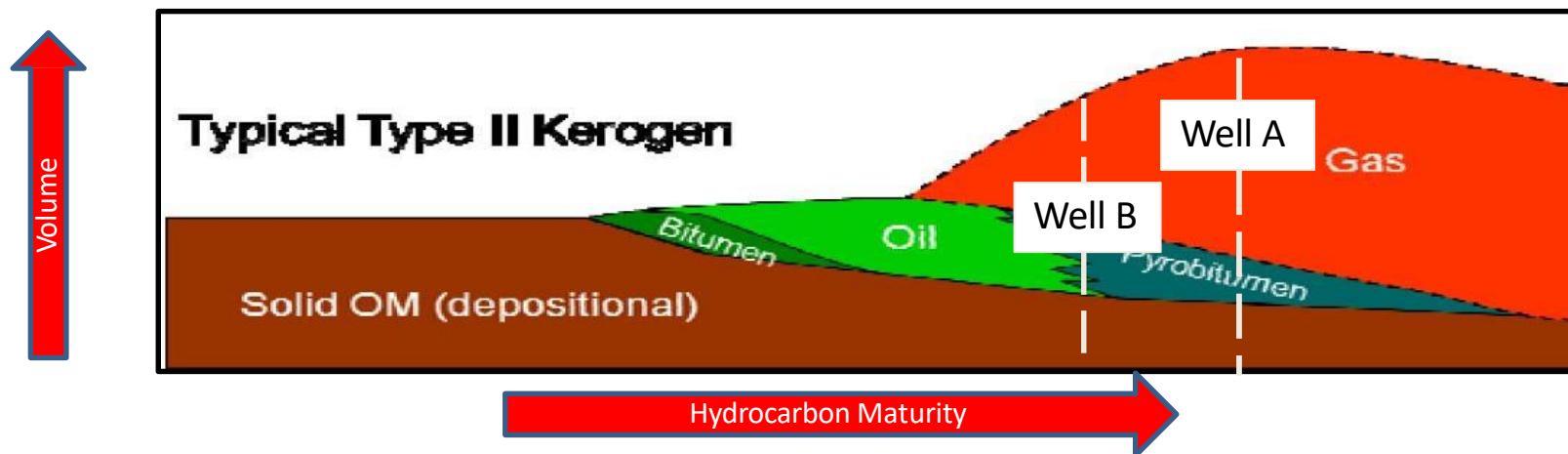
48 Wells - 34 Train, 14 Test



Marcellus ANN Model Sensitivities

Parameters \ Outputs	Peak Gas +10%	First 30 days Gas +10%
Top Marcellus (TVD ft)	7.4%	7.1%
No of Frac Stages	4.8%	5.0%
Upper Marcellus Thickness (ft)	3.5%	3.6%
Avg TG	2.7%	2.5%
Avg GR	-2.7%	-3.1%
Fraction C1	2.3%	3.0%
Proppant Mass (lb)	2.1%	2.5%
Net Perforated Length (ft)	1.7%	1.9%
Fluid Volume (bbl)	0.9%	1.2%
Average Rate (BPM)	-0.2%	-0.1%
Controllable Completion and Frac Parameter		
Non-Controllable Reservoir Related Parameter		

Two Marcellus Wells with Similar Completion and Frac Design



Horiz. Drilling Measurements

	Well A		Well B
Best Month Gas (MCF)	204,500	>	69,000
Total Gas Units	1,048	>	280
Methane Fraction	0.96	>	0.94
Marcellus TVD (ft)	7,409	>	5,890
Gamma Ray Count	151	≈	162
Thickness (ft)	157	≈	164

Conclusions

- Inexpensive measurements made at the surface during horizontal drilling operations along with known geology parameters can be useful in explaining horizontal well performance.
- The wetter gas components in combination with high TG are indicators of produce-ability in oil shale like the Bakken and Niobrara.
 - Production from the Niobrara appears to be influenced to a greater extent by mineralogy than completions in the Middle Bakken.
 - Gas dryness in combination with low total gas (TG) are characteristic of completions located in non-prospective oil producing strata.
- Gas dryness in combination with high total gas (TG) and deeper strata are characteristics of completions in prospective gas producing shale systems such as the Marcellus.
- Fracture spacing, proppant amount and type are the highest impact controllable production drivers for horizontal wells in both gas and oil producing shale.

Thank You!