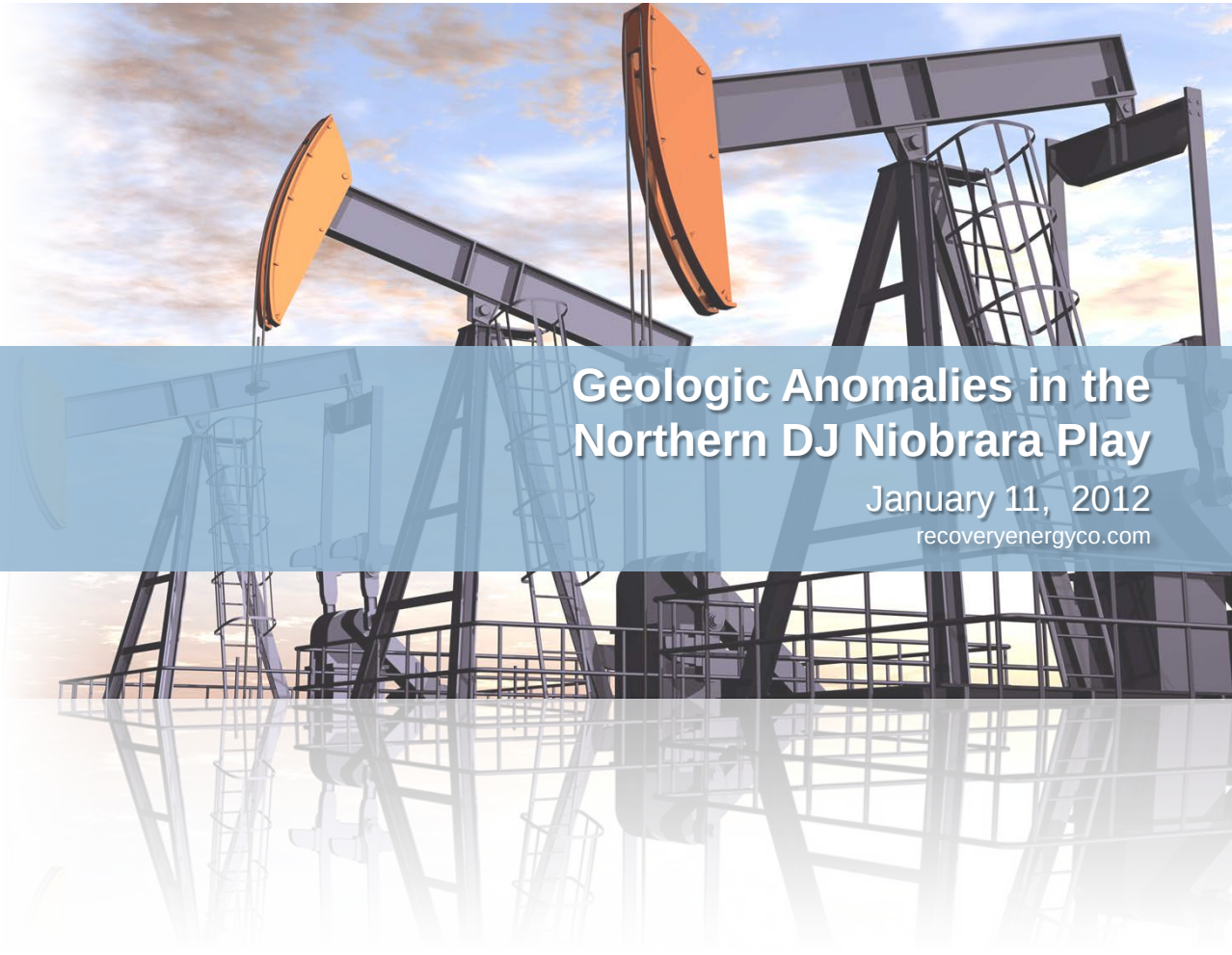


The background of the slide is a photograph of several oil pumpjacks (jack-o'-lanterns) in an oil field. The pumpjacks are dark metal structures with large, orange-colored walking beams. They are set against a sky with soft, wispy clouds in shades of blue and orange, suggesting a sunrise or sunset. The pumpjacks are arranged in a row, receding into the distance.

Geologic Anomalies in the Northern DJ Niobrara Play

January 11, 2012
recoveryenergyco.com

Overview and Outline

Background

- Activity
- Paleogeography and Stratigraphy
- Tectonics and Fractured Reservoirs

Consideration of Available Metrics

- Maturity, Resistivity and Heat Flow
- Lithology/Target Selection

Reservoir Distribution

- Silo Field
- Herrington Farms and “String o’ Silos”
- Hereford Field
- Mososaur
- Borie
- North

Summary and Conclusions

- Fractures, Migration, and Interception (Shoot 3D!!!)
- Interfacial Tension and Oil-Wet Reservoirs (Consider Drilling and Completion Modifications in Some Areas)

Acknowledgements



ANOMALIES

- **Hybrid Reservoir – so how do we estimate reserves?**

Corollary: What are we doing when we use resistivity cutoffs from a carbonate “carrier bed” instead of surrounding source rock?

- **Highly Variable Production – even within “sweet spots”**

- **Water Production – (and low volume) in some mature, highly resistive areas**

Niobrara Production

CHUGSPRING

SILO

BORIE

HEREFORD

WATTENBERG

WY NE

CO

WY NE

CO

WY NE

CO

Thermogenic "Play Fairway" - Matuszcak, 1973 inter alia

Muddy J Structure CI = 500'

Vertical Only

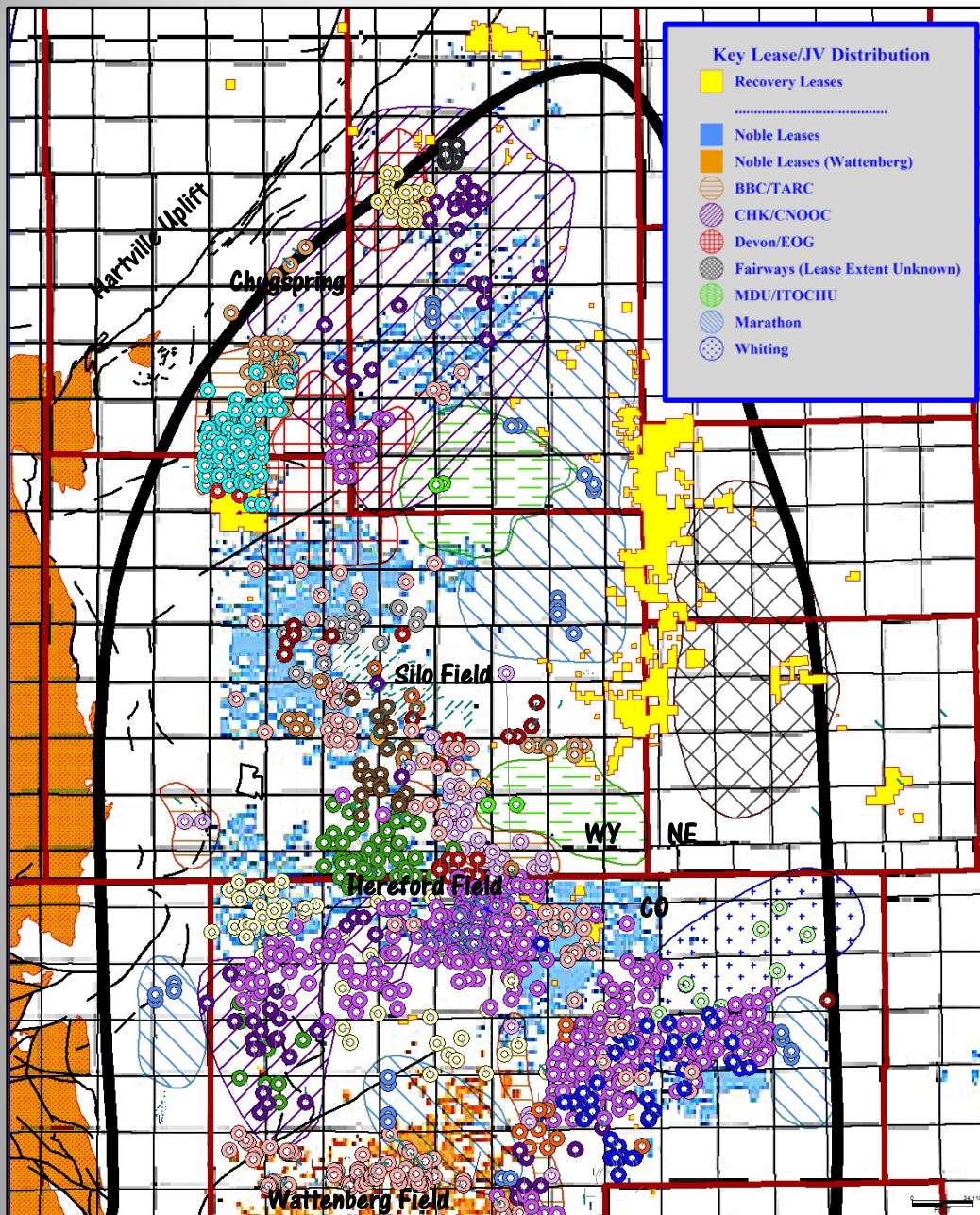
Vertical and Horizontal

Tectonic Framework

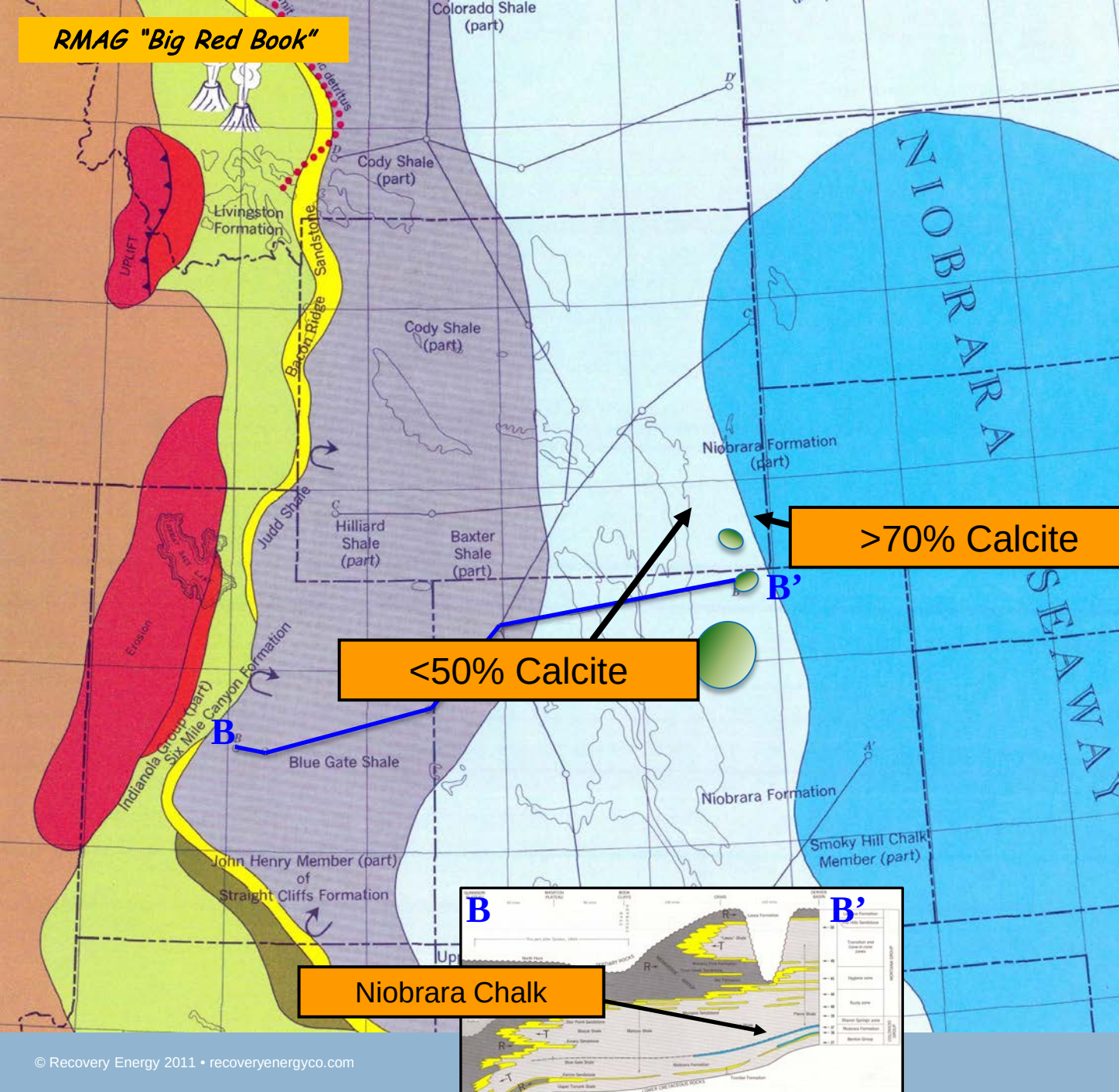
Bouger Gravity from RMA6 "Big Red Book"

ACTIVITY

Niobrara Joint Venture and Drilling/Permit Activity (Horizontal Wells/Permits as of 9/1/2011)



PALEOGEOGRAPHY AND STRATIGRAPHY



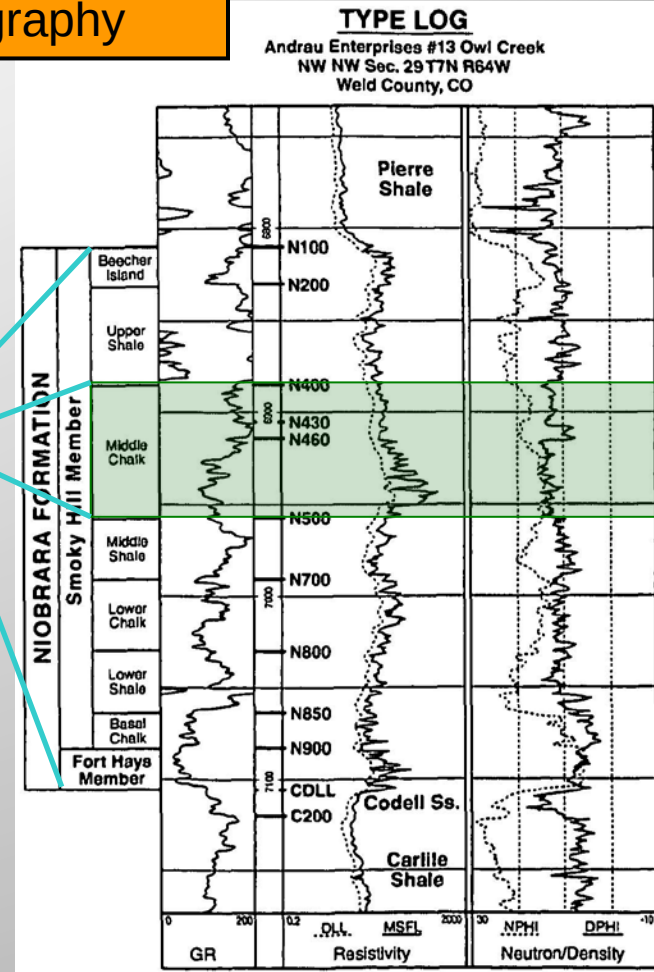
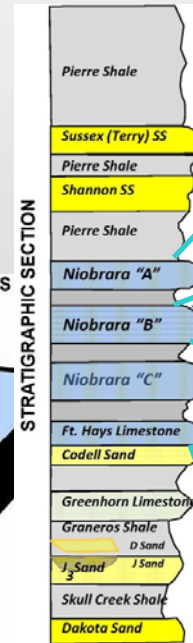
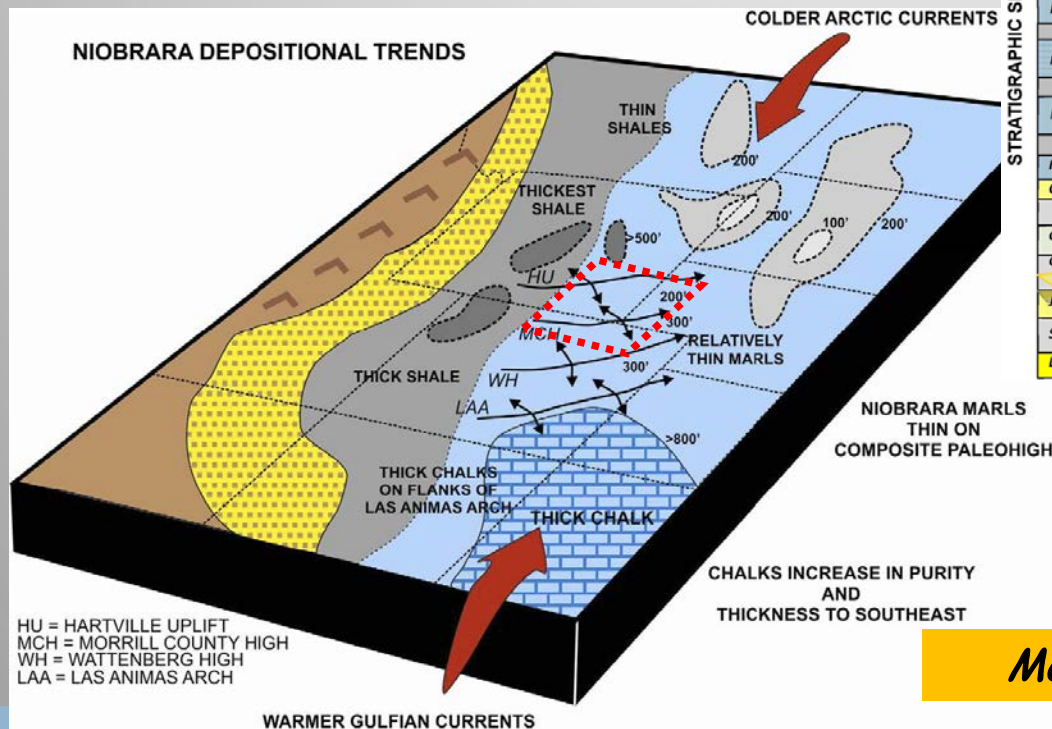
EXPLANATION

- Land, high to moderate elevation; sediment source.
- Land, moderate to low elevation; sediment source.
- Volcano or center of volcanic field.
- Piedmont deposit, fanglomerate.
- Nonmarine rocks of coastal plain; primarily sandstone, also local conglomerates and floodplain deposits.
- Coal swamps.
- Marine sandstone, barrier island, beach or near-shore deposits.
- Marine shale.
- Marine calcareous mudstone.
- Marine limestone.
- Direction of shoreline migration.
- Location of shoreline at maximum transgression.
- Line of section.
- Active thrust fault.
- Precambrian crystalline rocks exposed.

Niobrara Paleogeography

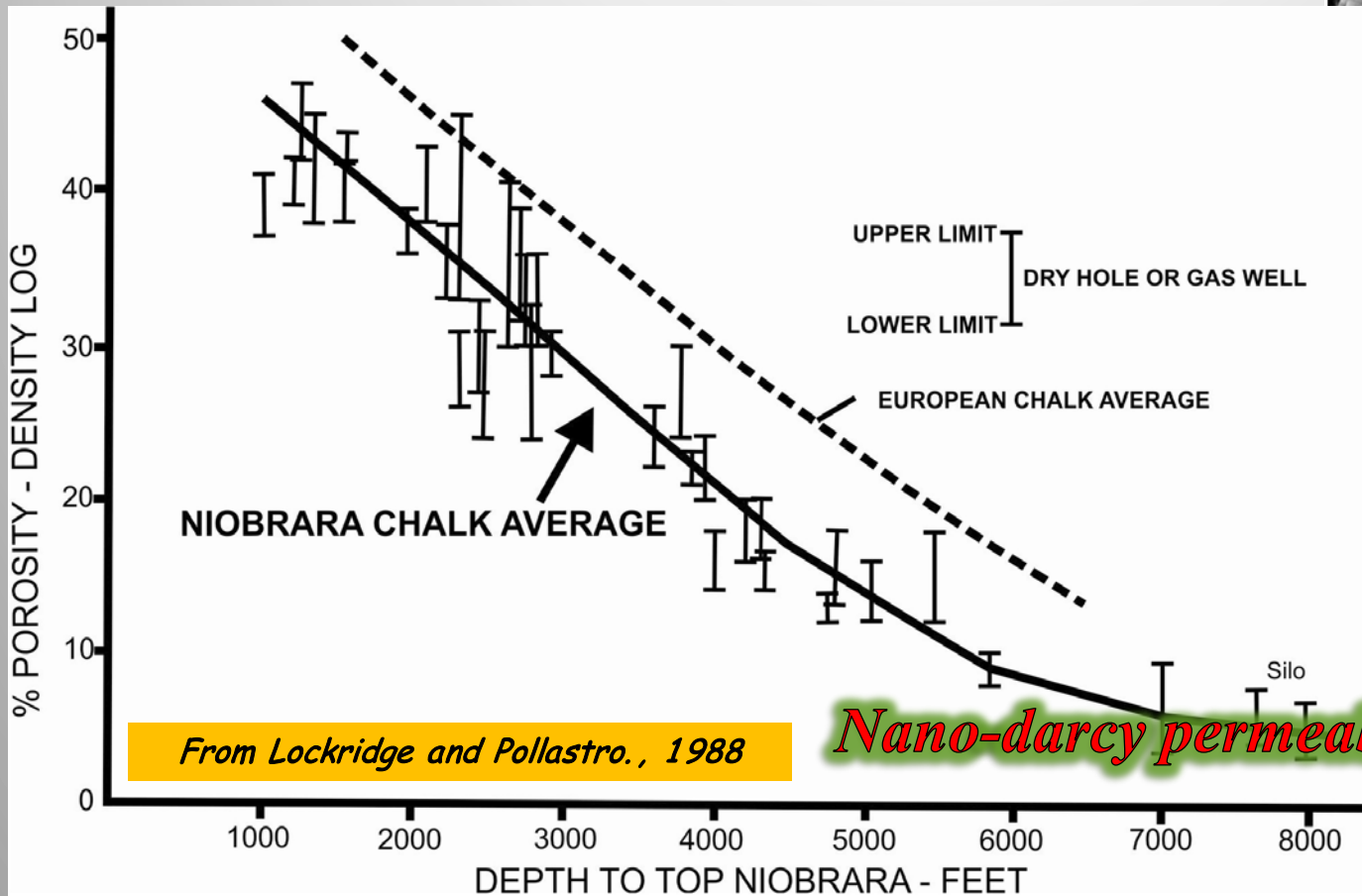
Niobrara Stratigraphy

Niobrara Paleogeography



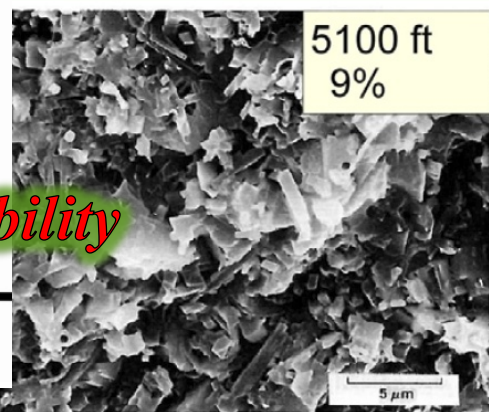
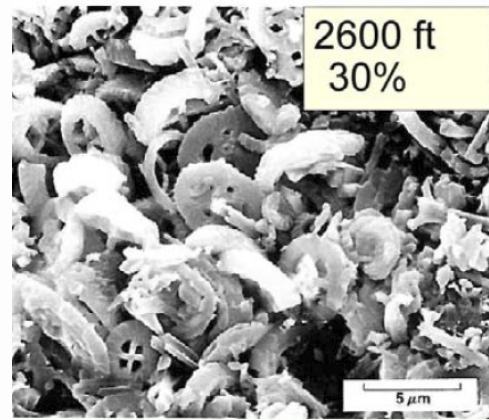
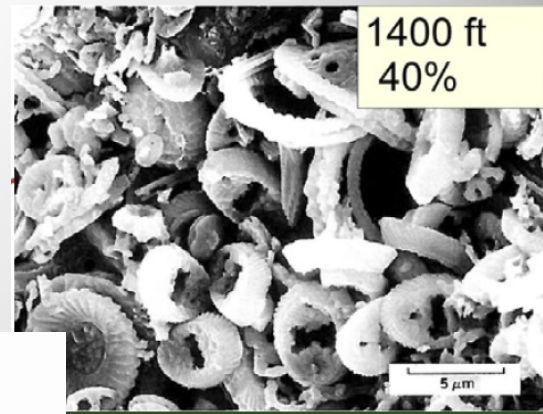
Modified from Longman et al., 1998

Niobrara Porosity and Permeability



From Lockridge and Pollastro., 1988

Nano-darcy permeability



Pollastro and Scholle, 1986

TECTONICS AND FRACTURED RESERVOIR

Tectonic Fabric in Vicinity of Silo Field

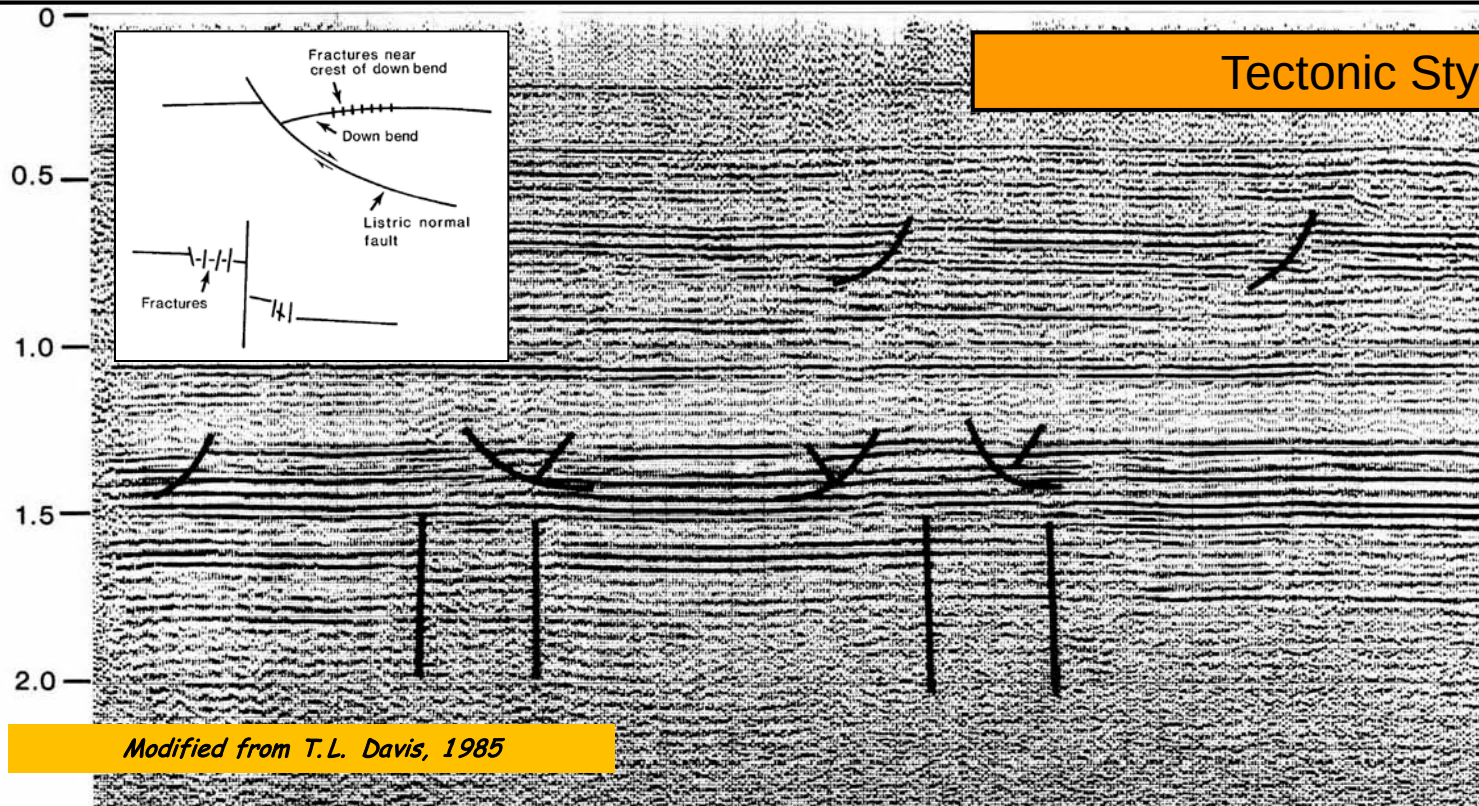
Modified Coherency Attribute at Niobrara



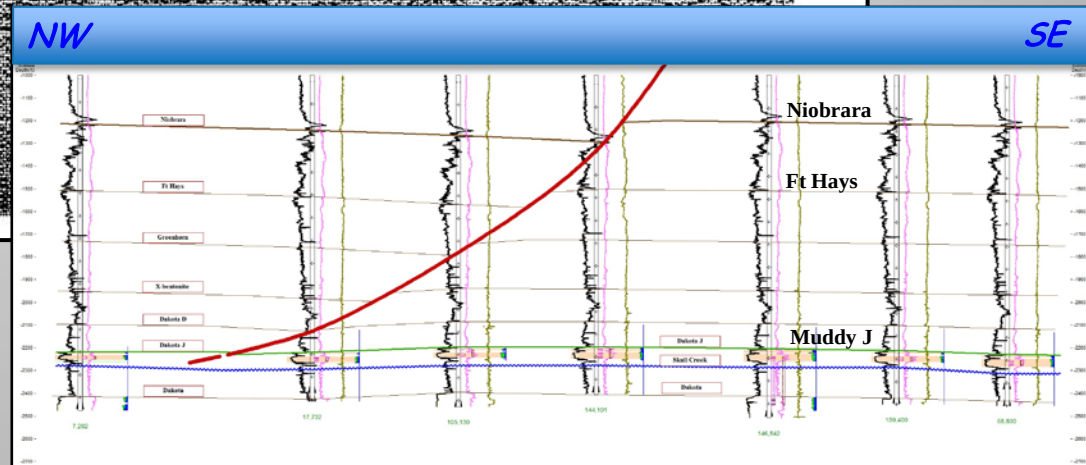
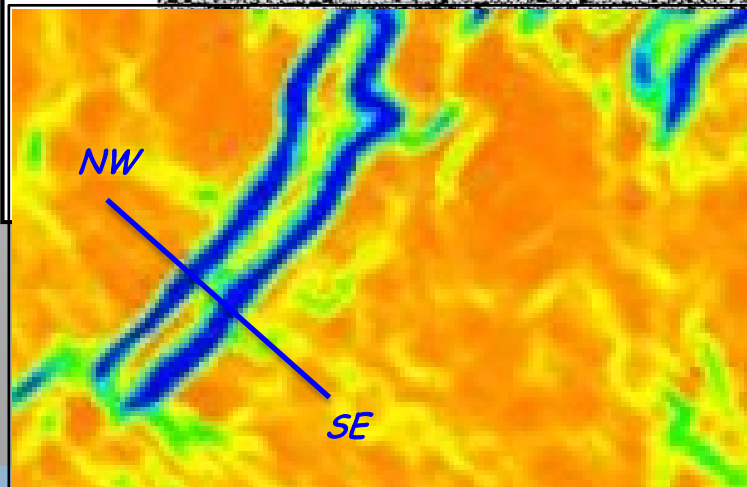
Thanks to Global Geophysical Services!!!

Tectonic Style

Time, sec



Modified from T.L. Davis, 1985



Fractured Reservoir Types in the Niobrara – Working Hypothesis

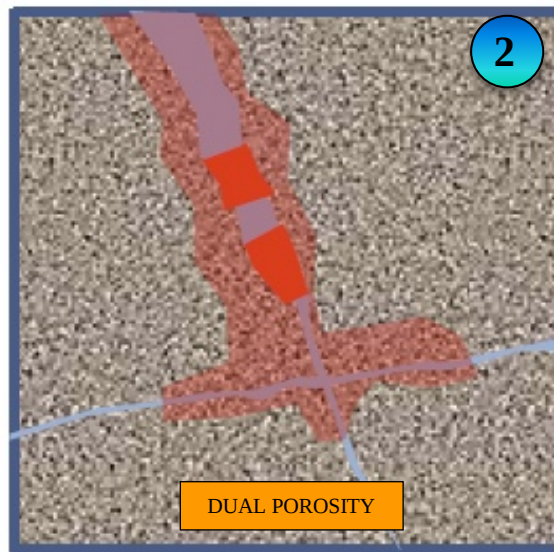


Figure adapted from Golder & Assoc., 2010

Type 1

Extremely low matrix permeability and effective porosity. Reservoir restricted to fractures only.

Type 2

Fracture network comprises most significant part of reservoir. Minor contribution from matrix.

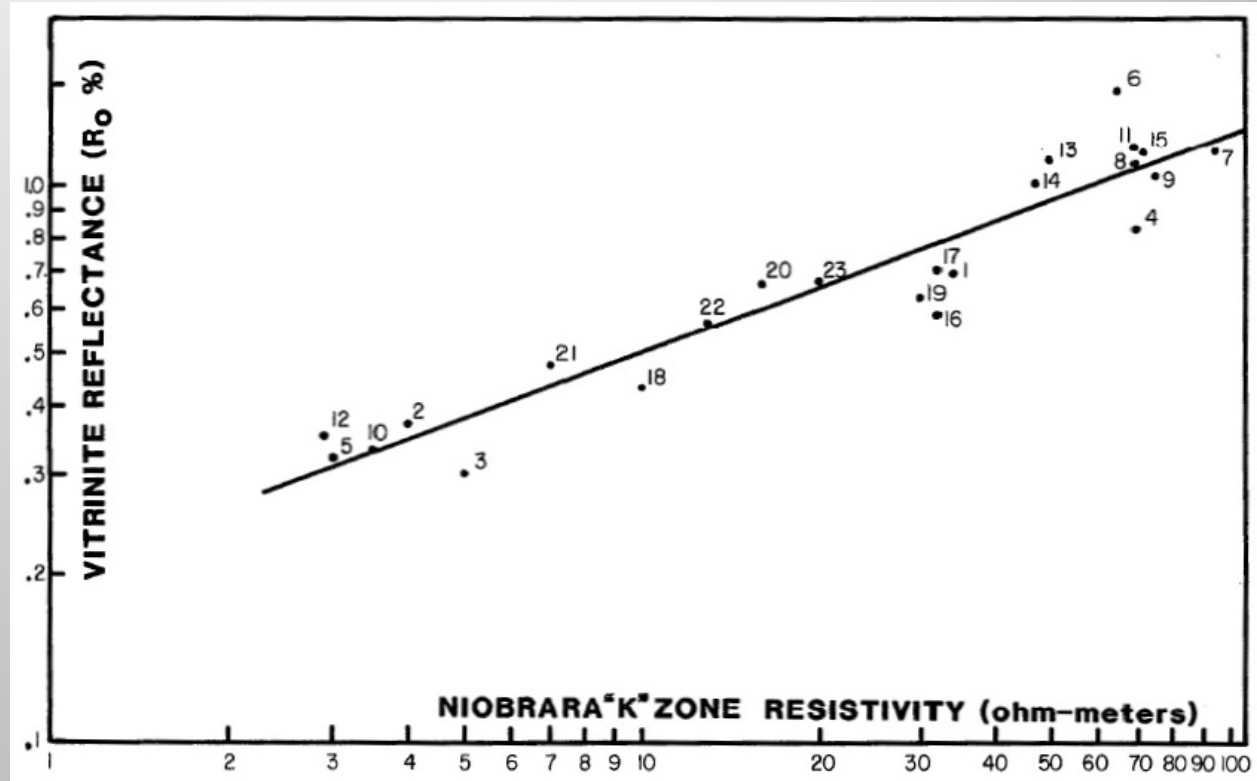
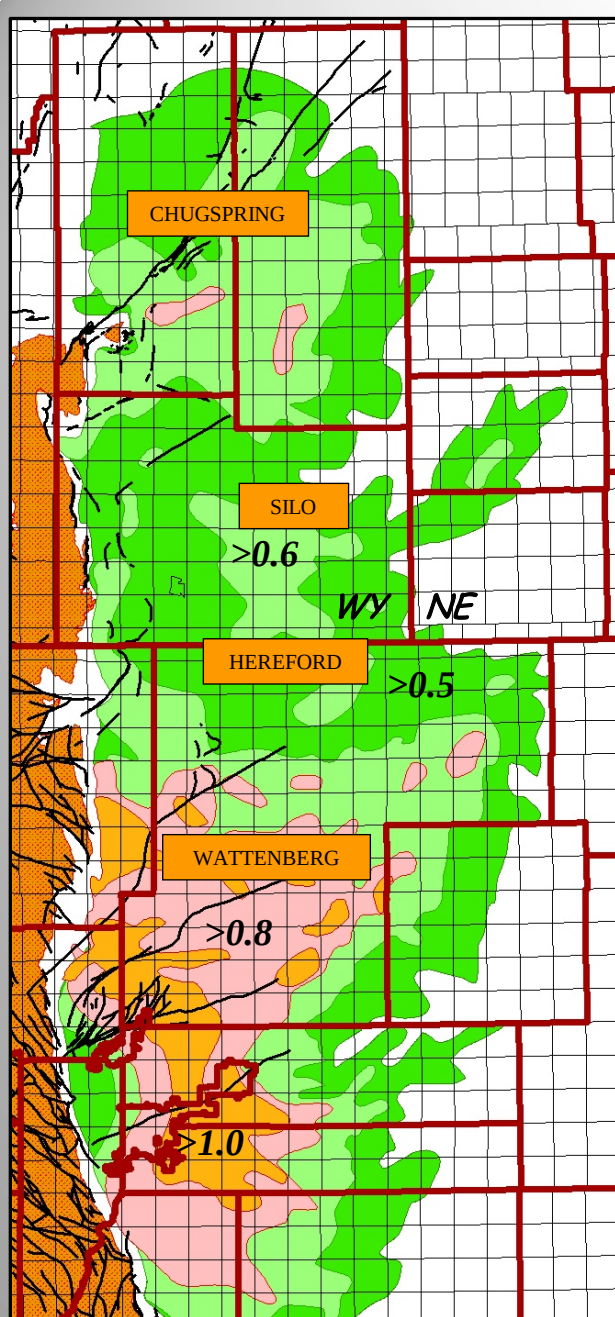
Type 3

Matrix contribution significant, but fractures important to economics (i.e. rates, and operations)

Micro-Frac's Might Look Like Matrix

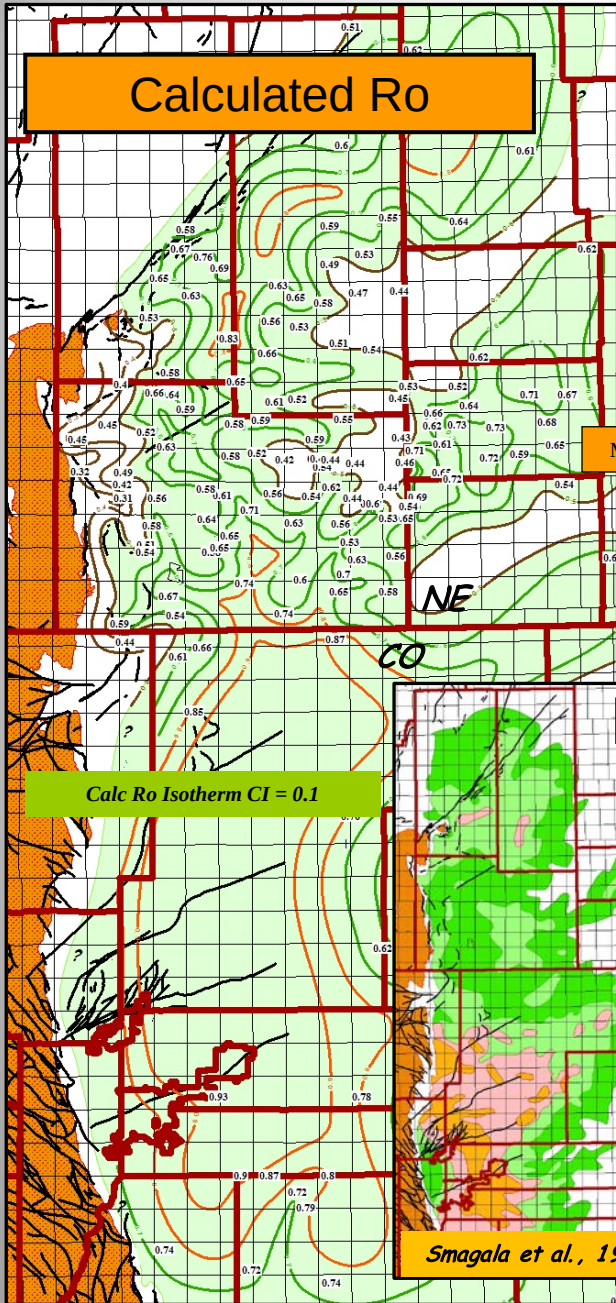
MATURITY, RESISTIVITY AND HEAT FLOW

Vitrinite Reflectance

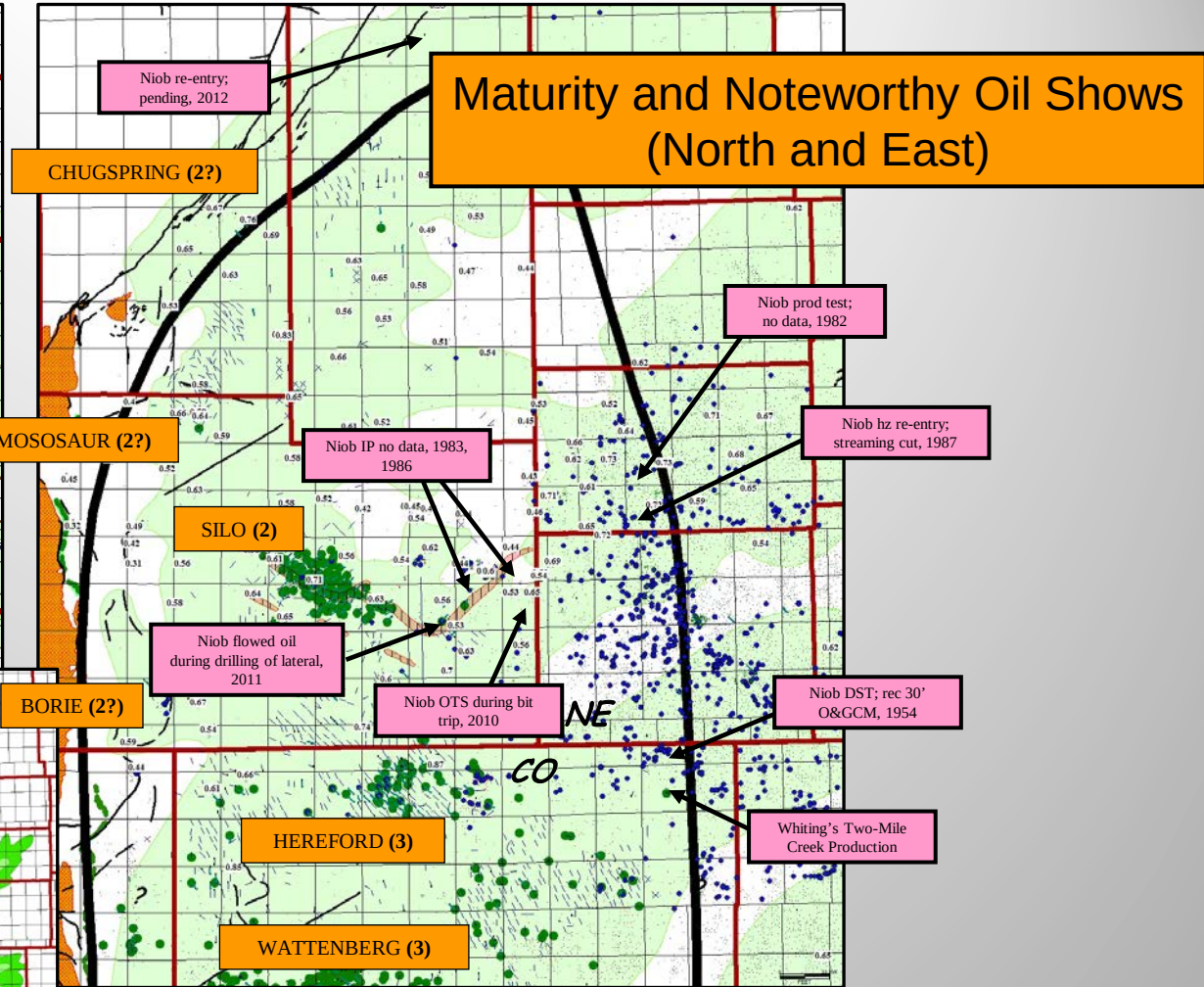


Modified from Smagala et al., 1984

Calculated Ro



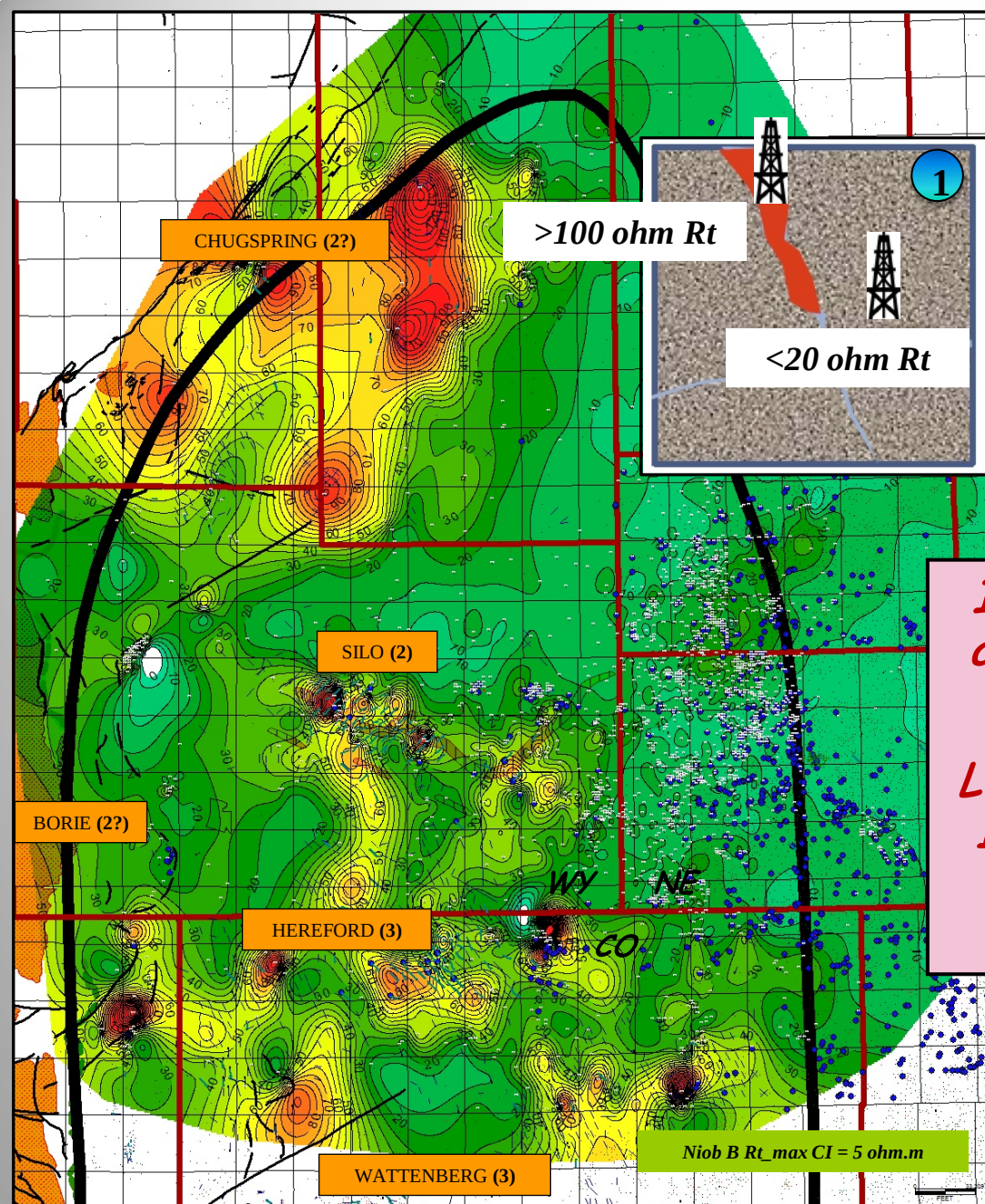
Maturity and Noteworthy Oil Shows (North and East)



Niob Ro calculated as function of Tmax:
 $Ro = 0.018 * Tmax - 7.16$ (Jarvie)
 Data proprietary, and from USGS CRC:

<http://my.usgs.gov/crc-browse/faces/wellcatalog.jsp>

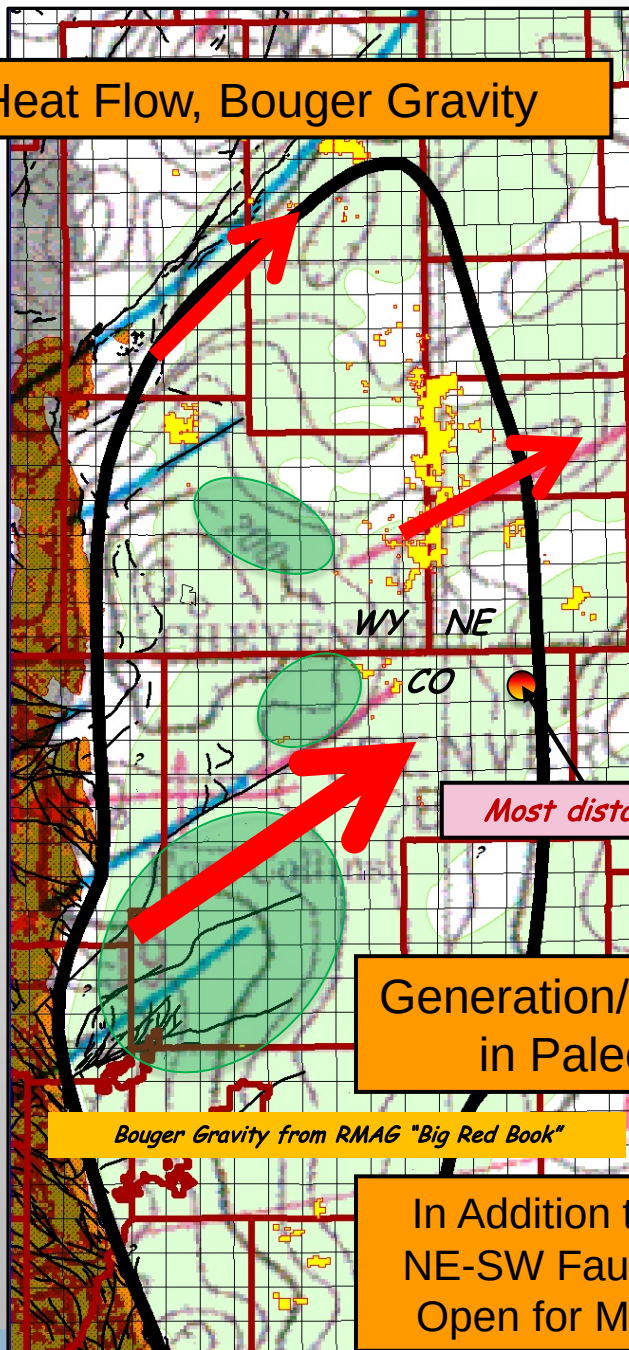
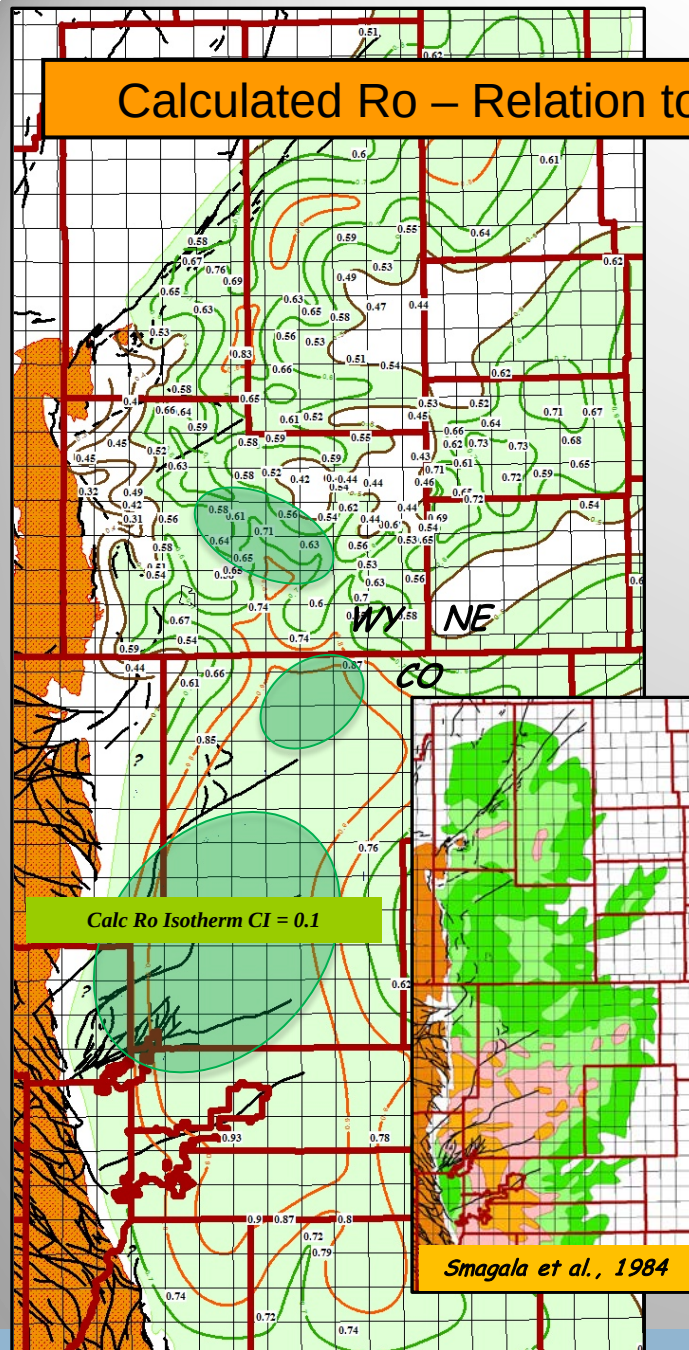
Rt Max in Niobrara B



In many cases, resistivity tools are responding to hydrocarbon-bearing fractures

Low Rt areas may be artifact of 1) low well density; 2) low frac density; and/or 3) low matrix saturation

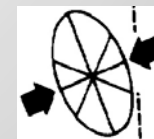
Calculated Ro – Relation to Heat Flow, Bouguer Gravity



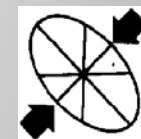
Approx Paleocene-Eocene
Max Horiz Stress



Generation, migration



Paleocene



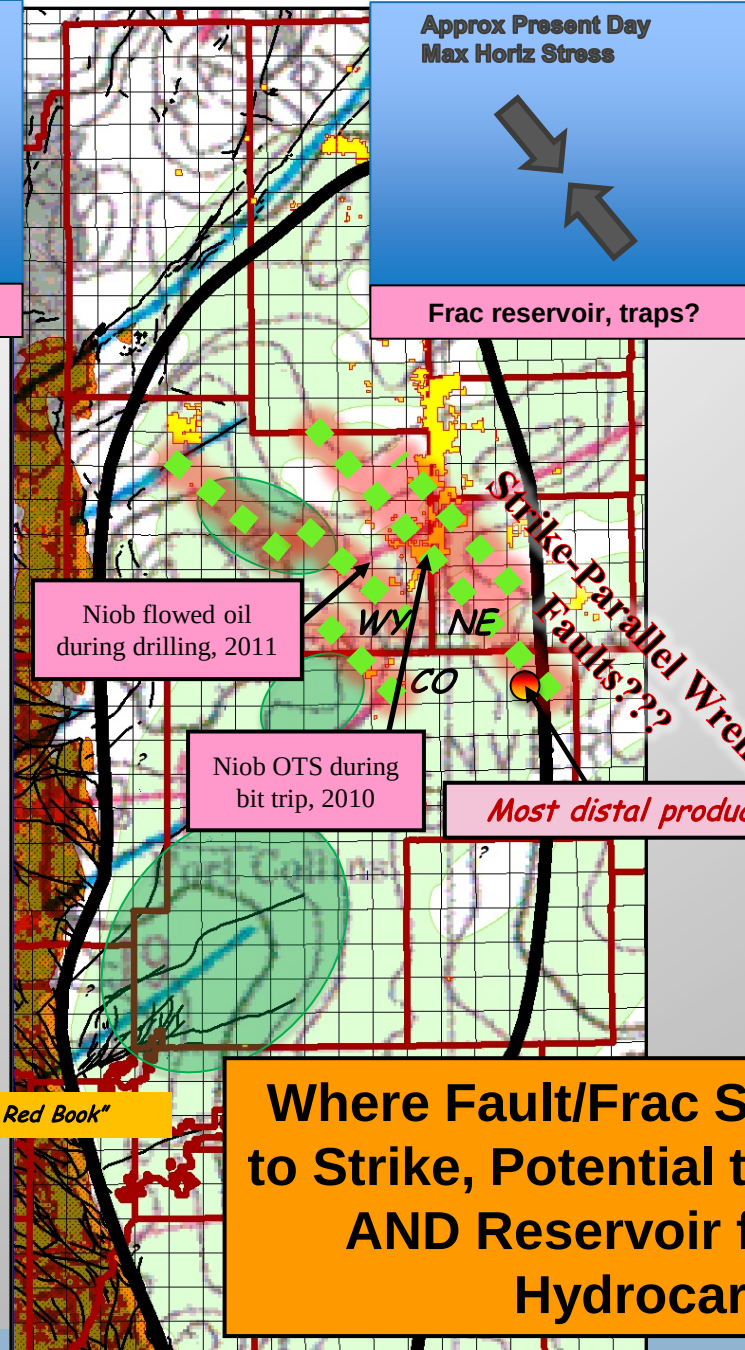
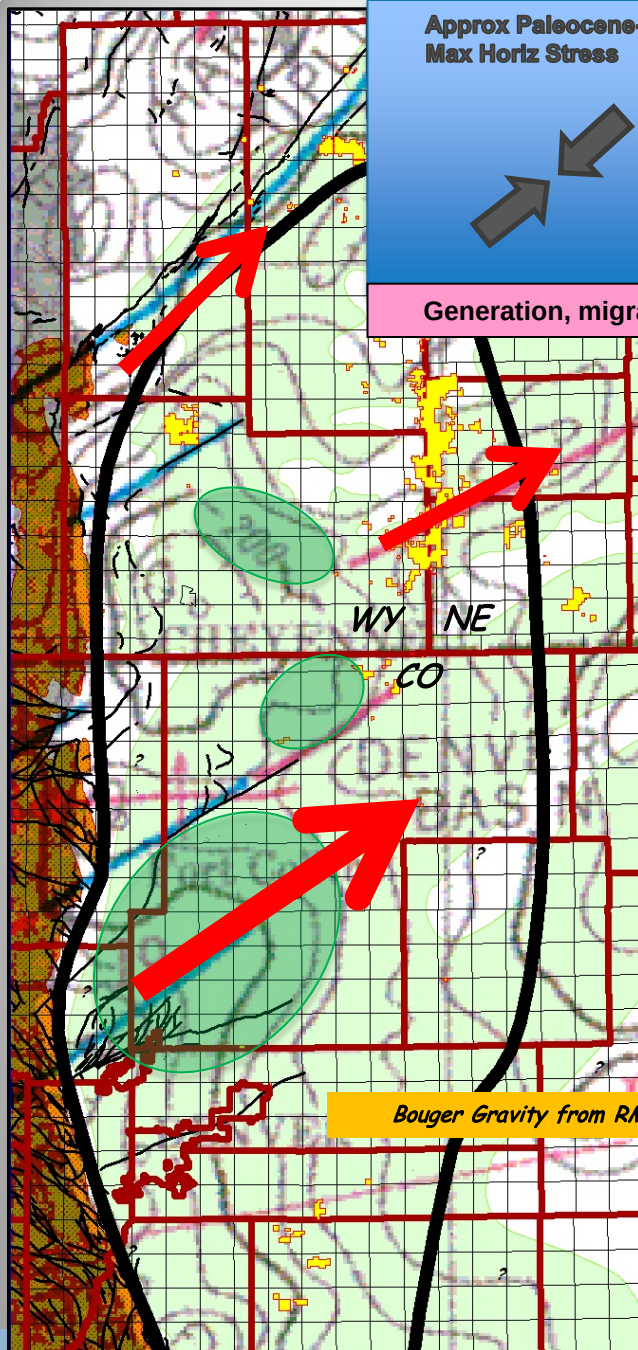
Eocene

Modified from Merin and Moore, 1986

Most distal production in "Colo Mineral Belt"

Generation/Migration Commencing
in Paleocene into Eocene

In Addition to Conducting Heat Flow,
NE-SW Fault/Frac Swarms Generally
Open for Migration of Hydrocarbons



Where Fault/Frac Swarms Parallel to Strike, Potential to Serve as Trap AND Reservoir for Migrated Hydrocarbons

LITHOLOGY/TARGET SELECTION

B1 or B2?

Higher uranium/kerogen in the B1 than in B2, similar calcite

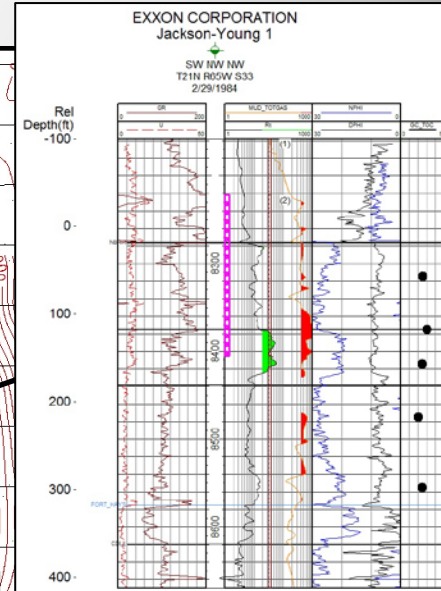
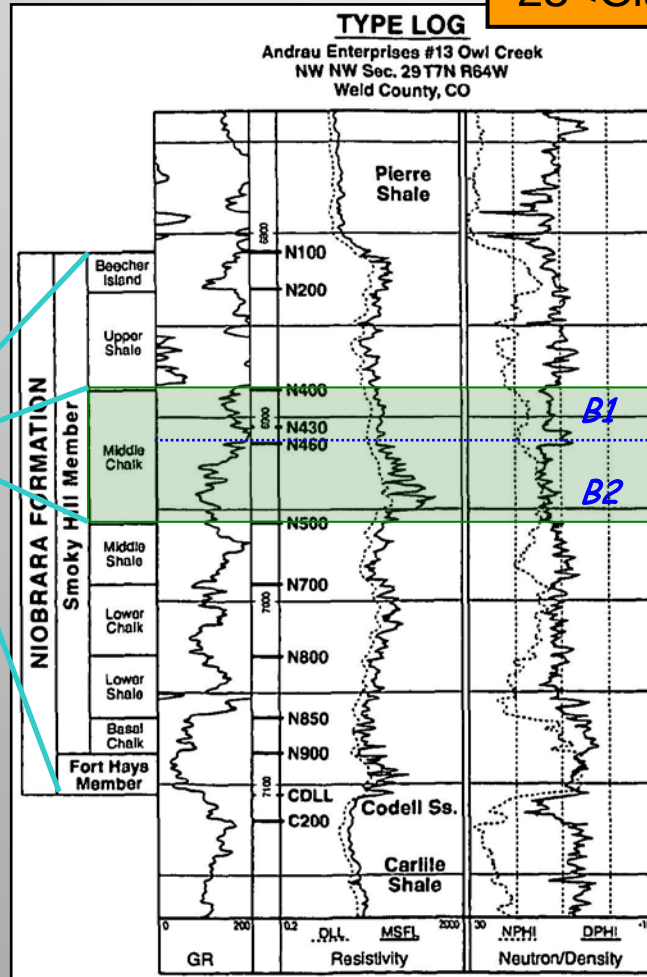
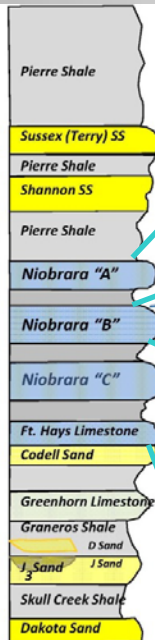
<50% Calcite
25<Clay<45%

Niobrara Structure CI = 50'

>70% Calcite
3<Clay<13%

Higher resistivity in B2 where highly fractured

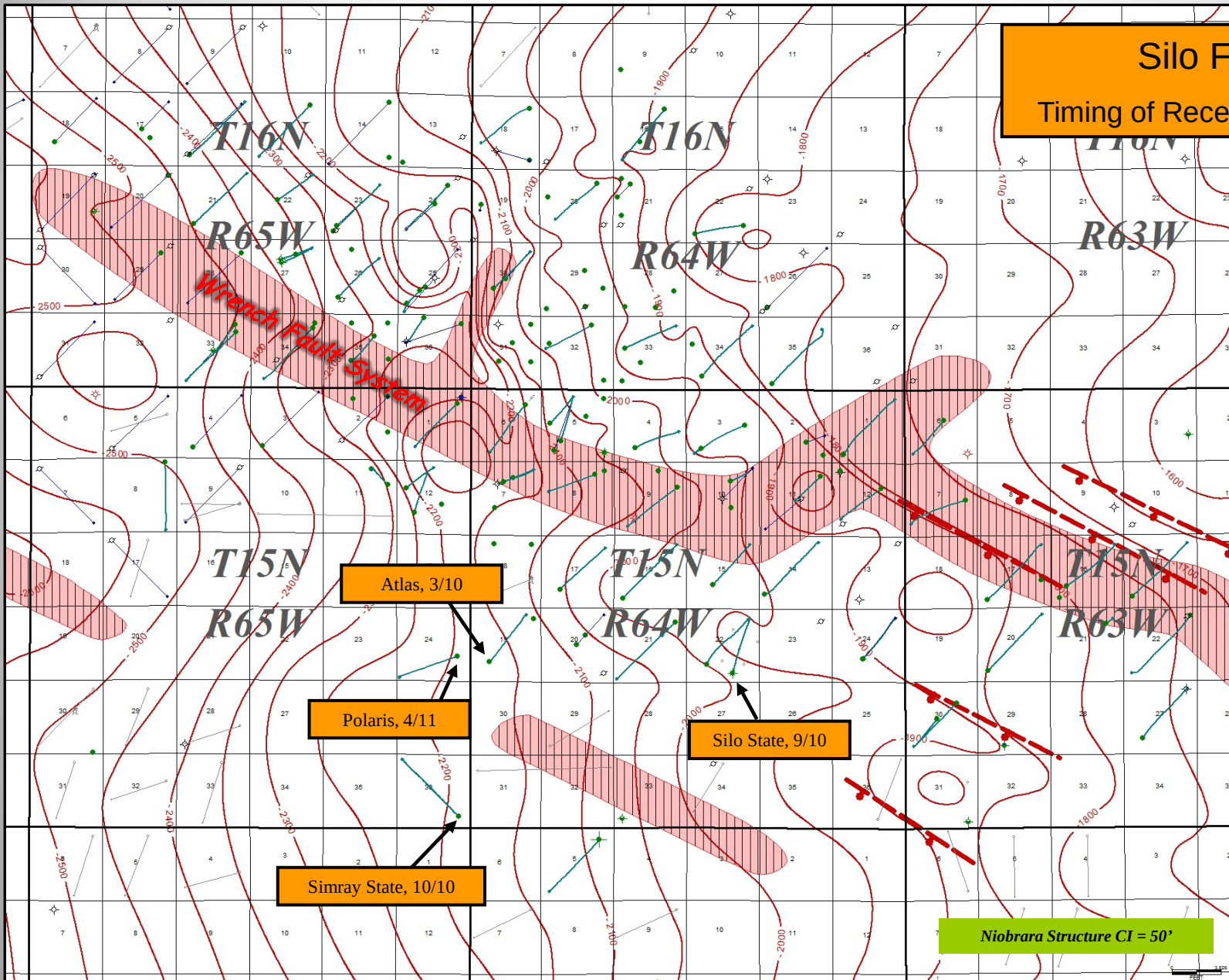
STRATIGRAPHIC SECTION



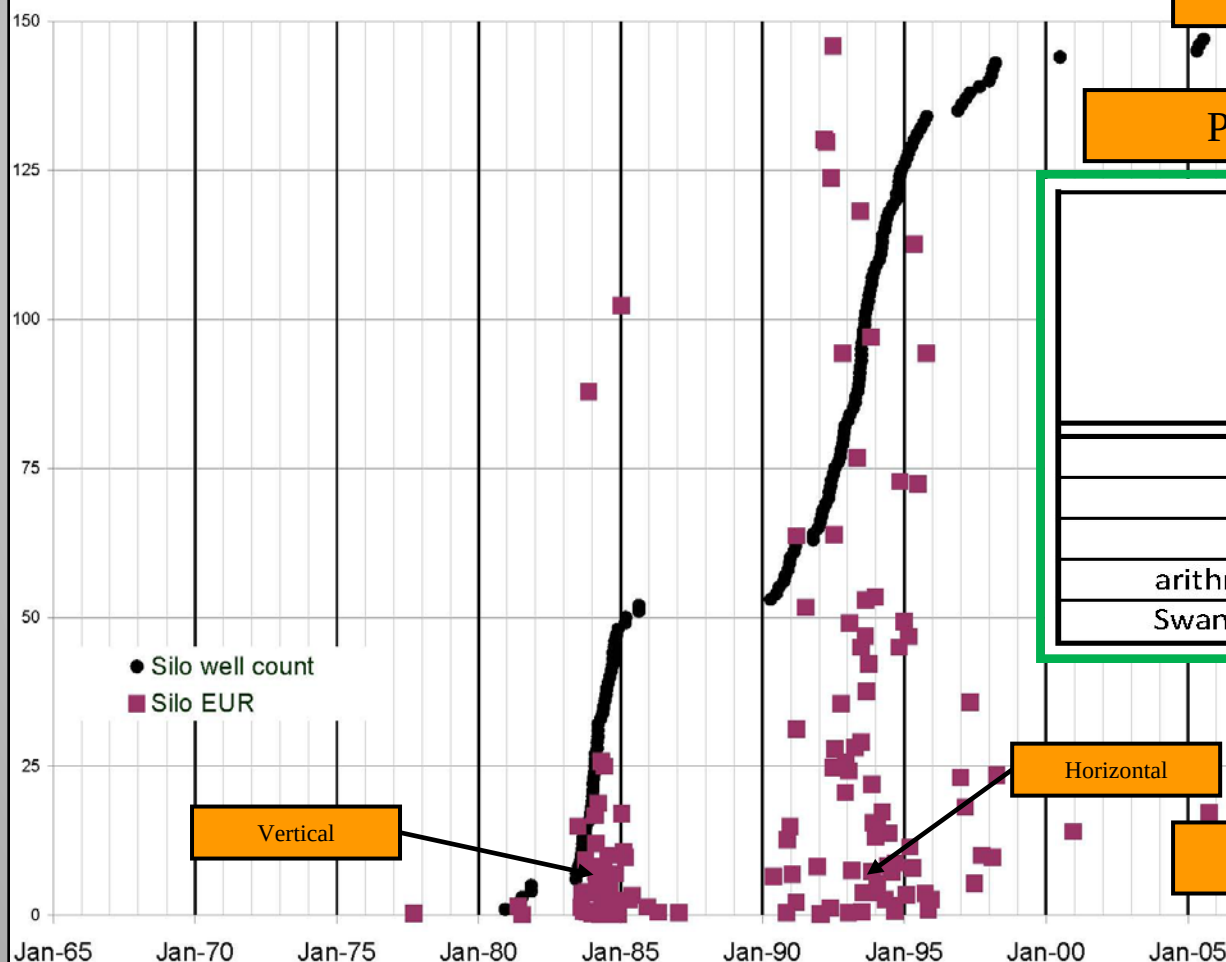
SILO FIELD

Silo Field

Timing of Recent Key Wells



Silo Field Niobrara Drilling/Production History



“Paleo-” Silo Field

Pete Rose Statistics (EUR)

	Inactive Vertical Mbo	Inactive Horizontal Mbo	Active Wells Mbo
P10	59.6	125.0	377.1
P50	11.3	29.1	197.0
P90	0.6	2.1	56.0
arithmetic	20.8	48.3	243.6
Swanson's	22.6	49.8	208.8

2X

10X

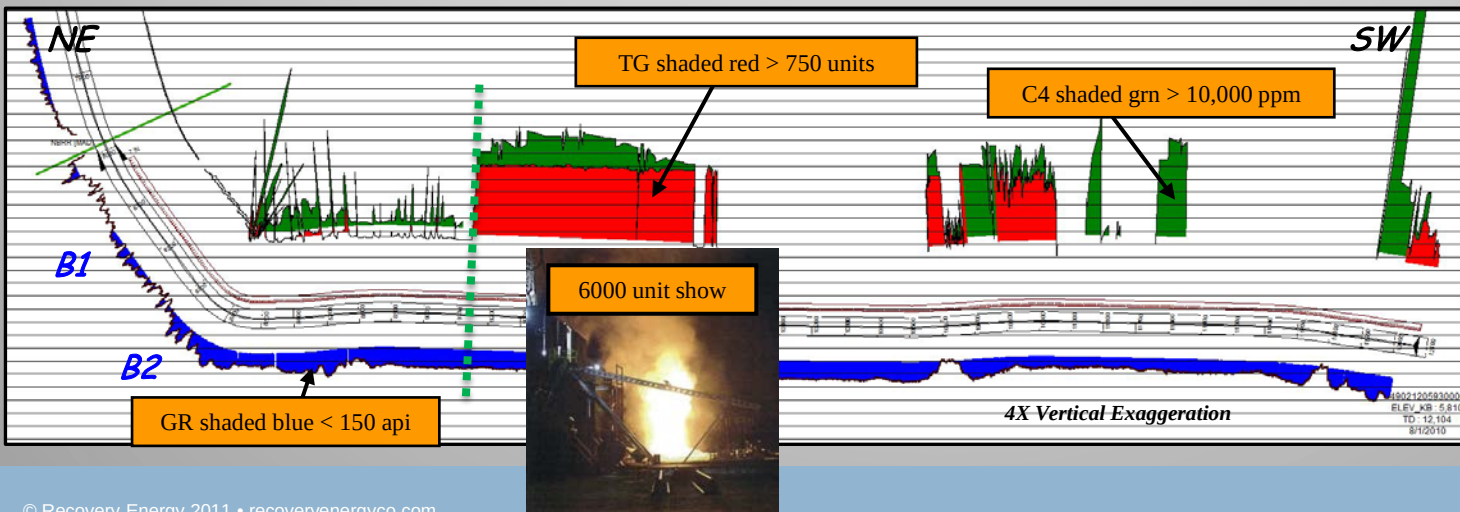
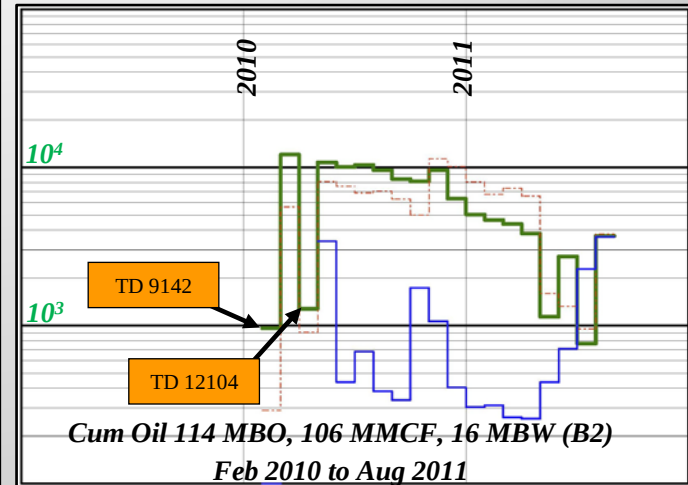
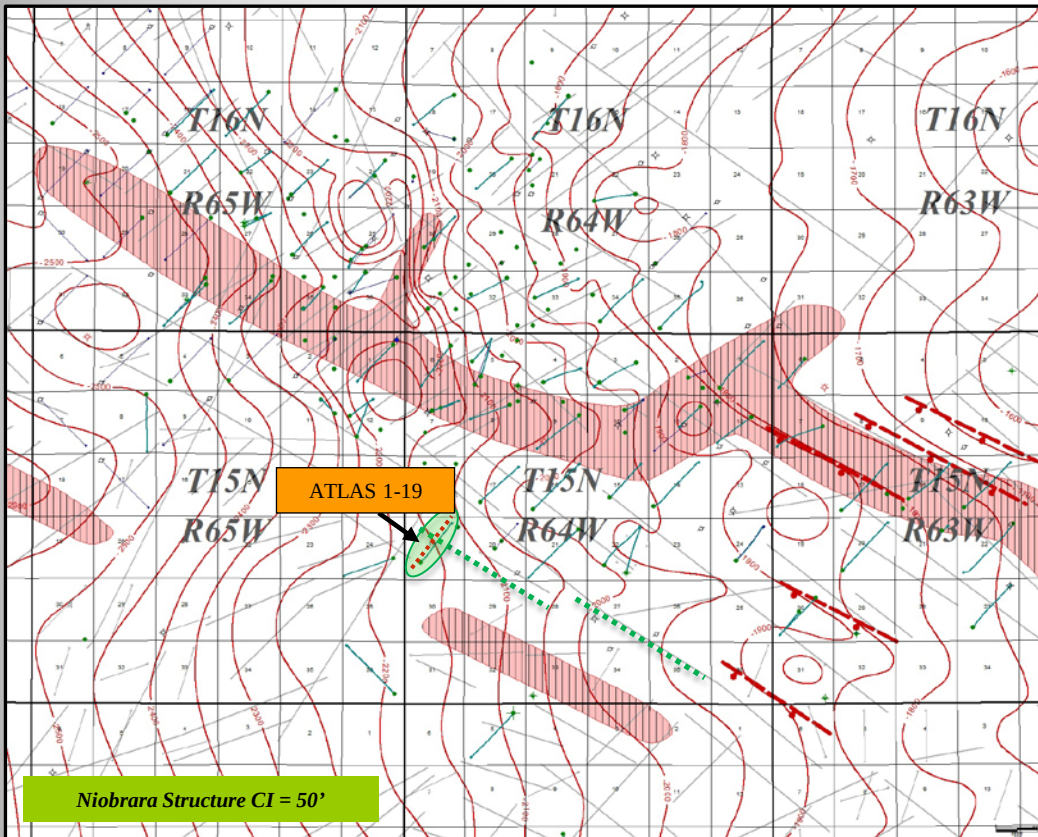
Silo Production 1980-2008

134 Total wells (53 vert, 81 horiz)	
39 active (only 4 vertical)	
1980 to present	
Cumulative	
9,731	12,705 Mbo (EUR)
8,480 Mmcf	
5,763 Mbw	

Production Metrics – Silo “Historical”

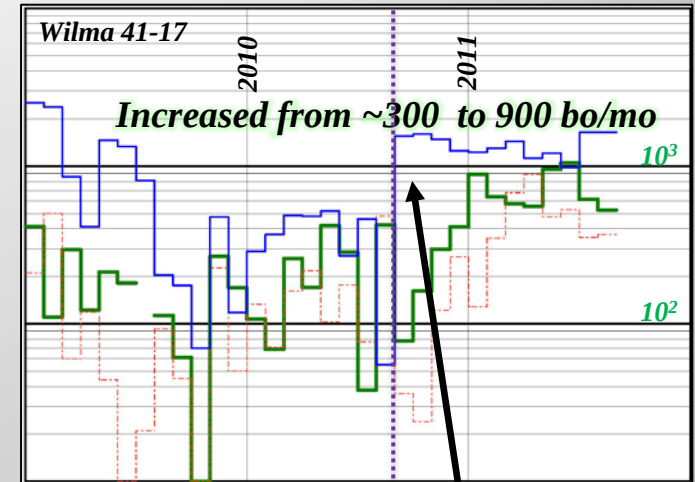
Atlas 1-19H

- Spud 12/13/09
- Initial lateral TD at 9,142 in January 2010 after encountering “well control issues”
- Commence lateral in March 2010 and TD at 12,104 on 3/30/2010



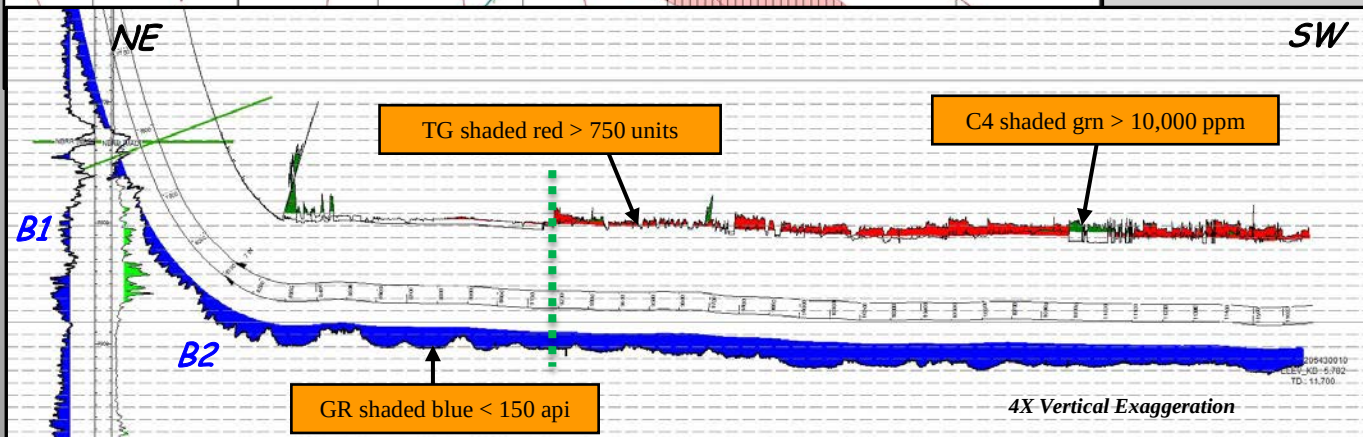
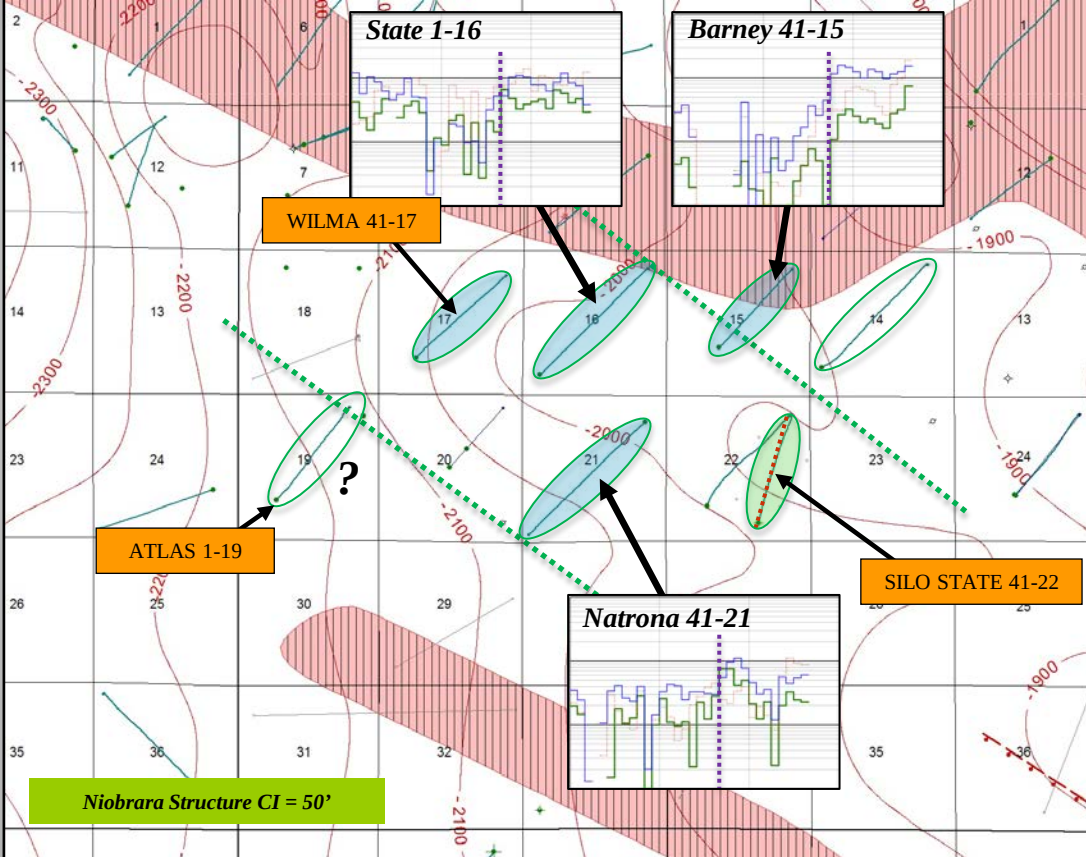
Silo State 41-22H

- Spud 7/27/10
- Lateral TD at 11,700 in 9/30/2010
- Frac early October 2010
- Produce 3.8 mbo, 15.1 mmcf, 35.4 mbw (B2) from Oct 2010 to Sep 2011



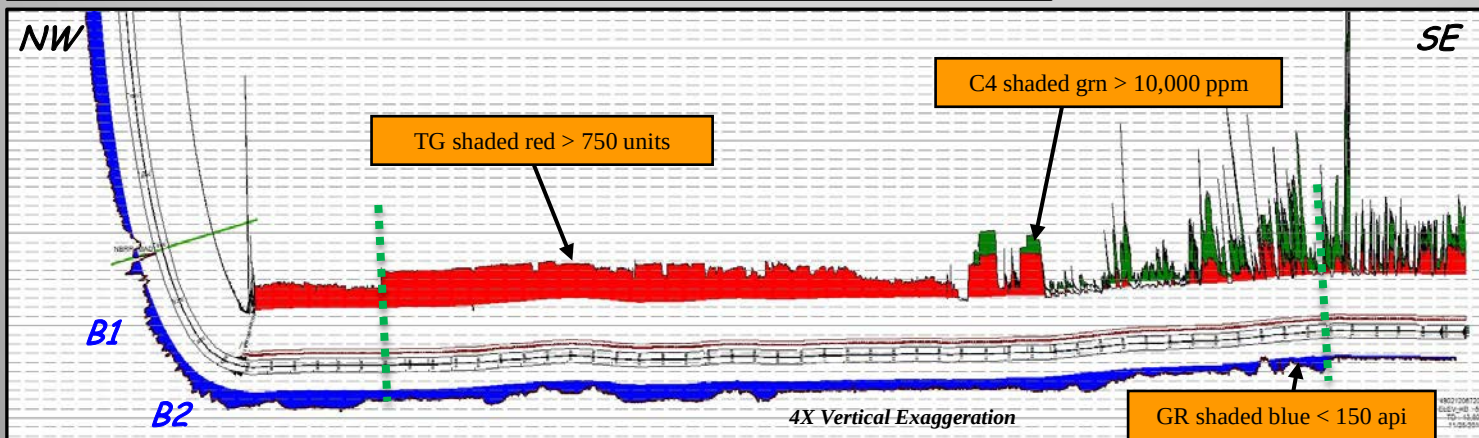
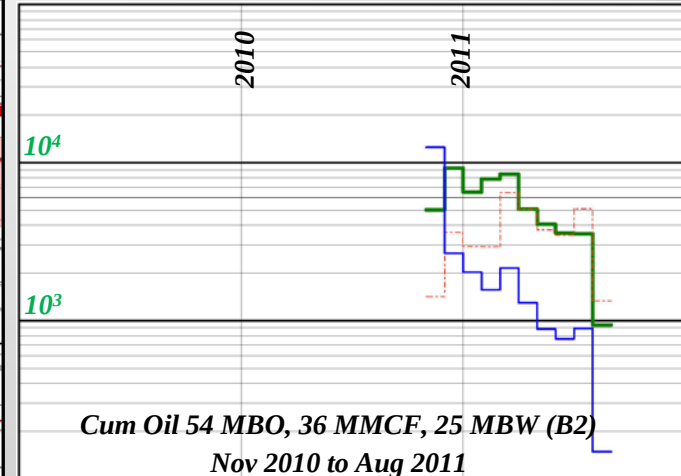
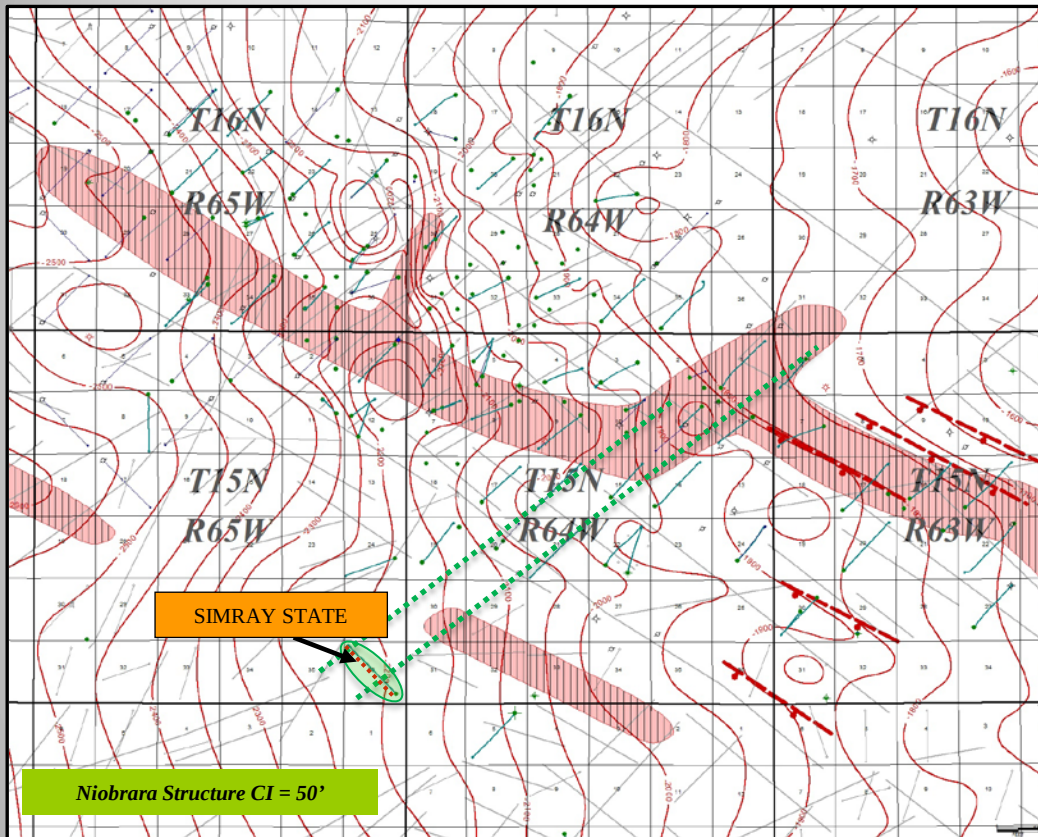
Results of "Silo State Injection"

Apparent effects
TWO MILES AWAY



Simray State 15-65-36-1

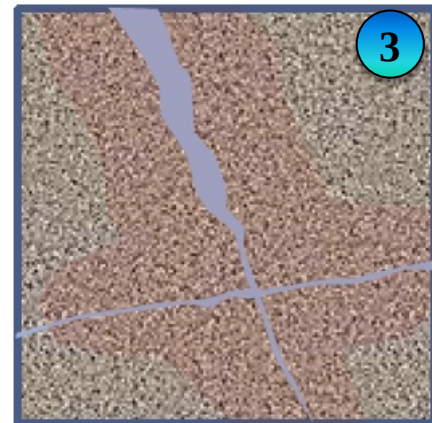
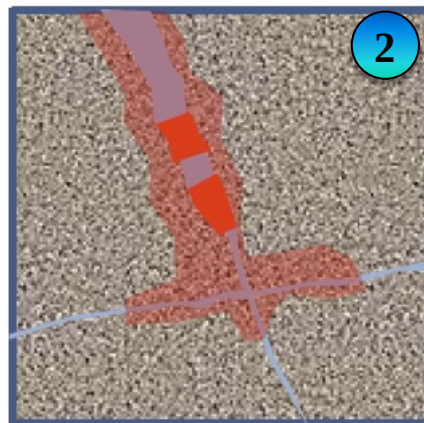
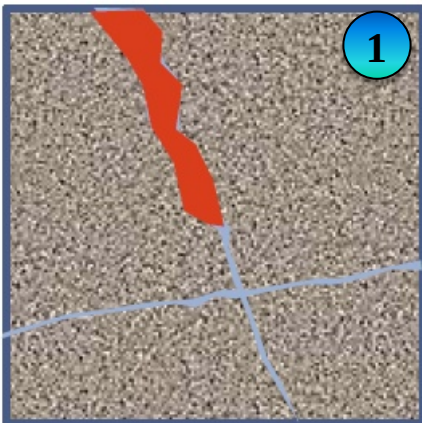
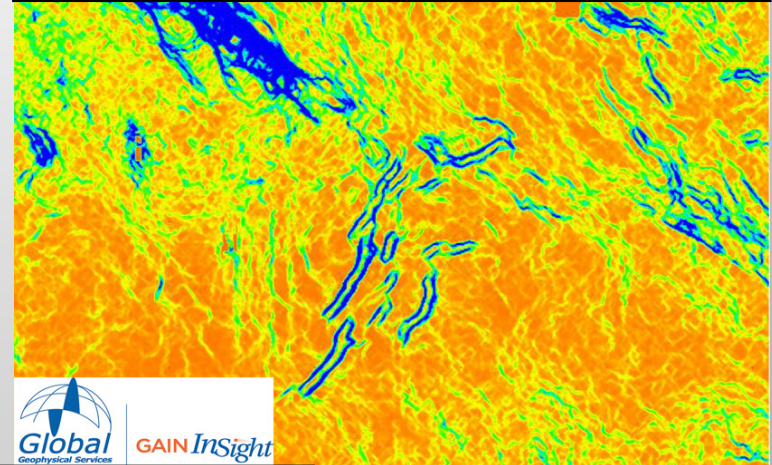
- Spud 9/9/10
- TD lateral at 13,800 on 10/24/2010
- Frac and Flowback November 2010



Silo Field – Type 2 Reservoir

Oil Window, Dual Porosity, Large Aperture Open Fractures

Production Keyed by Complex Wrench Faulting Sub-Parallel to Principal Horizontal Stress

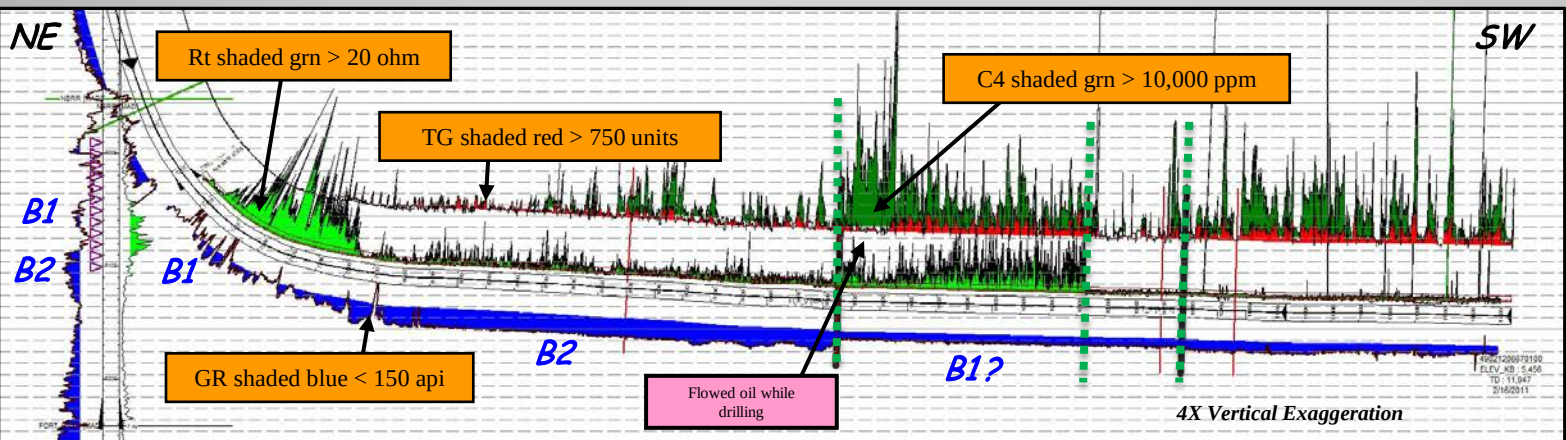
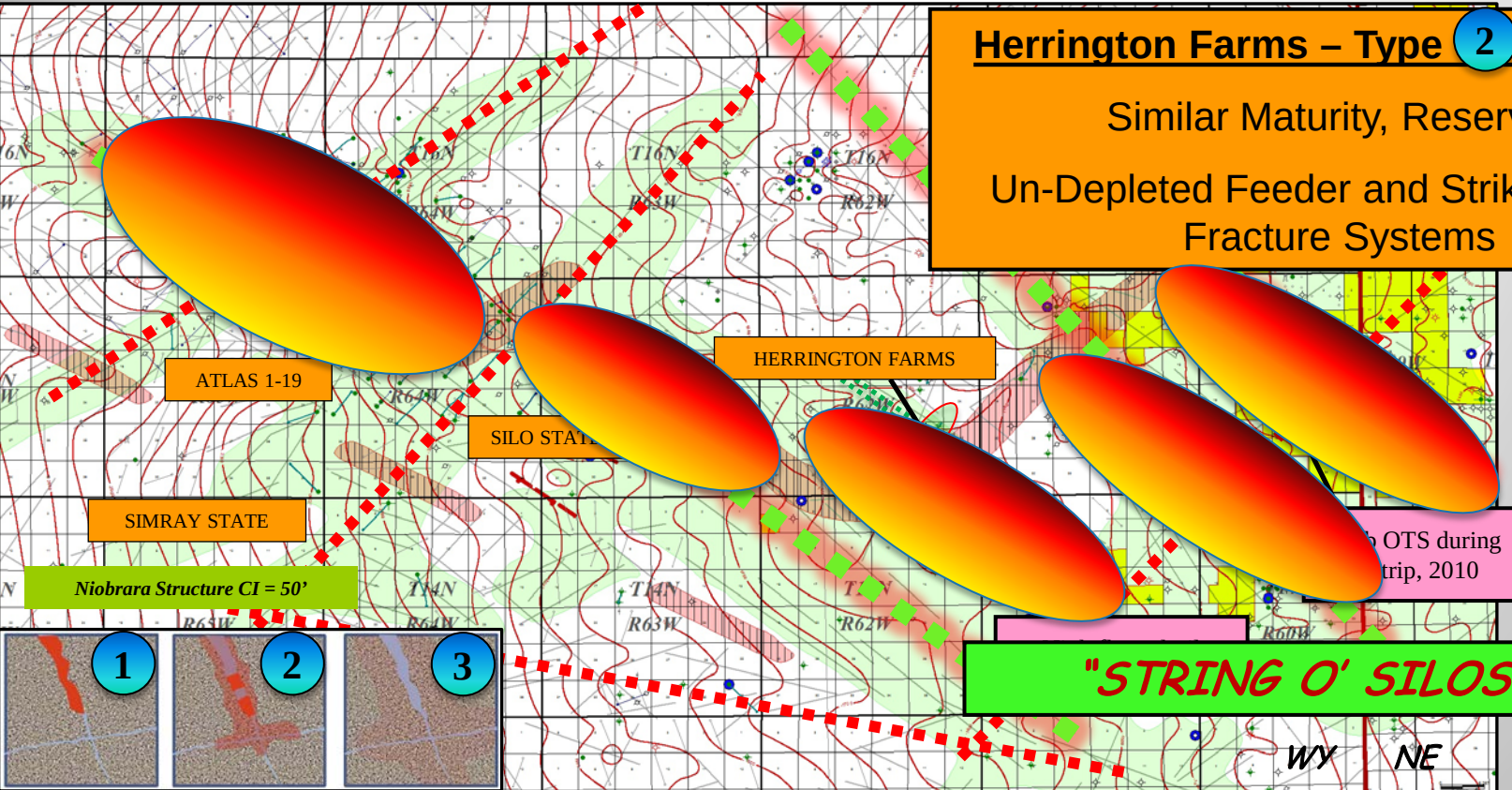


HERRINGTON FARMS

Herrington Farms – Type 2 Reservoir

Similar Maturity, Reservoir

Un-Depleted Feeder and Strike-Parallel Fracture Systems



HEREFORD FIELD

Hereford Field

LLOYD STATE

WY
CO

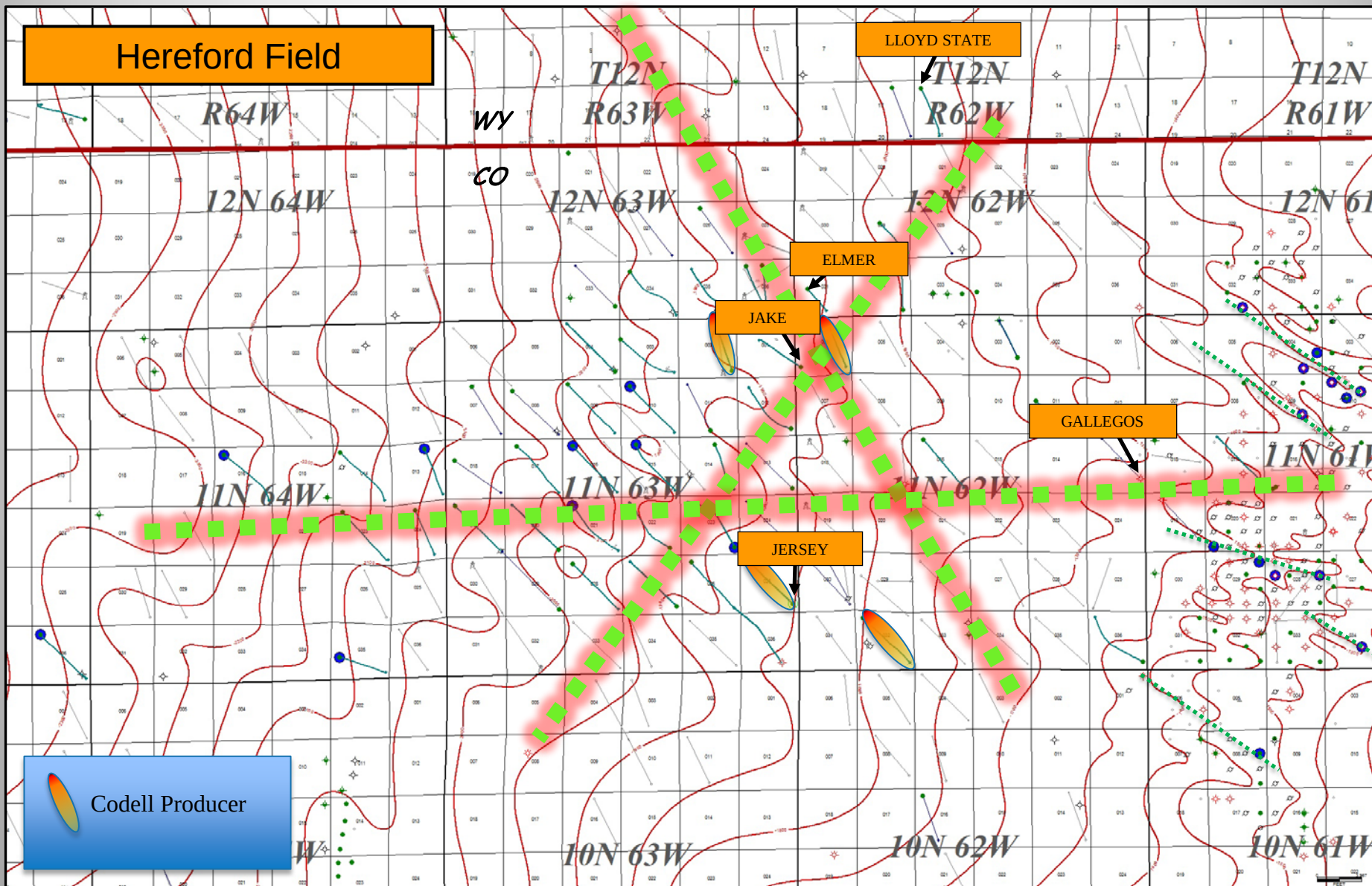
ELMER

JAKE

GALLEGOS

JERSEY

Codell Producer



Hereford Field

1,807 to 20,460 bo/mo max

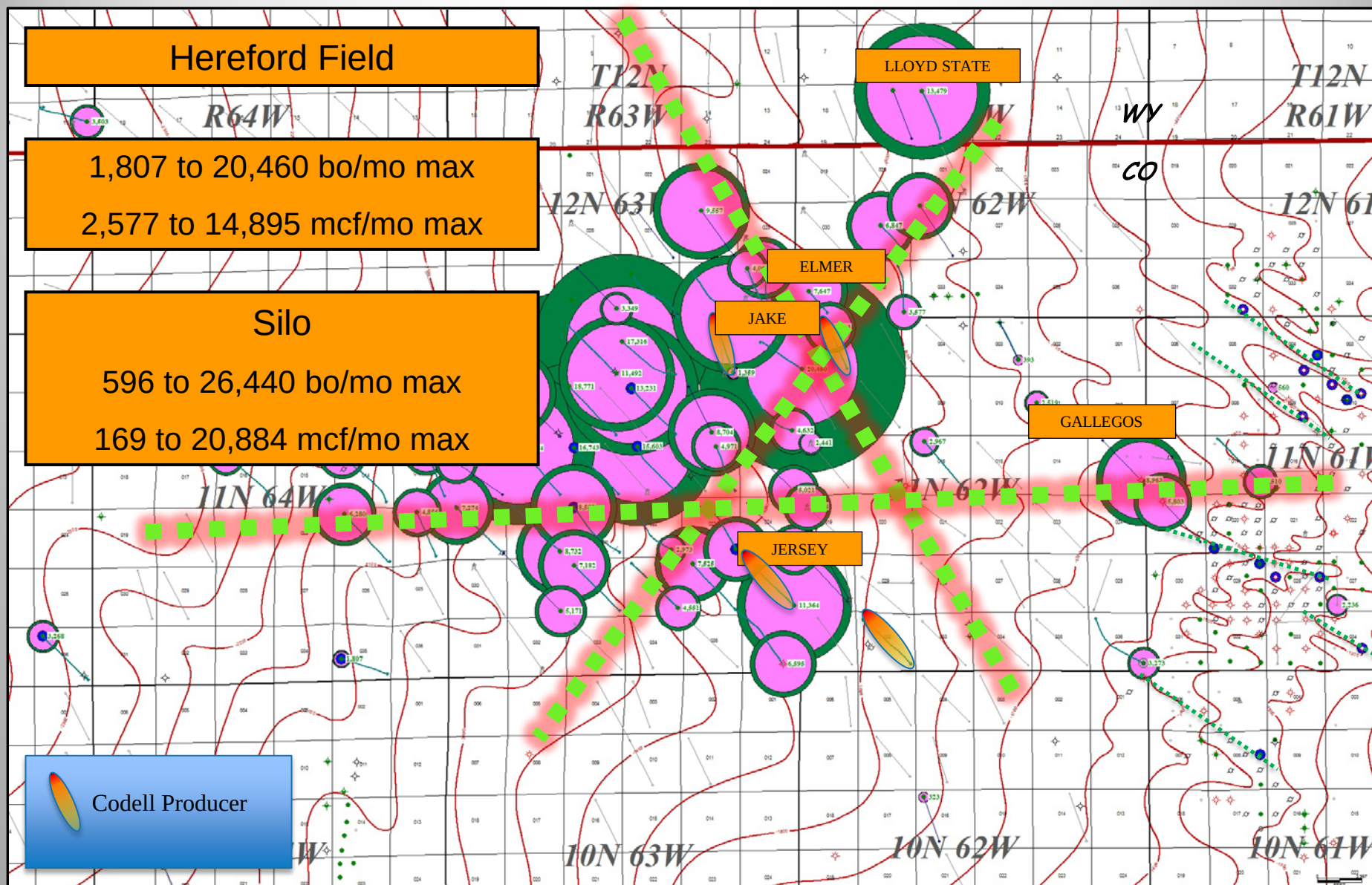
2,577 to 14,895 mcf/mo max

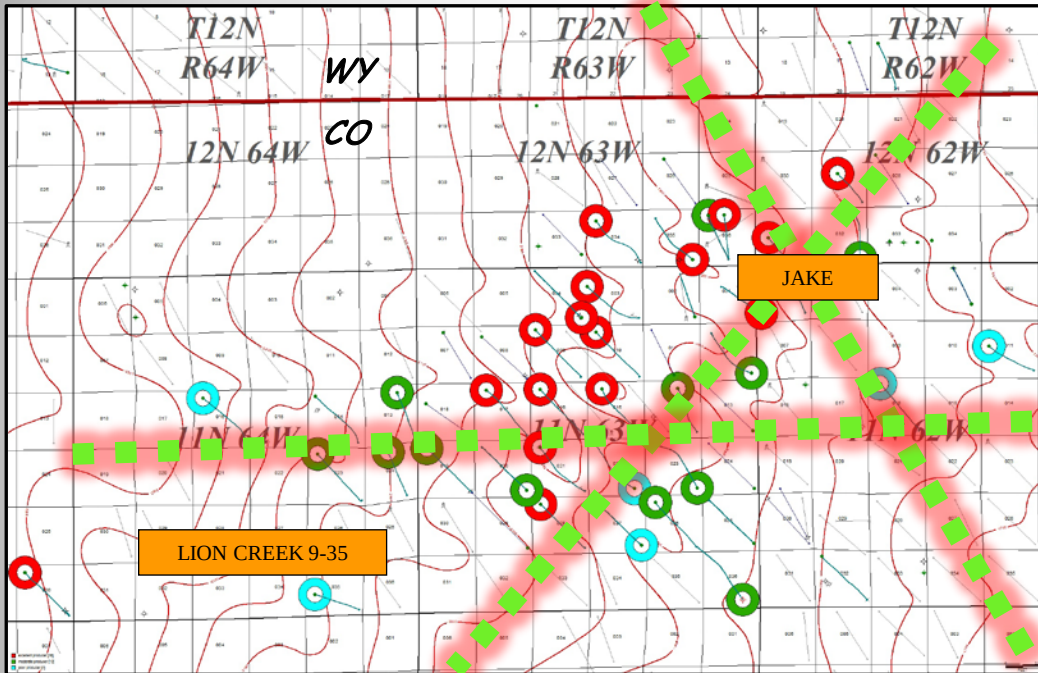
Silo

596 to 26,440 bo/mo max

169 to 20,884 mcf/mo max

Codell Producer



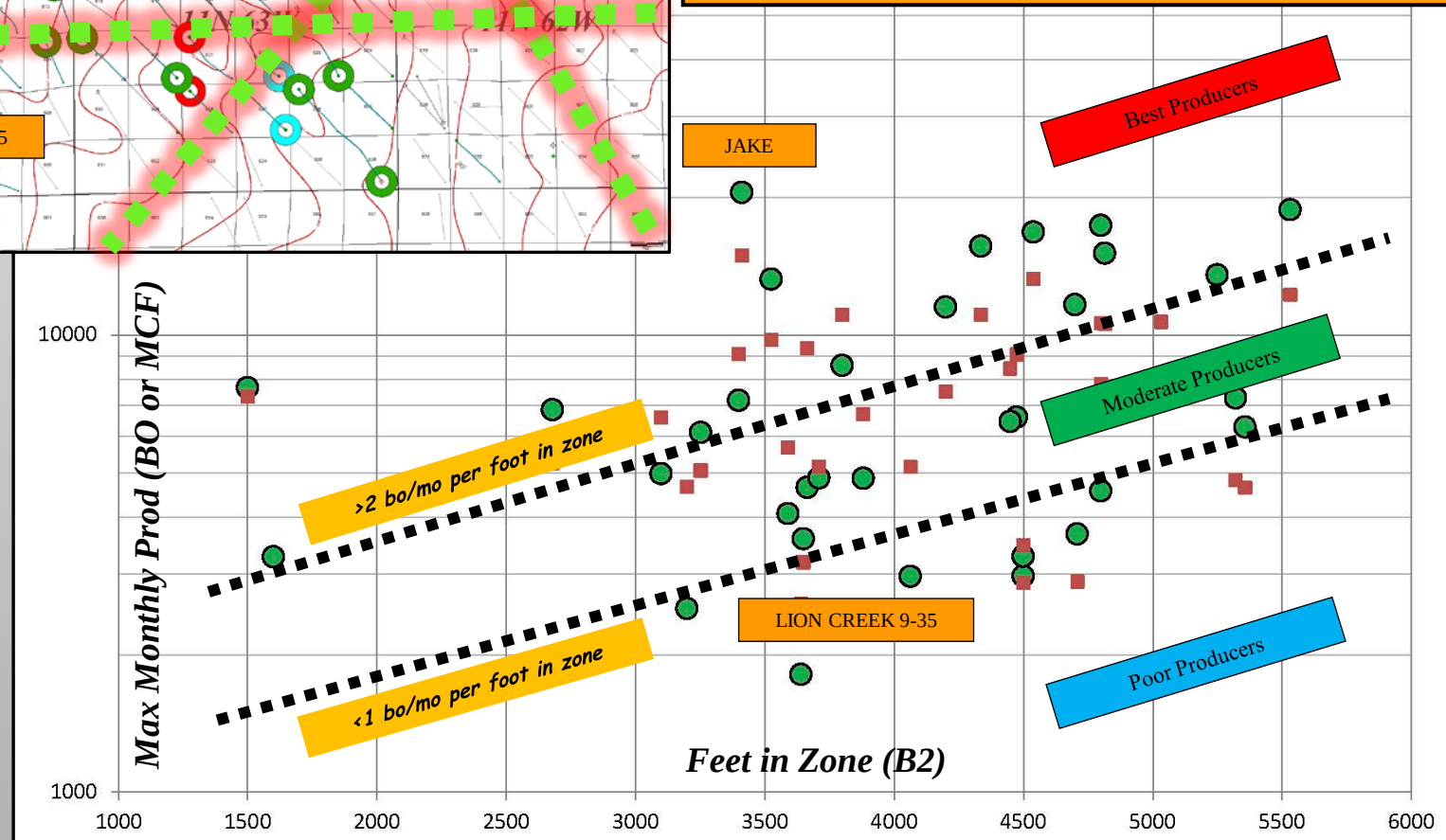


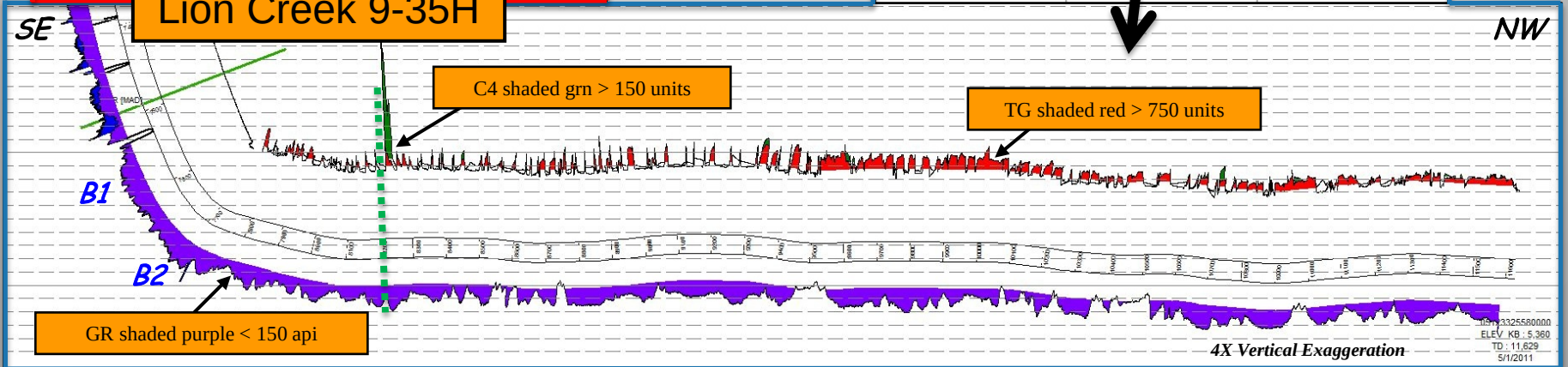
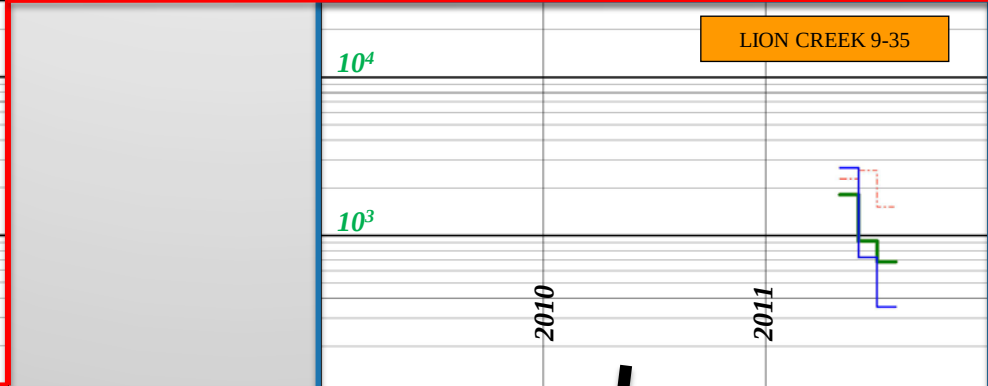
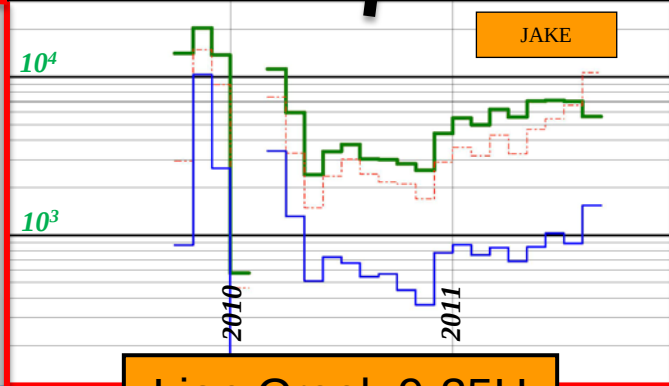
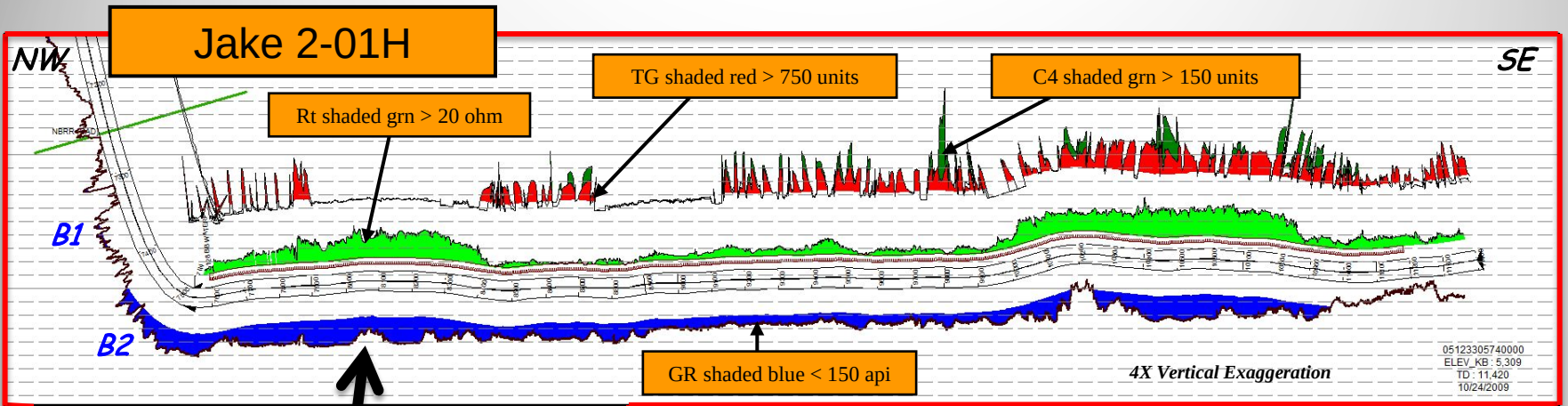
Hereford Field – Type 3 Reservoir

Wet Gas Window (Reservoir Energy)

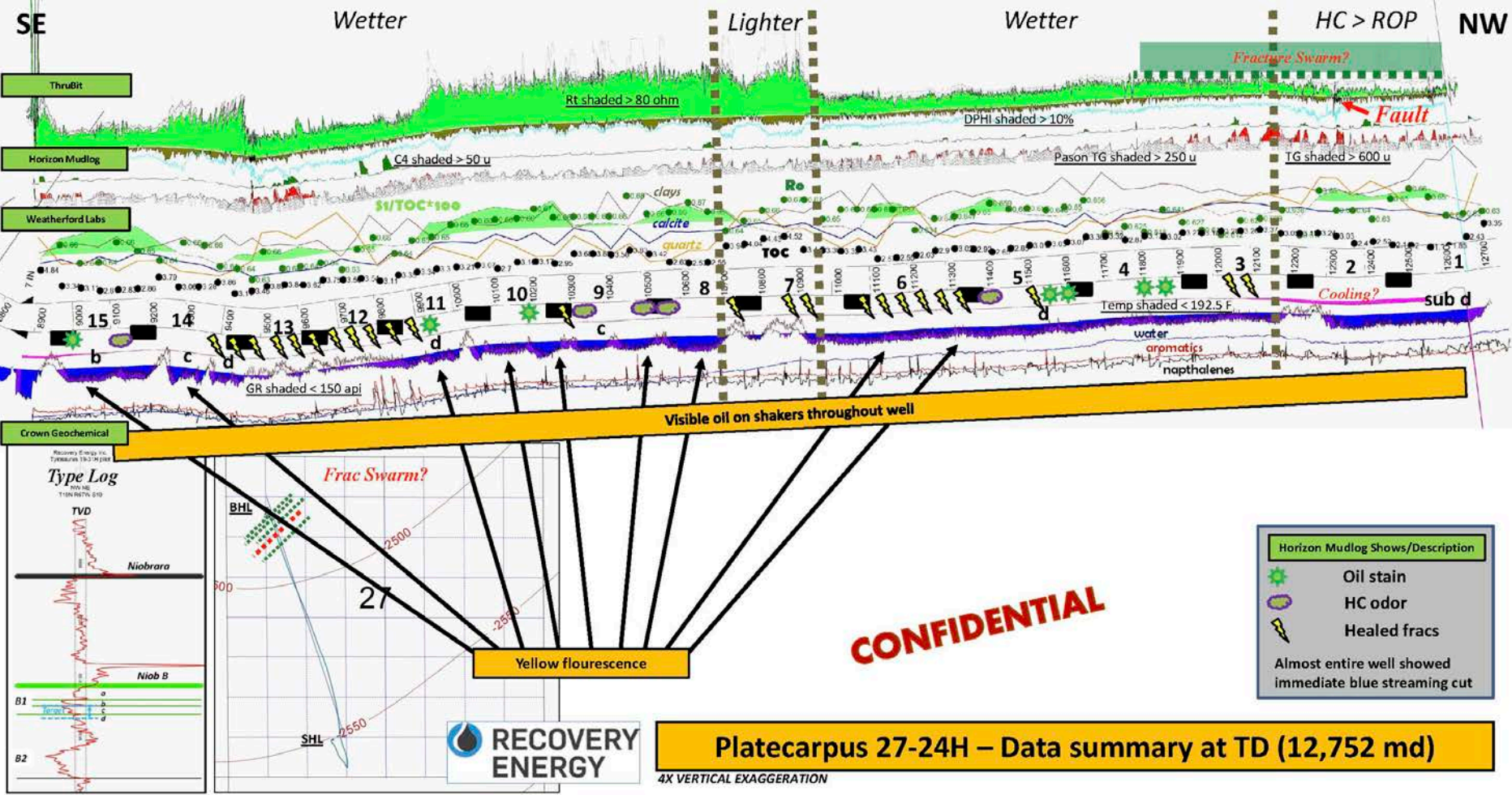
Production Related to Complex Wrench Faulting, but Significant Benefit from Matrix (microfrac?) and Energy

Drilled parallel to Max Hz Stress





MOSOSAUR



26 < calcite < 48%

25 < clay < 45%

1 < quartz < 7.5%



Platecarpus spp. clearing his ears

2 < TOC < 5%

433 < Tmax < 437

(0.63 < Ro < 0.71)

Mososaur – Type 2 Reservoir

Oil Window ($0.63 < R_o < 0.71$)

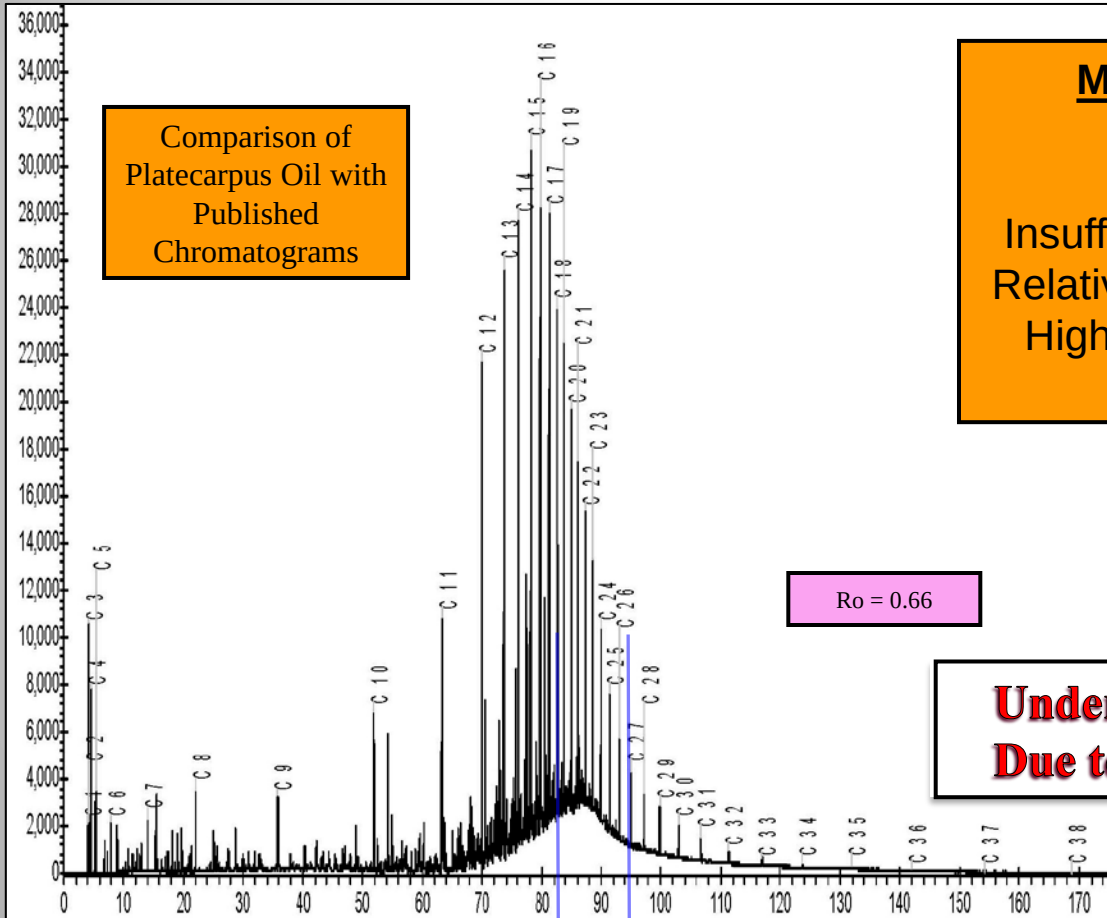
Insufficient Frac Frequency to Overcome
Relative Permeability Limitations, Liberate
Higher Oil Cuts; Well Drilled Parallel to
Maximum Horizontal Stress

$R_o = 0.66$

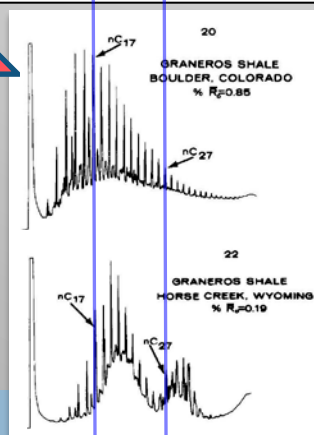
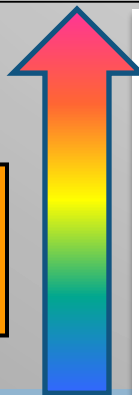
**Under-Representation of Heavy Ends
Due to Relative Perm Limitations?**

Propensity to Oil-Wet Conditions?

Comparison of
Platecarpus Oil with
Published
Chromatograms



Fractionation to
Light End with
Increased Maturity



$R_o = 0.85$

$R_o = 0.19$

BORIE

Borie Field

TG shaded RED > 1000 units

tr brt yel strng to
mlky cut, tr oil in
possum belly

B2

MWD-Gamma shaded PURPLE < 150 api

QEP Borie
16-4H
Fall, 2010

dull gld flr (A-sh), strg
strng mlky yel cut (B), diff
yel, grm cut, pale yel ring
cut (C)

vy fnt dull gld flr
w/bri yel resid cut,
vy sl tr yel/gld flr w/
mod strg mlky cut
when crshd (A-sh)

carb part, mlky yel
cut (B1), strg dry cut
(B2)

strg strng mlky wh
cut (B1), tr dry cut
(B2)

gd dry cut

NIOB B: Rec 1500' G, 200' MCO (1500cc
MCO); 1989

NIOB A: Rec 270' G&OCM,
50% So in core; 1950

fracs, pale yel
ring cut

tr dry ring cut

GR shaded BLUE < 150 api

Rt shaded GREEN > 20 ohm-m

Borie Field – Type 2 Reservoir

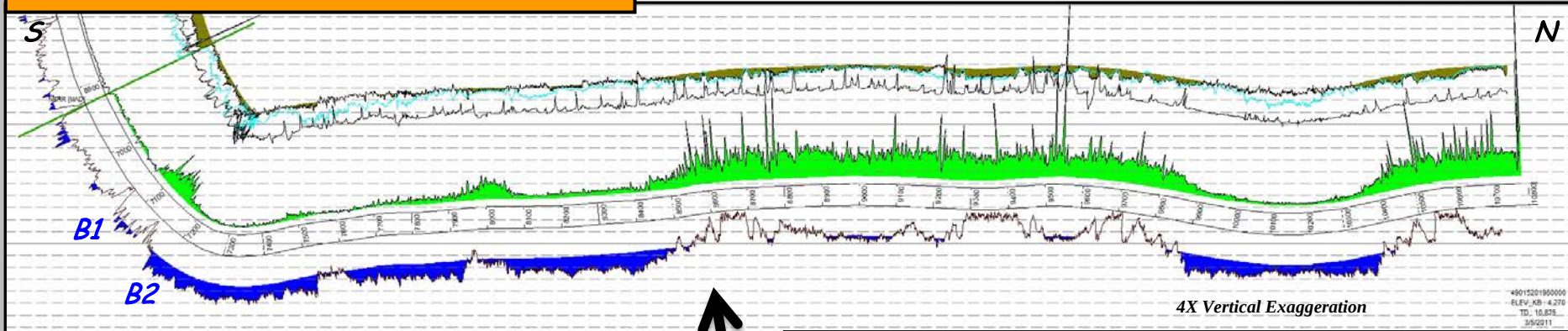
Oil Window

Production May Require Intersection with
Natural Fracs Parallel to Principle Stress
and Related to Laramide Border Fault

Best Shows Associated with NW-SE Faulting?
A Function of Target?

NORTH

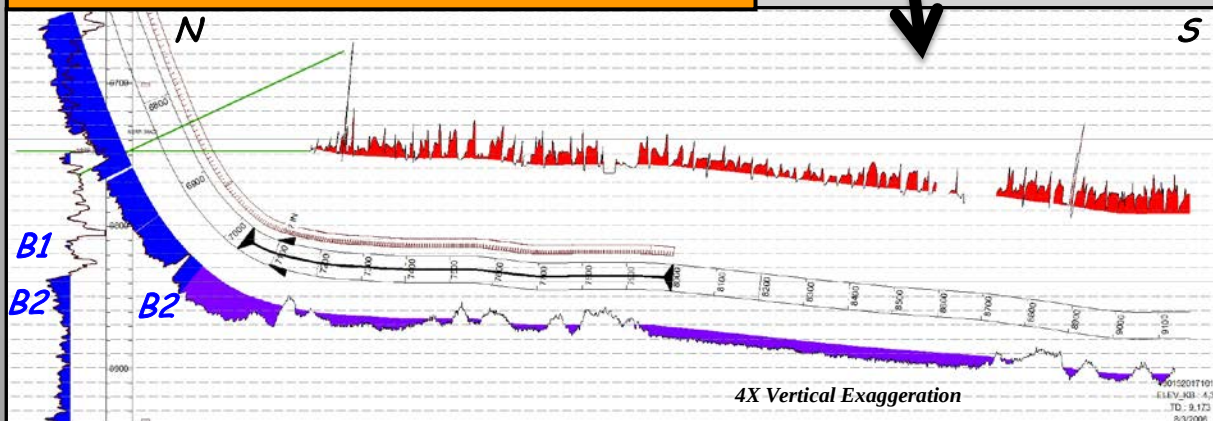
Ahlbrandt 23-63-4-1H



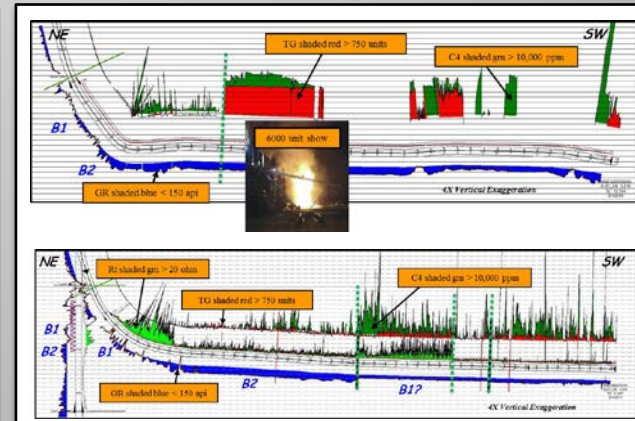
47 bo, 580 mcf, 4539 bw Jun-Oct, 2011

Little or No Indication of Faults/Fractures

London Flats 1-29H



Faults/Fractures Integral to Production





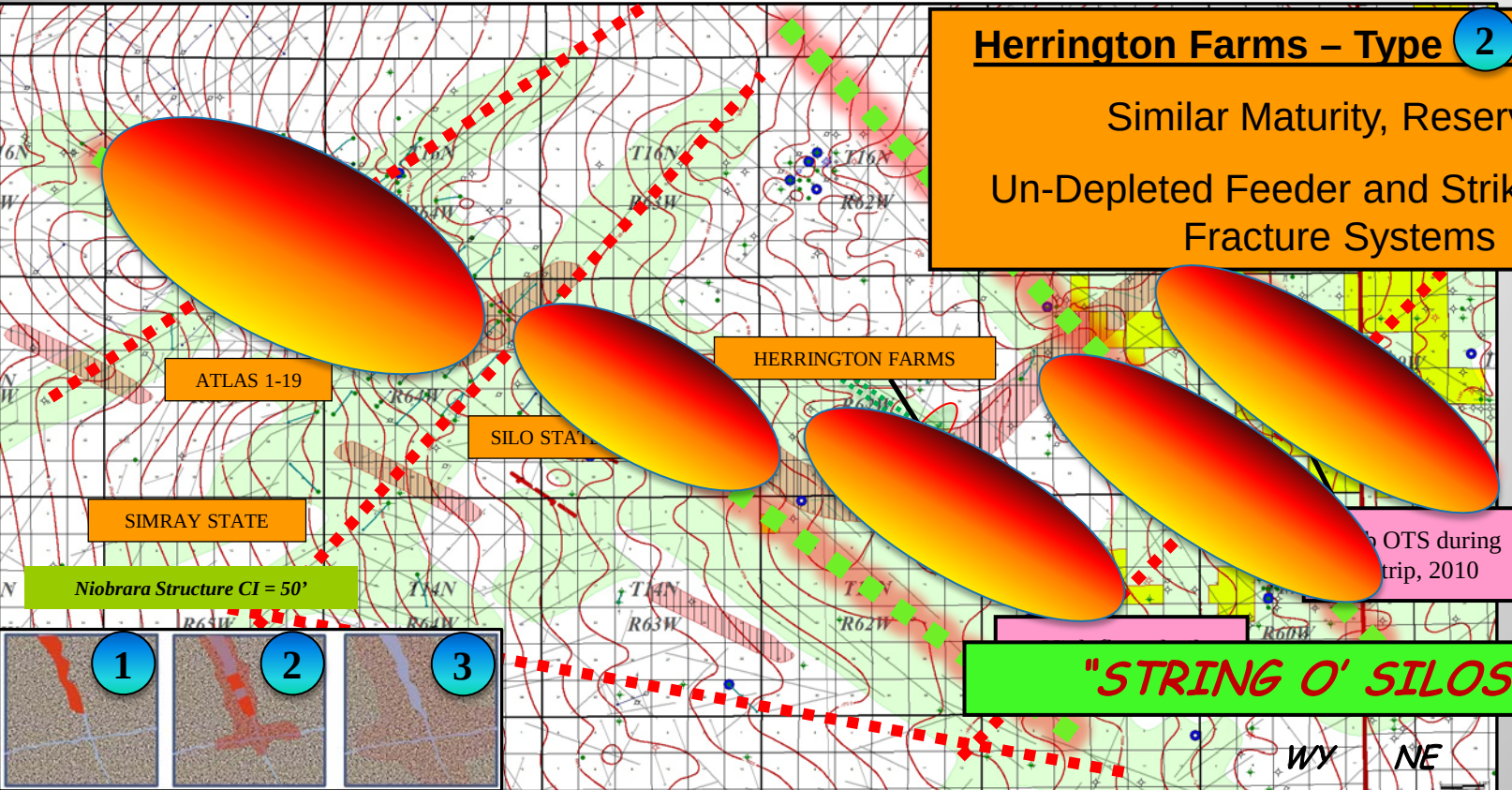
Conclusions About the Niobrara Reservoir in the Northern DJ Basin

- Tectonic Overprint, Including Elements of Wrench Faulting and Various-Distributed Fracture Networks, Appears to Affect:
 - The Distribution of Thermal Maturity
 - The Complexity of Reservoir Properties
 - The Potential for Oil Migration and Trapping
- Petrologic Characteristics May Impose “Oil-Wet” Conditions, Under Which Connate Water Can be Produced Preferentially to Oil
- It is Hypothesized That:
 - Fracture Networks are Integral to “Boosting” All Niobrara Reservoir Types
 - Sub-play Areas Outside of the “Wet-Gas” Window May Require Natural Fractures to Overcome Matrix Reservoir and Relative Permeability Properties
 - Drilling and Completion Procedures May Evolve to Address Oil-Wet Reservoir

Herrington Farms – Type 2 Reservoir

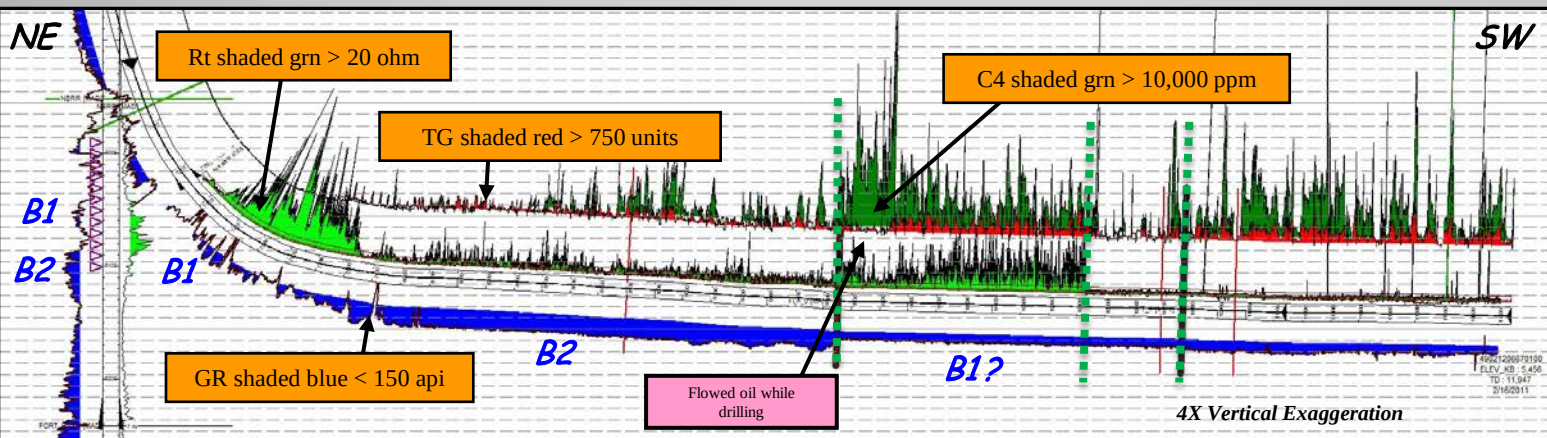
Similar Maturity, Reservoir

Un-Depleted Feeder and Strike-Parallel Fracture Systems



OTS during trip, 2010

"STRING O' SILOS"



“I DON’T ALWAYS DRILL NIOBRARA, BUT WHEN I DO, I PREFER IT TO BE NATURALLY FRACTURED”

