[PS]Keys to Niobrara and Codell Production, East Pony/Redtail Area, Denver Basin, Colorado*

Stephen A. Sonnenberg[1]

Search and Discovery Article #10991 (2017)**
Posted September 11, 2017

*Adapted from poster presentation given at AAPG Rocky Mountain Section Annual Meeting, Billings, Montana, June 25-28, 2017

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Abstract

The Niobrara Formation and Codell Sandstone are important producers in the East Pony and Redtail areas of the Denver Basin. These formations are currently being developed with horizontal drilling and multi-stage hydraulic fracturing. Many geological and technological factors influence production in this area. Principal source beds are the Sharon Springs Member of the Pierre Shale, Niobrara marls, Carlile Formation shales, and Greenhorn Formation organic-rich marl/shale intervals. Source bed maturity is an important control on production. Elevated maturity values as compared to surrounding areas appears to be related to continuation of the Wattenberg Field geothermal anomaly. Maturity is recognized by source rock and petrophysical analyses. Other important keys to production include matrix and fracture porosity and permeability, reservoir facies, mechanical stratigraphy, and drilling and completion technologies.

The Niobrara is approximately 300 feet thick and consists of the Smoky Hill and Fort Hays members. Vertical depths to the Niobrara are approximately 5600 to 5950 feet for the area. The Smoky Hill is approximately 280 feet thick and can be divided into five chalks units (in descending order: A, B1, B2, C, and D). Porosities as measured on density logs for the chalk interval ranges from 12% to 16%. The most important source rocks in the Smoky Hill member are found in the A marl, and C marl units. TOC contents range from 3-5.5 wt. %. The C marl unit has anomalously high resistivity as compared to other areas in the Denver Basin. The Codell is 7-10 feet thick in the area. It is also targeted with horizontal drilling. The overlying Fort Hays Member of the Niobrara and Codell are thought to be a common- source-of-supply. Oil-in-place for the area is estimated to be 40-70 MMBOE per section. Operators are planning for 16 wells per drilling and spacing units (640 to 9660-acre). Recoverable oil per well at a 10% recovery factor is 370 MBOE. Initial production has been up to 860 BOEPD for B chalk completions.

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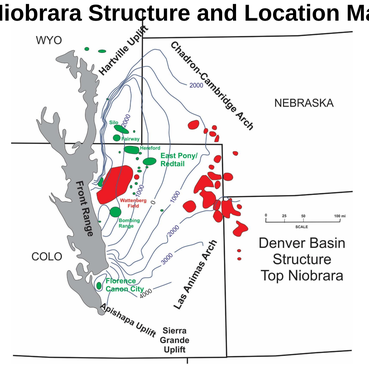
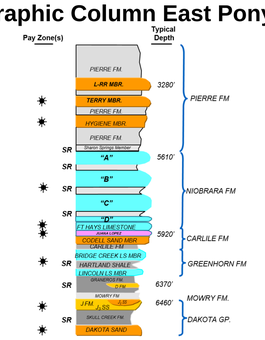
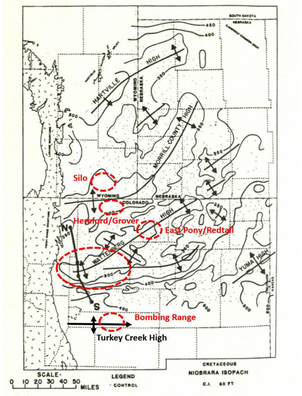
Niobrara Structure and Location Map



Stratigraphic Column East Pony Area



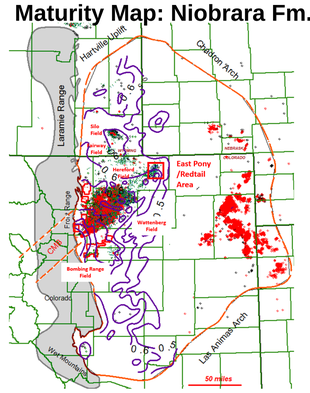
Regional Isopach Niobrara Fm.



Most Niobrara Fields are located on paleostructural high features!

"The older the structure, the more likely it is to contain oil or gas for whatever reason"
Bob Weimer, 1978

Maturity Map: Niobrara Fm.



Ro Data for Denver Basin from Smagala et al., 1984

Structure Top Codell

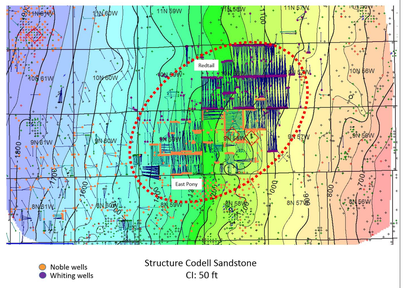
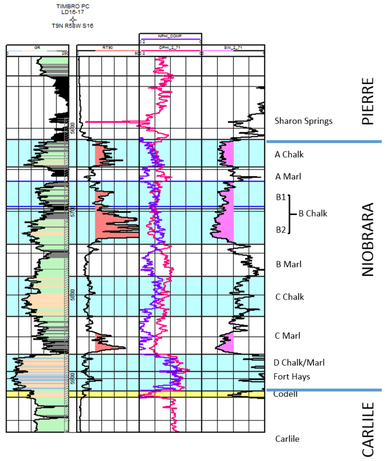


Table 1. Field data for East Pony/Redtail area

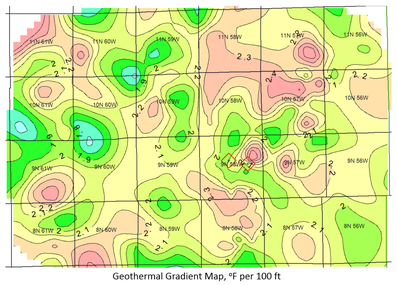
Depth: 5300-6200 ft (vertical)
Thickness:
- ***Niobrara A chalk – 20-40 ft***
- ***Niobrara A marl – 20-70 ft***
- ***Niobrara B chalk – 60-80 ft***
- ***Niobrara B marl – 30-70 ft***
- ***Niobrara C chalk – 40-70 ft***
- ***Niobrara C marl – 20-55 ft***
- ***D chalk – 15-35 ft***
- ***Niobrara Fort Hays – 20-25 ft***
- ***Codell – 5-20 ft***

Porosity: Niobrara 10-13%; Codell 14-18%
Permeability: < 0.1 md
GOR: 300-500 cf/bbl
Tmax: 440 deg. C (Niobrara marls)
Ro: 0.9-1.0% (Niobrara marls)
Pressure gradient: 0.39 psi/ft (DST Niobrara Formation)
Temperature gradient: 1.9-2.3 deg. F /100 ft

Type Log

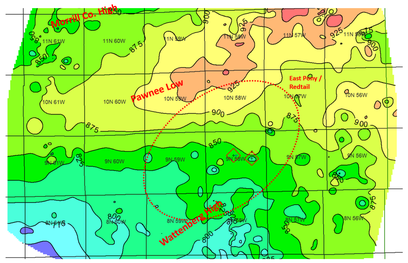


Geothermal Gradients



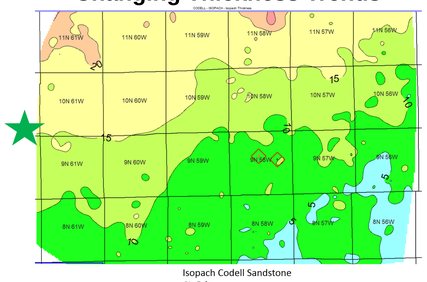
Geothermal Gradient Map, °F per 100 ft

Paleostructure

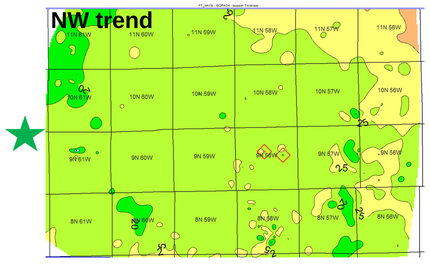


J – Niobrara Isopach

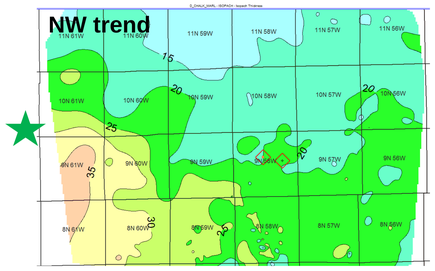
Isopach Maps
Changing Thickness Trends



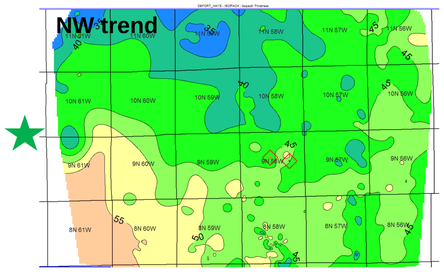
Isopach Codell Sandstone
CI: 5 ft



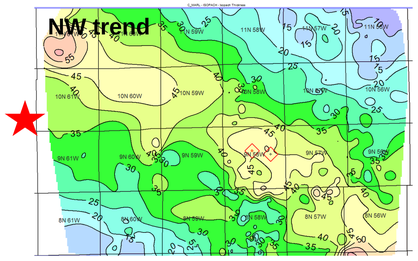
Isopach Fort Hays
CI: 5 ft



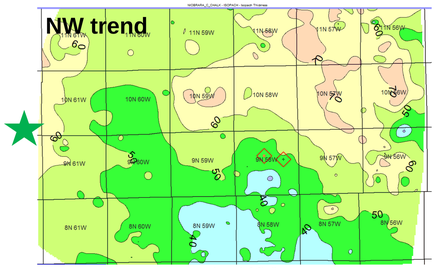
Isopach D Chalk/Marl
CI: 5 ft



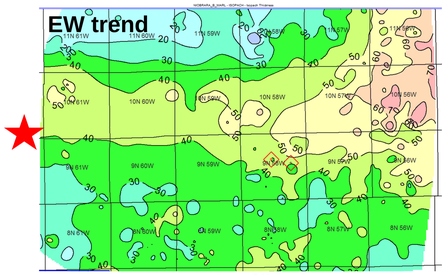
Isopach Fort Hays & D Chalk/Marl
CI: 5 ft



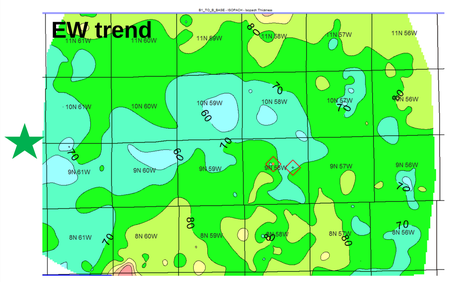
Isopach C Marl
CI: 5 ft



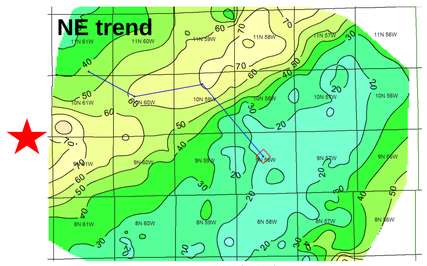
Isopach C Chalk
CI: 10 ft



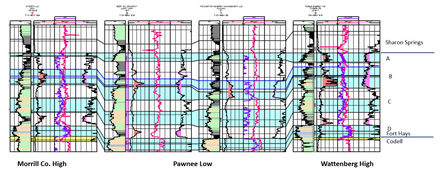
Isopach B Marl
CI: 10 ft

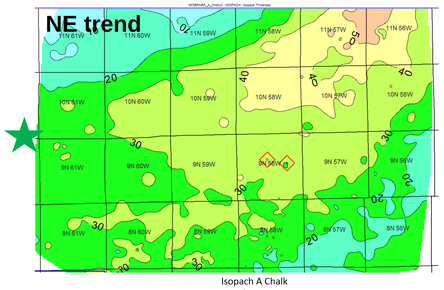


Isopach B Chalk (B1 & B2)
CI: 10 ft

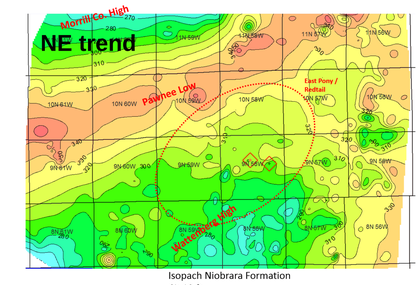


Isopach A Marl
CI: 10 ft

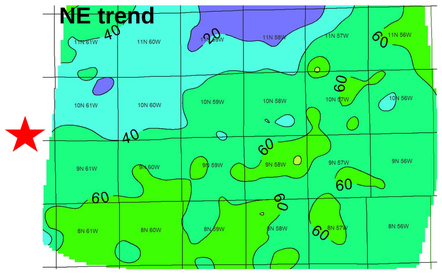




Isopach A Chalk
CI: 5 ft



Isopach Niobrara Formation
CI: 10 ft



Isopach Sharon Springs
CI: 20 ft

Source Rock Intervals

Reservoir Rock Intervals

Changing thickness trends through time!

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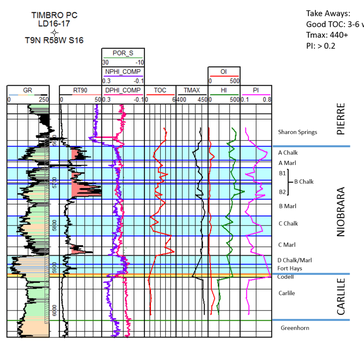
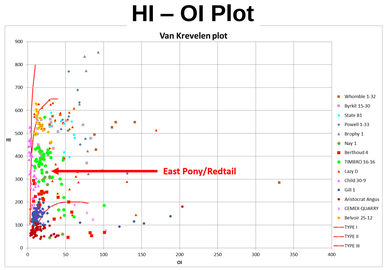
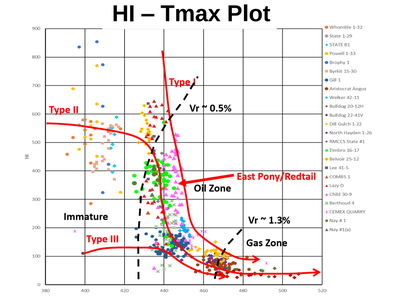
Pyrolysis Data & TOC



HI – OI Plot



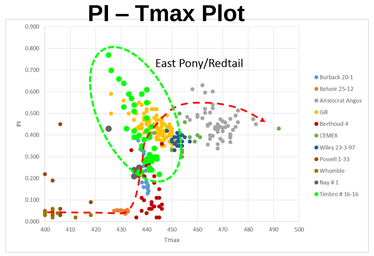
HI – Tmax Plot



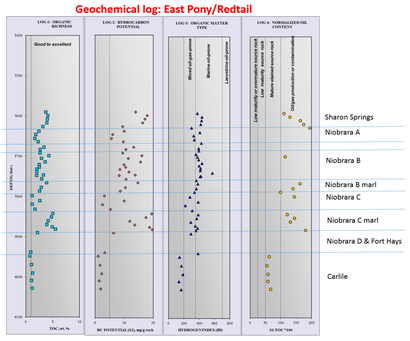
$$TR_{HI} = 1 - \frac{HI_{pd}\,[1200 - HI_o\,(1 - PI_o)]}{HI_o\,[1200 - HI_{pd}\,(1 - PI_{pd})]}$$

TR_{HI} East Pony/Redtail: 35%
TR_{HI} Wattenberg: 87%

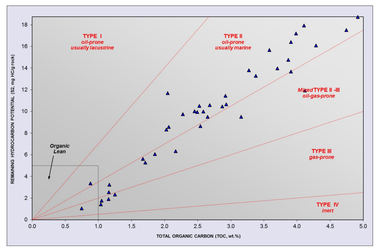
PI – Tmax Plot



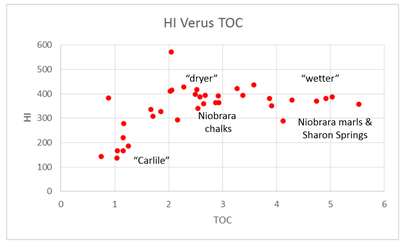
Geochemical log: East Pony/Redtail

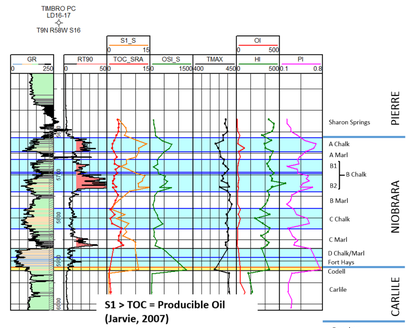


S2 & TOC Plot



HI & TOC Plot



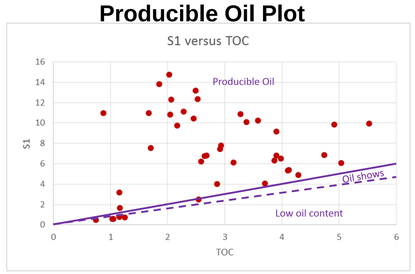


S1 > TOC = Producible Oil (Jarvie, 2007)

OSI = Oil Saturation index
((S1*100)/TOC)
> 100 potentially producible oil

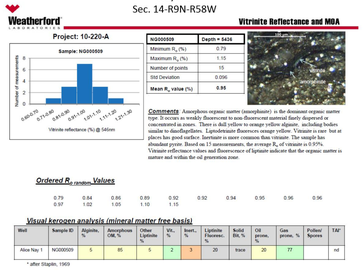
S1, OSI, and PI high in Chalk Reservoirs

Producible Oil Plot



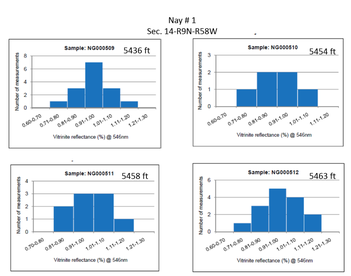
Vitrinite Reflectance Data

Nay # 1
Sec. 14-R9N-R58W

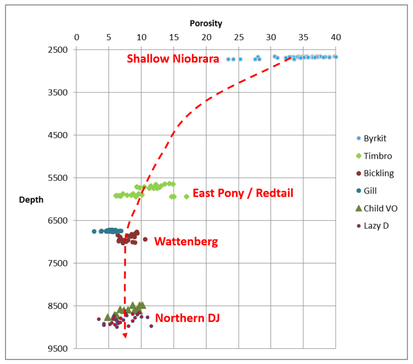


* after Slapkin, 1969

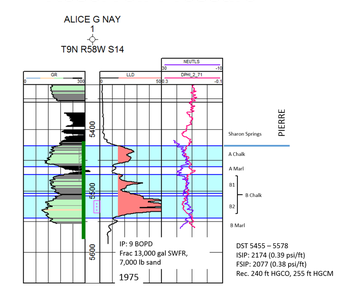
$$HI_o = \left(\frac{\%\ \text{type I}}{100} \times 750\right) + \left(\frac{\%\ \text{type II}}{100} \times 450\right) + \left(\frac{\%\ \text{type III}}{100} \times 125\right) + \left(\frac{\%\ \text{type IV}}{100} \times 50\right) = 430$$

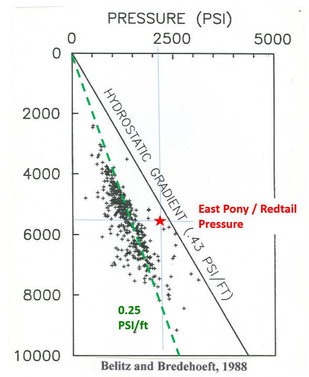


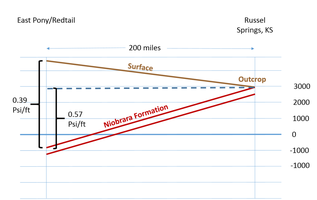
Porosity Data



Reservoir Pressure

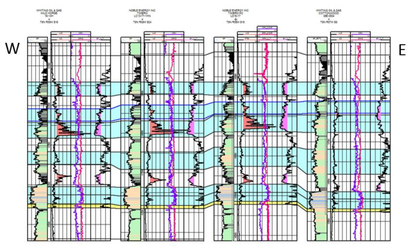




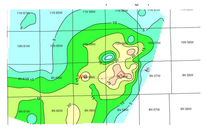


Niobrara Overpressured!

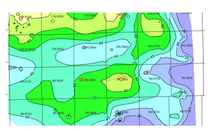
Resistivity Changes



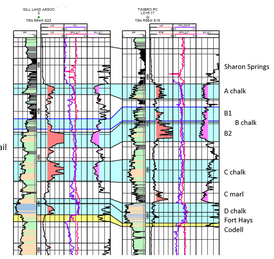
A). Stratigraphic Cross Section East Pony / Redtail area.



B). Map of A chalk resistivity > 15 ohm-m



C). Map of B chalk resistivity > 15 ohm-m

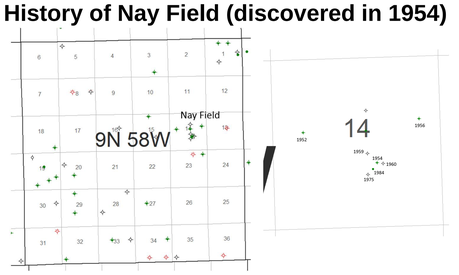


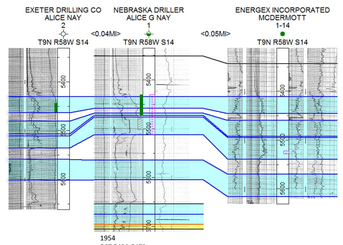
Comparison of Wattenberg with East Pony / Redtail

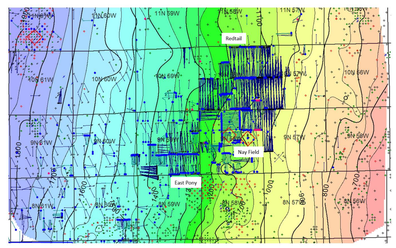
Wattenberg Field East Pony / Redtail

Resistivity may indicate oil accumulation in chalks

History of Nay Field (discovered in 1954)

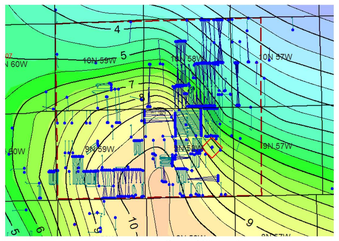






Structure Codell Sandstone
CI: 50 ft

SoPhiH & OOIP



SoPhiH 4 - 12.2
DPhi > 0.08
Sw < 0.65
Res > 15

Area = 164 sq mi
OOIP = 45,53,608,000 BO
OOIP per sq mi = 27.7 MMBO
EUR @ 10% RF = 2.7 MMBO per section
EUR = 442 MMBO

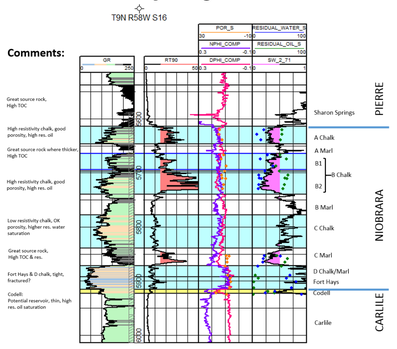
Drilling & Completion

- Laterals
  - 1 mile & l.5 miles
  - 8 wells per spacing unit Niobrara A
  - 8 wells per spacing unit Niobrara B
  - CWC: $5.5 MM (960); $4.5 MM (640)
  - East-west and north-south
  - ~400 MBOE per well
- Completions
  - 640 – 24 stages (150 ft/stage)
  - 960 – 40 stages (150 ft/stage)
- 4-6 MM pounds of sand per well
- ~ 110,000 to 130,000 barrels of water per well

Summary

- Paleostructure!
- Geothermal gradients
- Source bed maturity (Tmax & Ro data)
- Source bed quality (thick Kn marls & Sharon Springs, TOC 3-6 wt. %)
- Porous chalk reservoirs (10-13%)
  - A, B, C chalks and Fort Hays limestone present across the area
  - A&B show high resistivity
- Resistivity proxy for accumulation and production
- Niobrara overpressured
- Good residual core oil saturations (low water)
- Older vertical Niobrara & Codell production
- High resistivity & TOC C marl
- Technology: 24 - 40 frac stages (~150,000 lbs sand per stage)

Summary Log Plot



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