Reservoir Characterization of the Codell Sandstone at Redtail Field, Weld County, Colorado

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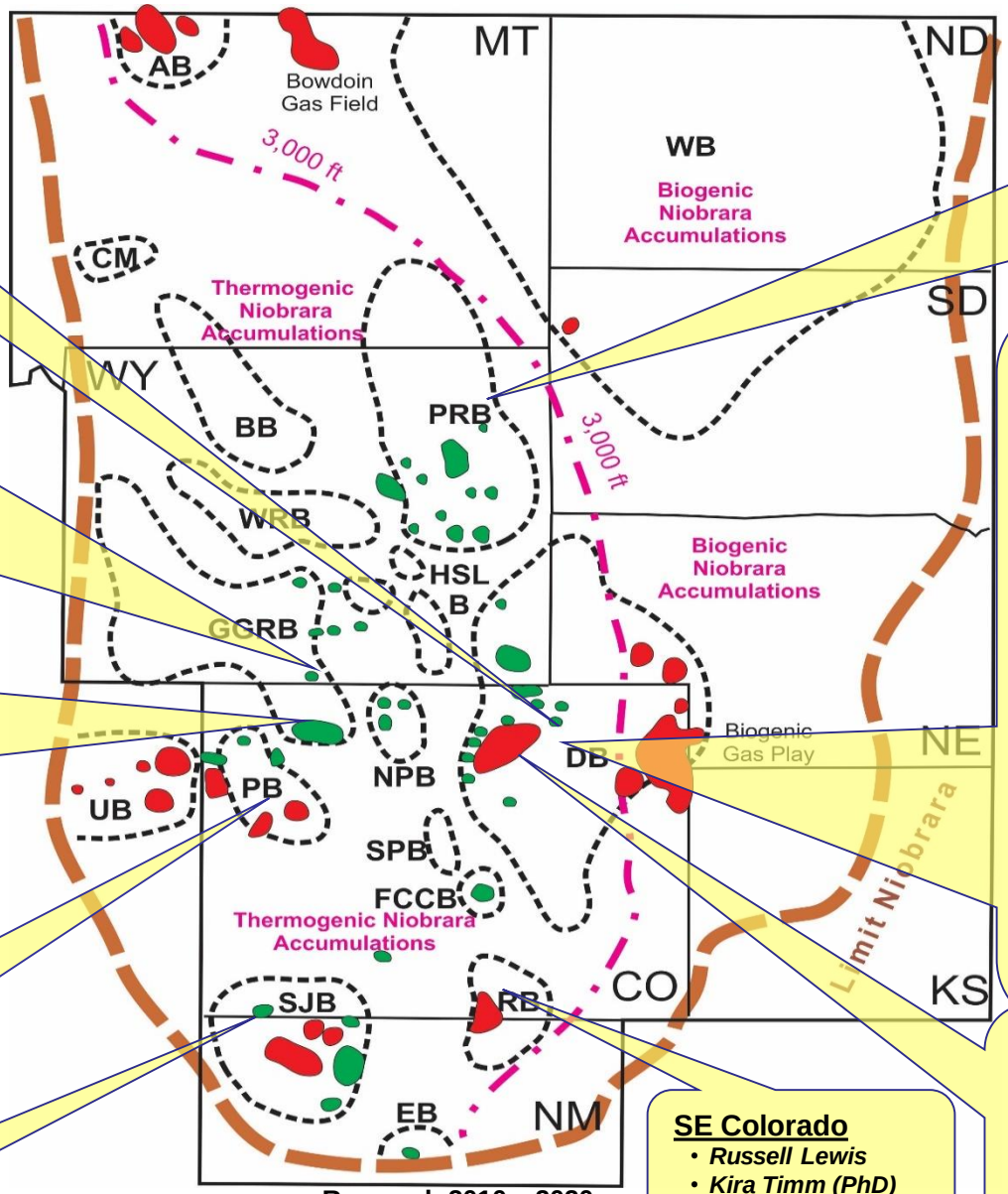
Outline

- Project Overview
- Geologic History
- Codell Sandstone - Redtail Field
- Razor 25-2514H Core
- Conclusions

Project Overview

MUDTOC Research 2010 - 2020



Codell SS
- *Adam Anderson*
- *John Stamer*
- *Tofer Lewis*
- *Steve Crouch*
- ❖ Nick Damon

Niobrara Regional Studies
- *Phylicia Saner*
- *David Thul*
- *Lauren Stout*
- *David Underwood*
- *Evan Allred*
- *Julia Wood*
- *John Stamer*
- Michael Harty (Juana Lopez)
- ❖ Cankut Kondacki (PhD)

NW Colorado
- *Jon Charzynski*
- *Katarzyna Kuzniak*
- *Vivian Lin*
- *Kelly Bruchez*
- *Ben Dellenbach*
- *Michael Harty III*
- *Shawn Lopez*

Piceance Basin
- *Kasia Kuzniak*
- *Martin Krueger*
- *John Harper*
- *Marcus Hinricher*

San Juan Basin
- *Tom Arthur*
- *Walter Nelson*
- Scott Kennedy

Powder River Basin
- *James Taylor*
- *Armagan Kaykun*
- *Andrew Heger*
- *Cankut Kondakci*
- *Courtney Bone*
- ❖ Brain Hankins
- ❖ Corey Milar
- ❖ Rebekah Parks
- ❖ Lisa Reeves

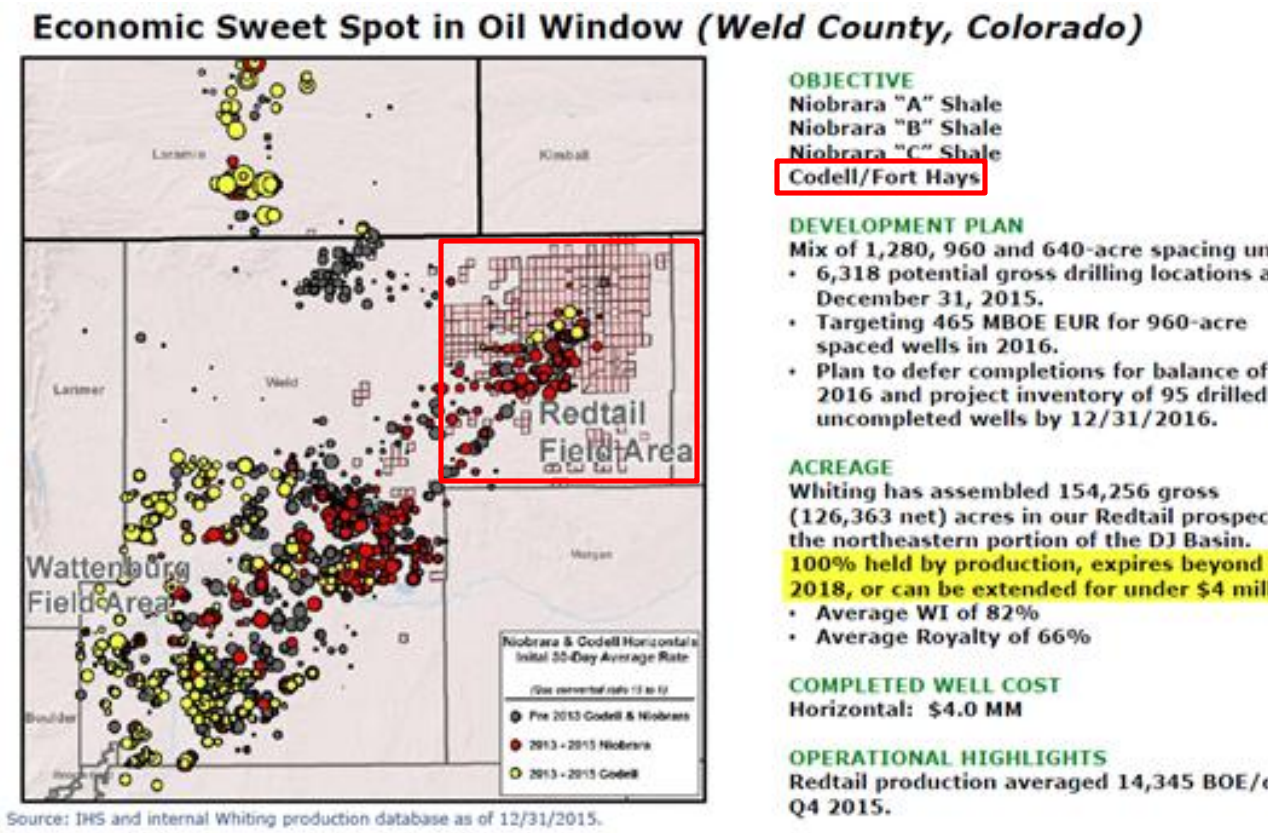
Denver Basin
- *Mike Collins*
- *Melanie Peterson*
- *Teresa Malesardi (Silo)*
- *Alejandra Maldonado*
- *Elena Finley (Silo)*
- *Denton O'Neal*
- *Nico Kernan (Wyo)*
- *Kazumi Nakamura (PhD)*
- *Devin Murray*
- *Lindsay Hefton*
- *Hannah Durkee (Greenhorn)*
- *Isabel Gary*
- *David Thul*
- *Lauren Stout*
- *David Underwood*
- *Caleb Garbus*
- *Lauren Bane*
- ❖ Scott Manwaring
- ❖ Adam Simonsen
- ❖ Chris Beliveau
- ❖ Chris Matson
- ❖ Adrienne Bryant

Denver Basin: Wattenberg
- *Craig Kaiser*
- *Nick Matthies*
- *Rana ElGhonimy*
- *Jennie Rietman*
- *Elvan Aydin*
- Daniel Brugioni
- ❖ Patrick Sullivan

SE Colorado
- *Russell Lewis*
- *Kira Timm (PhD)*
- *Nick Matthies*

Research 2010 – 2020
- *Completed Theses*
- ❖ In Progress

Redtail Field – By the Numbers



OBJECTIVE
Niobrara "A" Shale
Niobrara "B" Shale
Niobrara "C" Shale
Codell/Fort Hays

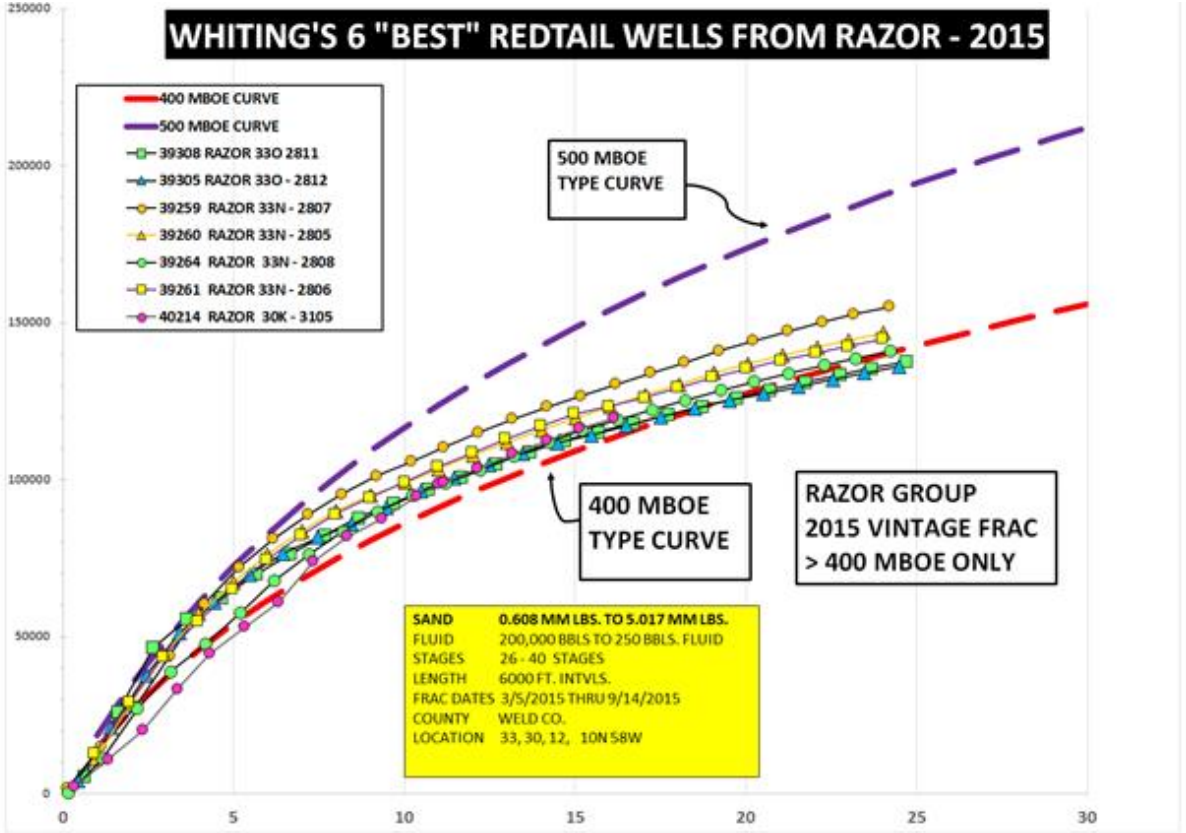
DEVELOPMENT PLAN
Mix of 1,280, 960 and 640-acre spacing units
- 6,318 potential gross drilling locations as of December 31, 2015.
- Targeting 465 MBOE EUR for 960-acre spaced wells in 2016.
- Plan to defer completions for balance of 2016 and project inventory of 95 drilled uncompleted wells by 12/31/2016.

ACREAGE
Whiting has assembled 154,256 gross (126,363 net) acres in our Redtail prospect in the northeastern portion of the DJ Basin.
100% held by production, expires beyond 2018, or can be extended for under $4 million.
- Average WI of 82%
- Average Royalty of 66%

COMPLETED WELL COST
Horizontal: $4.0 MM

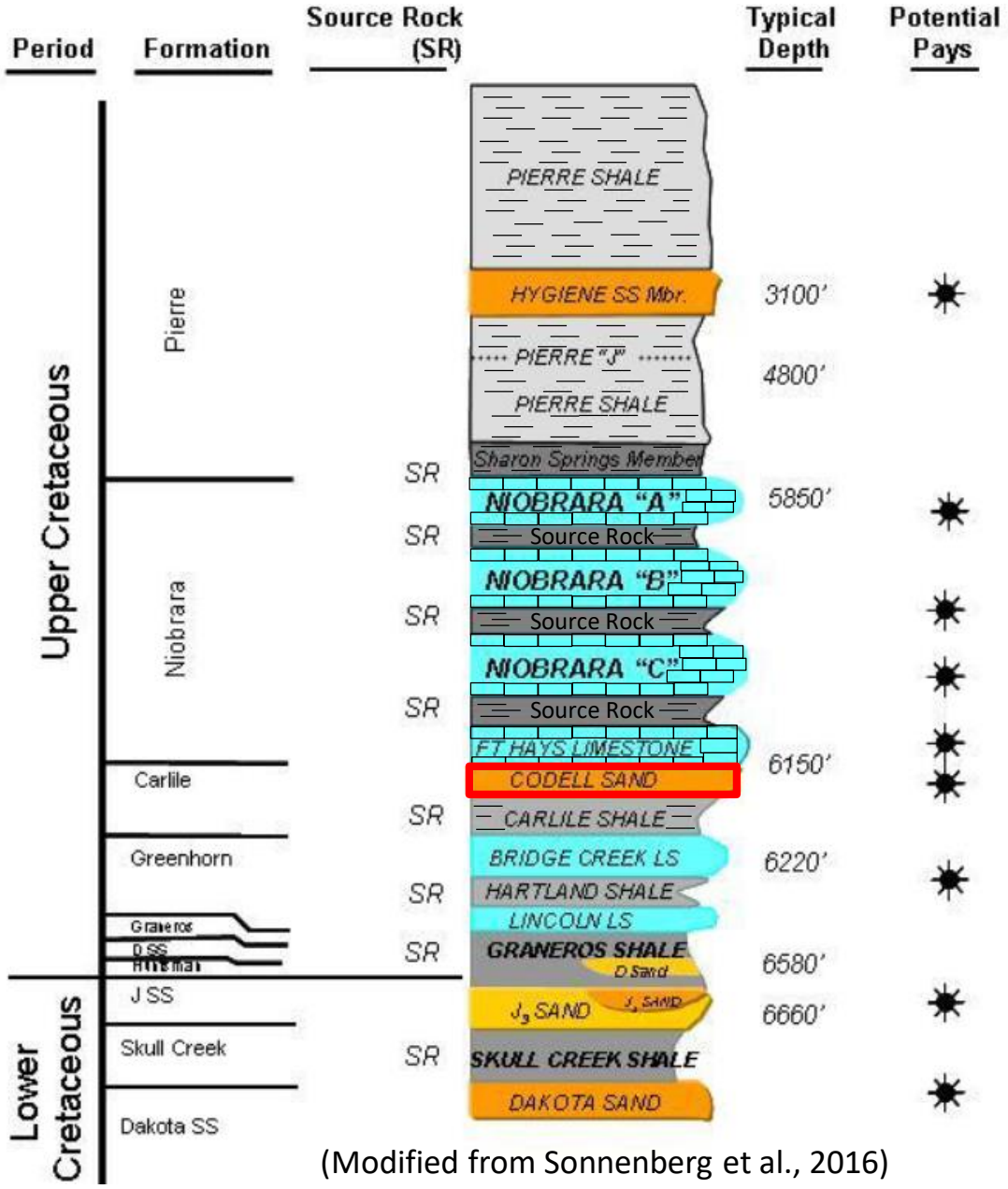
OPERATIONAL HIGHLIGHTS
Redtail production averaged 14,345 BOE/d in Q4 2015.

(Modified from Whiting Petroleum, 2015)



(Whiting Petroleum, 2015)

Denver Basin Stratigraphic Column



(Modified from Sonnenberg et al., 2016)

Redtail/East Pony Data

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***

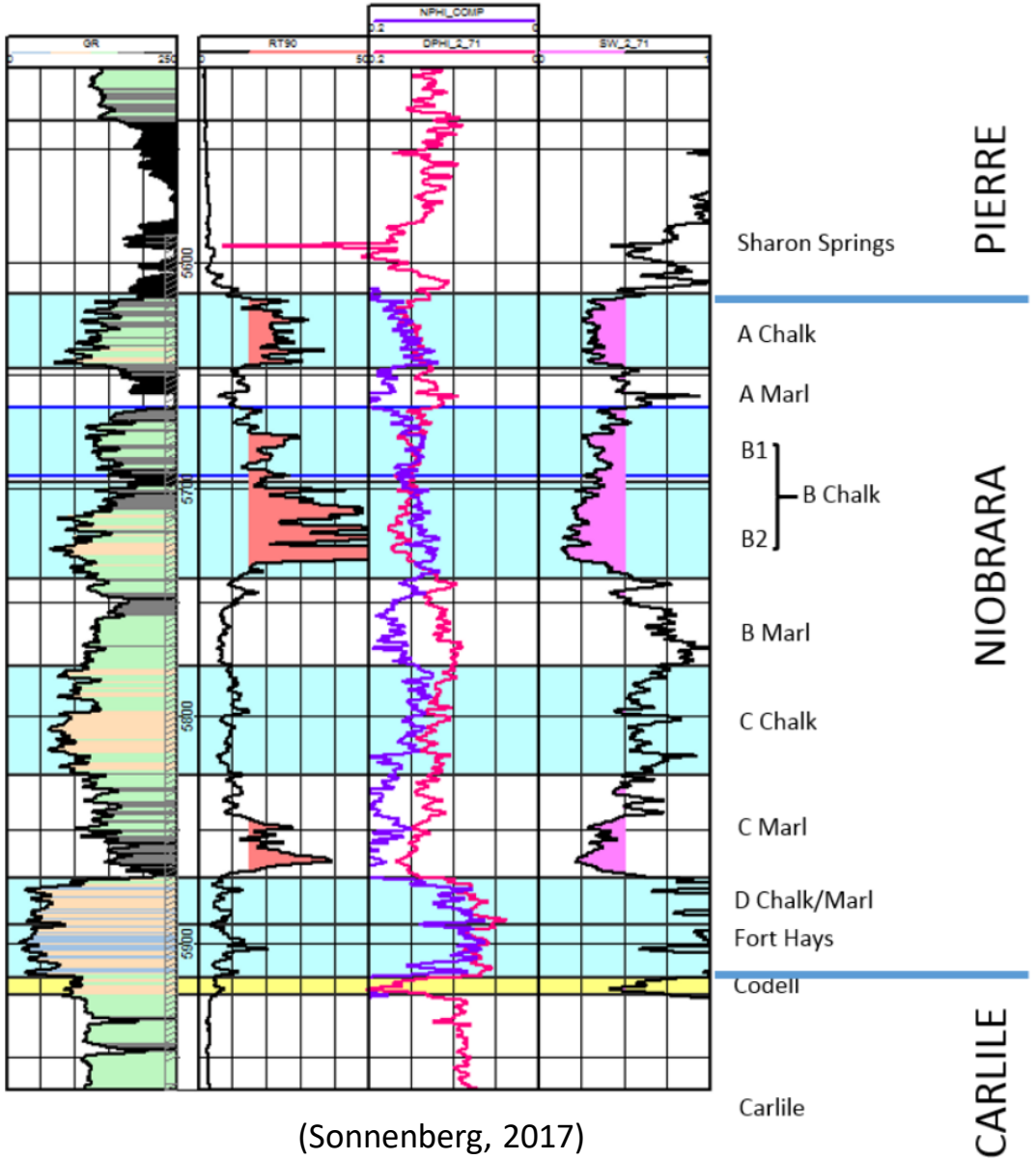
Porosity: Niobrara 10-13%; Codell 14-18%

Permeability: < 0.1 md

(Modified from Sonnenberg, 2017)

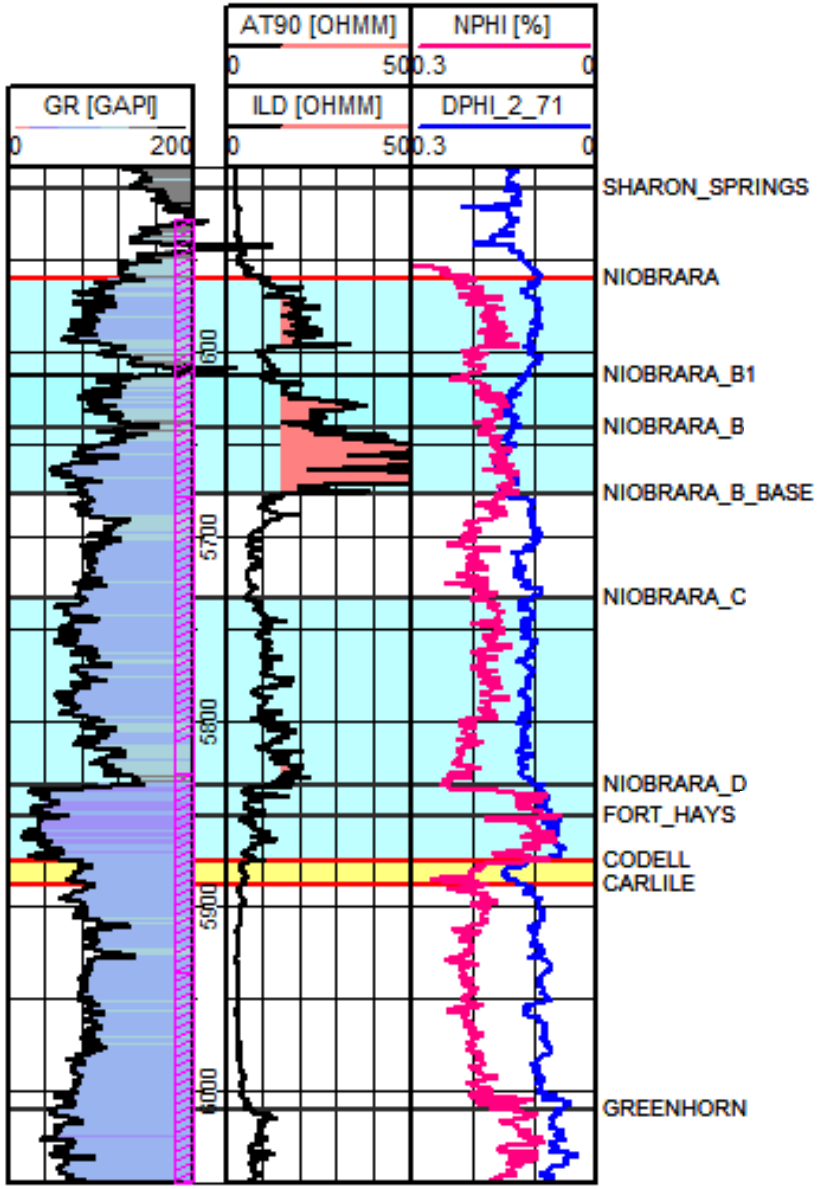
Type Wells – DJ and Redtail

DJ Type Well: Timbro PC LD16-17

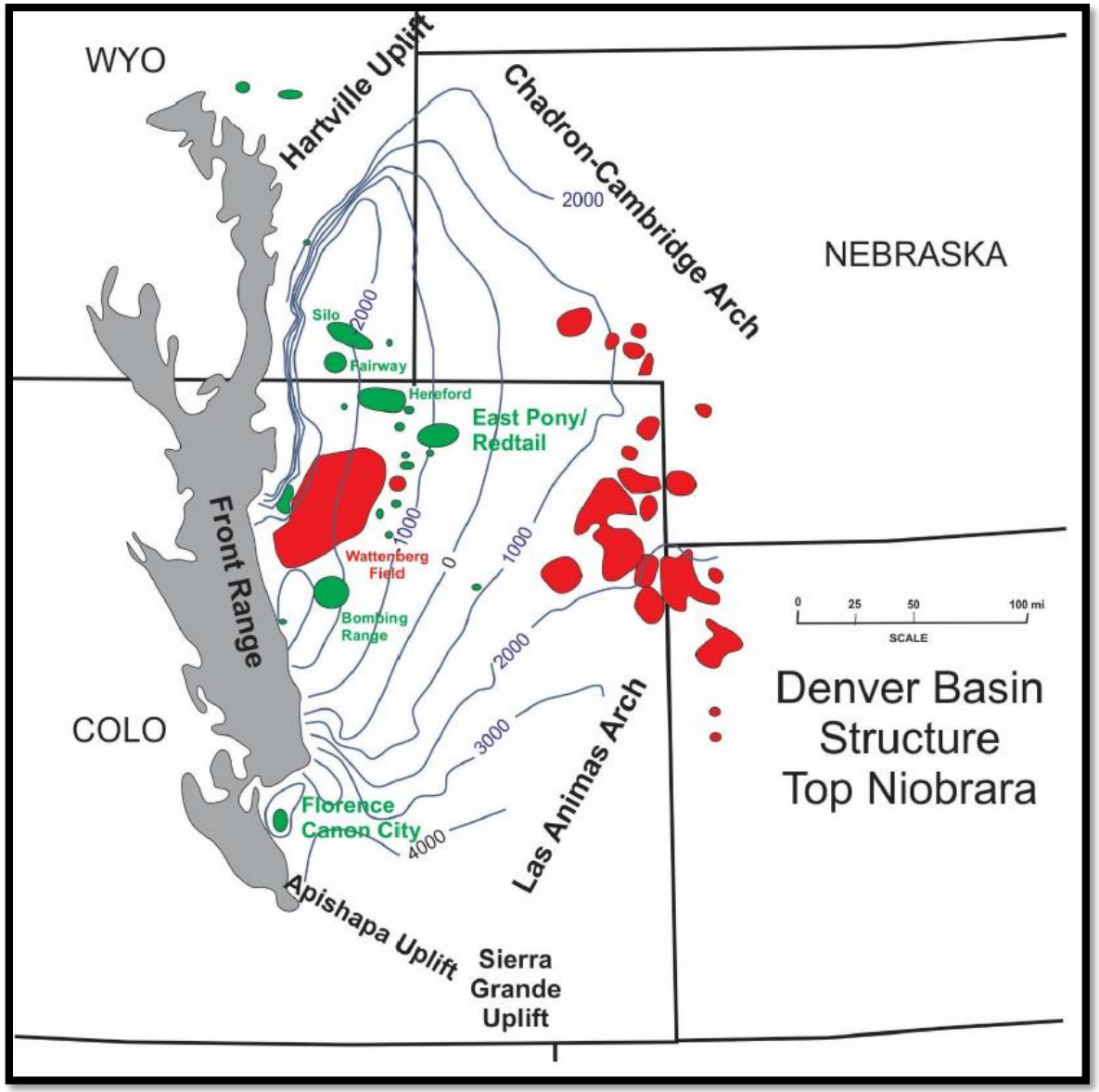


(Sonnenberg, 2017)

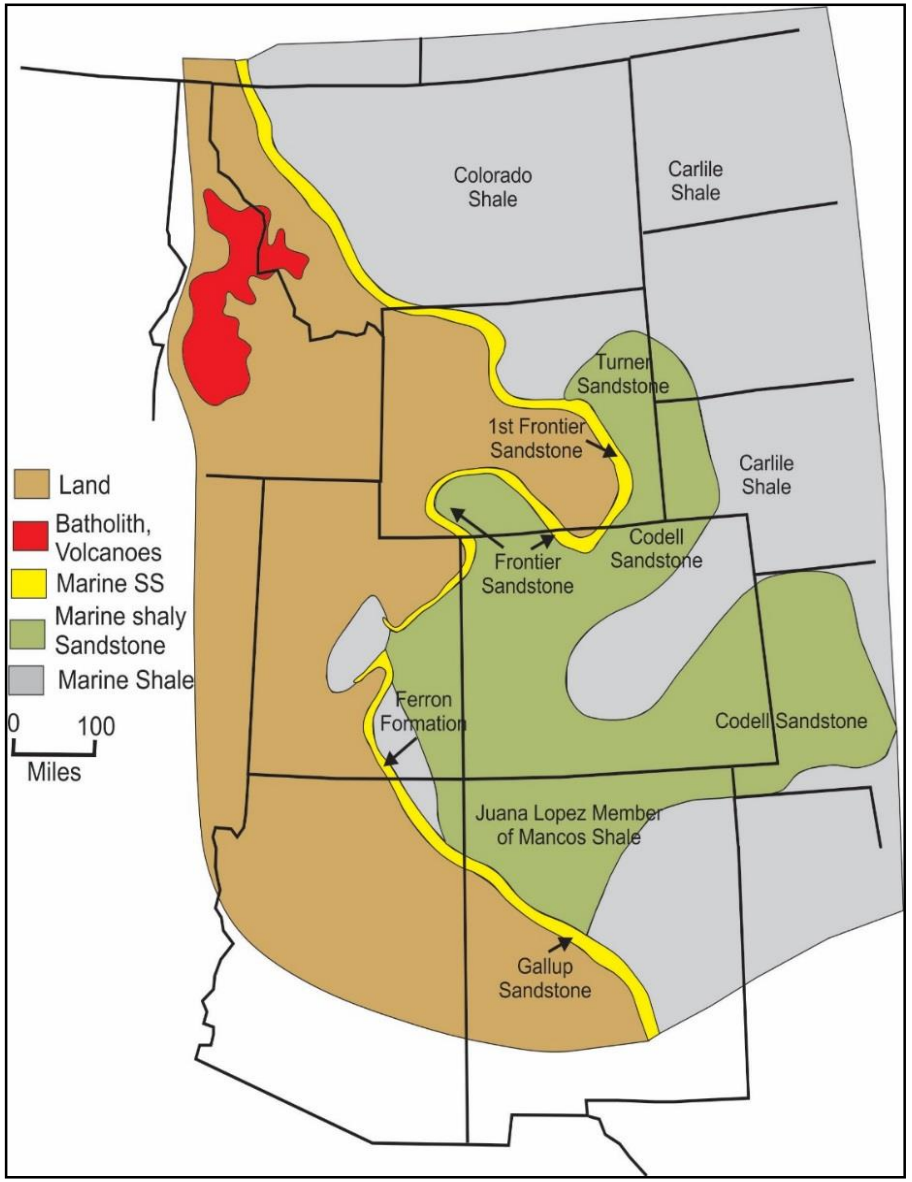
Redtail Type Well: Razor 25-2514H



East Pony/Redtail Field Locality



(Sonnenberg, 2017)



(Modified from Mallory, 1972)

Codell Extent and Environment

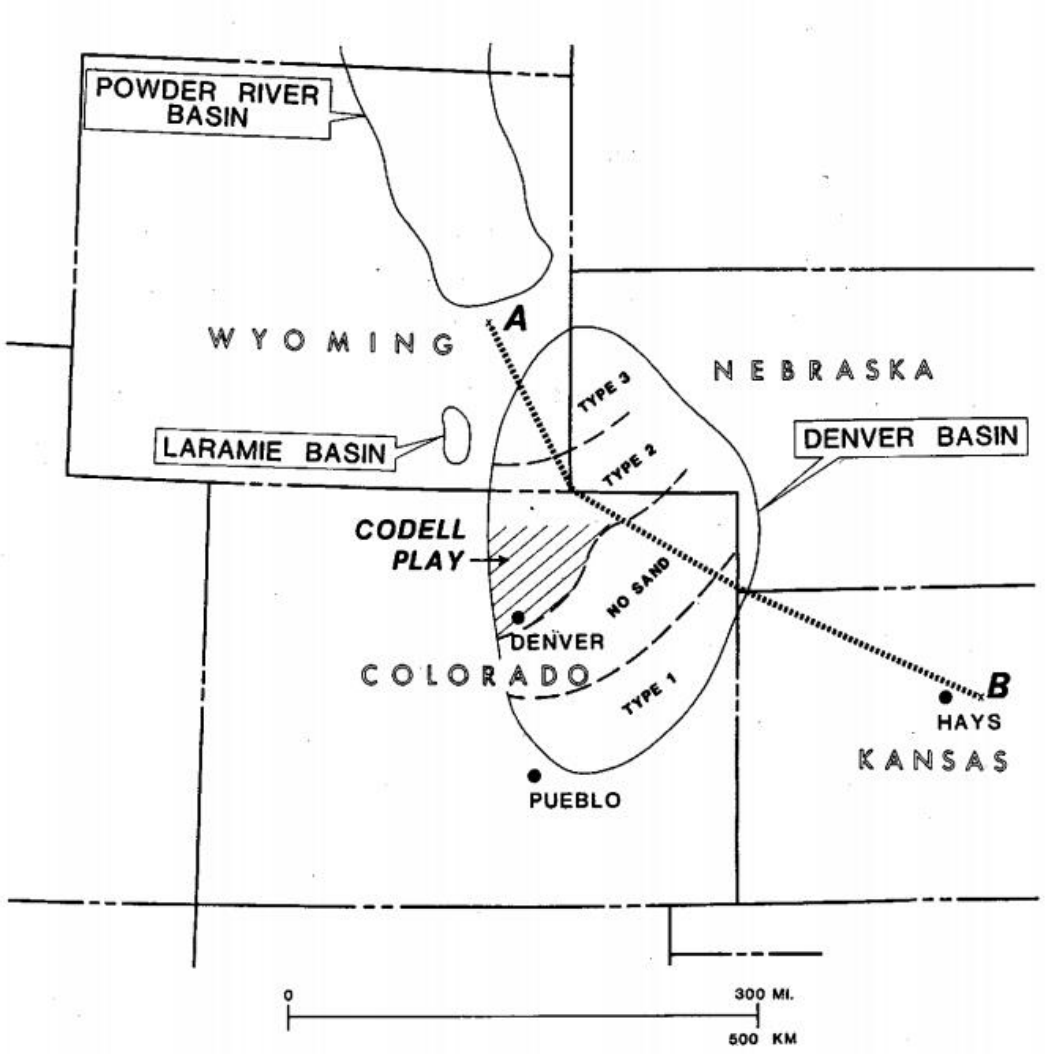
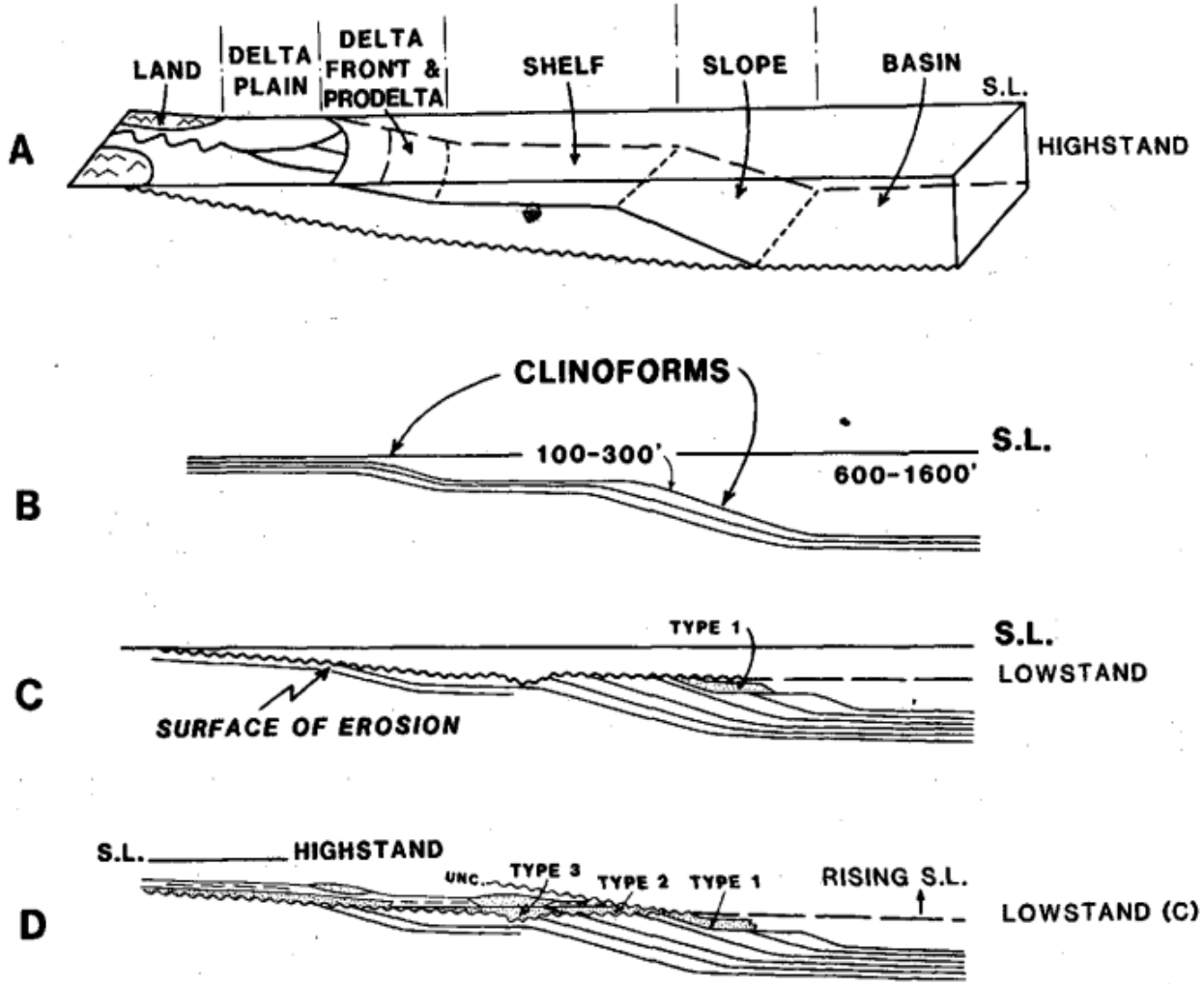


Figure 1 Distribution of Codell Sandstone

(Modified from Weimer and Sonnenberg, 1983)



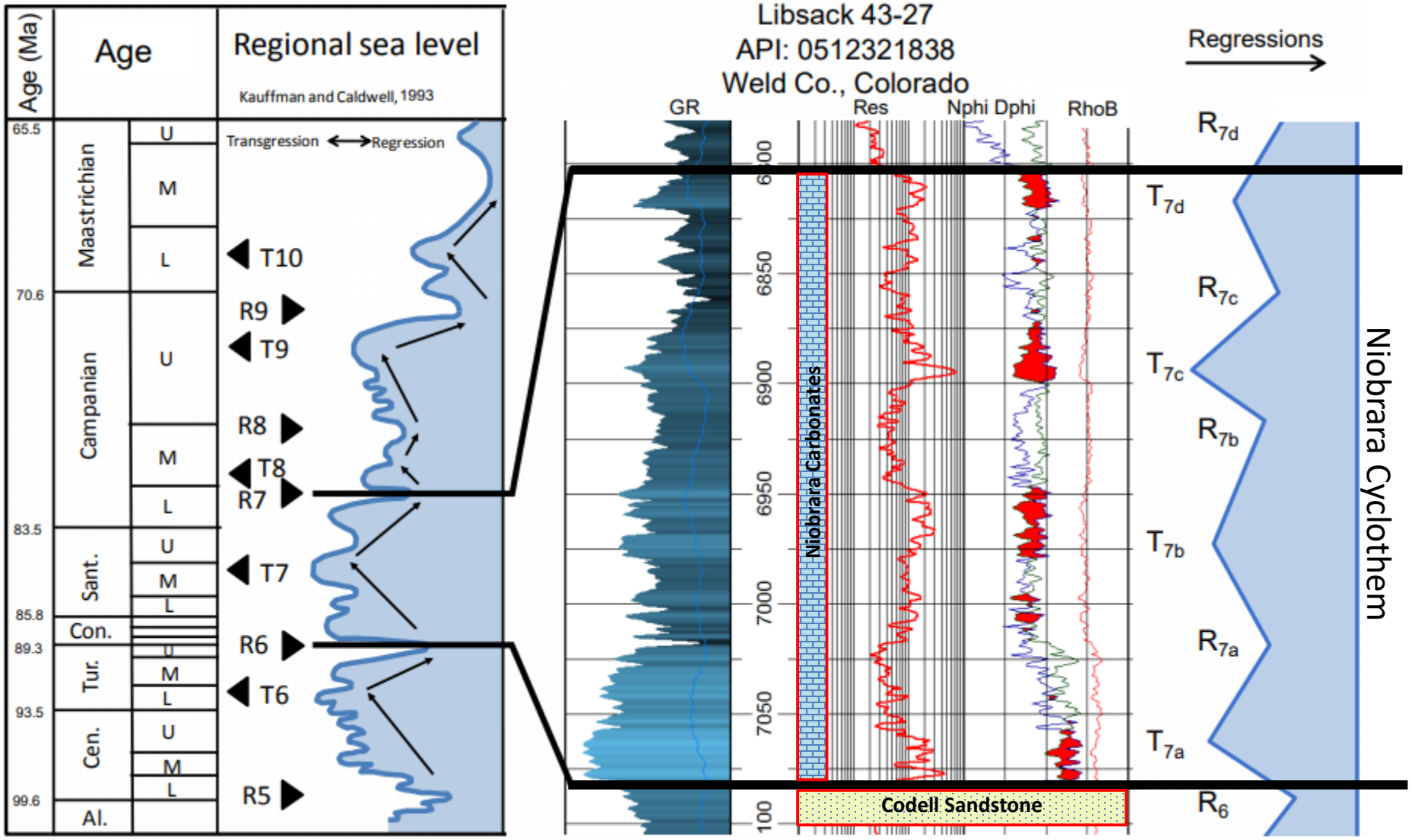
(Modified from Weimer and Sonnenberg, 1983)

Geologic History

Geologic History – Greenhorn Cyclothem

(Modified from Blakey, 2016)

Geologic History – Sea Level Fluctuation

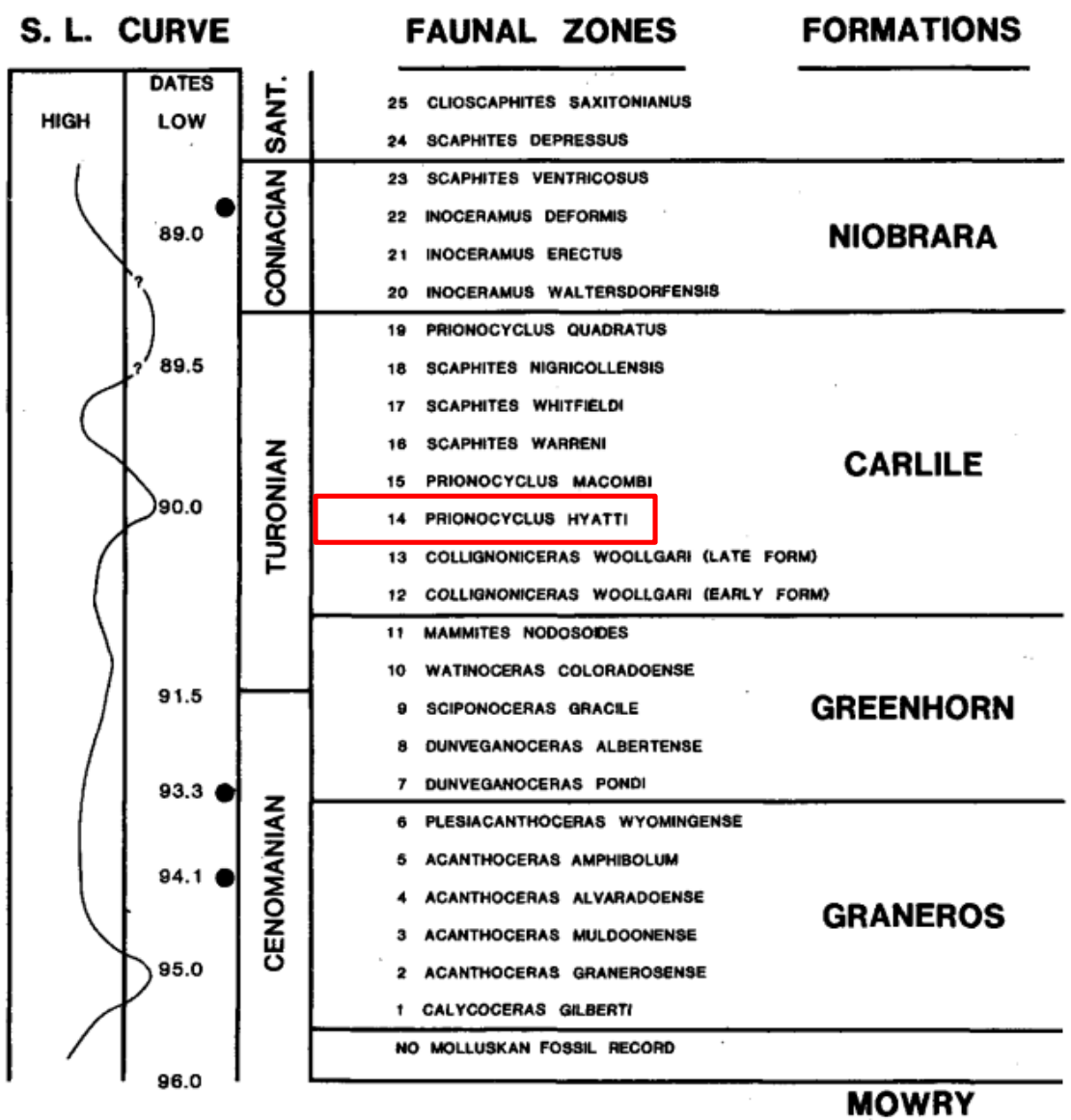


End of Niobrara Cyclothem

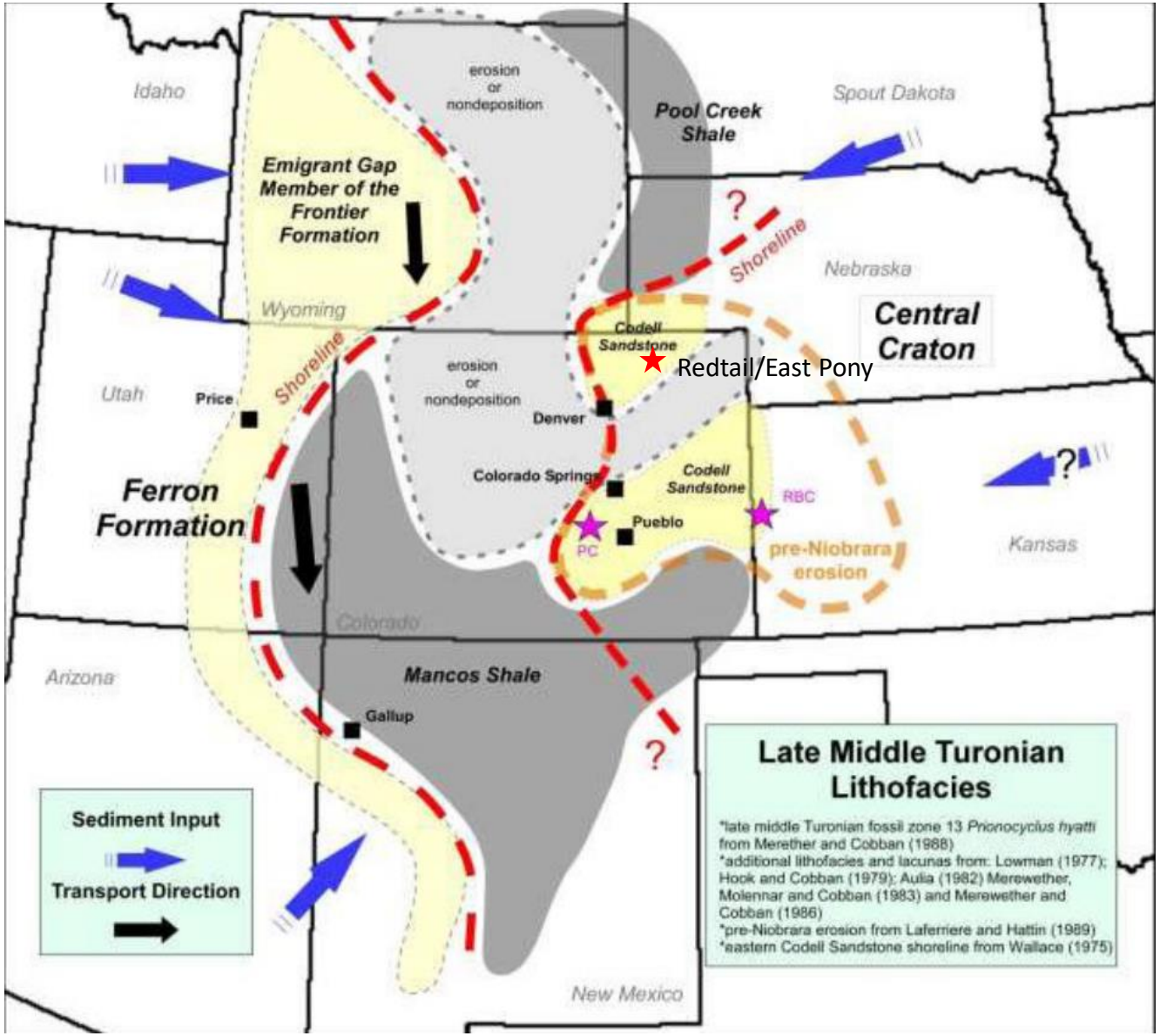
Beginning Niobrara Cyclothem (major transgression); end of Greenhorn Cyclothem (major regression) associated with Codell deposition

(Modified from Drake and Hawkins, 2012)

Geologic History – Lithofacies and Faunal Zones

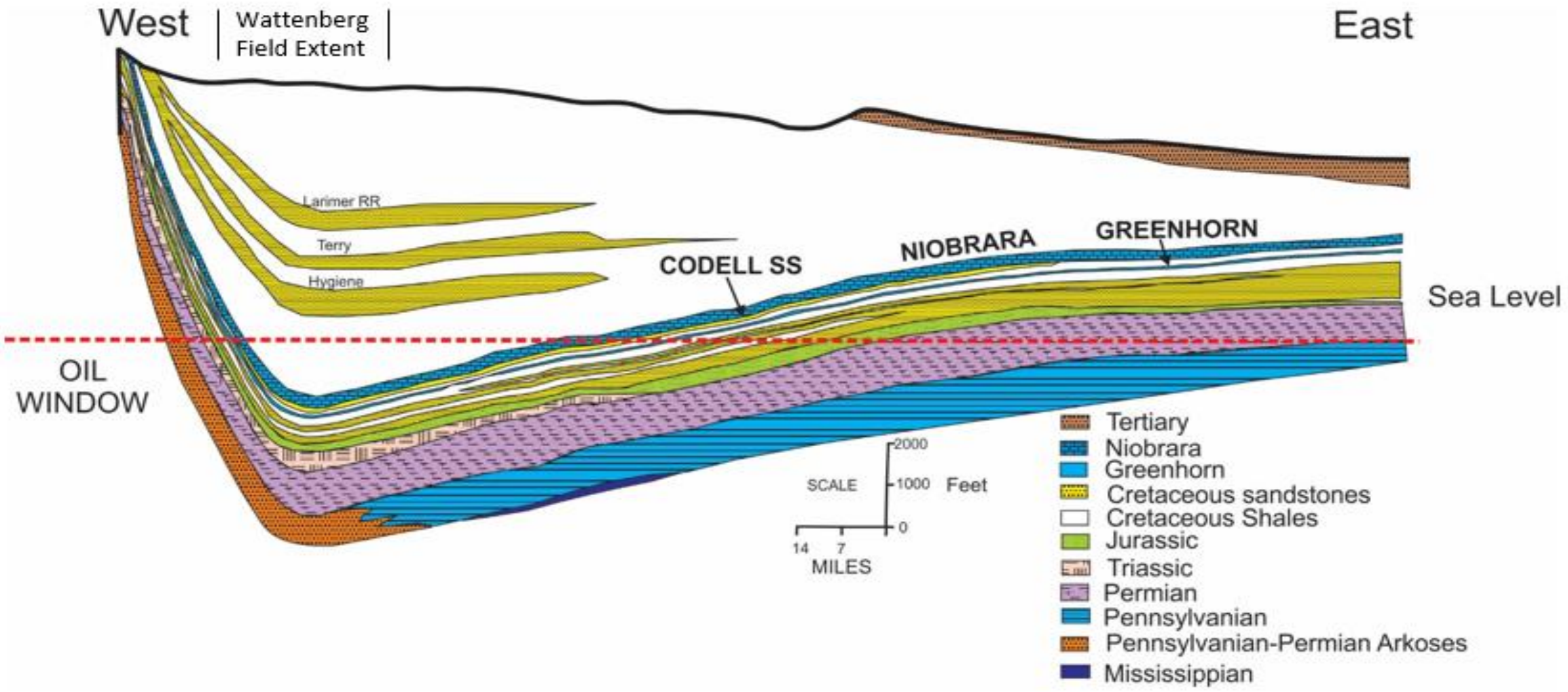


(Modified from Weimer and Sonnenberg, 1983)



(Modified from Lewis, 2013)

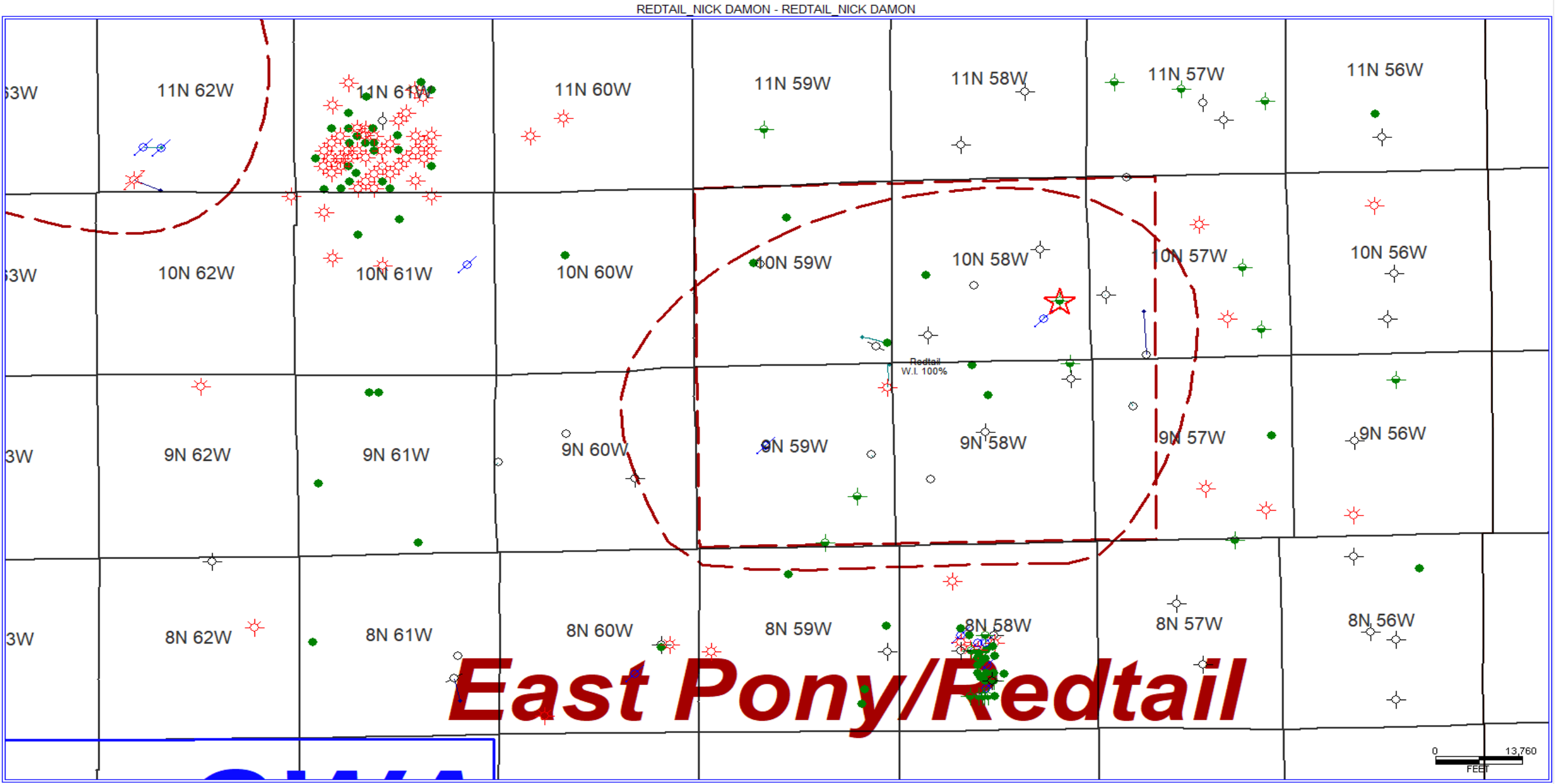
Petroleum System Cross Section



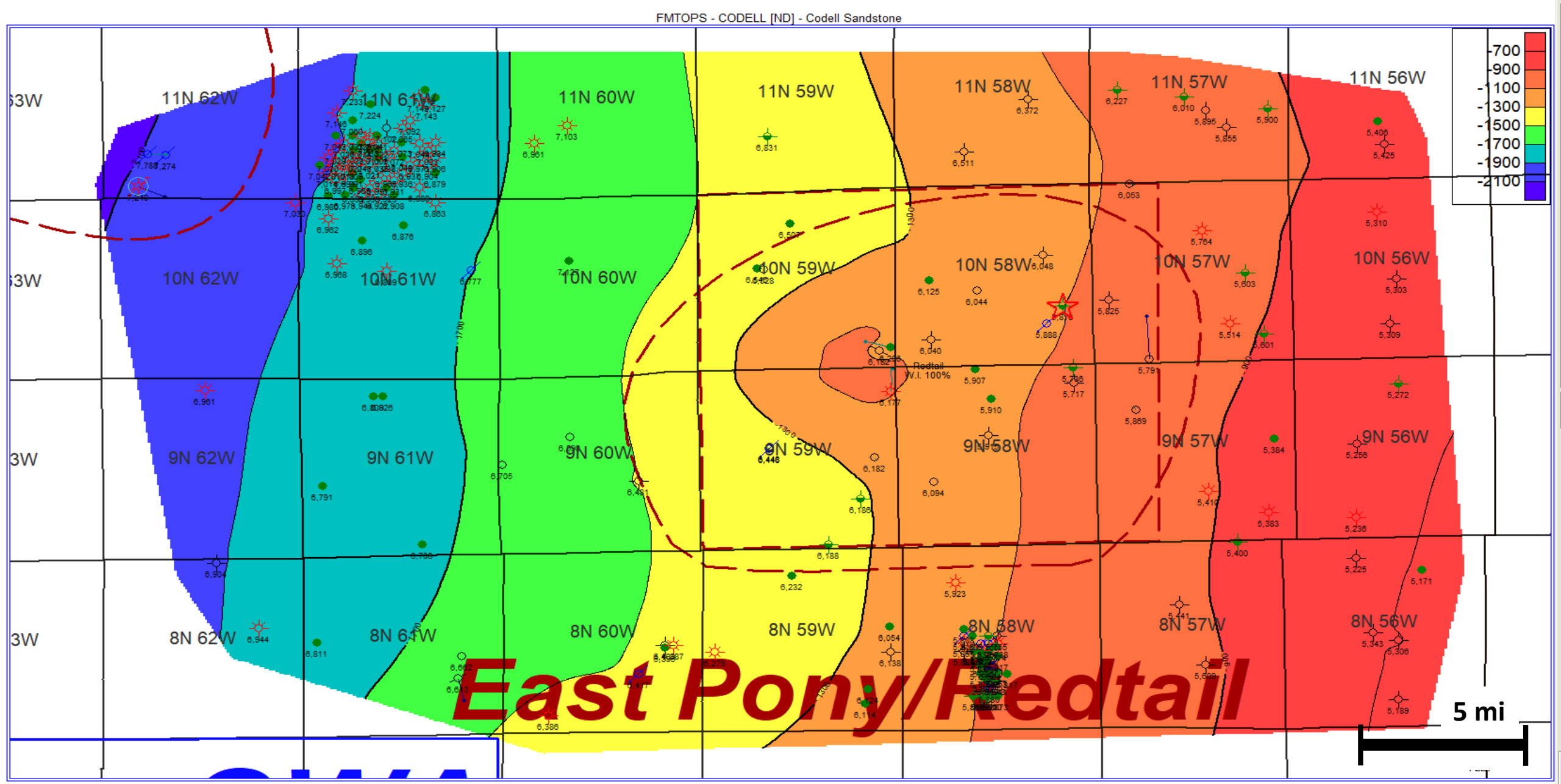
(Modified from Sonnenberg, 2015)

Codell Sandstone – Redtail Field

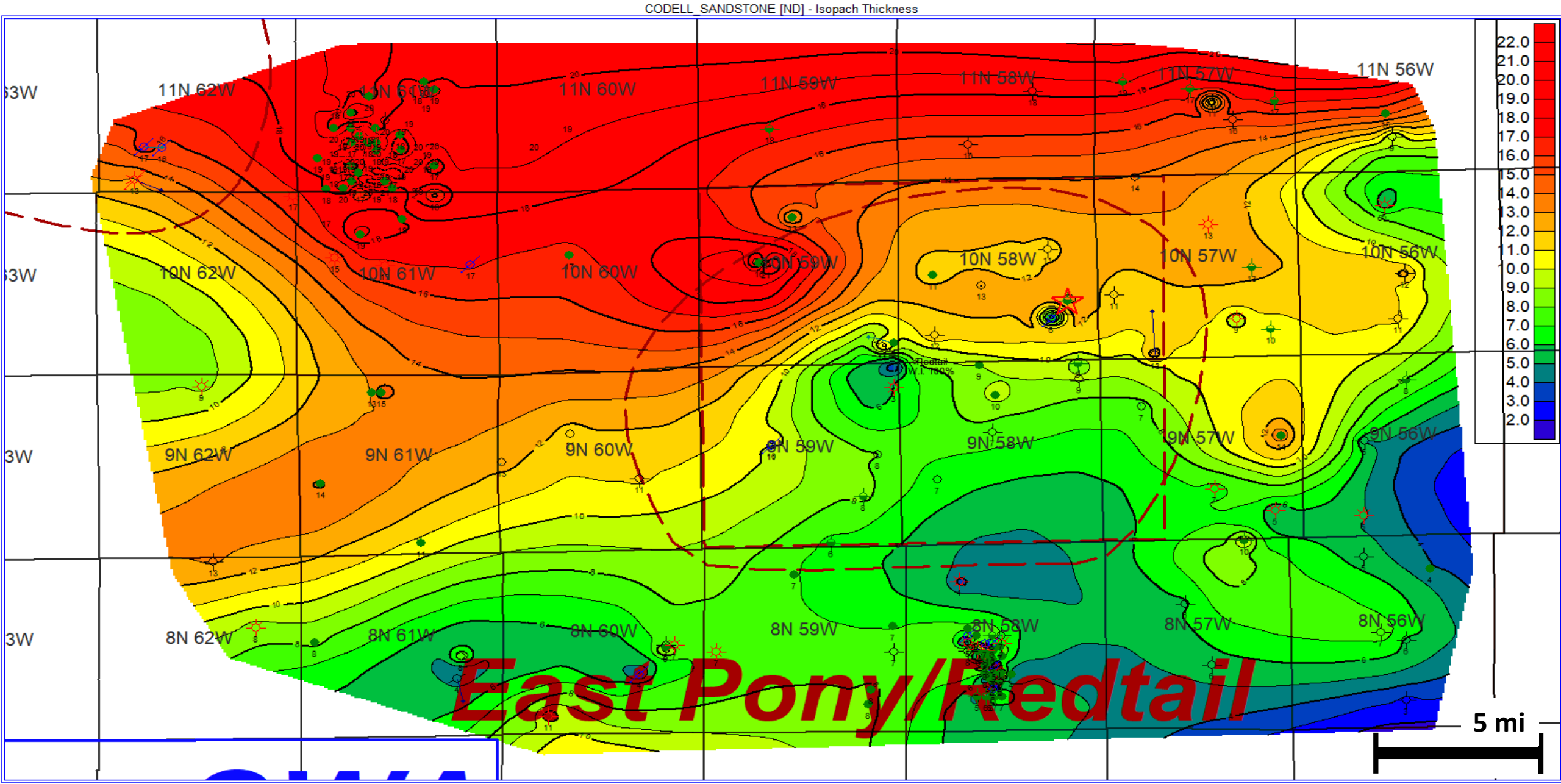
Mapping Area – Redtail Field Area



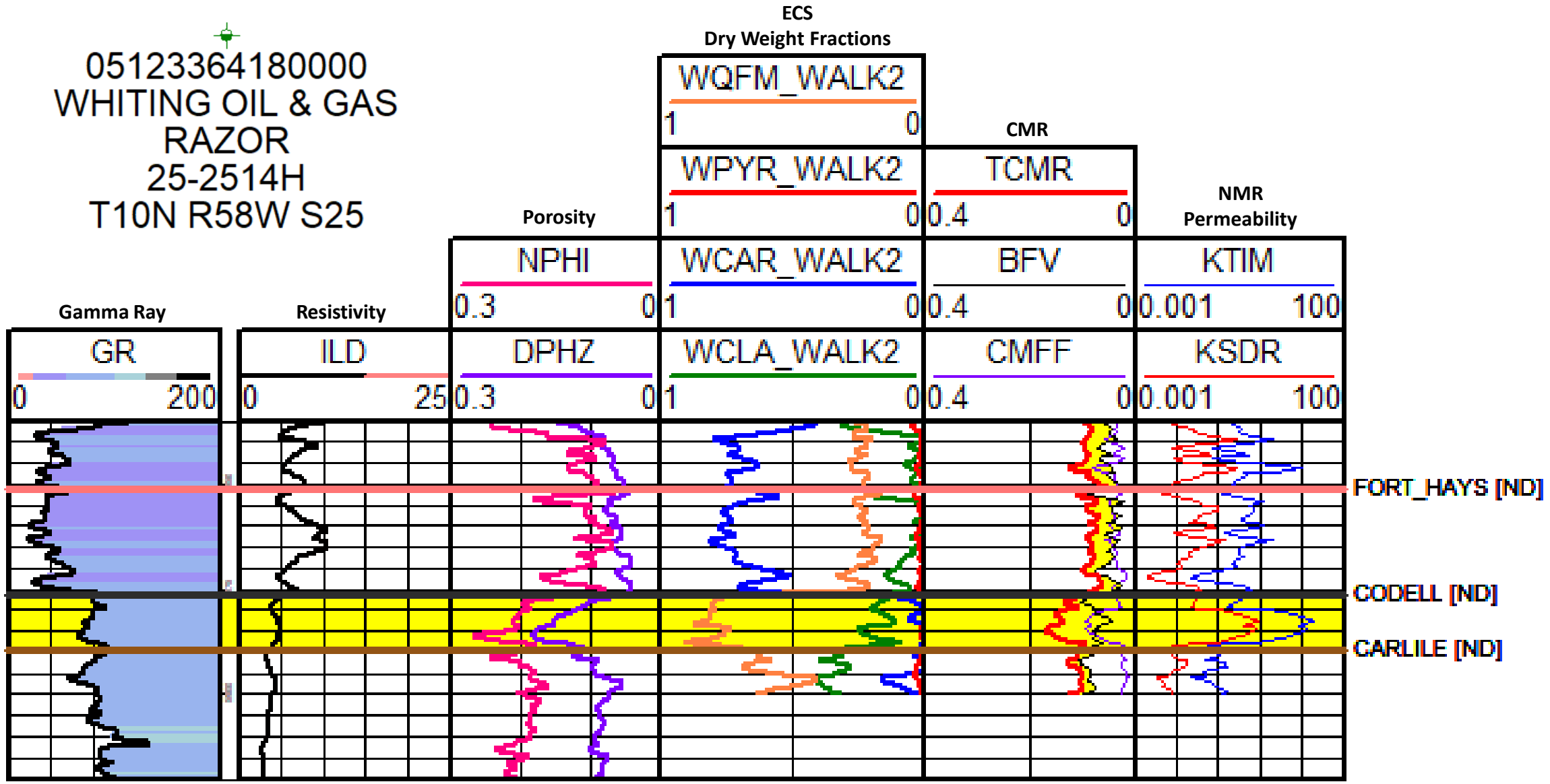
Codell Sandstone Structure – Redtail Field Area



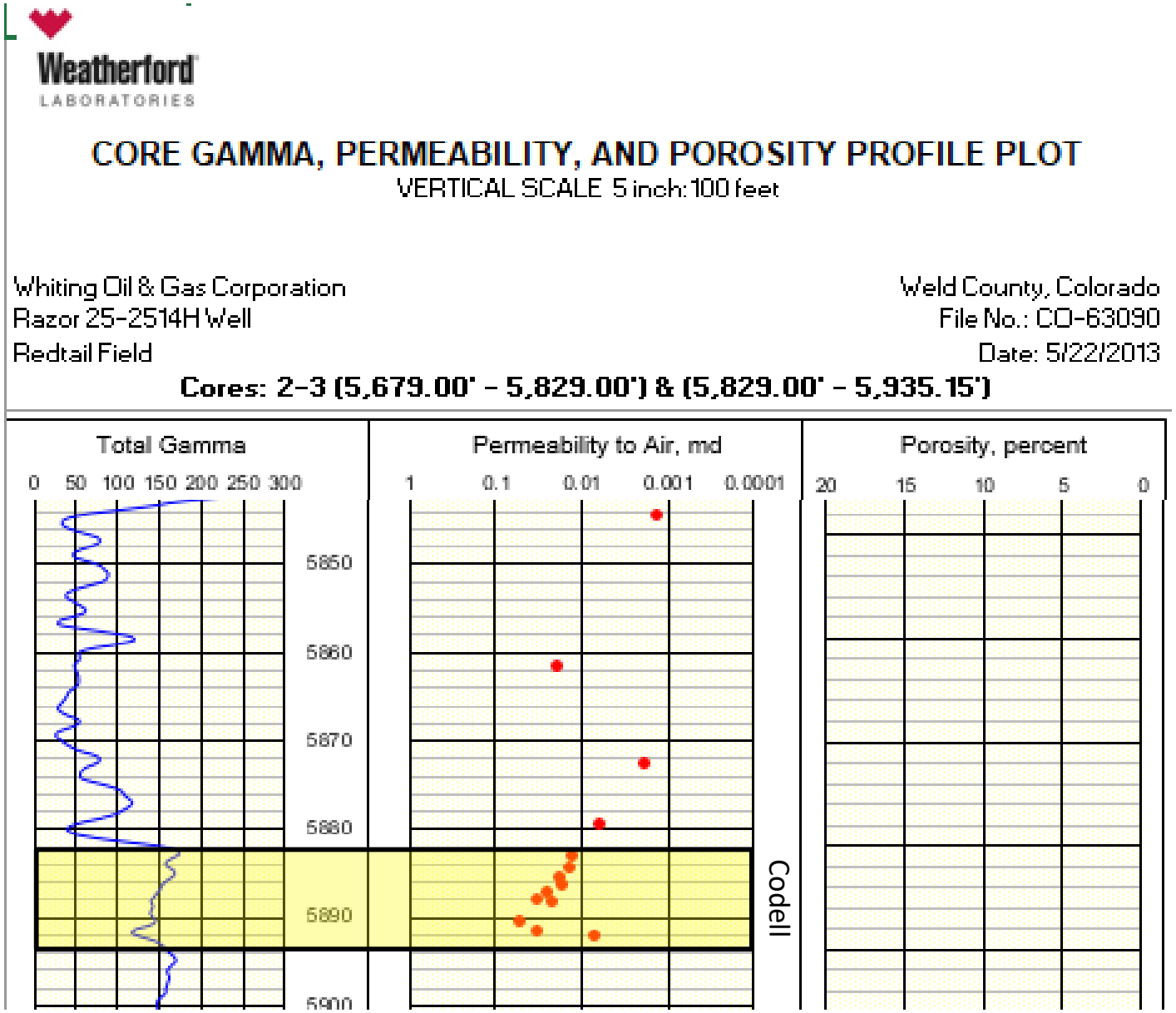
Codell Sandstone Isopach – Redtail Field Area



Reservoir Properties



Reservoir Properties - Permeability



Permeability: ~.01 to .1 md

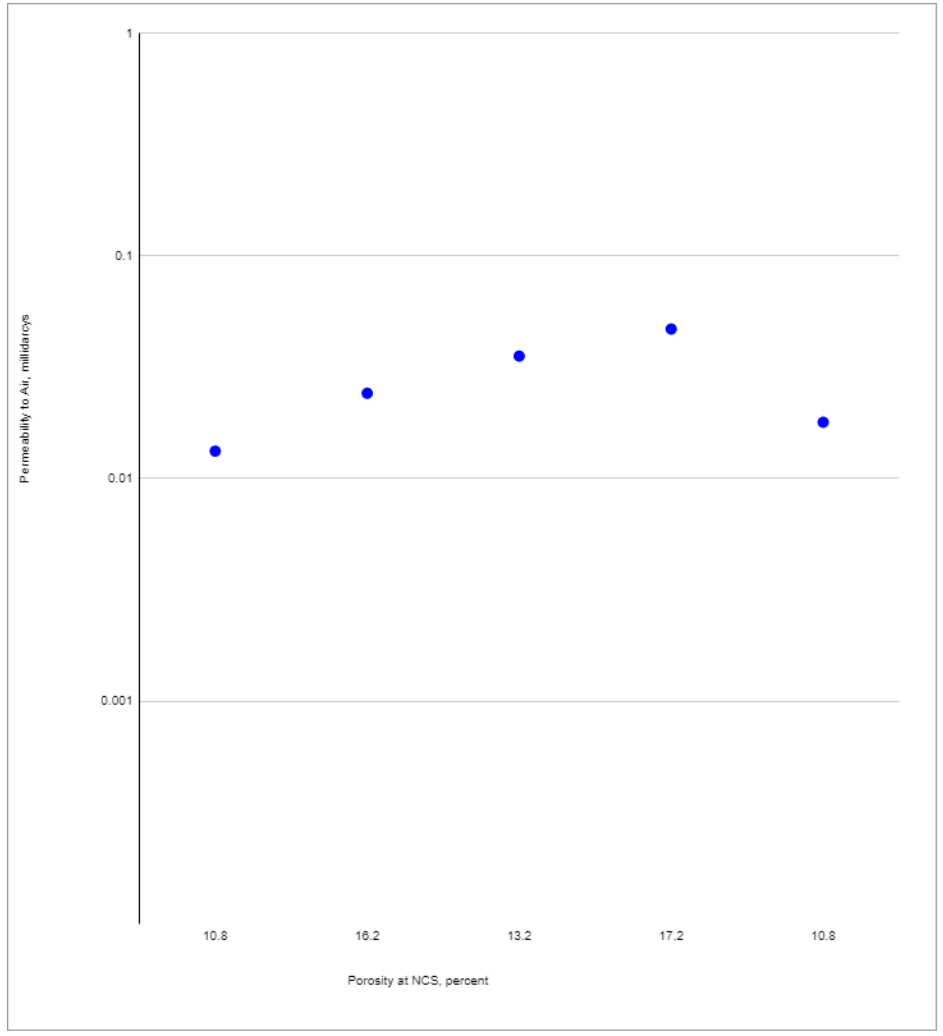
(Modified from Whiting Petroleum, 2013)

PERMEABILITY VERSUS POROSITY

Convection Oven Dried at 140° F Net Confining Stress: 2,000 psi

Whiting Oil and Gas Corporation
Razor 25-2514H Well
Redtail Field

Weld County, Colorado
File No.: CO-63090
Date: 9/23/2016



SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Convection Oven Dried at 140° F Net Confining Stress: 2,000 psi

Whiting Oil and Gas Corporation

Weld County, Colorado

Razor 25-2514H Well

File No.: CO-63090

Redtail Field

Date: 9/23/2016

Core Number	Sample Number	Sample Depth, feet	Permeability, millidarcys		Porosity, percent		Grain Density, gm/cc
			to Air	Klinkenberg	Ambient	NCS	
3	3-56	5,884.80	0.013	0.0064	11.0	10.8	2.68
3	3-59	5,887.35	0.024	0.013	16.4	16.2	2.67
3	3-60	5,888.50	0.035	0.020	13.4	13.2	2.67
3	3-62	5,890.60	0.047	0.028	17.4	17.2	2.66
3	3-64	5,892.10	0.018	0.0091	11.0	10.8	2.67
		Average values:	0.028	0.016	13.8	13.6	2.67

(Modified from Whiting Petroleum, 2013)

SARA & GC Data

SampleID	15	16	17	Pr	18	Ph	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Pr/Ph	Pr/nC17	Ph/nC18	nC27/nC17	CPI
XCL0067	*Sample was missing from the start*																											
XCL0068	6.80	7.78	8.32	4.19	7.89	2.46	7.80	7.32	7.21	6.43	5.95	5.11	4.53	3.80	3.23	2.51	2.25	1.74	1.42	1.09	0.91	0.67	0.60	1.70	0.50	0.31	0.39	1.06

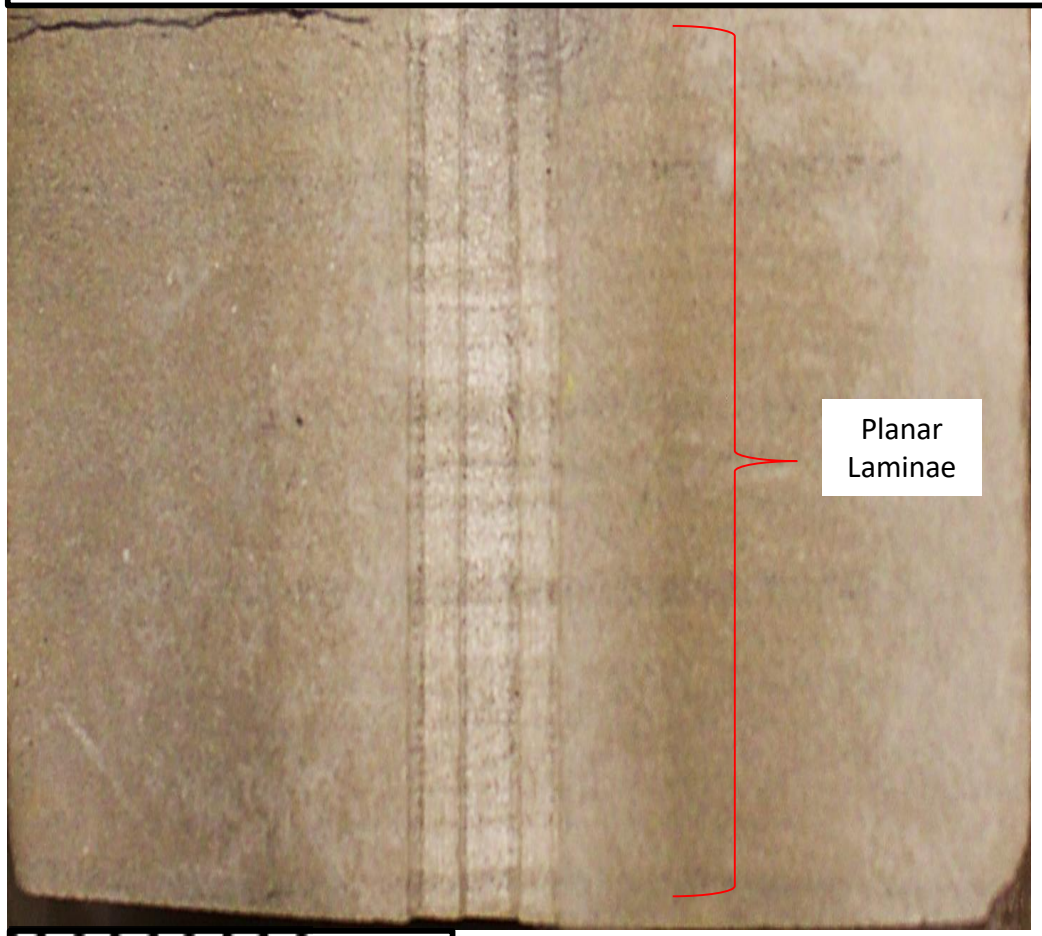
(Modified from Whiting Petroleum, 2013)

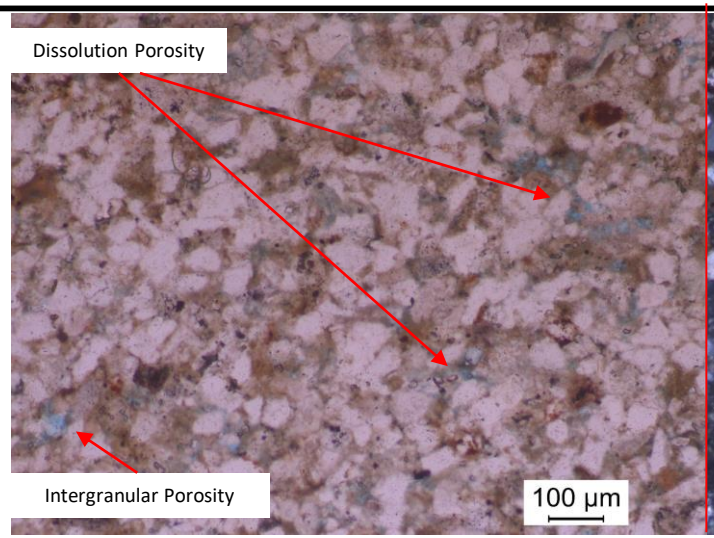
- SARA:
  - **S**aturate, **A**romatic, **R**esin, and **A**sphaltene
  - Analytical method for dividing crude oil components
- Pristane (Pr)/Phytane (Ph) Ratio:
  - Can be used to show redox conditions during diagenesis
  - Pristane – Oxic Conditions; Phytane – Anoxic Conditions
  - **Pr/Ph ratio of 1.70** is coincident with a **marine siliciclastic environment** (range between 1-3)
    - Pr/Ph ratios of 0-1 are associated with carbonate and sulphur-rich environments
    - Pr/Ph ratios of 3-5 are associated with terrigenous and coaly environments

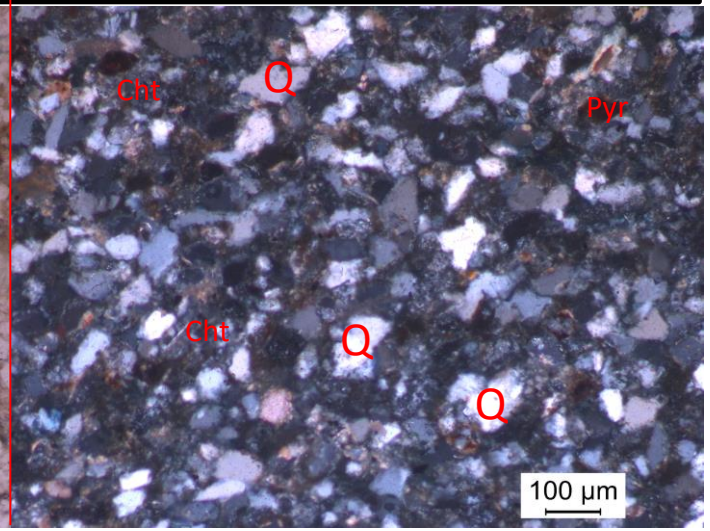
Razor 25-2514H Core

Razor 25-2514H - Facies 1: Planar Laminated Sand

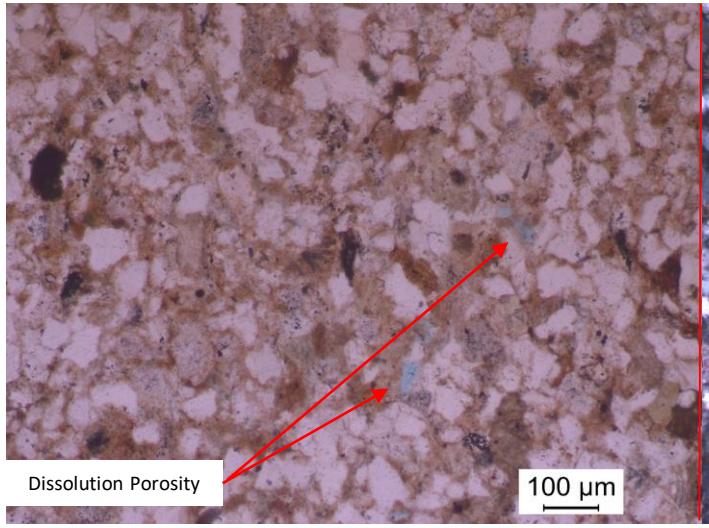
Razor 25-2514H: Facies 1

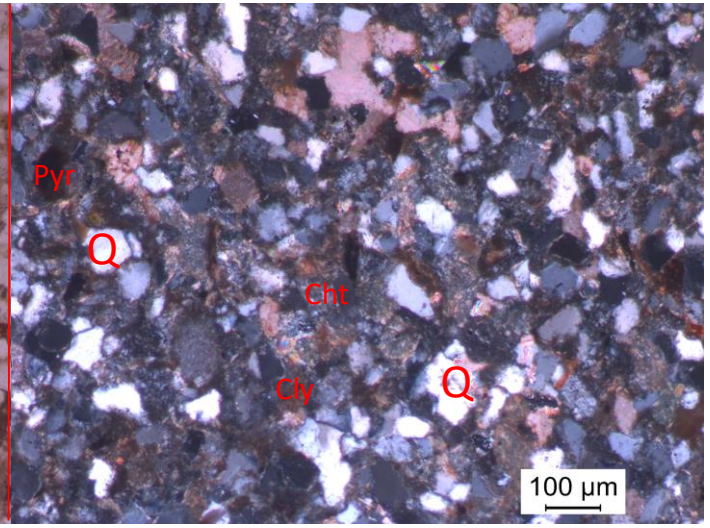






5890'

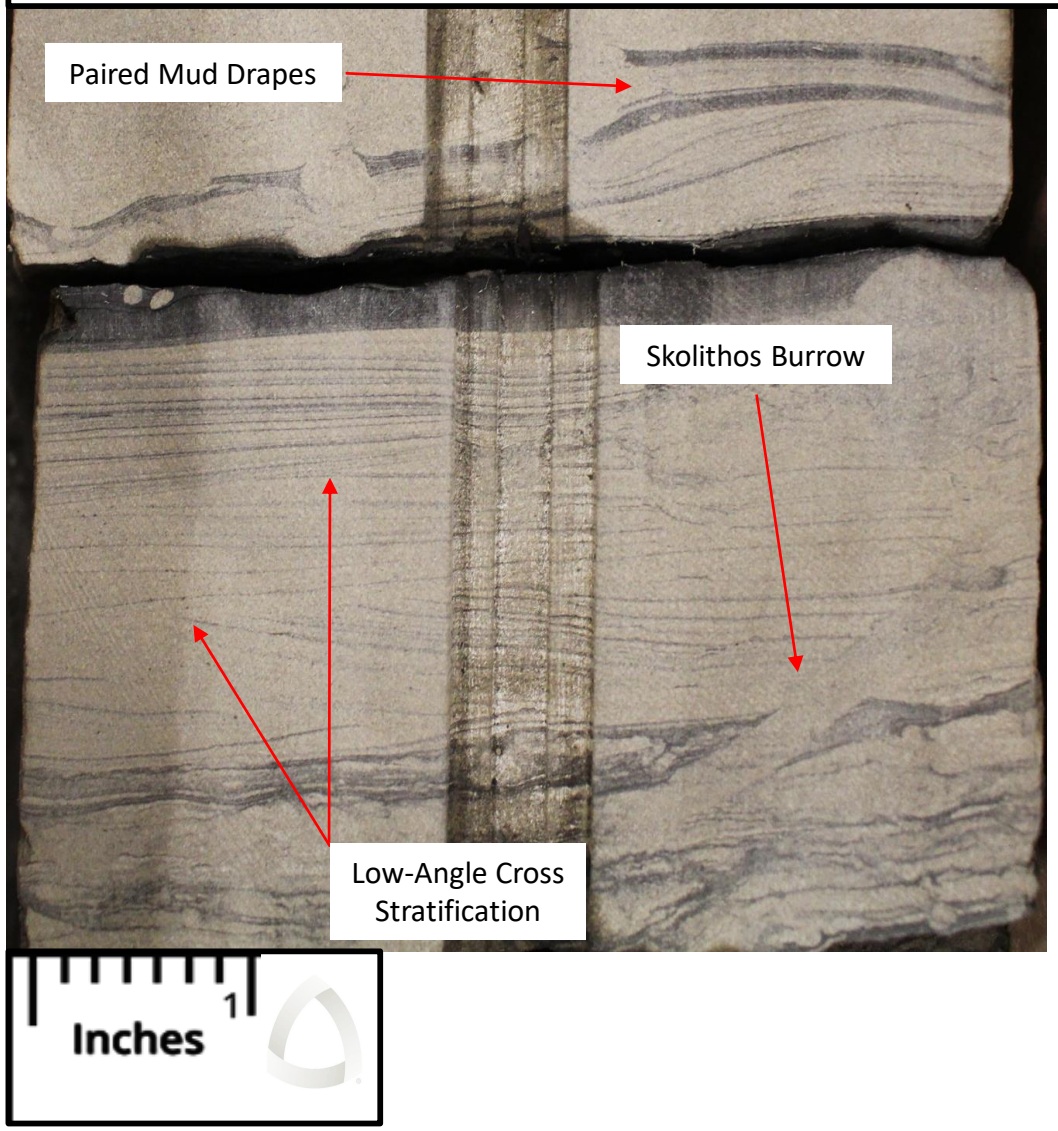


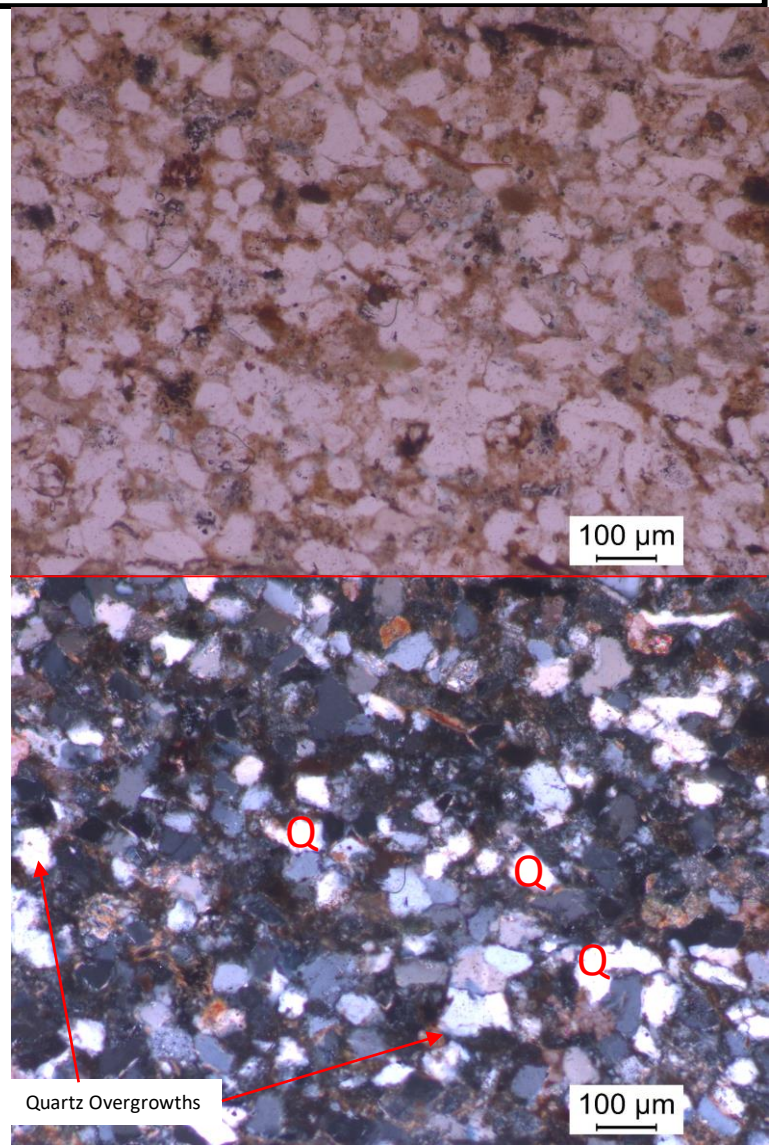


5888'

Razor 25-2514H - Facies 2: Heterolithic Low Angle Cross Stratified Sand

Razor 25-2514H: Facies 2

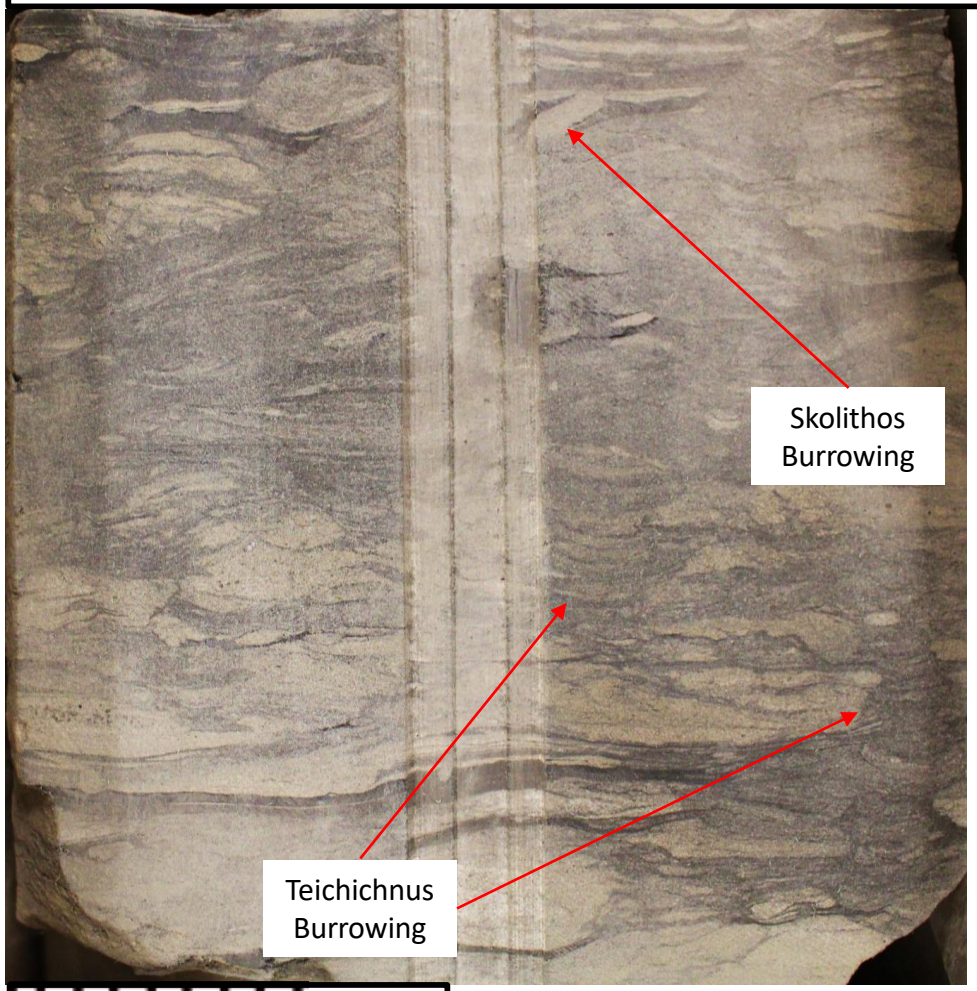


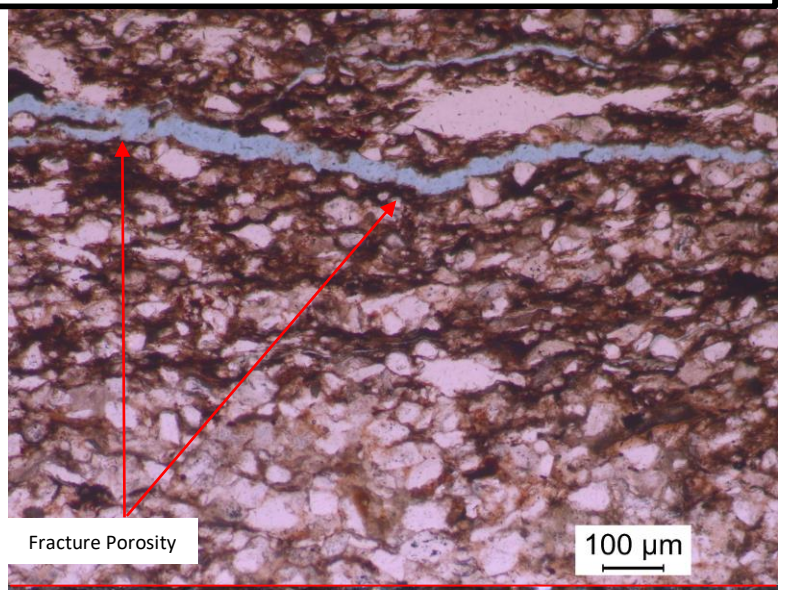


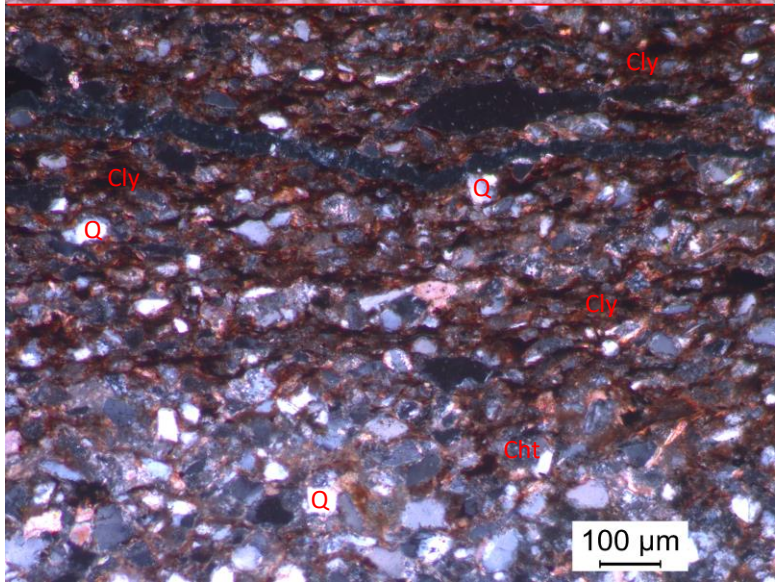
5889.5’

Razor 25-2514H - Facies 3: Lower Bioturbated Silty Sand

Razor 25-2514H: Facies 3



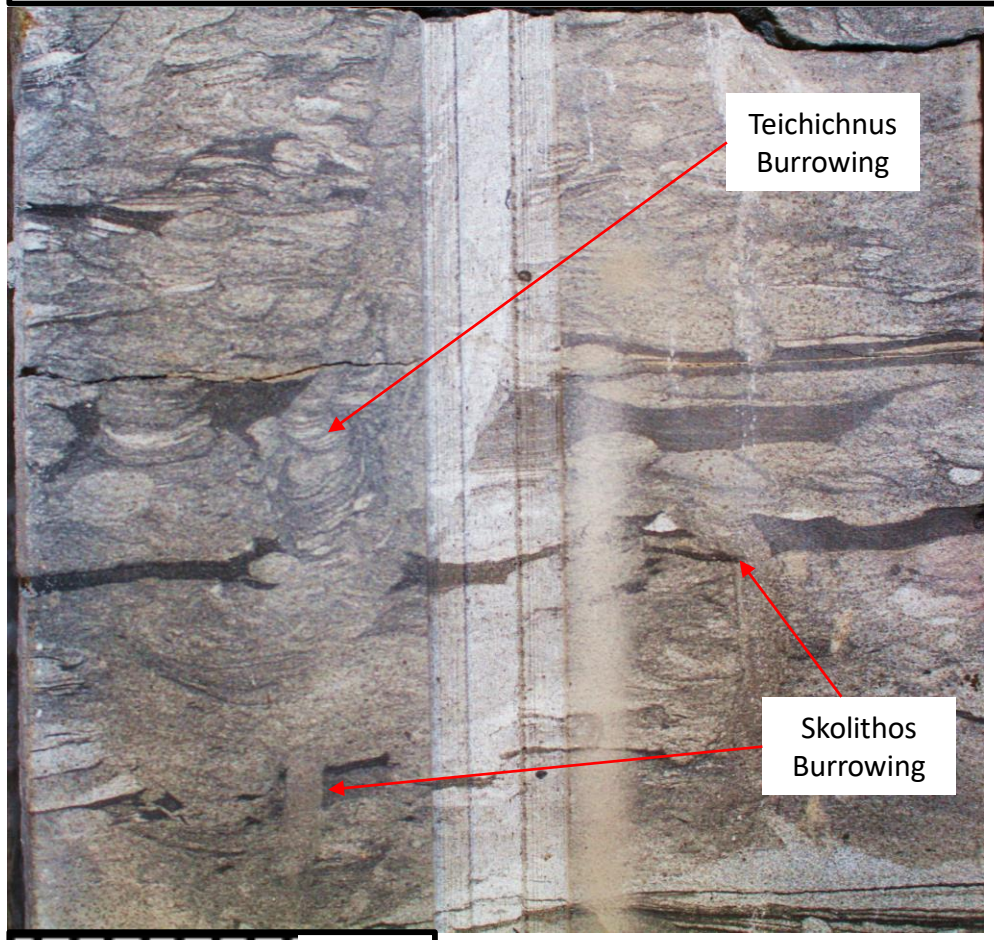


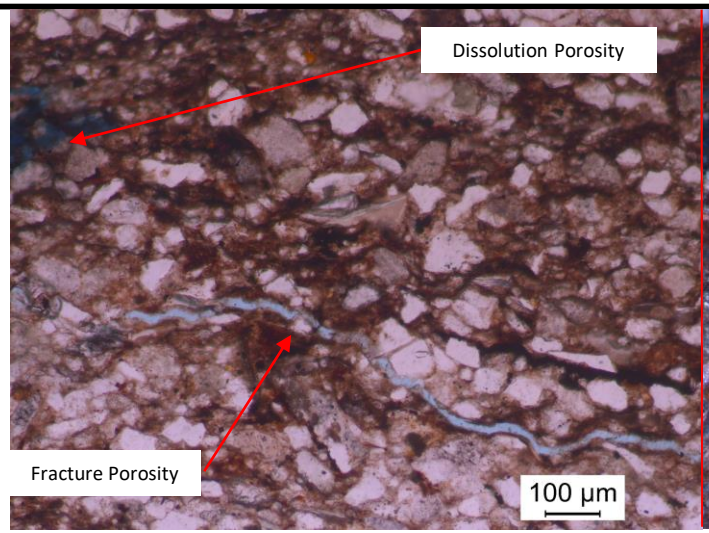


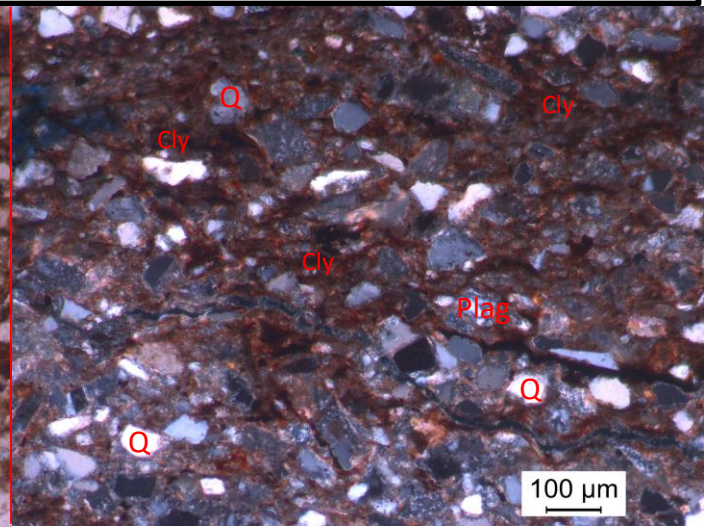
5885.5’

Razor 25-2514H - Facies 4: Upper Bioturbated Sandy Silt

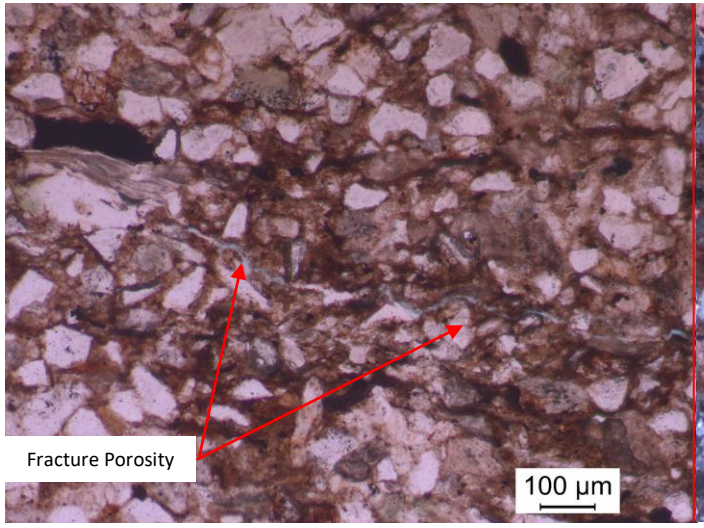
Razor 25-2514H: Facies 4

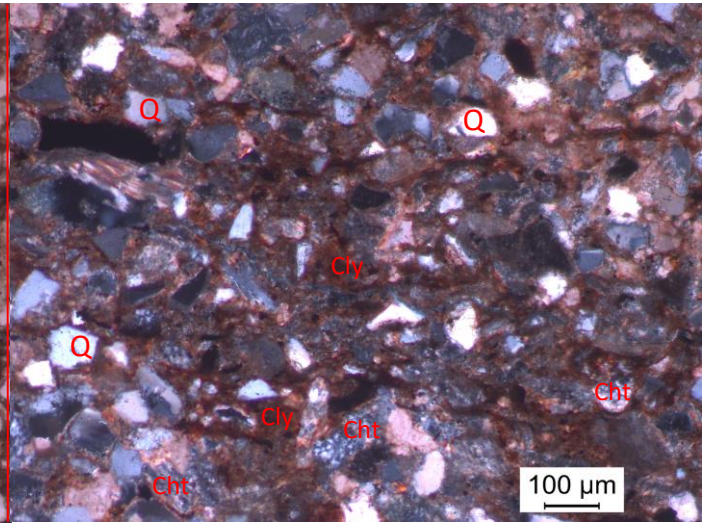






5884'

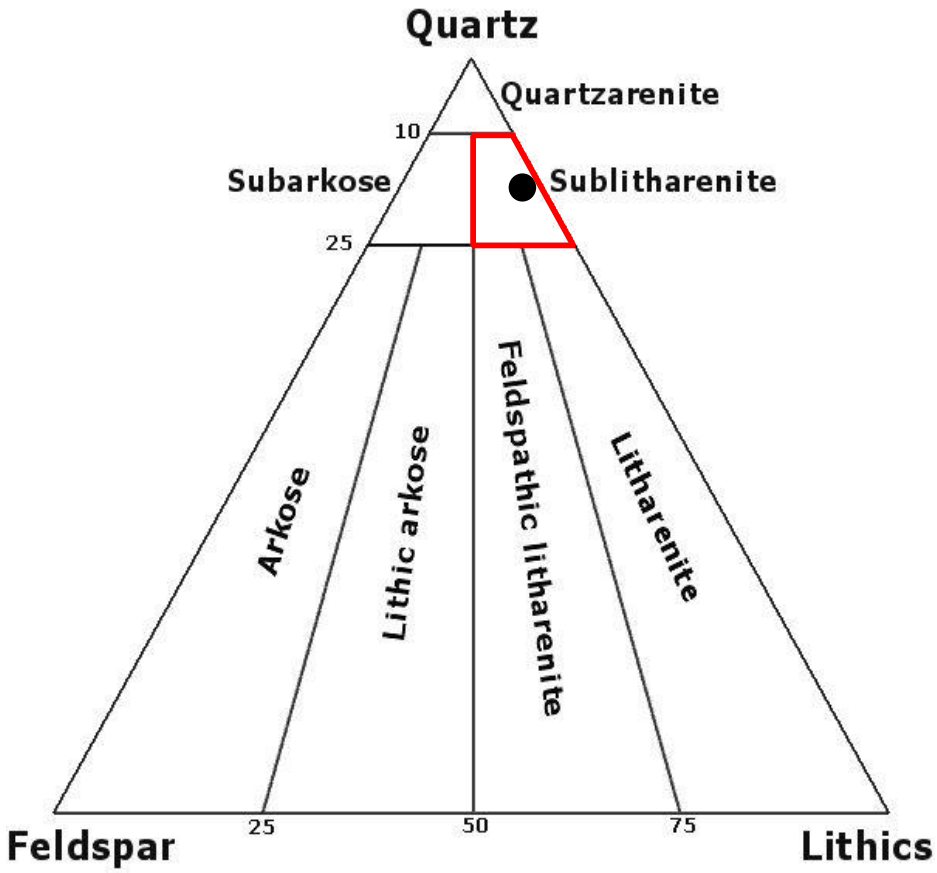




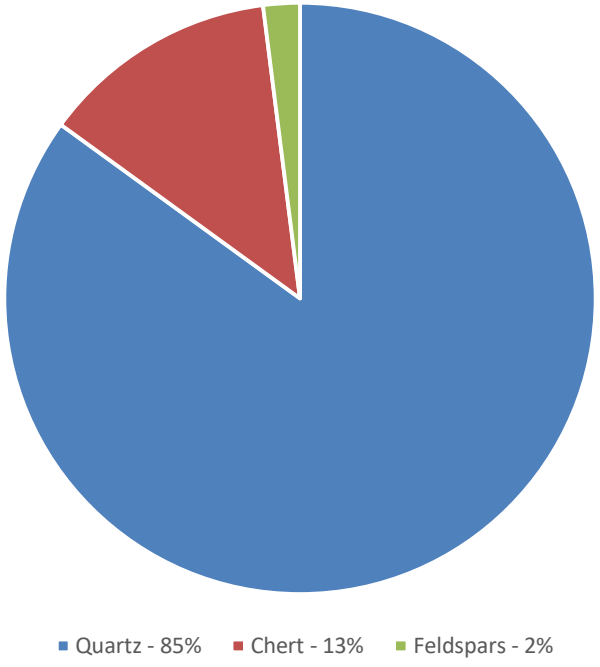
5881'

Razor 25-2514H Modal Mineralogy – Codell Sandstone

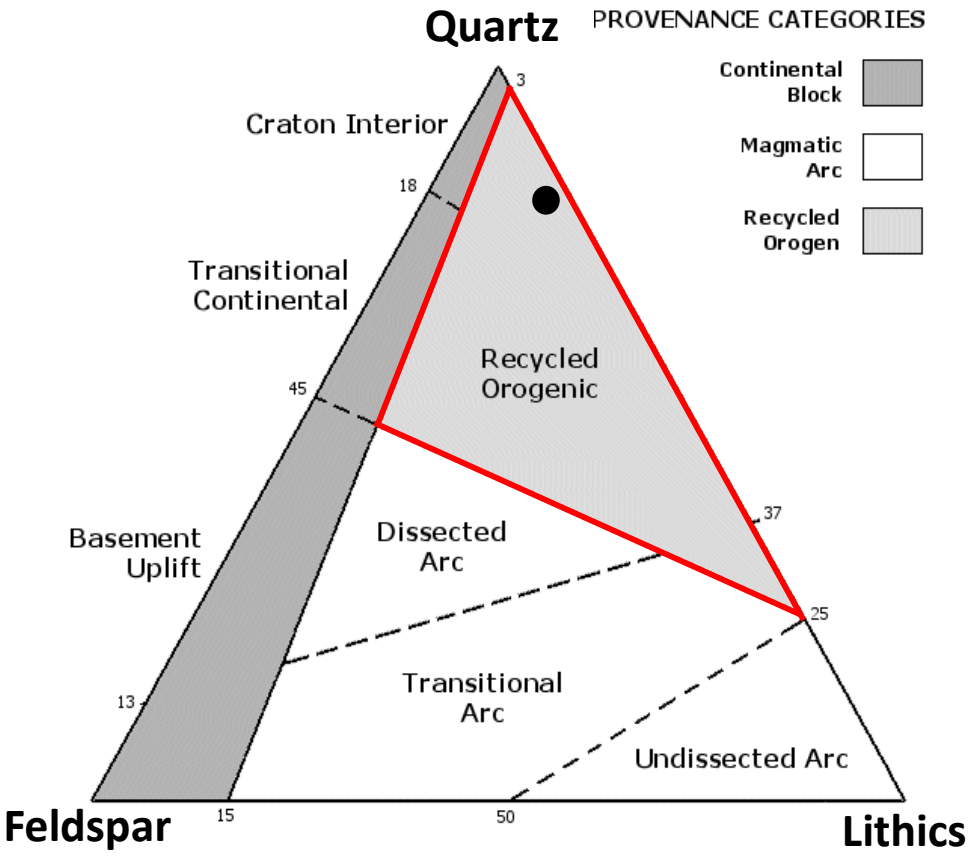
Sandstone Classification



Codell Sandstone Modal Mineralogy

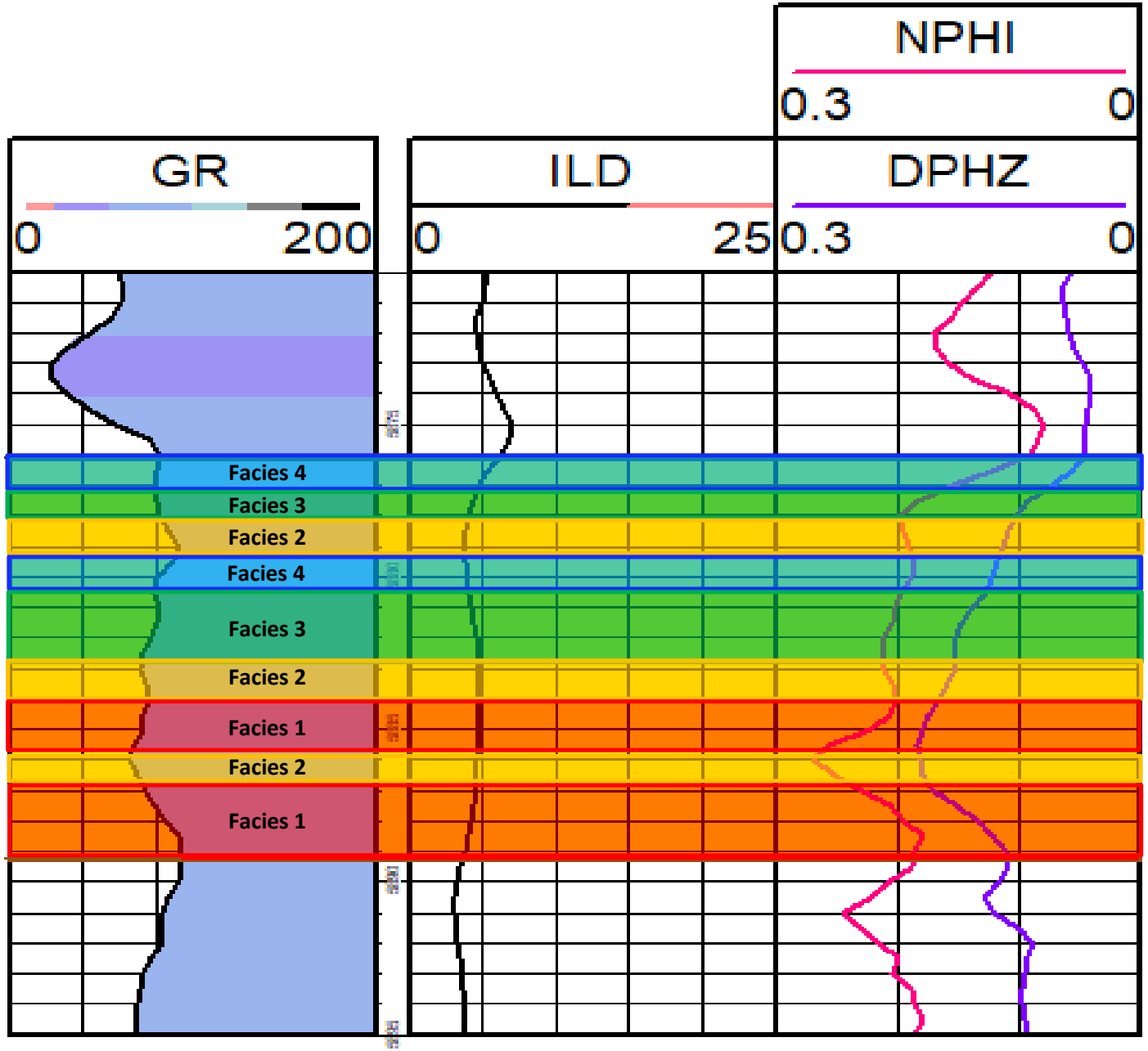


Sandstone Provenance



Reservoir Facies in Core

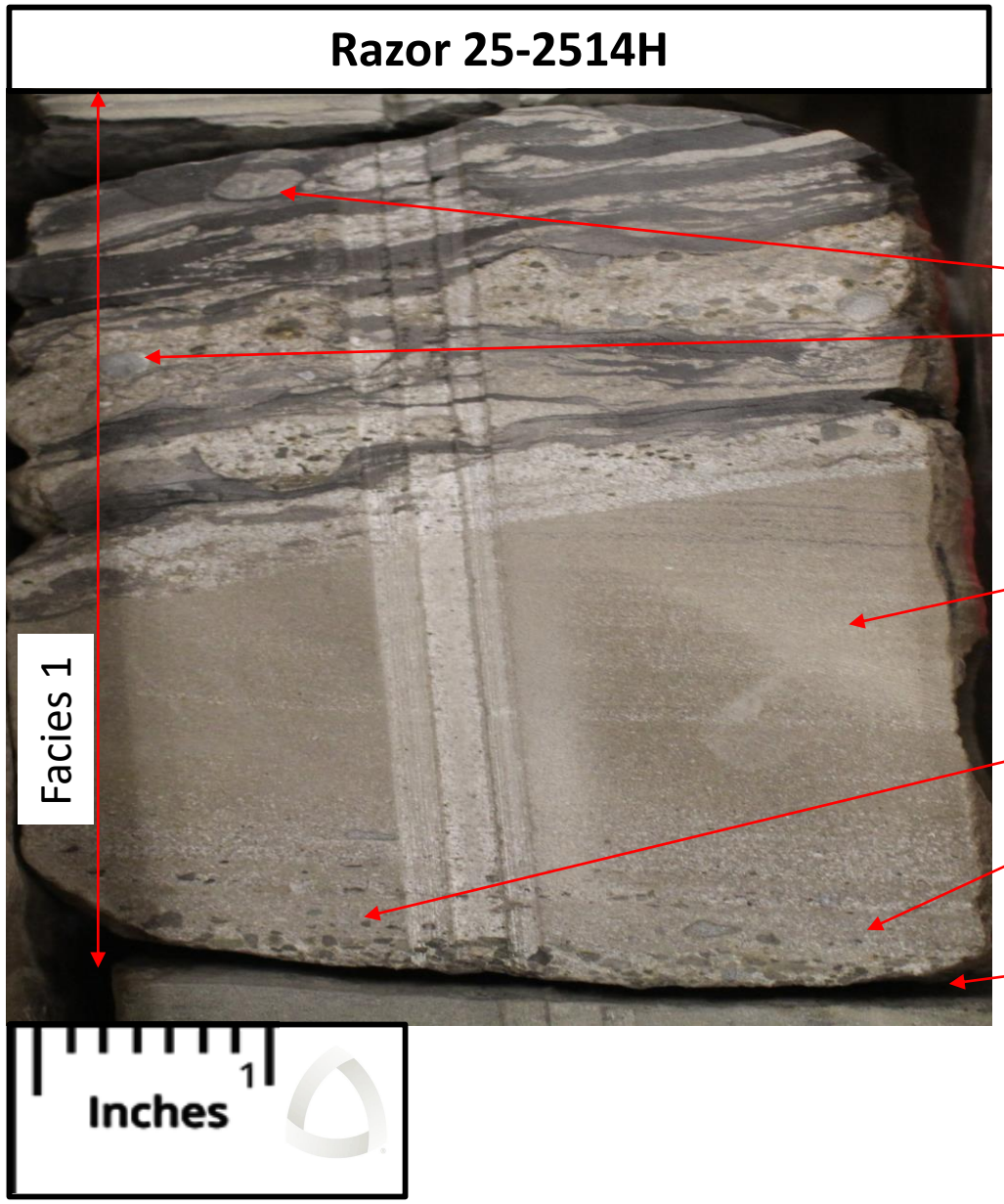
05123364180000
WHITING OIL & GAS
RAZOR
25-2514H
T10N R58W S25



Codell Top/Fort Hays Base
5876’

Codell Base/Carlile Top
5889’

Razor 25-2514H – Lower Codell/Carlile Unconformity



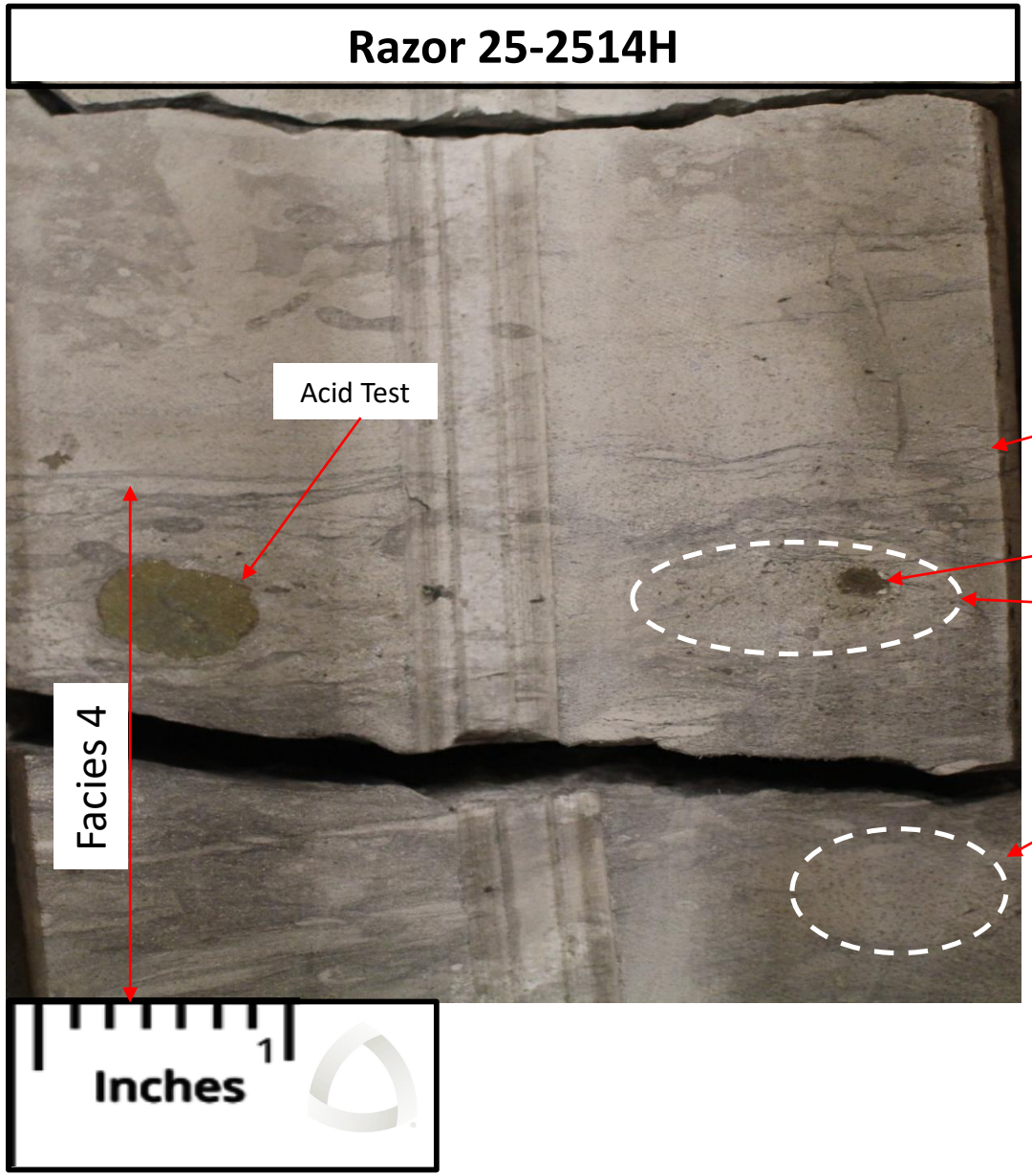
Chert Pebbles

Planar Laminae

Granule-Sized Lithic Fragments

Codell-Carlile Shale Unconformable Contact

Razor 25-2514H – Upper Ft. Hays LS Unconformity

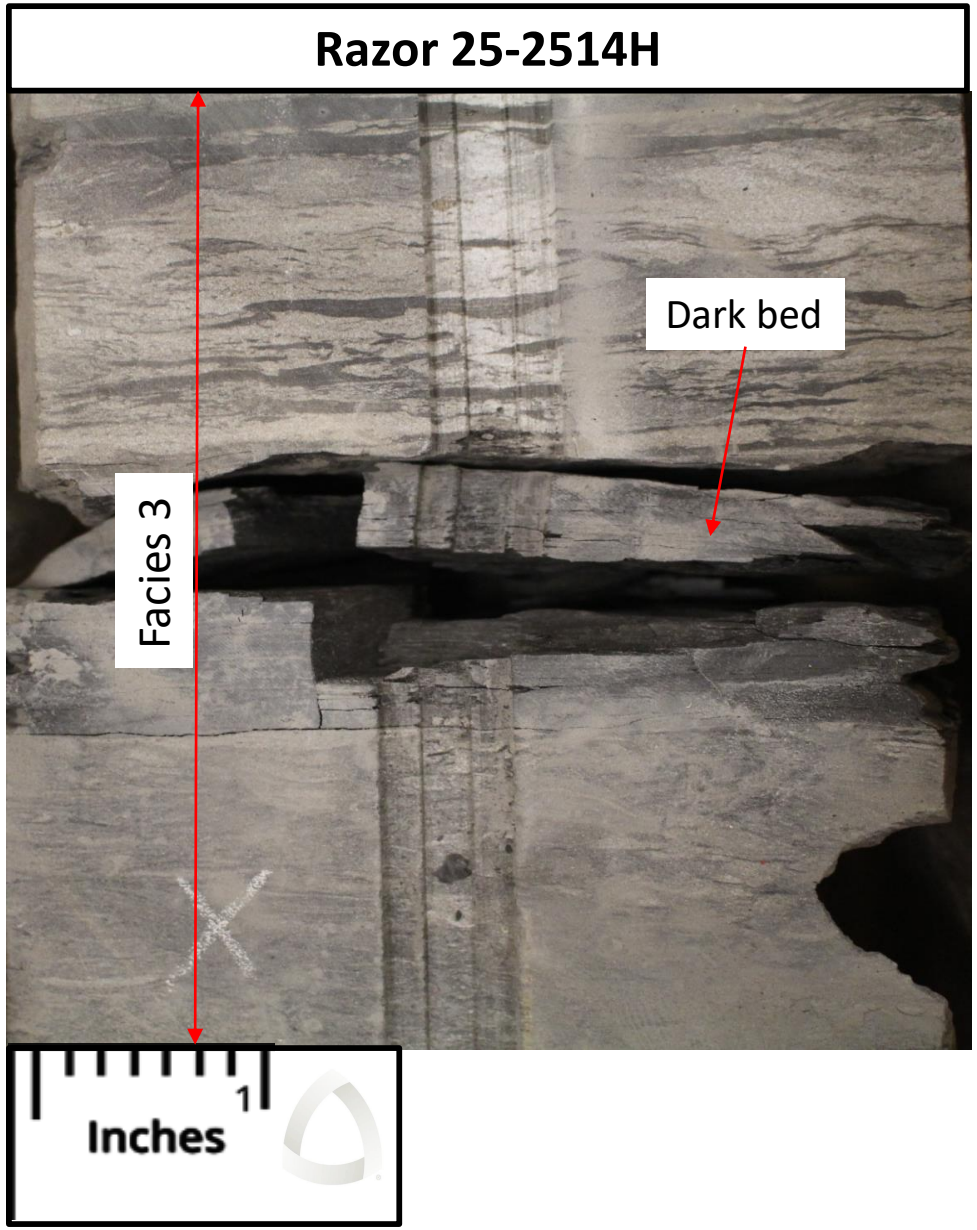


Codell-Fort Hays Limestone Unconformable Contact

Pyrite

Siderite Blebs

Razor 25-2514H – Dark-Colored Codell Beds



- **Three** individual dark-colored beds exist within the Razor 25-2514H Codell interval
- ***Presumed*** to be organic-rich
  - *SRA testing required*

Conclusions

Conclusions

- The Codell Sandstone represents a prolific formation targeted in the Denver Basin
- Increased understanding of the controls on effective reservoir extent and quality will assist future drilling endeavors
  - Lower half of Codell interval appears to display favorable reservoir properties
- Initial analysis and examination has identified a potential causational relationship between facies and reservoir quality at Redtail Field
  - Additional analyses and conclusions are underway
- Analysis and Thesis completion in December 2021

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