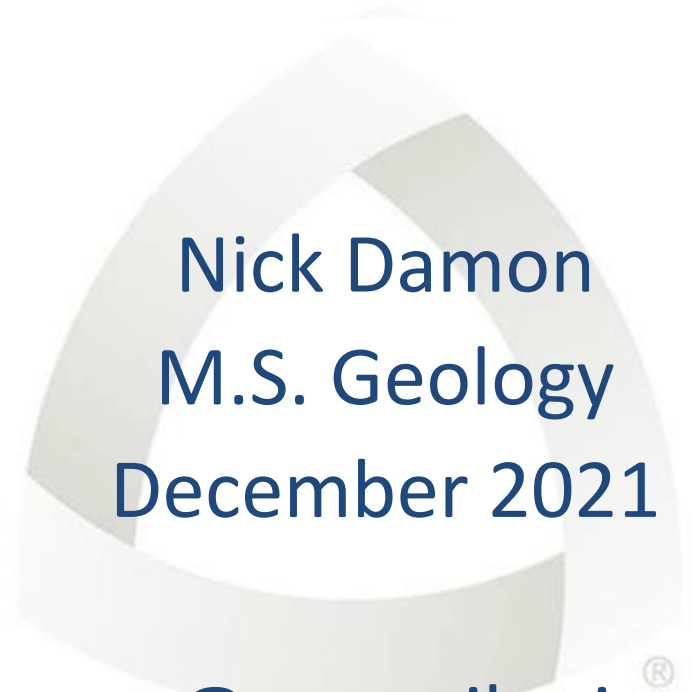


Reservoir Characterization of the Codell Sandstone in the Redtail Area, Weld County, Colorado



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M.S. Geology
December 2021

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Project Overview
Geologic History
Petroleum System
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

- Phyllicia Saner
- David Thul
- Lauren Stout
- David Underwood
- Evan Allred
- Julia Wood
- John Stamer
- Michael Harty (Juana Lopez)
- ❖ Cankut Kondacki (PhD)

NW Colorado

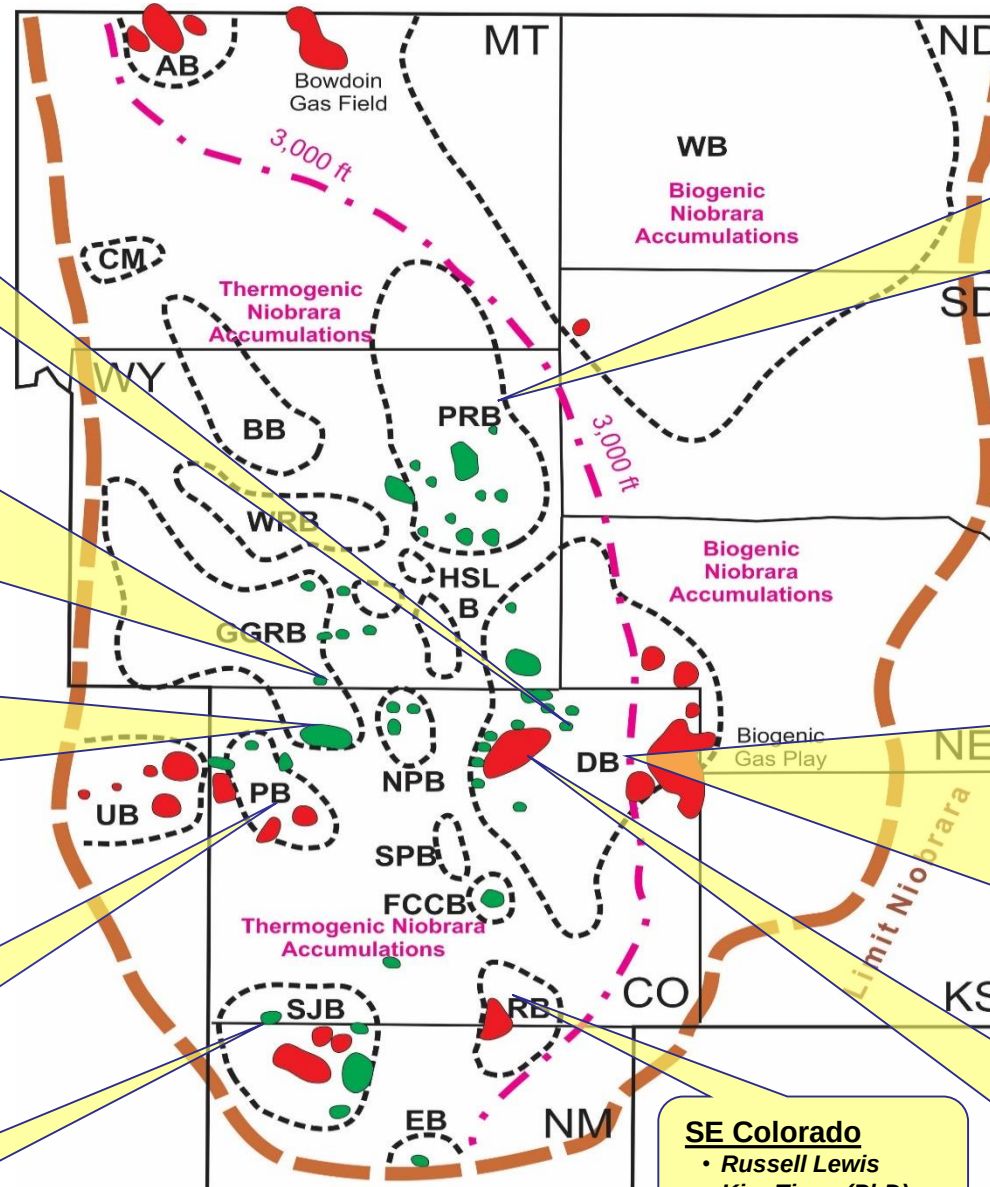
- Jon Charzynski
- Katarzyna Kuzniak
- Vivian Lin
- Kelly Bruchez
- Ben Dellenbach
- Michael Harty III
- Shawn Lopez

Piceance Basin

- Kasia Kuzniak
- Martin Krueger
- John Harper
- Marcus Hinricher

San Juan Basin

- Tom Arthur
- Walter Nelson
- Scott Kennedy



Research 2010 – 2020

• Completed Theses

❖ In Progress

Powder River Basin

- James Taylor
- Armagan Kaykun
- Andrew Heger
- Cankut Kondacki
- 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

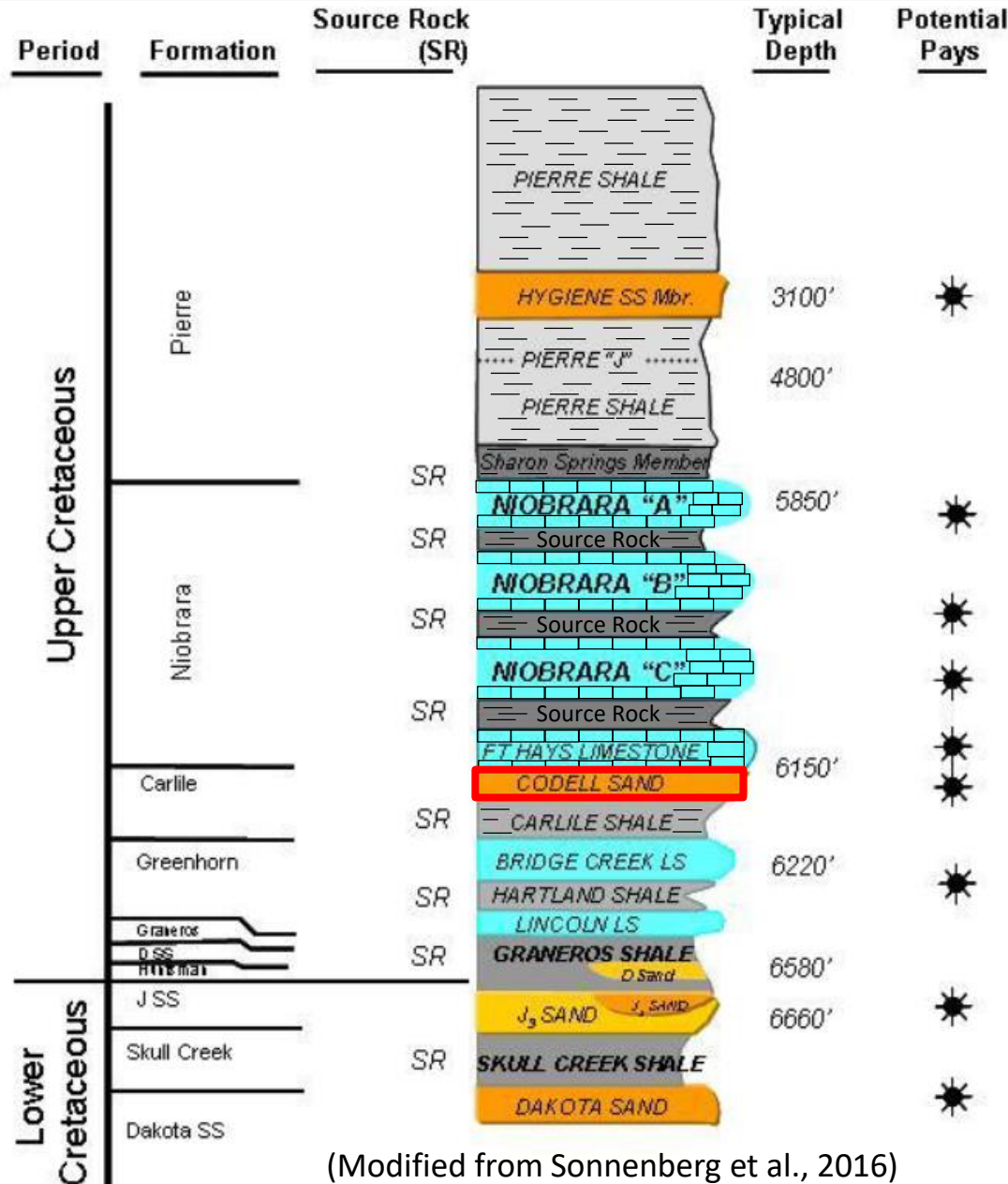
Denver Basin: Wattenberg

- Craig Kaiser
- Nick Matthies
- Rana ElGhonimy
- Jennie Rietman
- Elvan Aydin
- Daniel Brugioni
- ❖ Patrick Sullivan

SE Colorado

- Russell Lewis
- Kira Timm (PhD)
- Nick Matthies

Denver Basin Stratigraphic Column



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

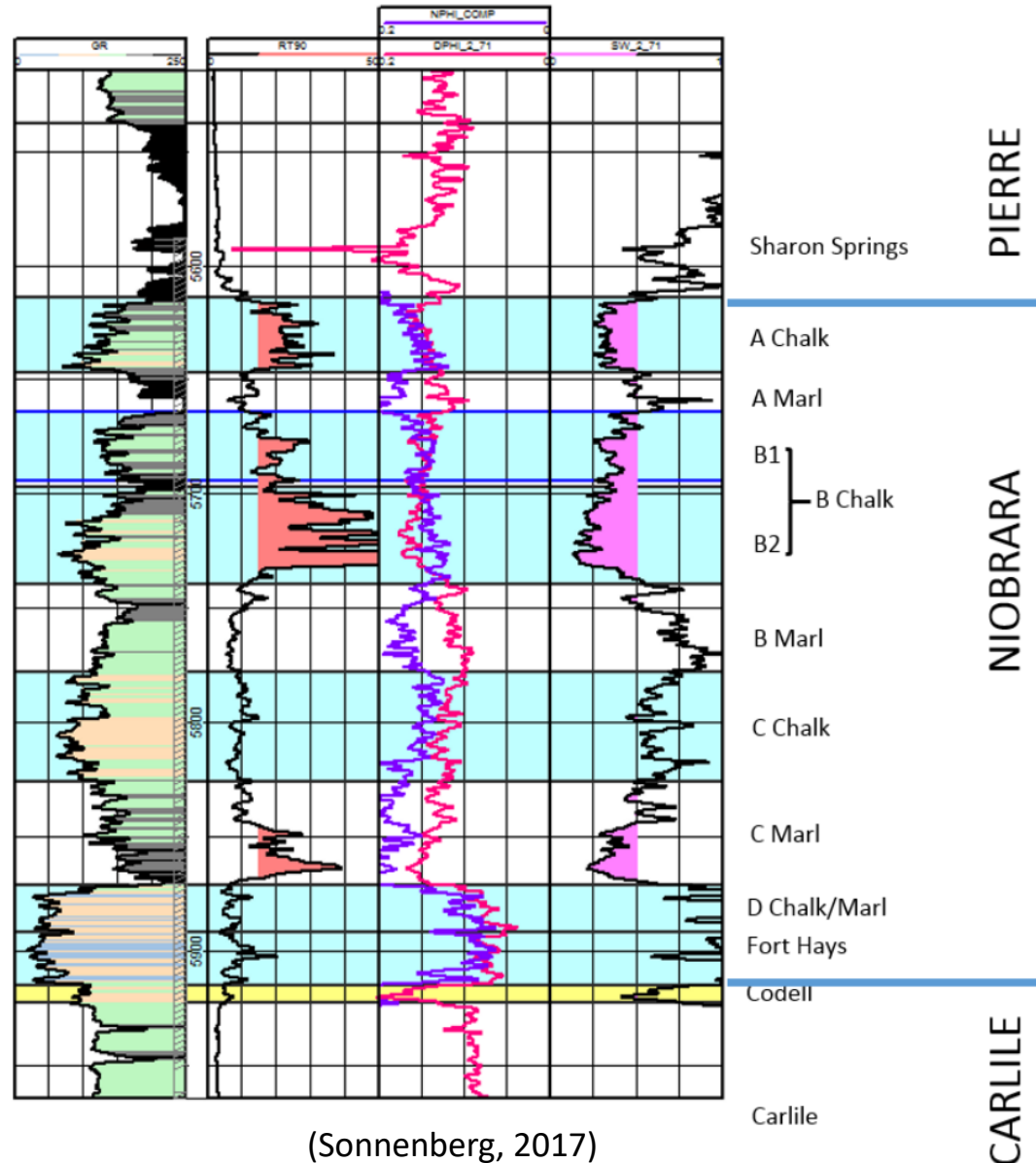
(Modified from Sonnenberg et al., 2016)

(Modified from Sonnenberg, 2017)

Type Wells – DJ and Redtail

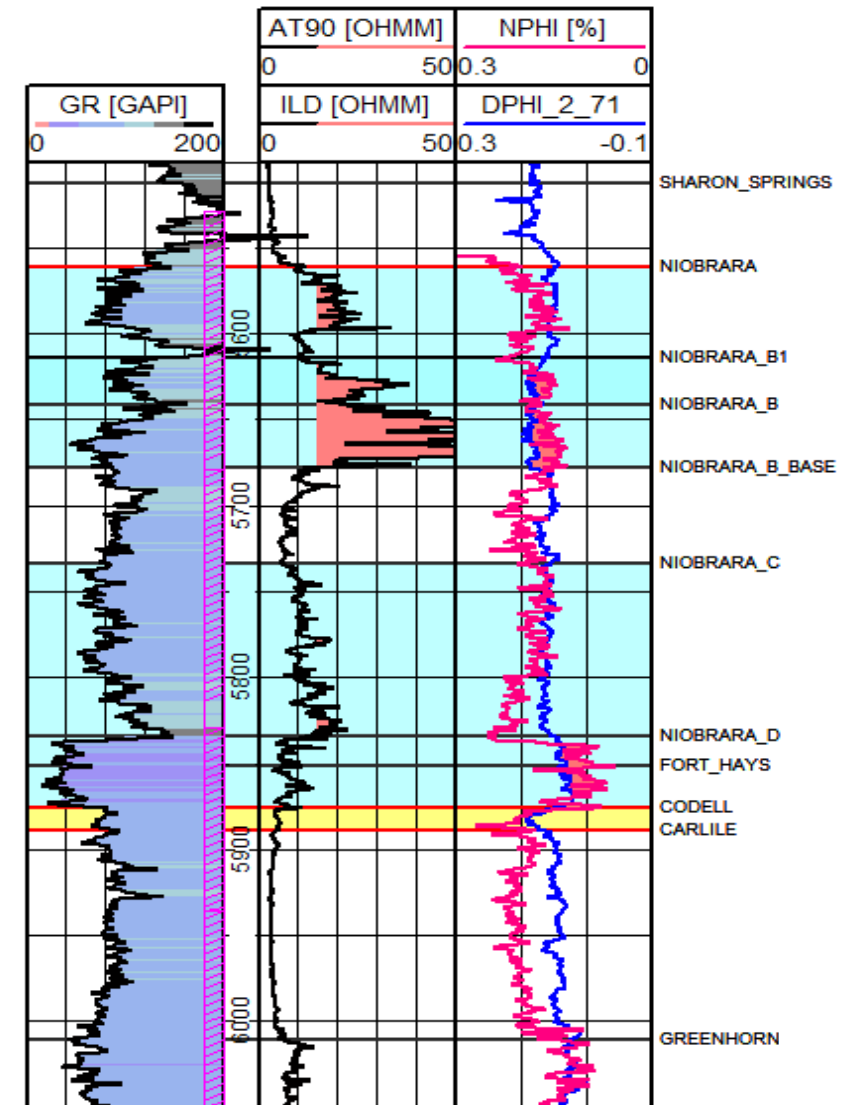


DJ Type Well: Timbro PC LD16-17

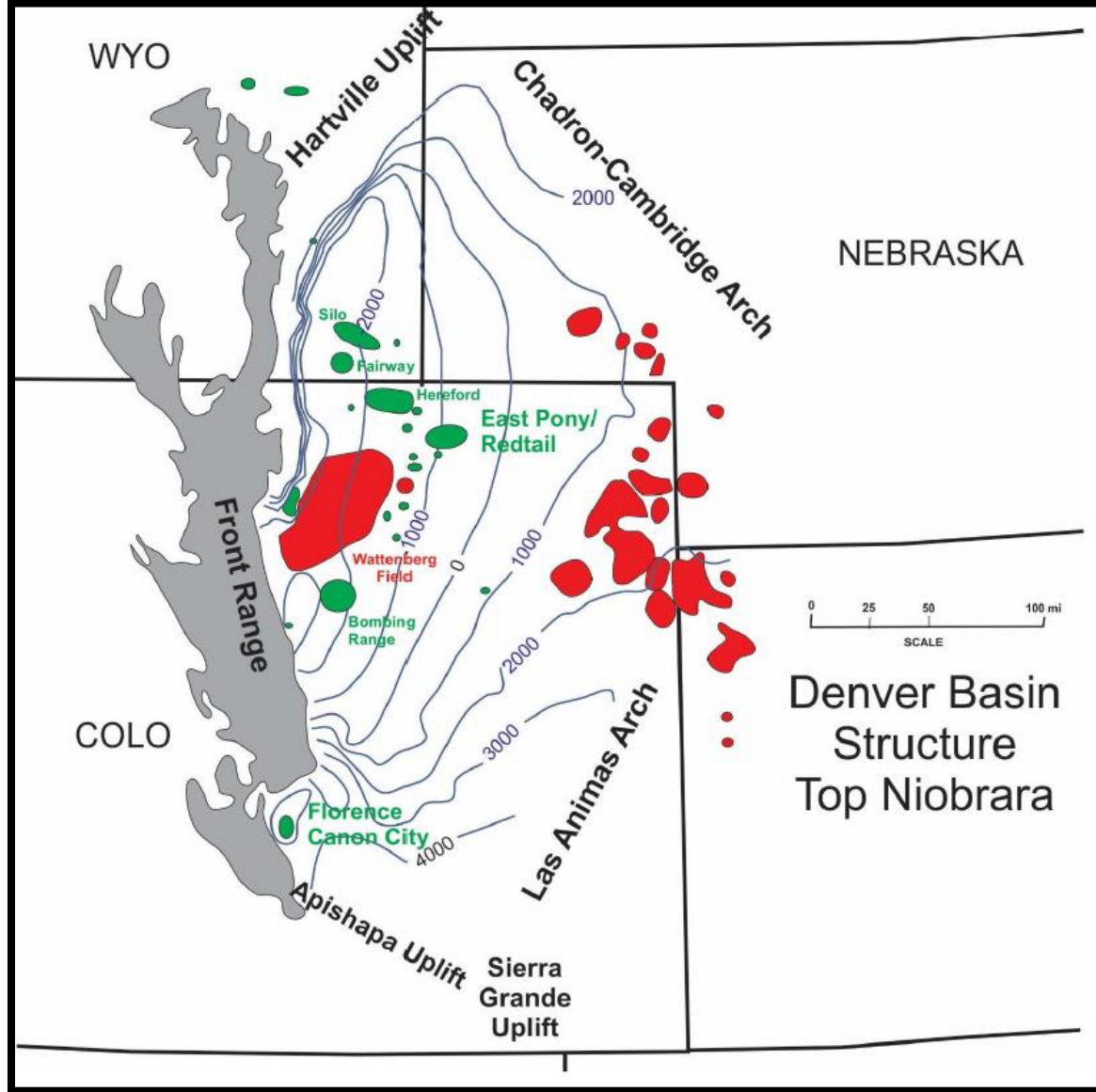


(Sonnenberg, 2017)

Redtail Type Well: Razor 25-2514H



East Pony/Redtail Field Locality



(Sonnenberg, 2017)

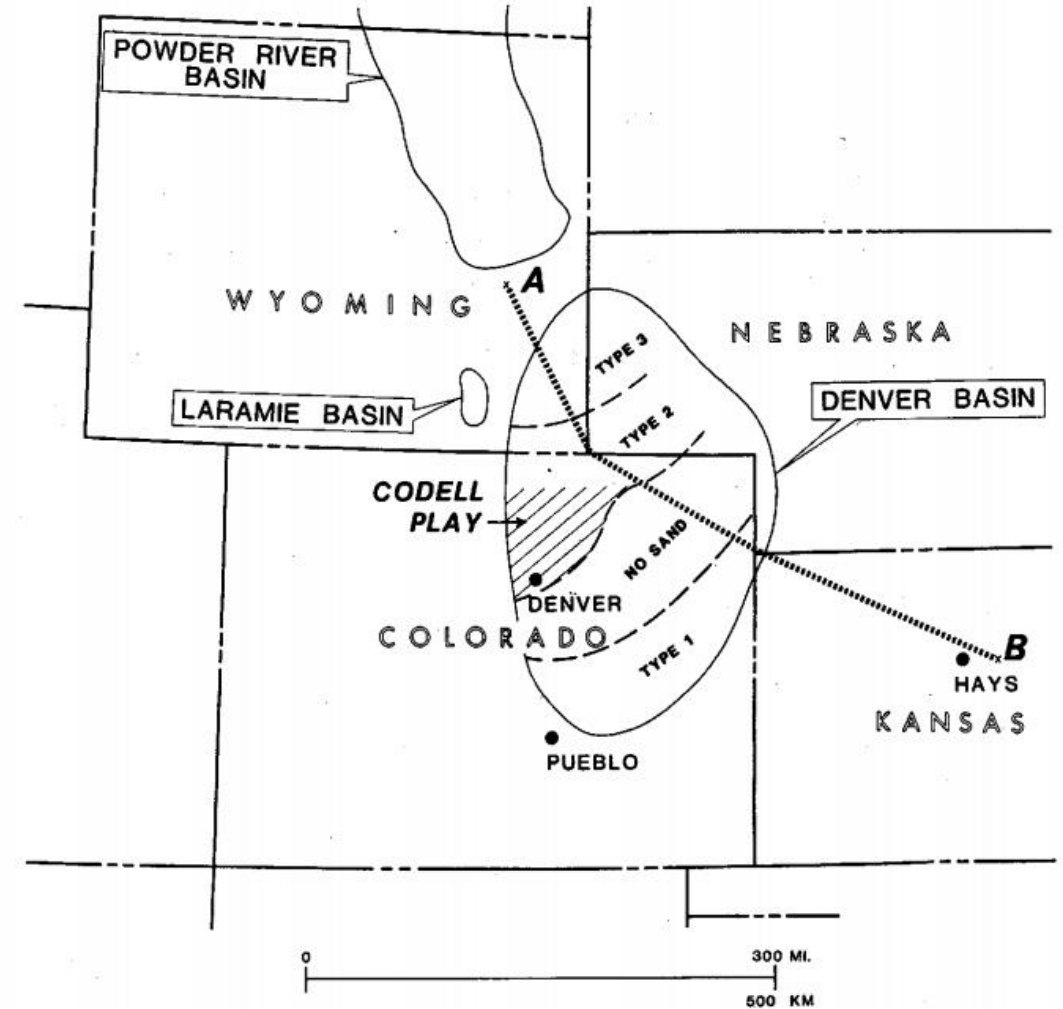


Figure 1 Distribution of Codell Sandstone

(Modified from Weimer and Sonnenberg, 1983)

Geologic History

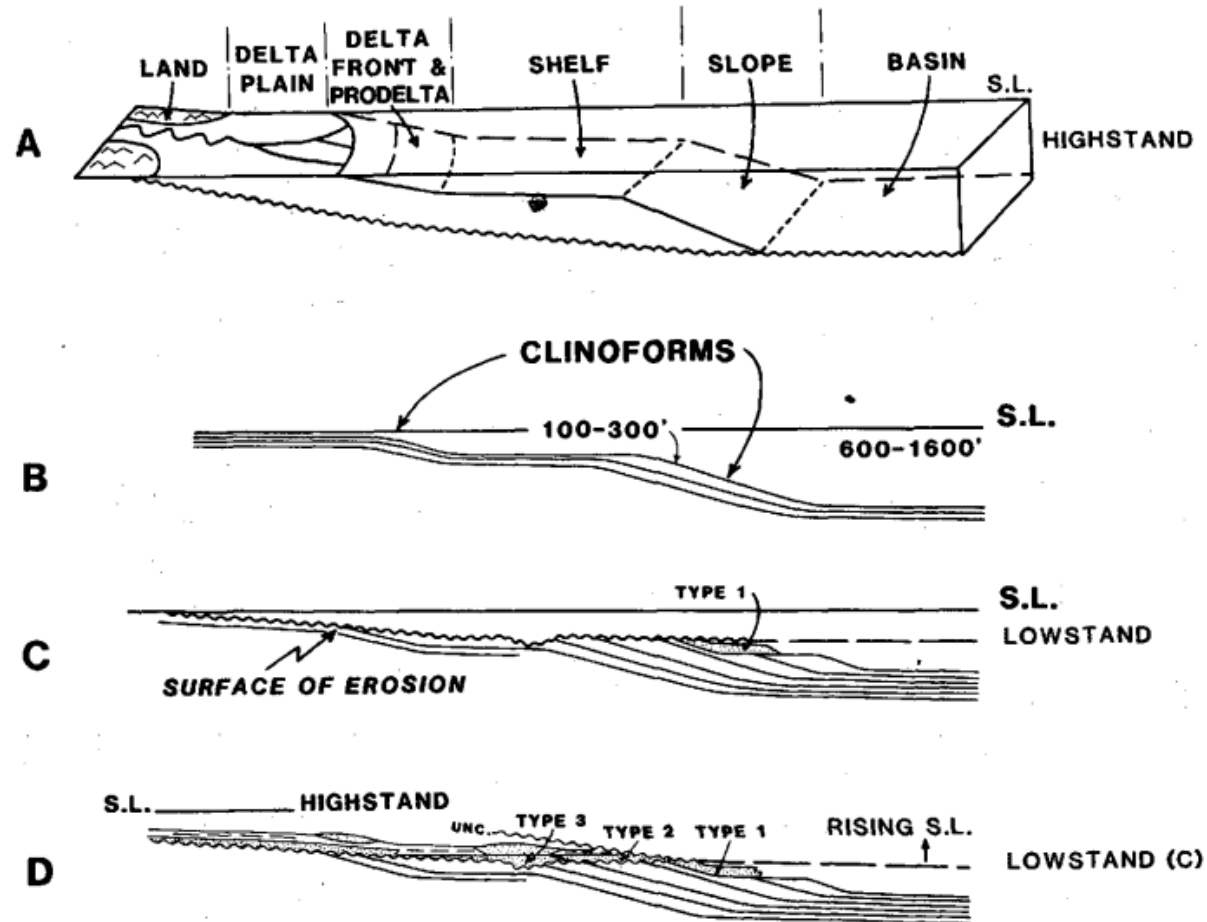


Geologic History – Greenhorn Cyclothem

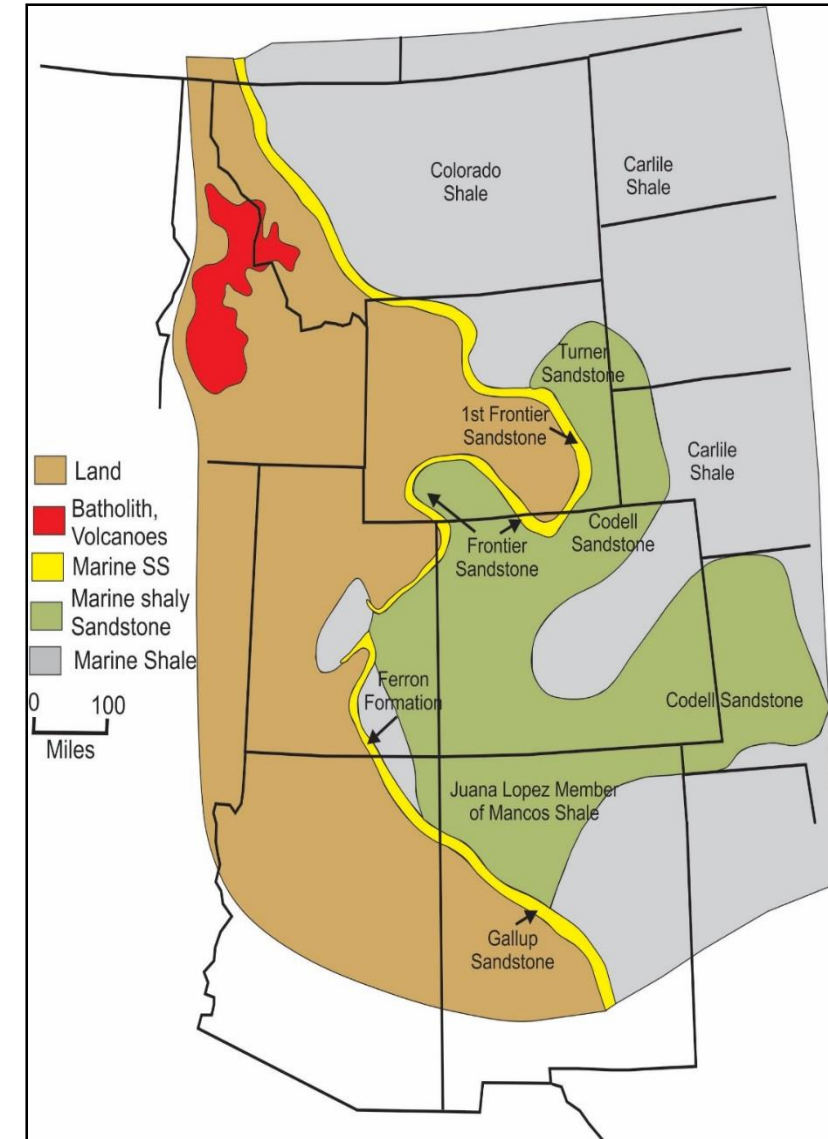


(Modified from Blakey, 2016)

Depositional Environment(s)

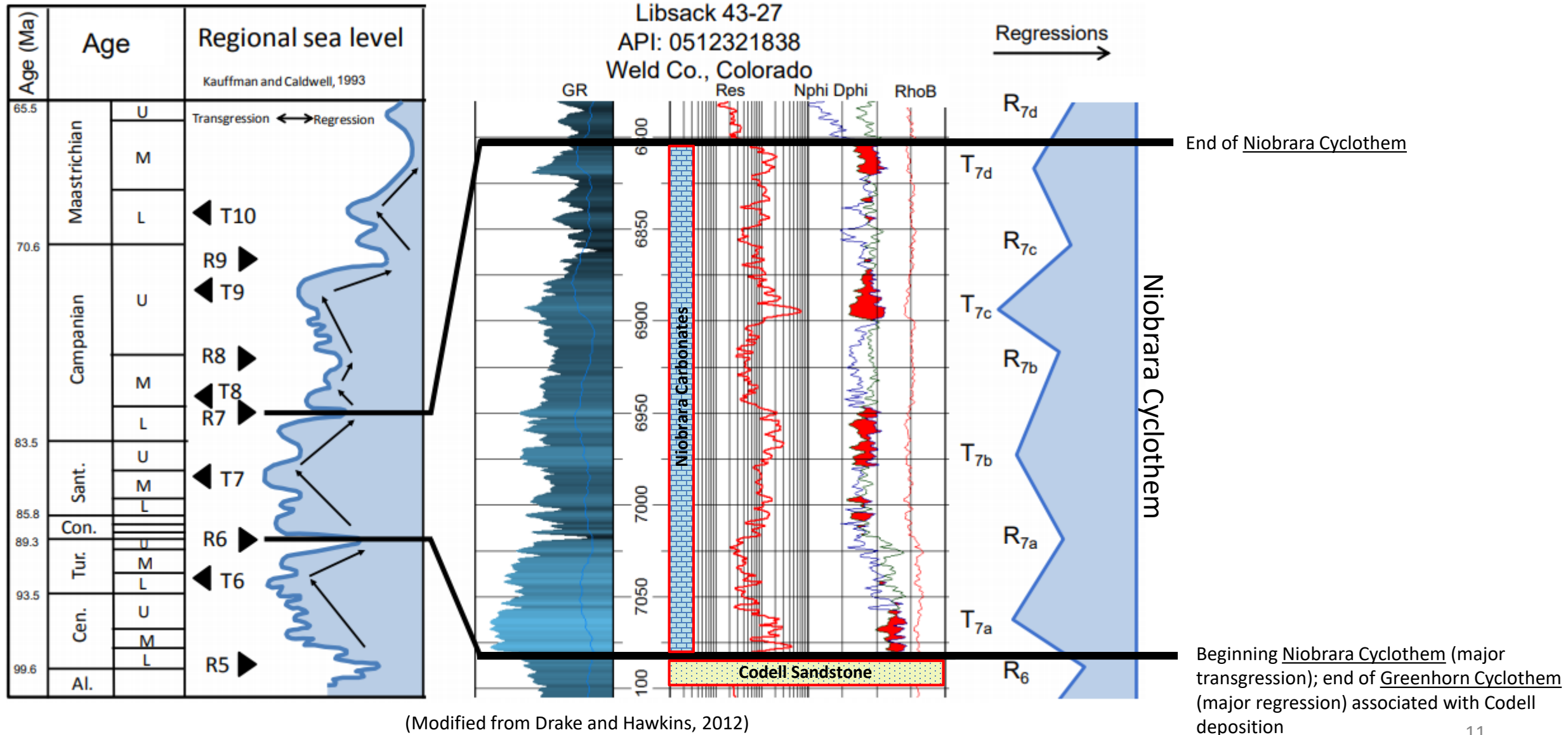


(Modified from Weimer and Sonnenberg, 1983)

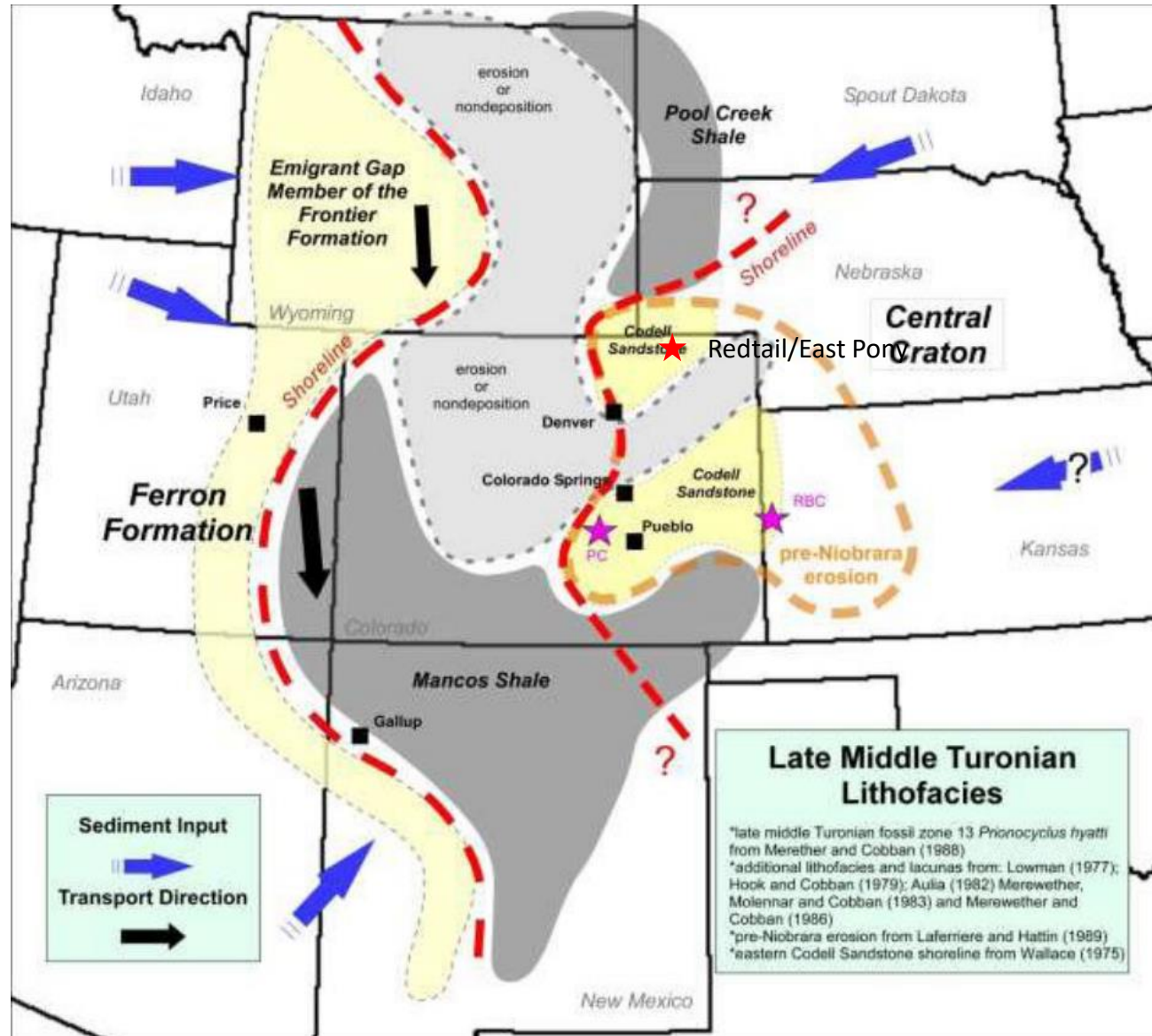


(Modified from Mallory, 1972)

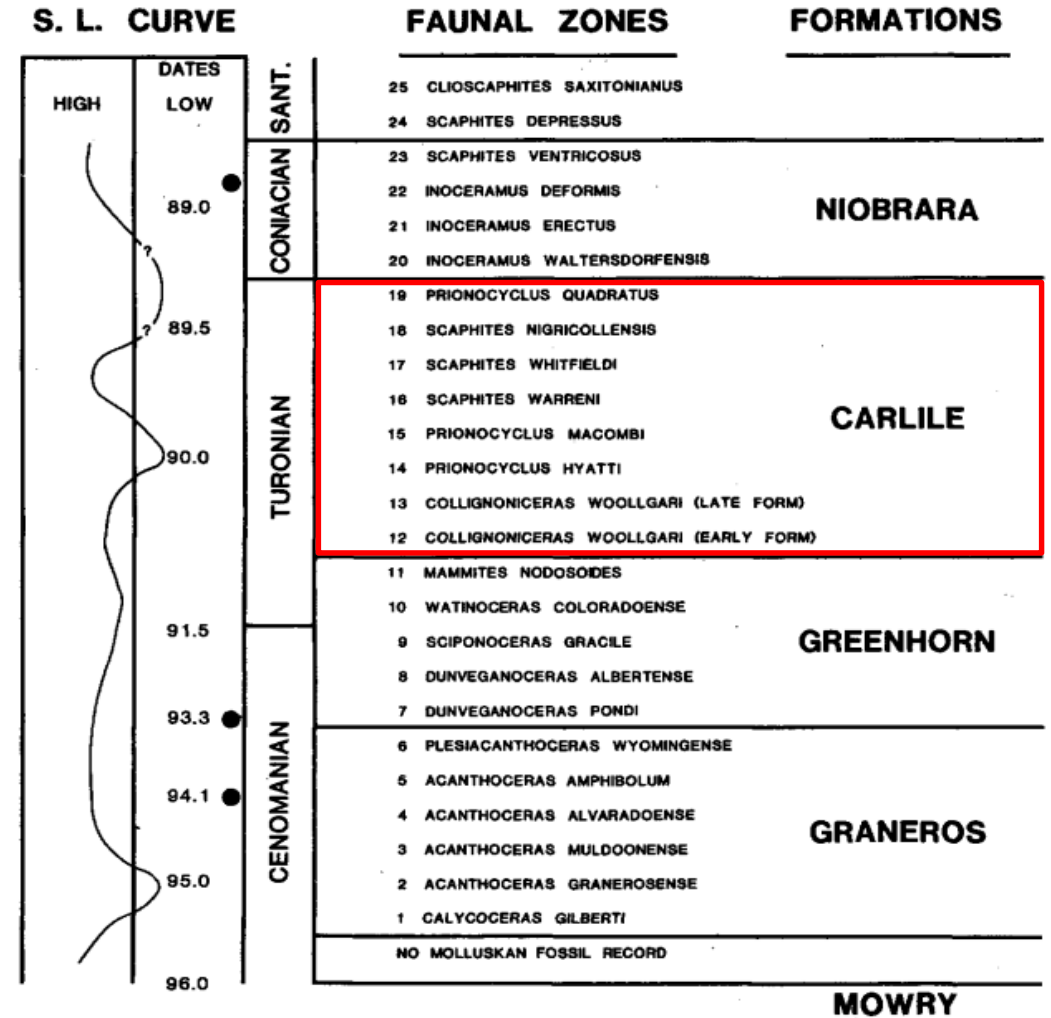
Geologic History – Sea Level Fluctuation



Geologic History – Lithofacies and Faunal Zones

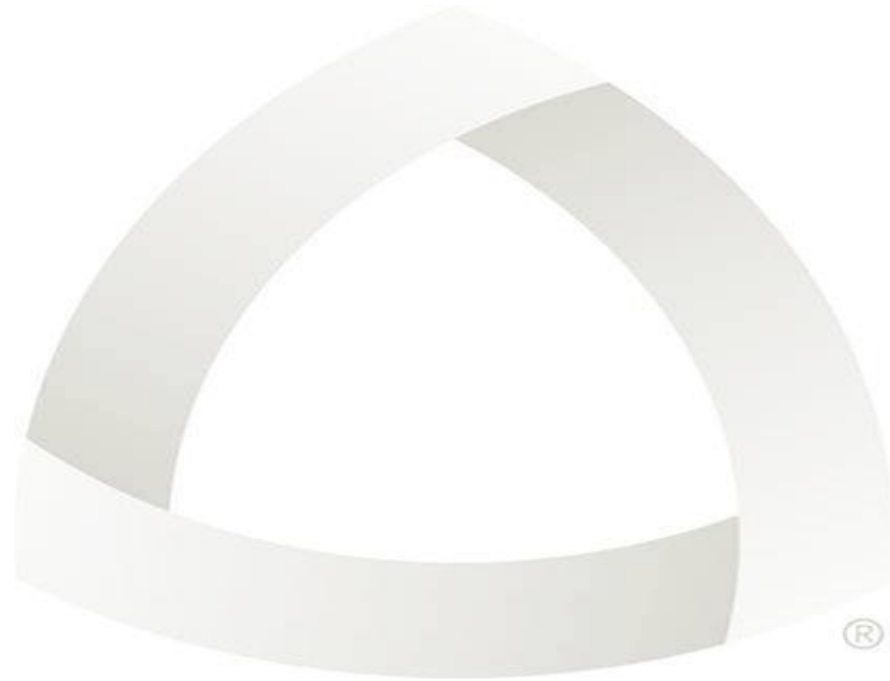


(Modified from Lewis, 2013)

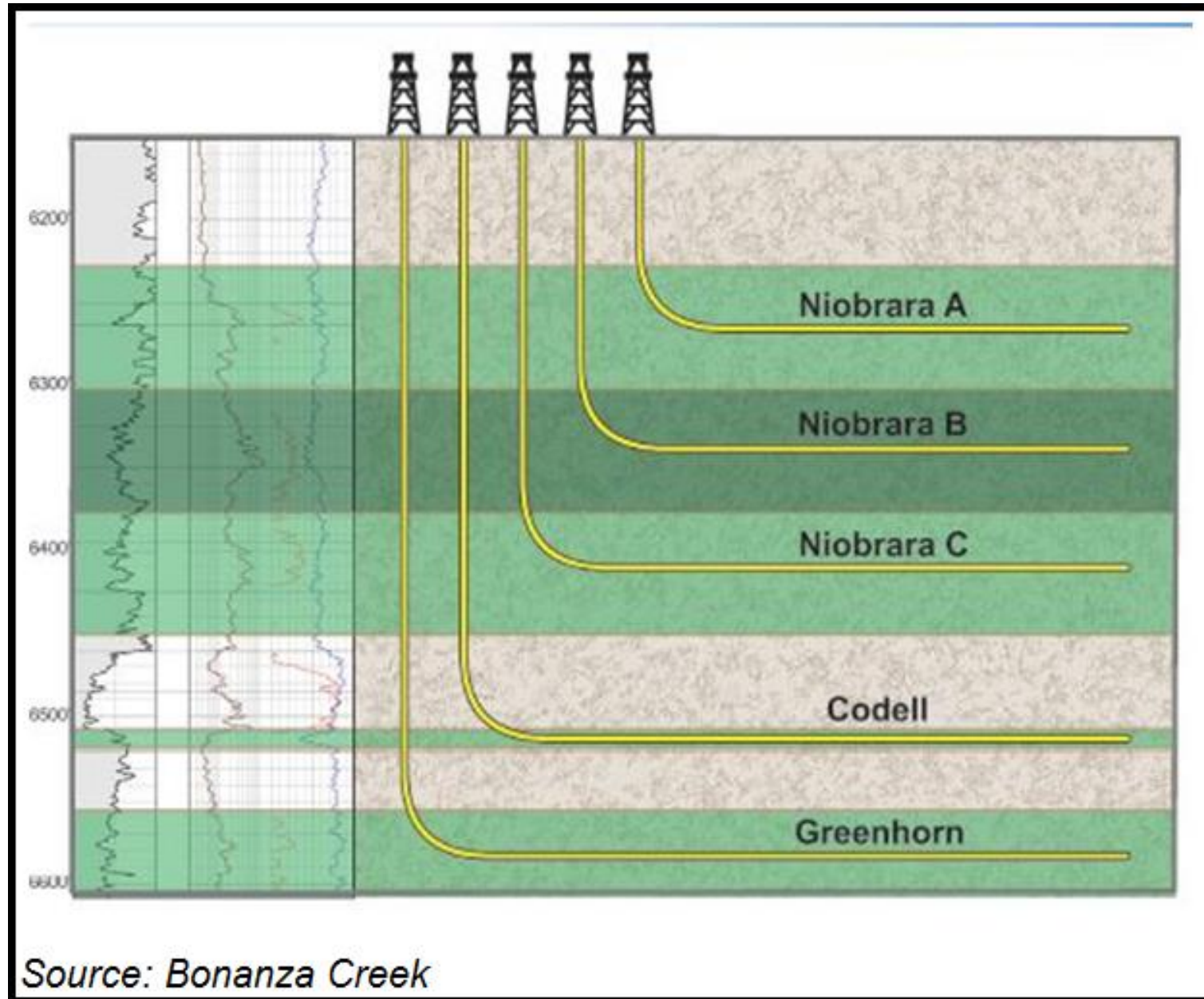


(Modified from Weimer and Sonnenberg, 1983)

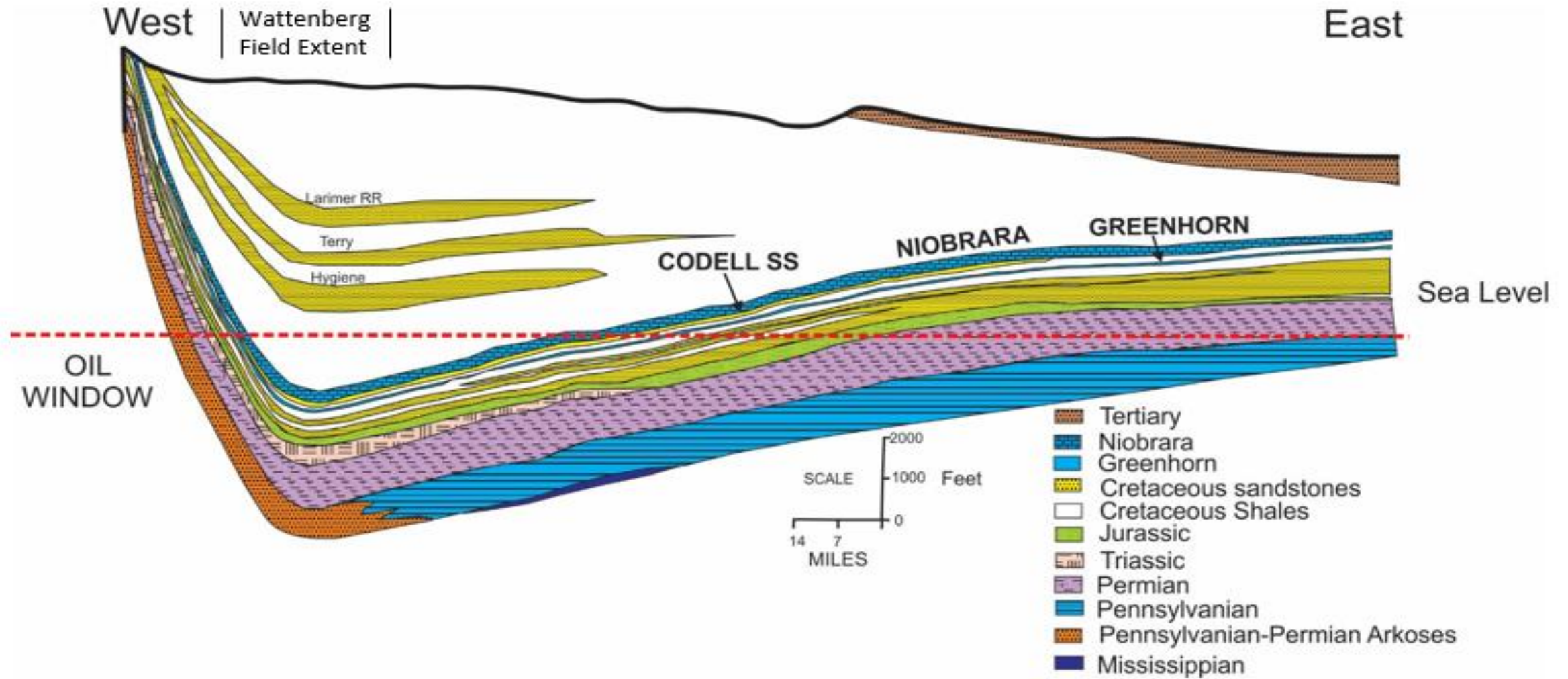
Petroleum System



Targeted Reservoirs

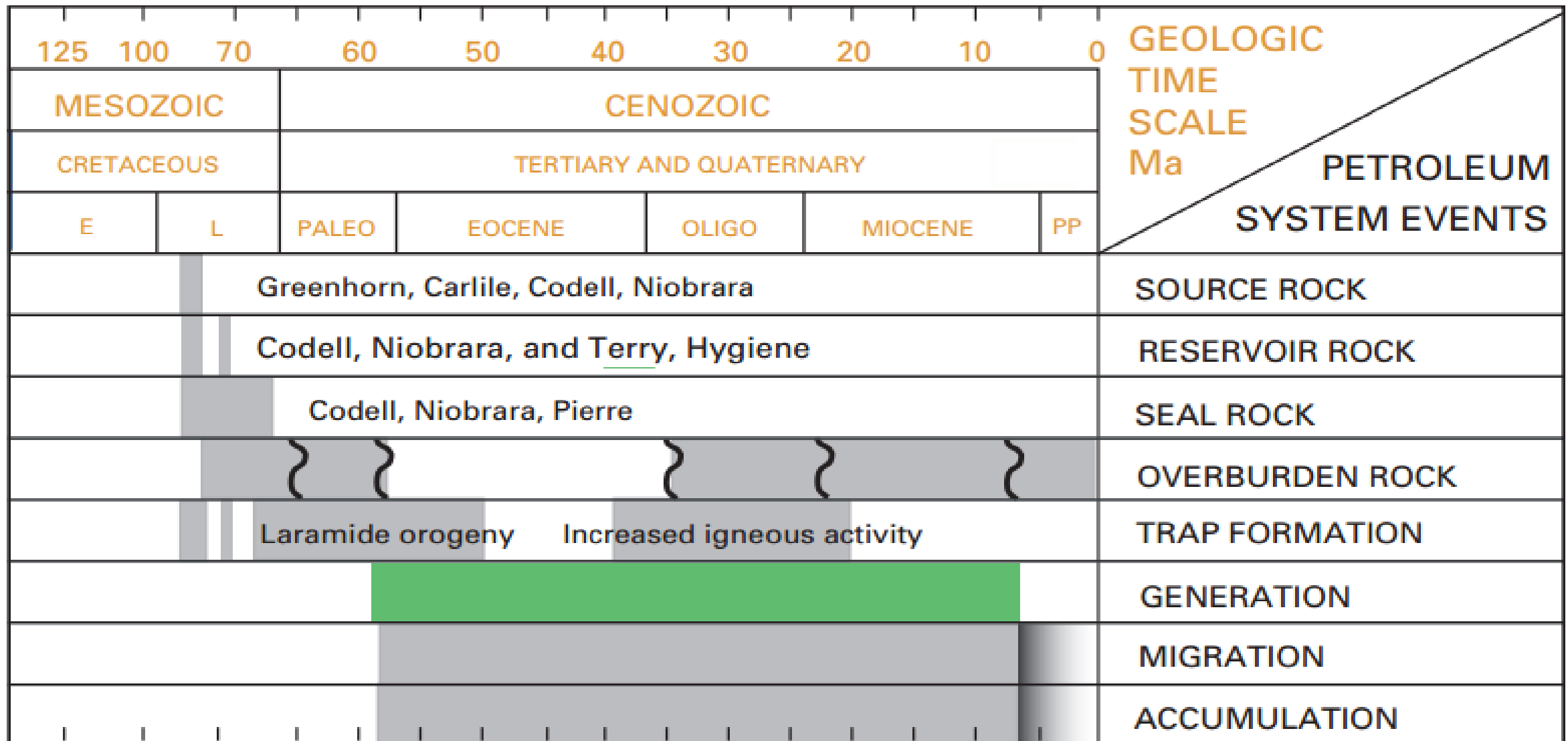


Petroleum System Cross Section



(Modified from Sonnenberg, 2015)

Petroleum System Timeline

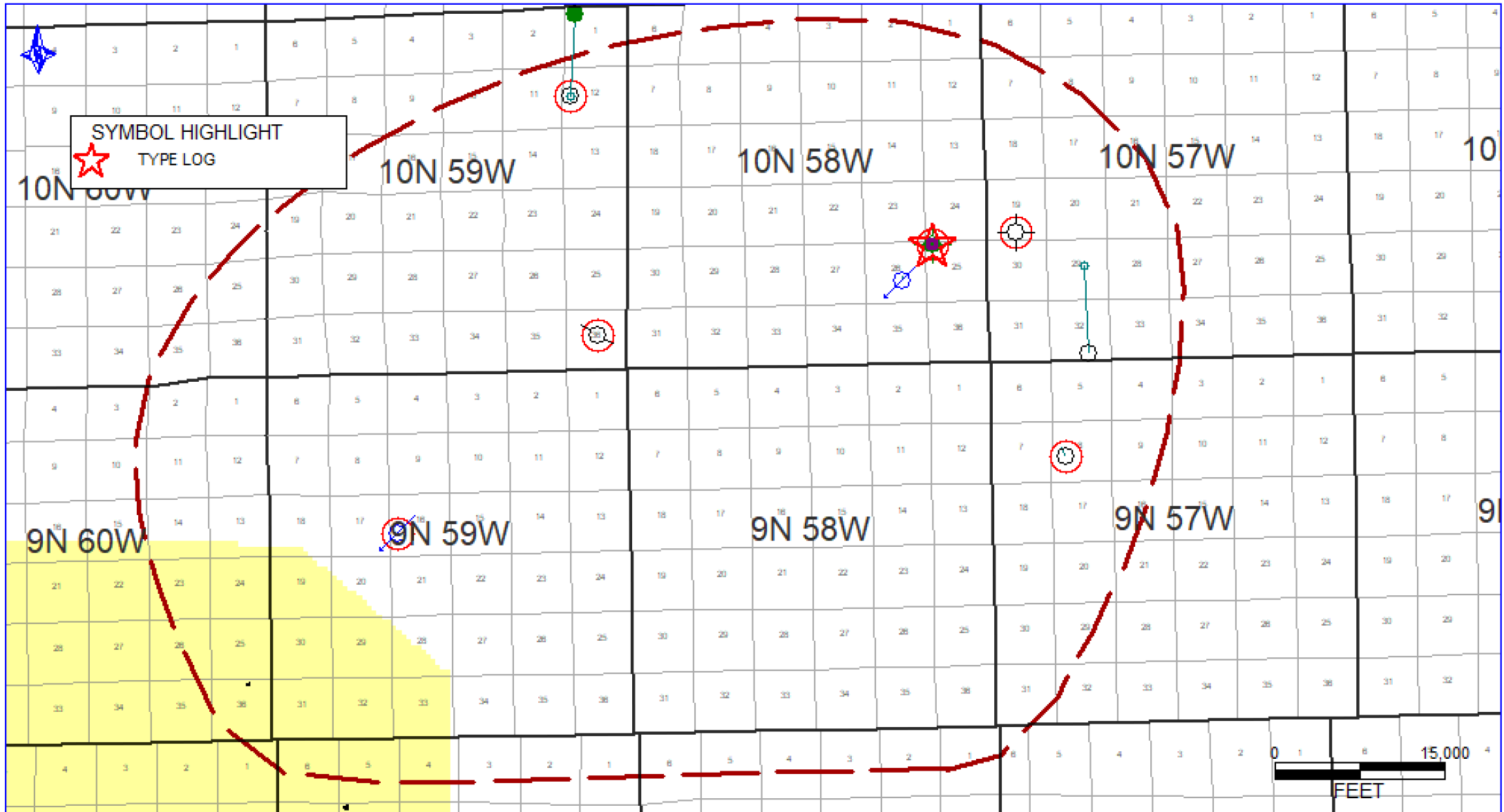


(Fishman, 2005)

Codell Sandstone – Redtail Field



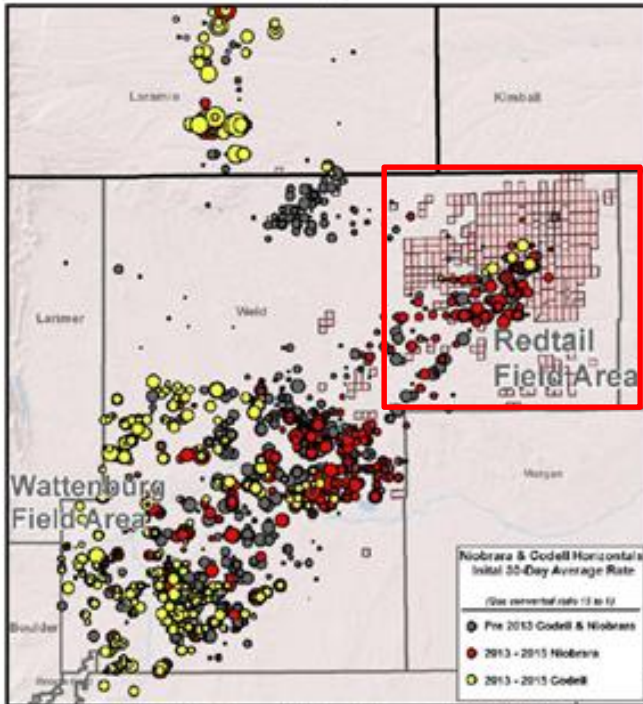
Redtail Field



Redtail Field – By the Numbers



Economic Sweet Spot in Oil Window (Weld County, Colorado)



Source: IHS and internal Whiting production database as of 12/31/2015.

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%

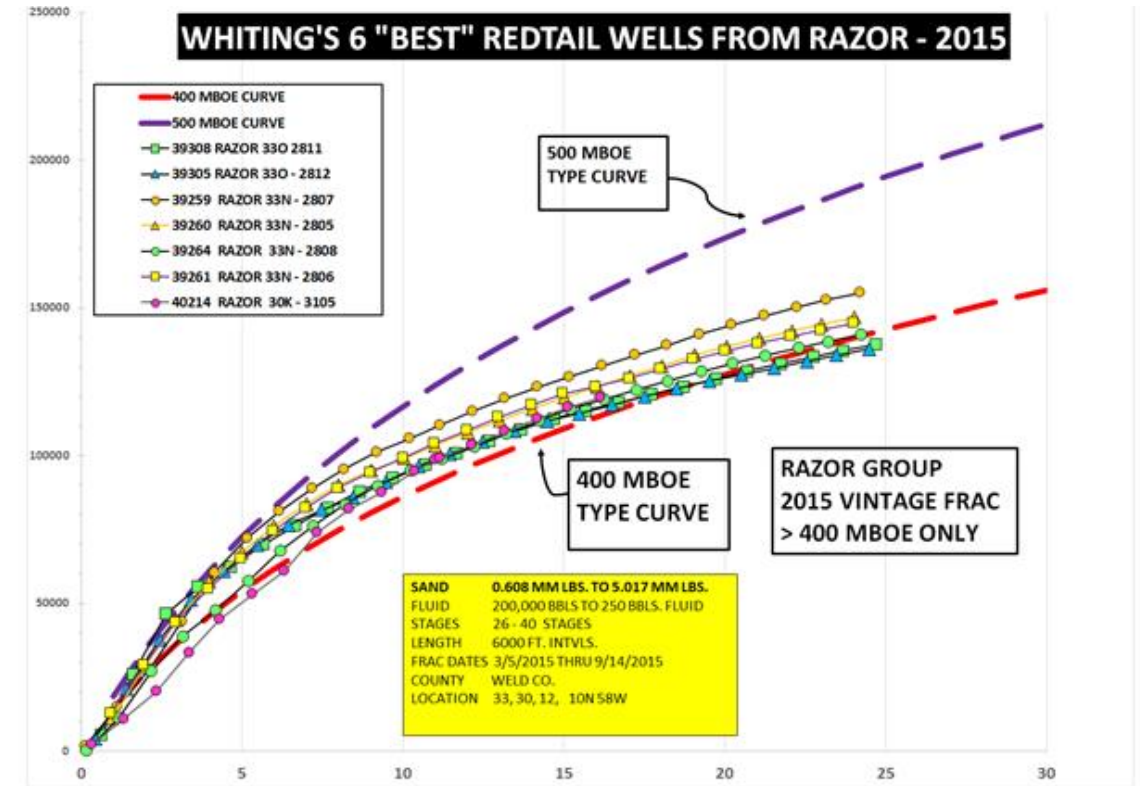
COMPLETED WELL COST

Horizontal: \$4.0 MM

OPERATIONAL HIGHLIGHTS

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

WHITING'S 6 "BEST" REDTAIL WELLS FROM RAZOR - 2015



(Modified from Whiting Petroleum, 2015)

(Whiting Petroleum, 2015)

Reservoir Properties - Permeability



Weatherford
LABORATORIES

CORE GAMMA, PERMEABILITY, AND POROSITY PROFILE PLOT

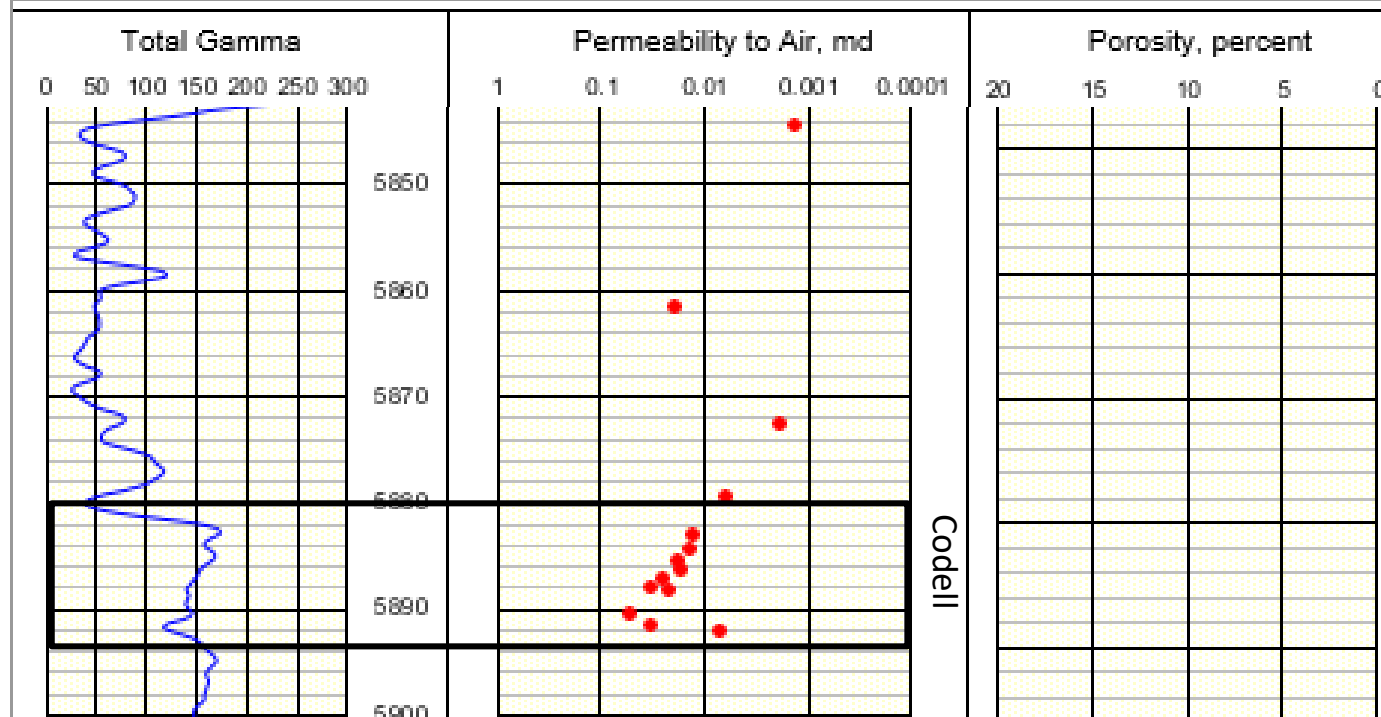
VERTICAL SCALE 5 inch:100 feet

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

Weld County, Colorado
File No.: CO-63090
Date: 5/22/2013

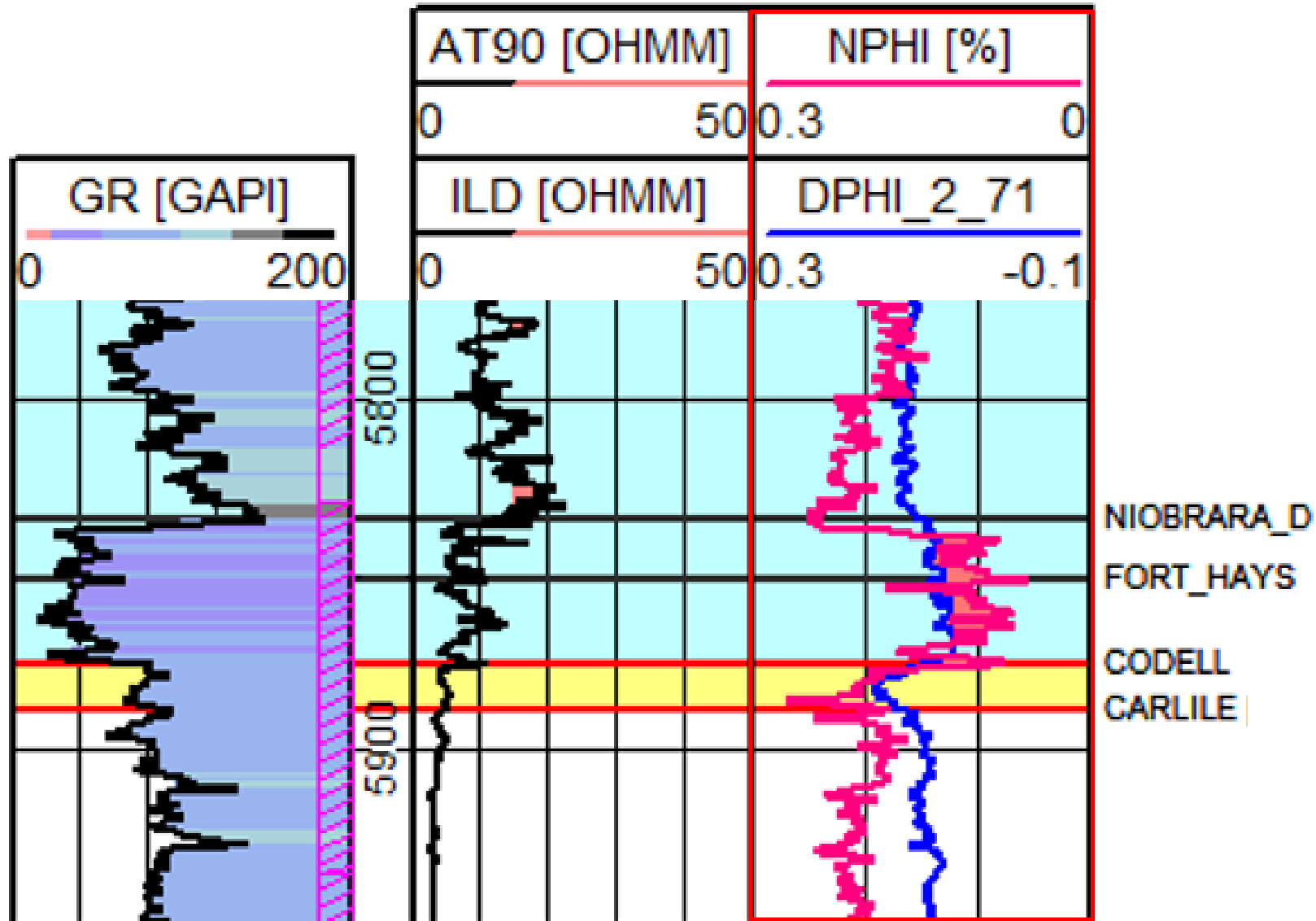
Cores: 2-3 (5,679.00' - 5,829.00') & (5,829.00' - 5,935.15')

Permeability: ~.01 to .1 md



(Modified from Whiting Petroleum, xxxx)

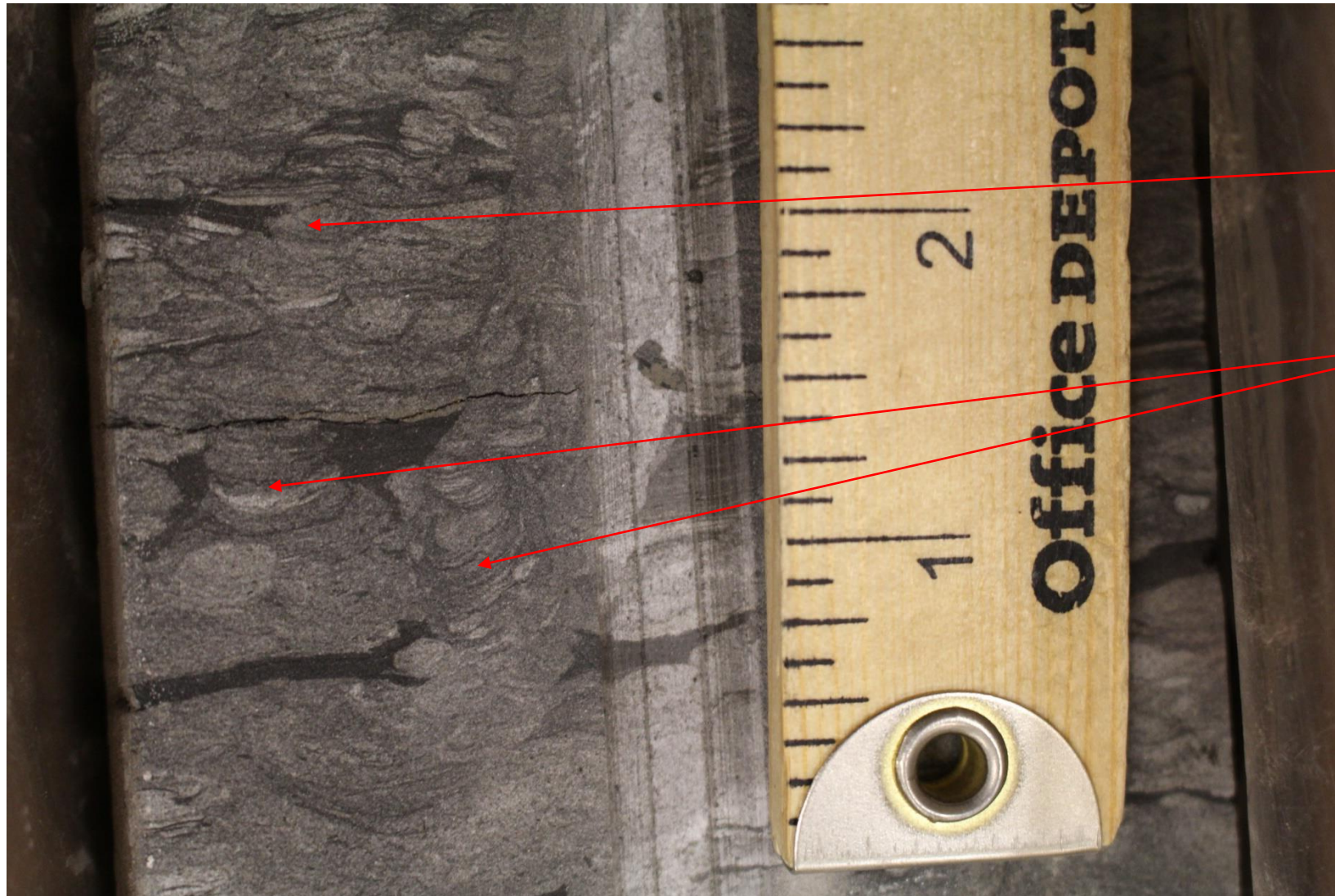
Reservoir Properties - Porosity



Porosity: 10-25%

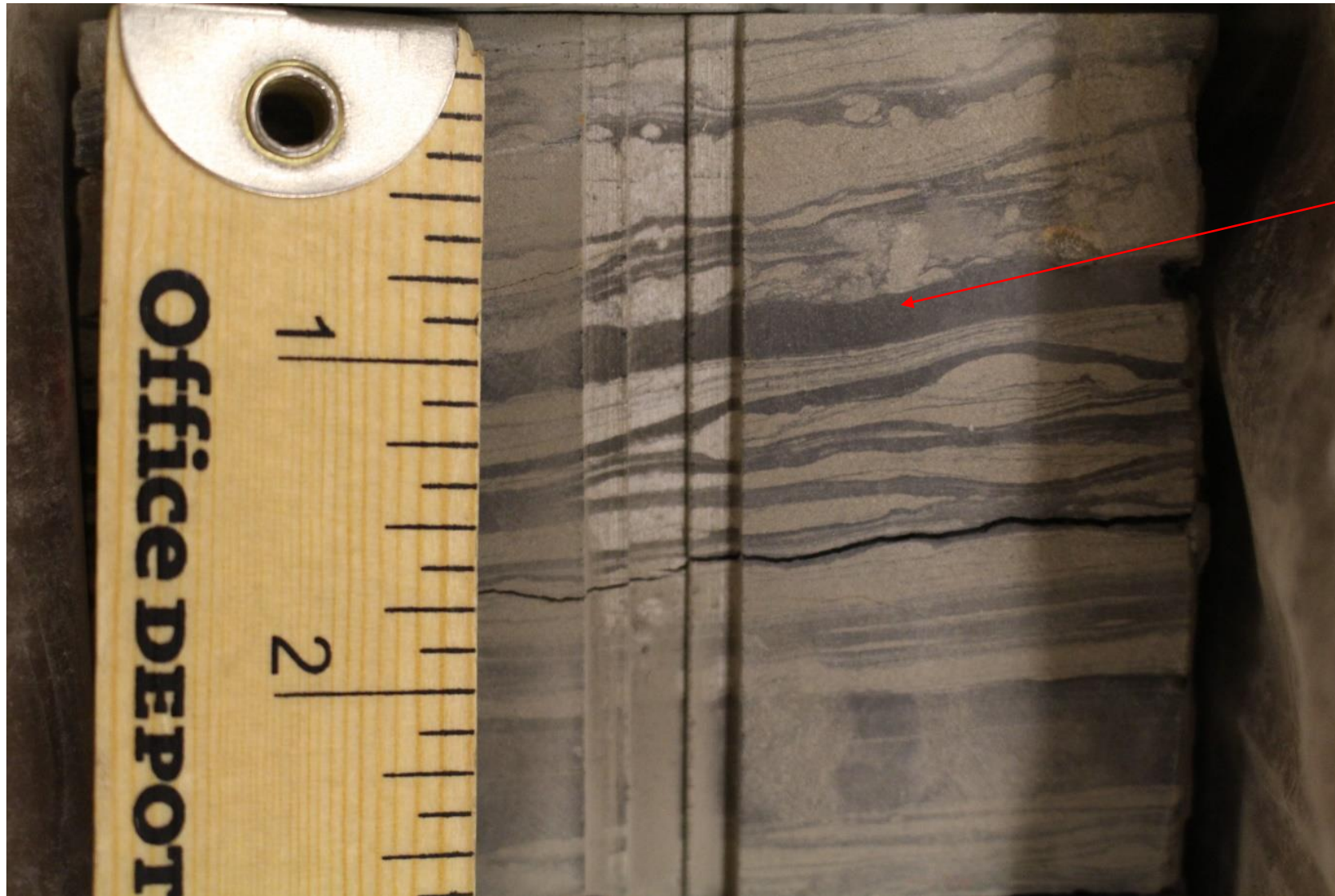
Razor 25-2514H Core



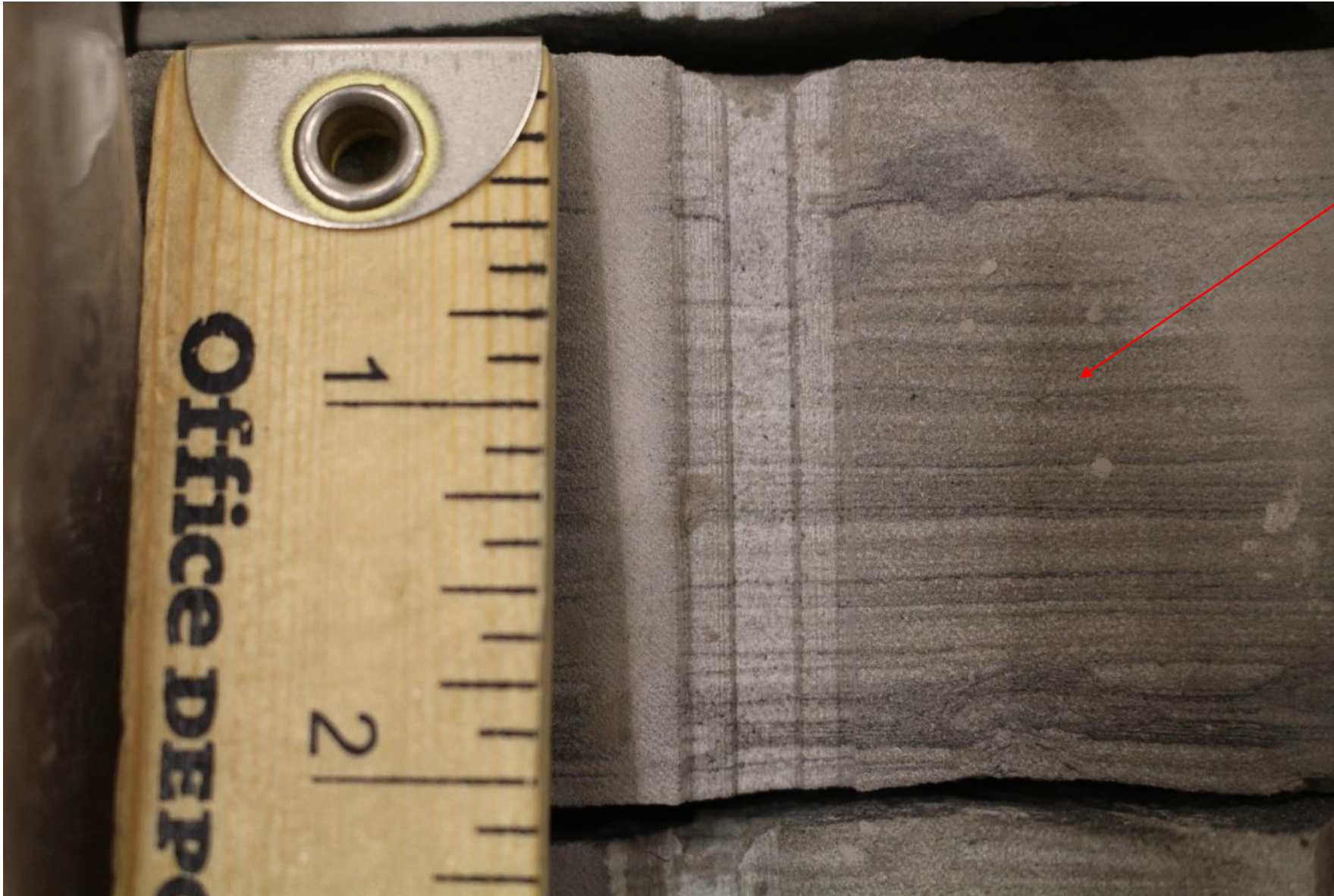


Burrowed Mud Drape

Teichichnus Burrowing

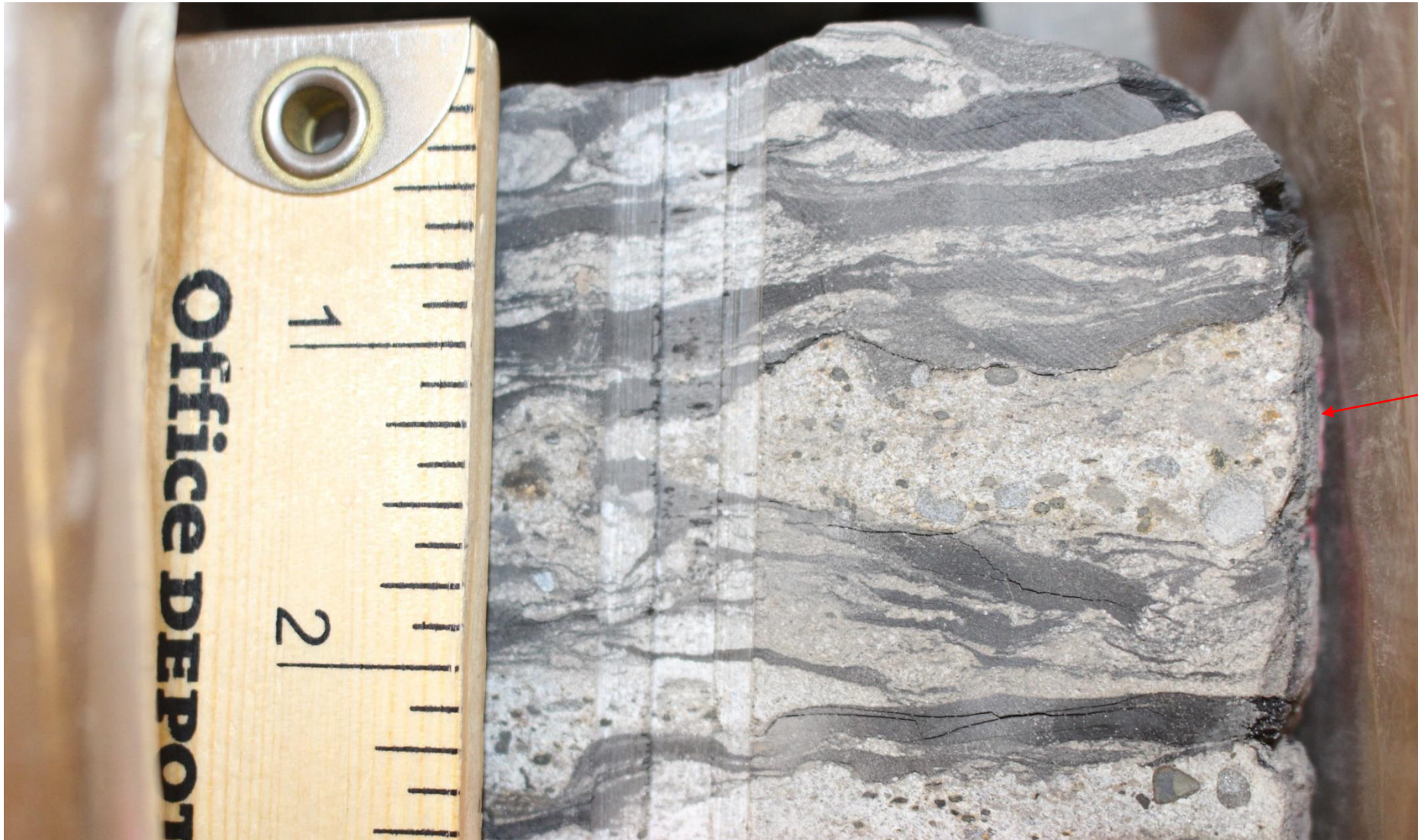


Mud Drape

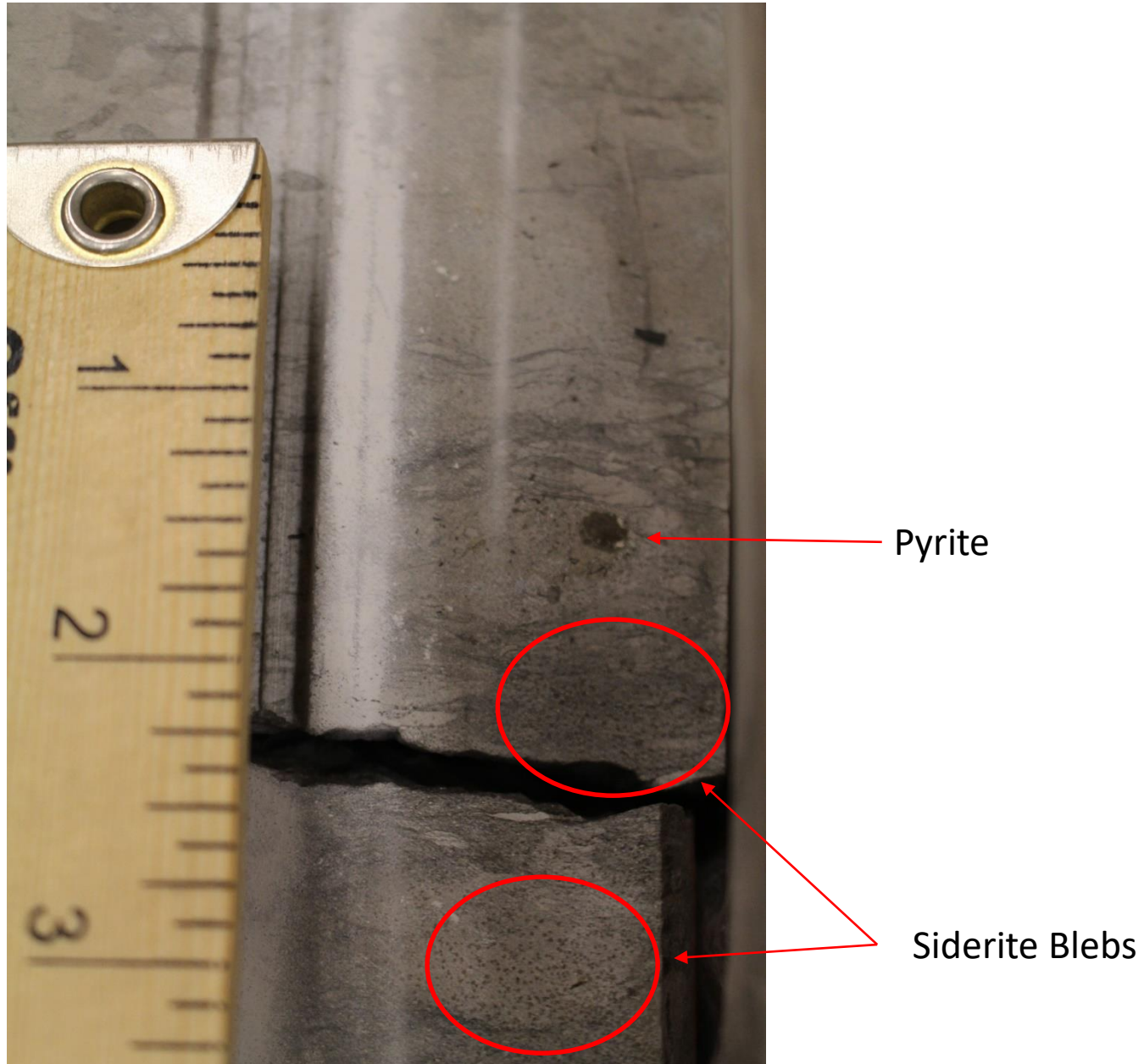


Planar Laminations

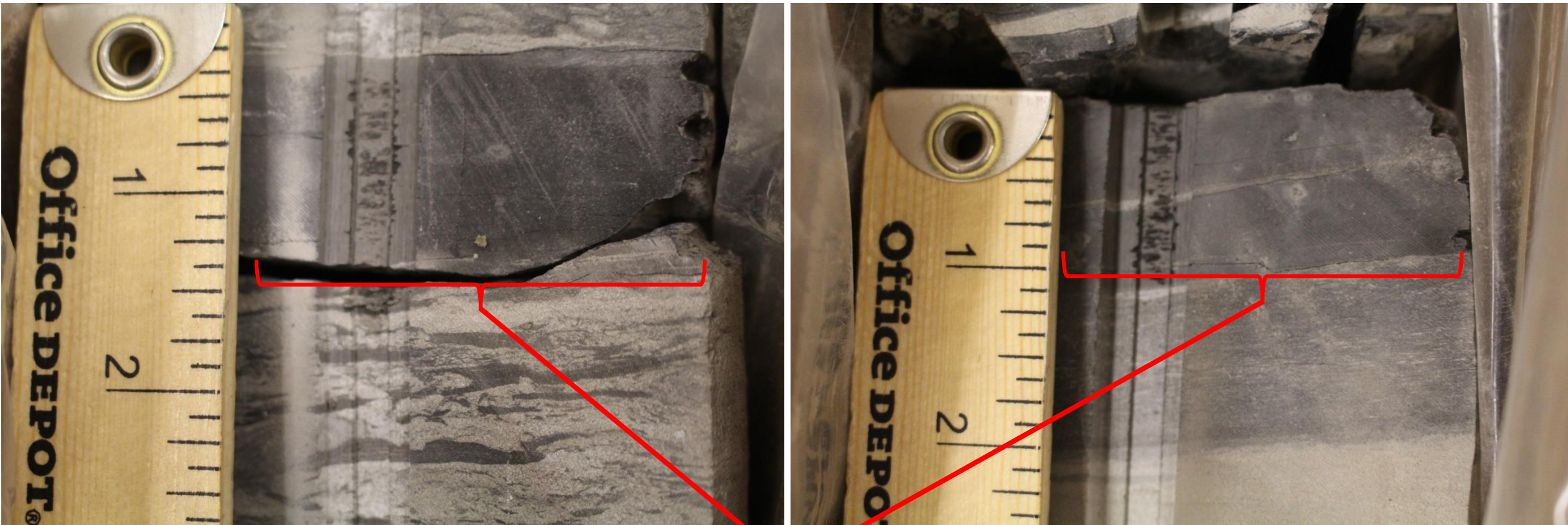




Very Coarse
Conglomeratic Bed



Razor 25-2514H – Organic Rich Codell Beds



Organic Rich Beds

Conclusions





- The Codell Sandstone is a very important reservoir in the DJ Basin
- The goal of this project is to improve future drilling endeavors in the Codell
 - Further understanding of controls on reservoir quality and extent
- Hypothesis formation and testing underway
- Fully-integrated research project ready by December 2021

MUDTOC Consortium Sponsors

Fall 2020



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