# Reservoir Quality and Characterization of the Codell Sandstone, NE Silo Field Area

COLORADO SCHOOL OF MINES
MUDTOC

**Matthew Keator**

Anticipated Graduation: August 2023

# Outline

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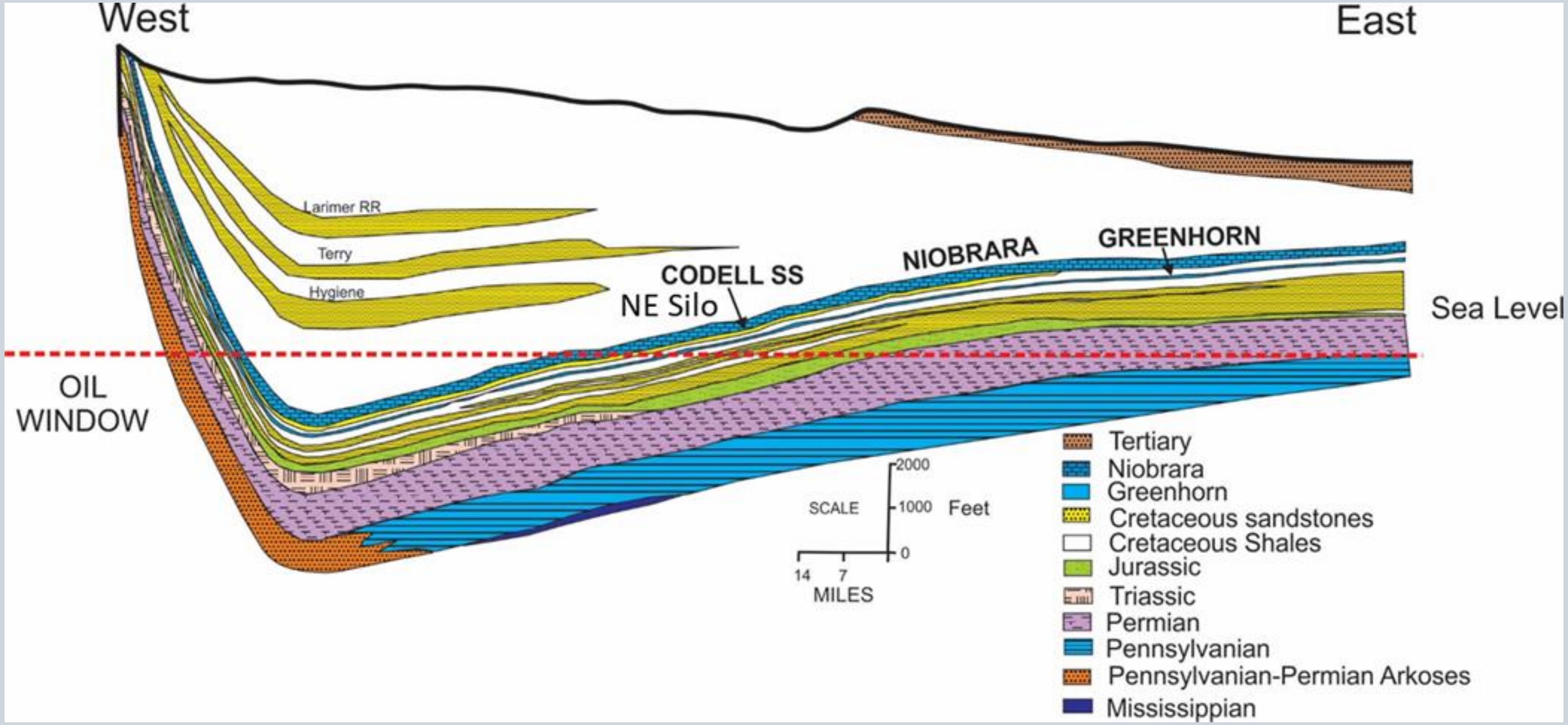
- DJ Basin cross section and geologic background
- Subsurface maps
- Production update NE Silo Helis wells
- Facies distribution and description
- Log analysis and XRD/XRF
- Reservoir Characterization

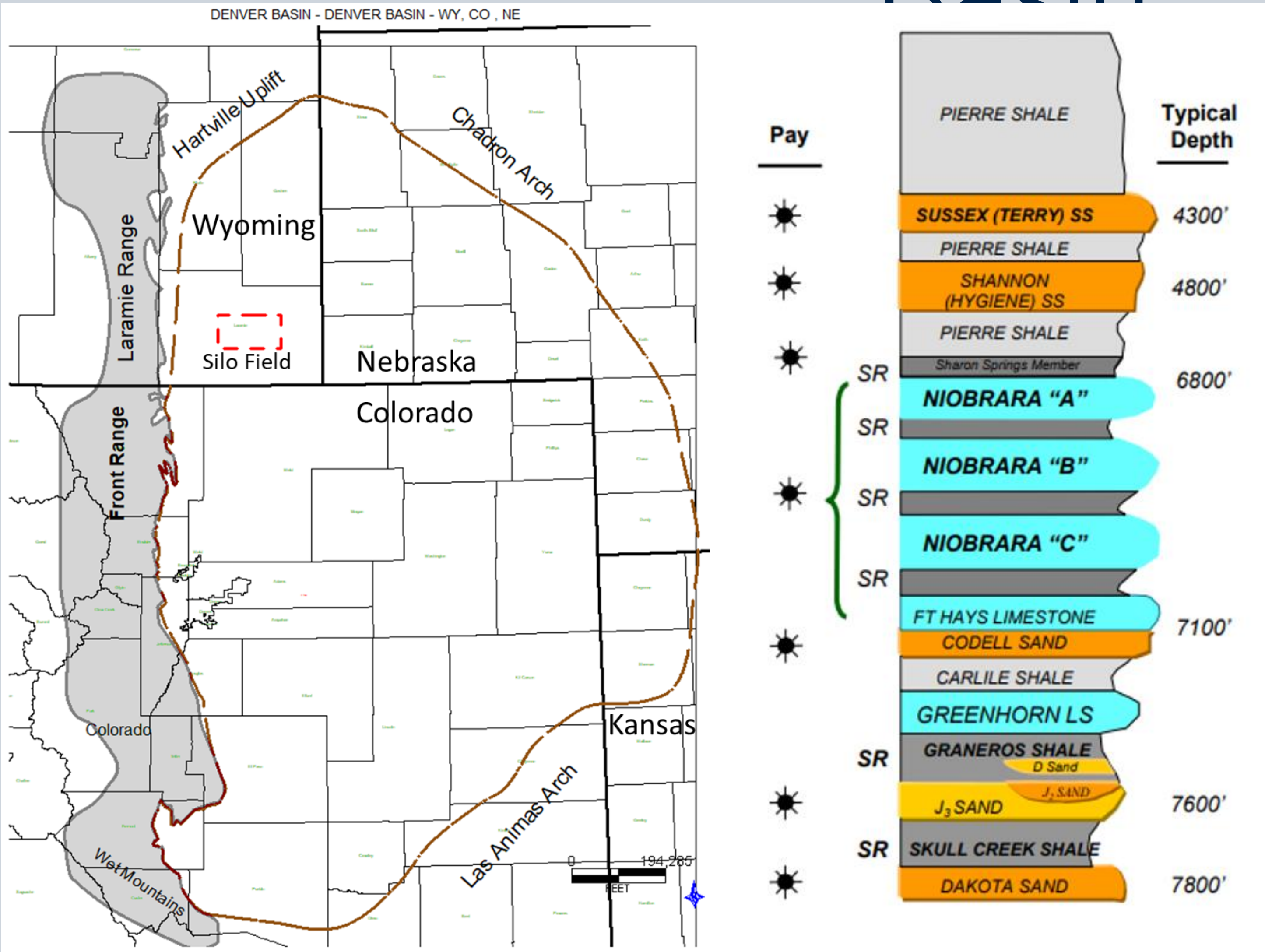
# Typical Cross Section – Denver Basin




(Sonnenberg 2015)

- Denver Basin is deepest in the western portion and shallows to the east
- Formations shallowly dip to the west in the eastern portion of the basin

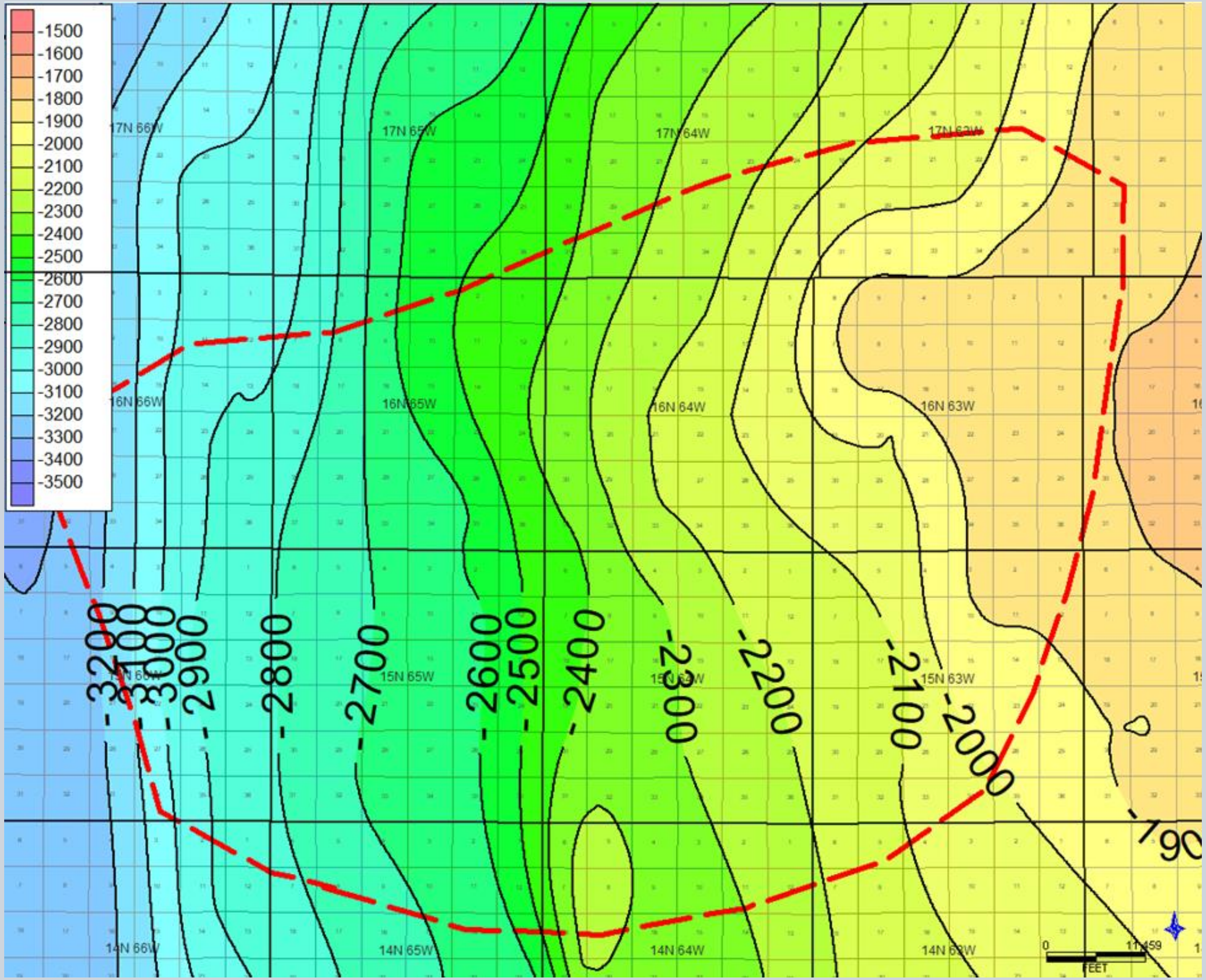
# Location and Stratigraphy – Denver Basin




(Sonnenberg 2011)

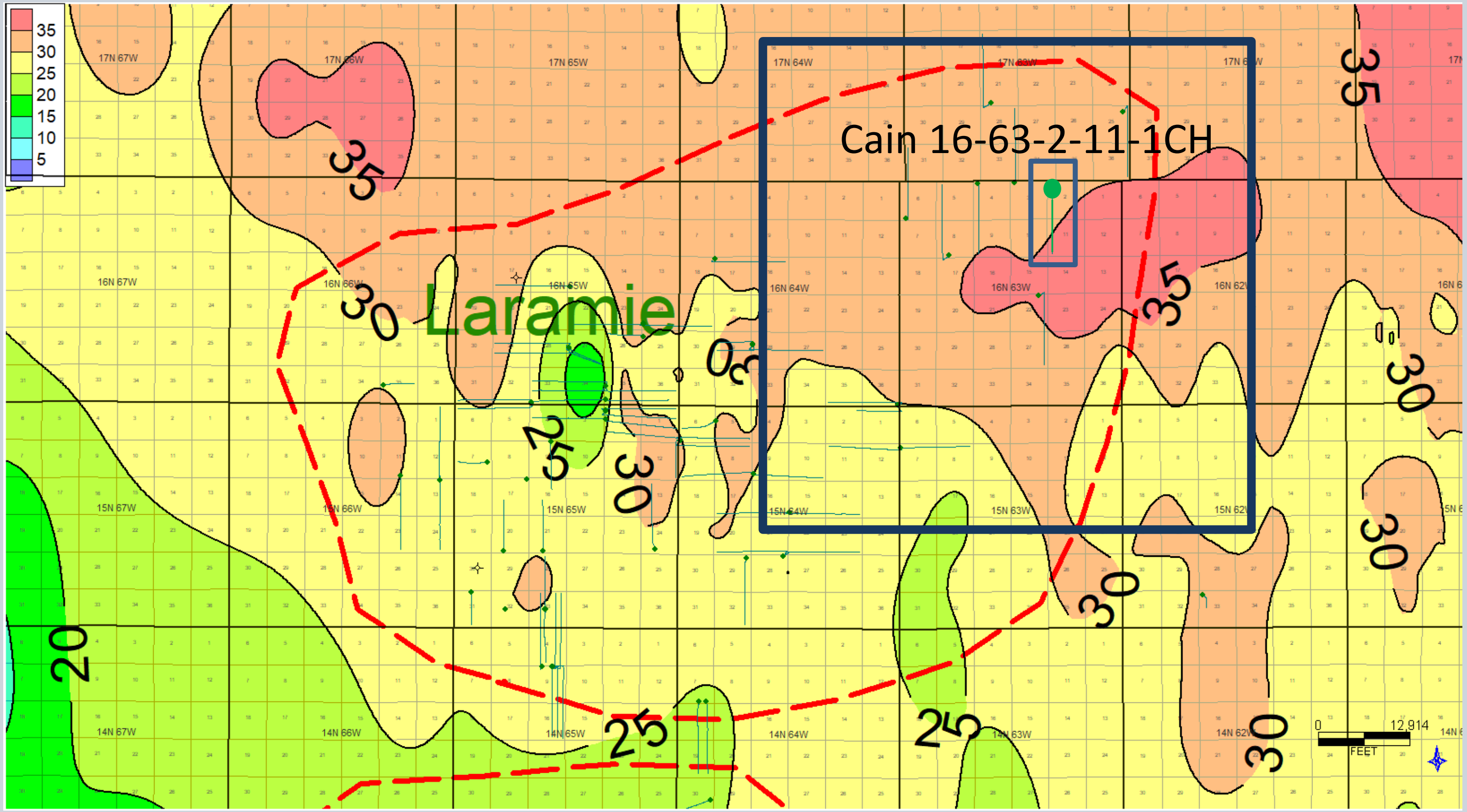
- Silo Field is located in Laramie County, Wyoming
- Encompasses townships 15 and 16N and sections 63, 64, 65W
- Produces out of the Niobrara and Codell, which is a tight sand reservoir
- Source rock intervals include the Sharon Springs Member, multiple benches of the Niobrara, Carlile, and Graneros
- Oil migrates into the Codell from one of the mentioned source rock intervals

# Codell Structure Map (SS) – Silo Field




- Codell subsea depth in Silo Field ranges from approximately -2000 to -3000 feet , with subsea depth in NE Silo Field near -2000 feet
- Follows general structure of DJ Basin
- Silo Field sits on the eastern part of the basin, so the Codell dips gently to the west

# Codell Isopach Map – Silo Field




- Codell approximately 25-30 feet thick in Silo Field
- 30 feet thick in NE Silo Field
- Thickens to the north

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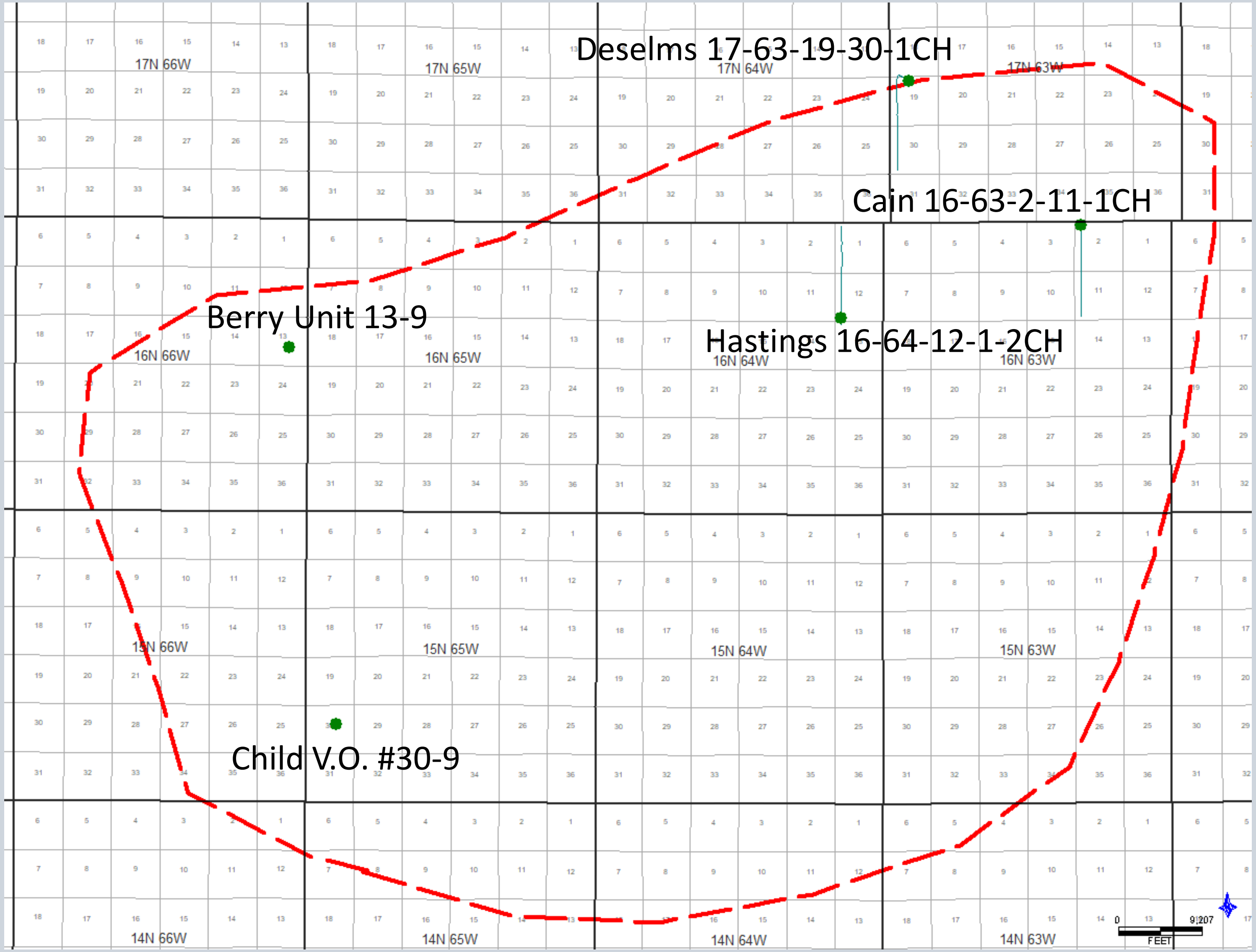
# Study Wells

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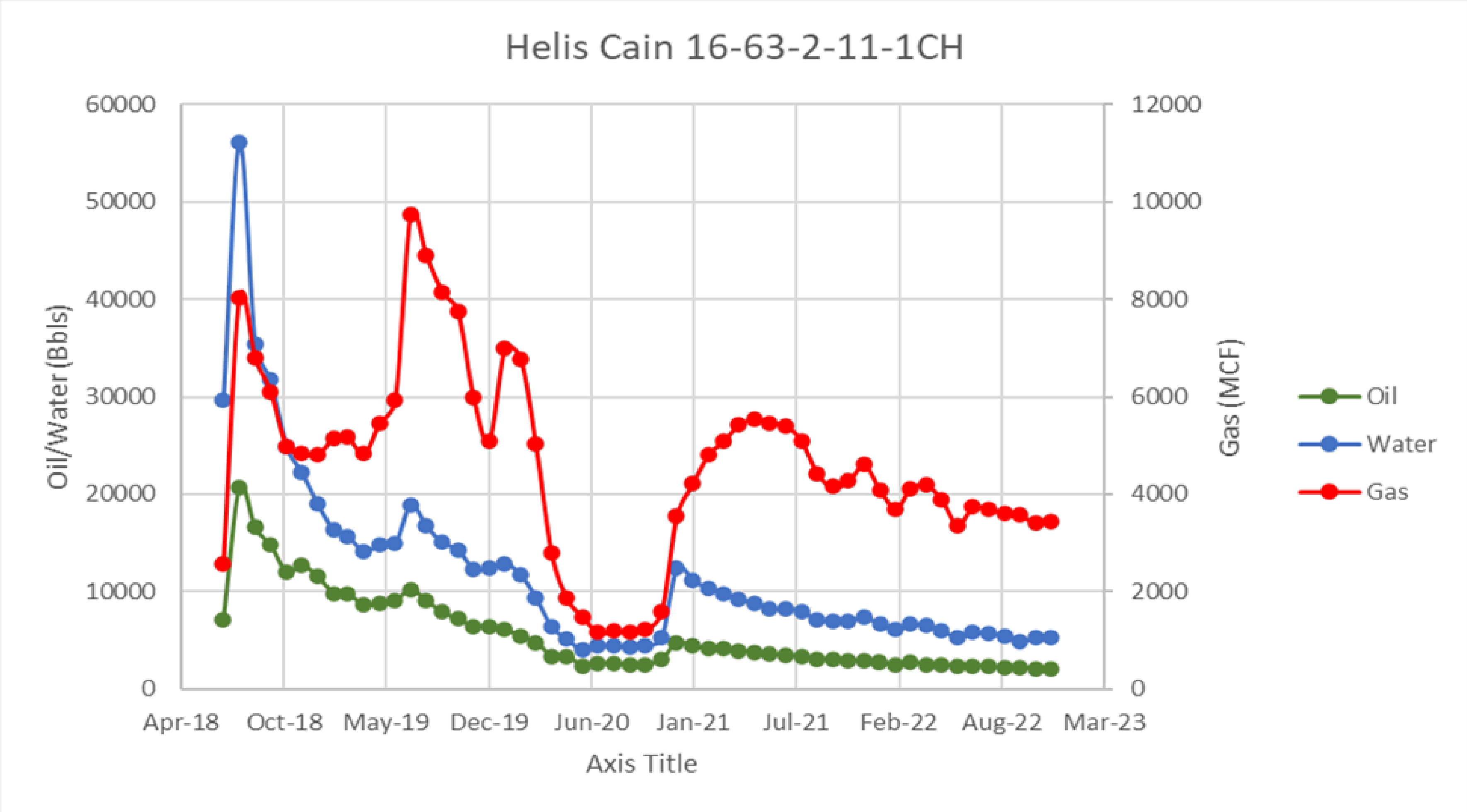
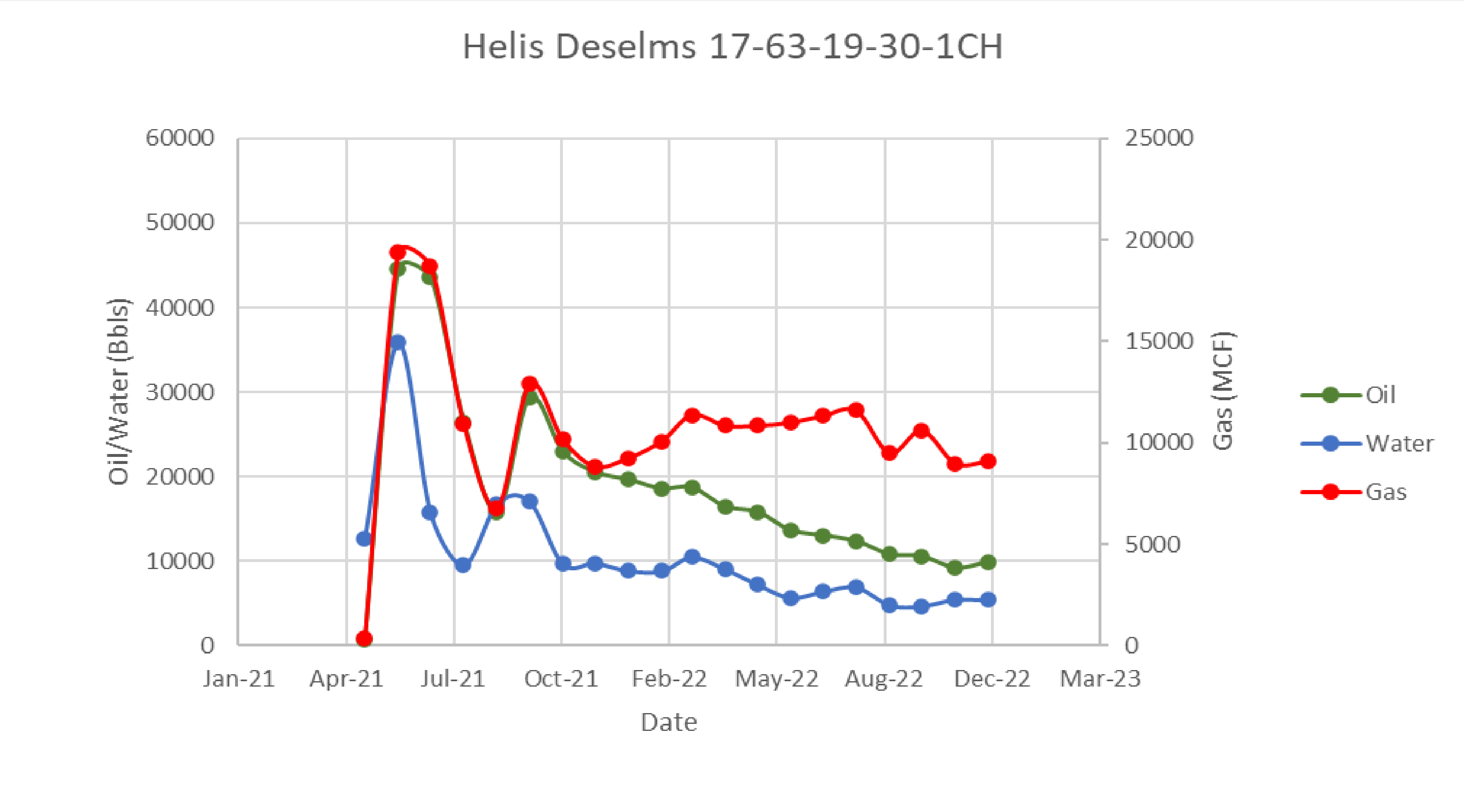
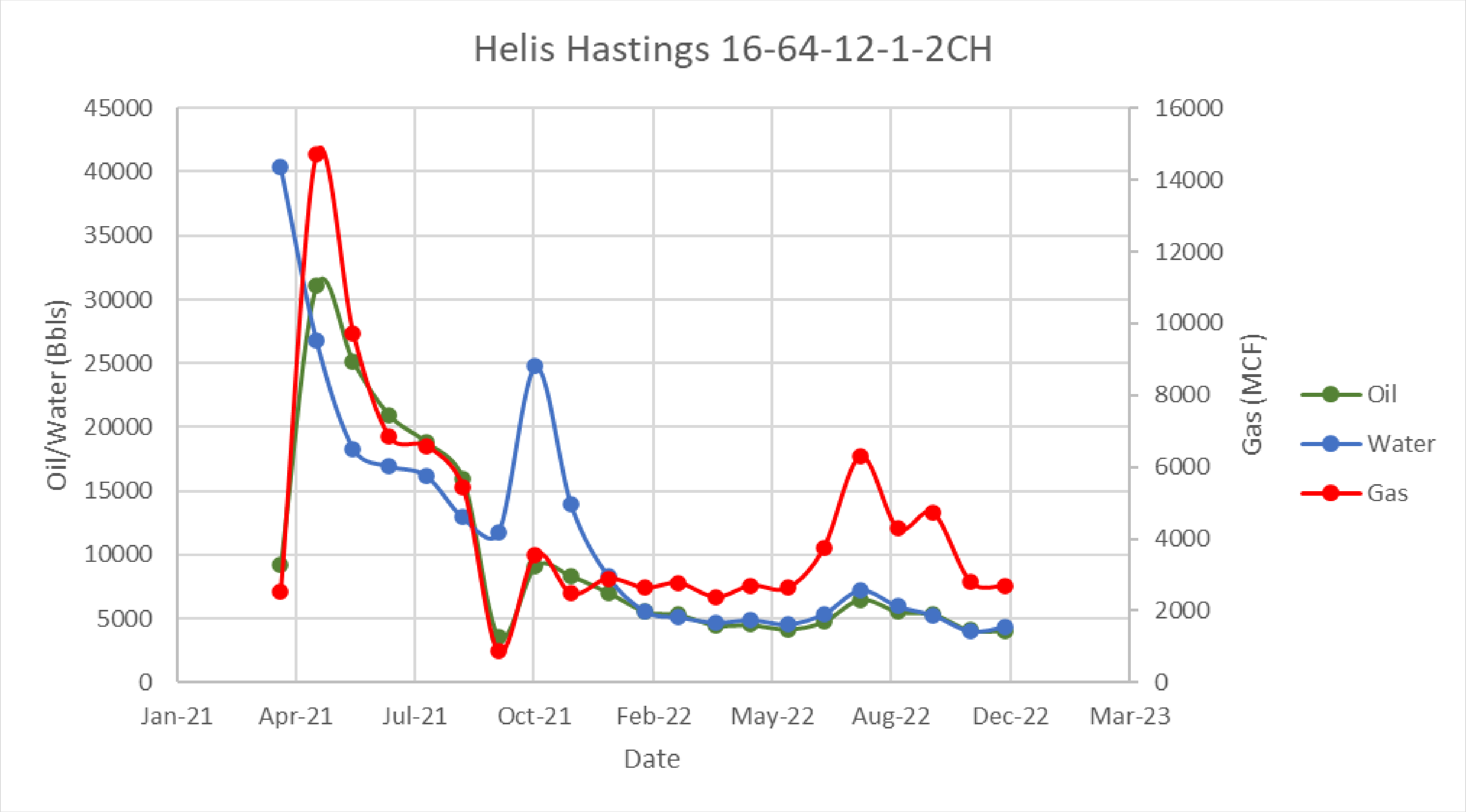
# Monthly Production



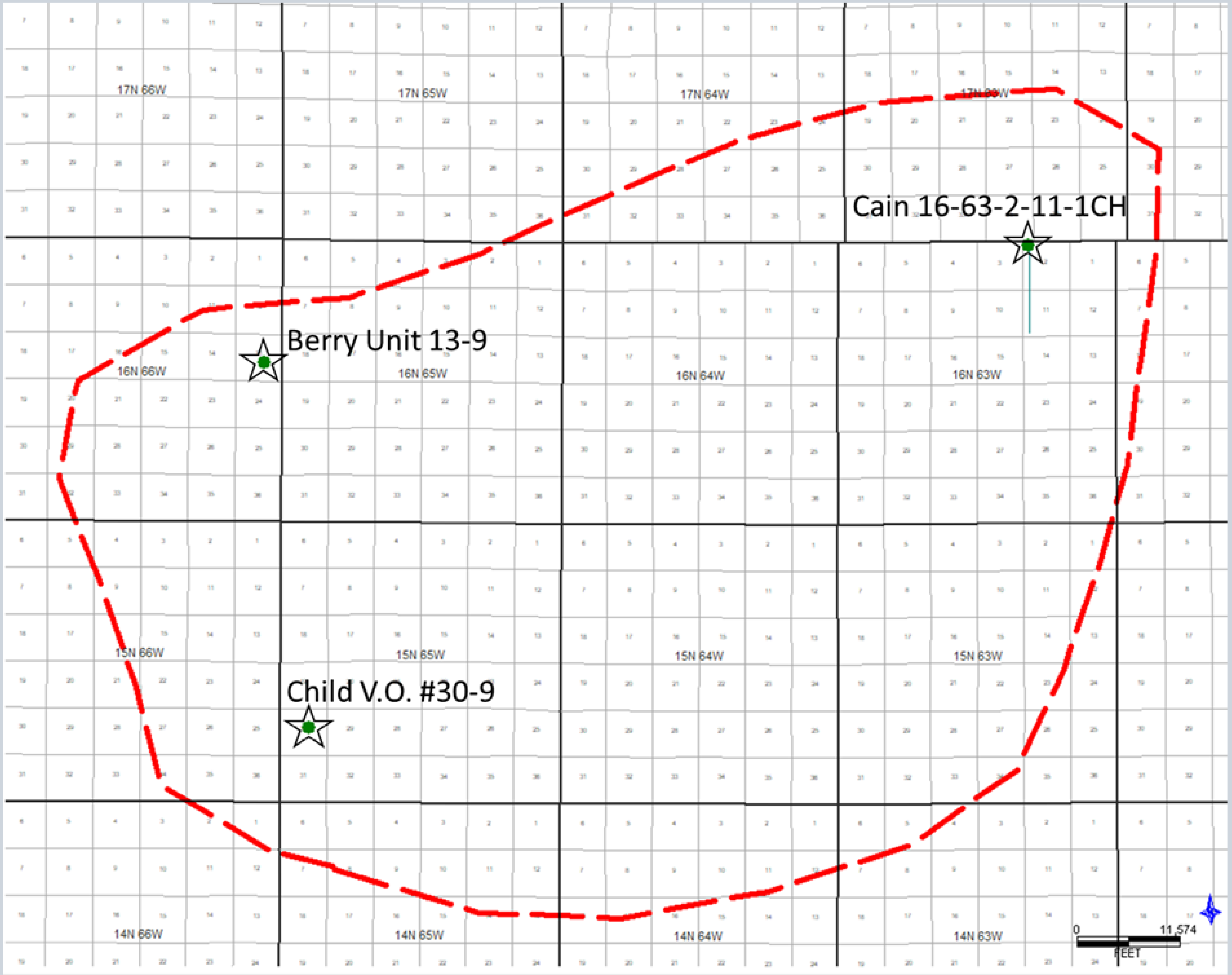
# Monthly Production



# Monthly Production



# Core Locations

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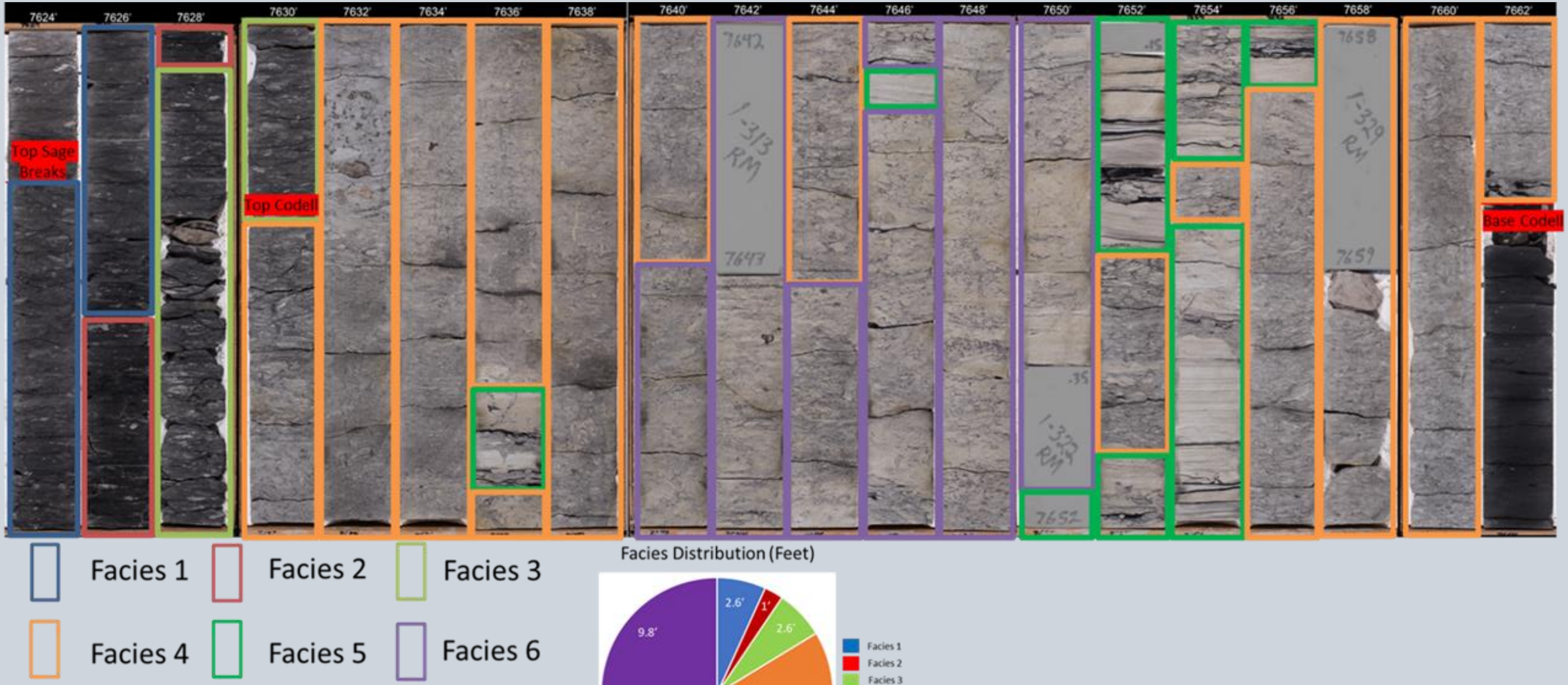
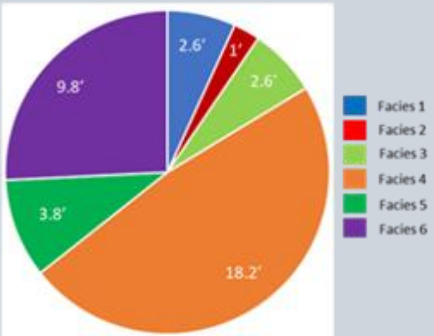
# Facies Distribution - Cain



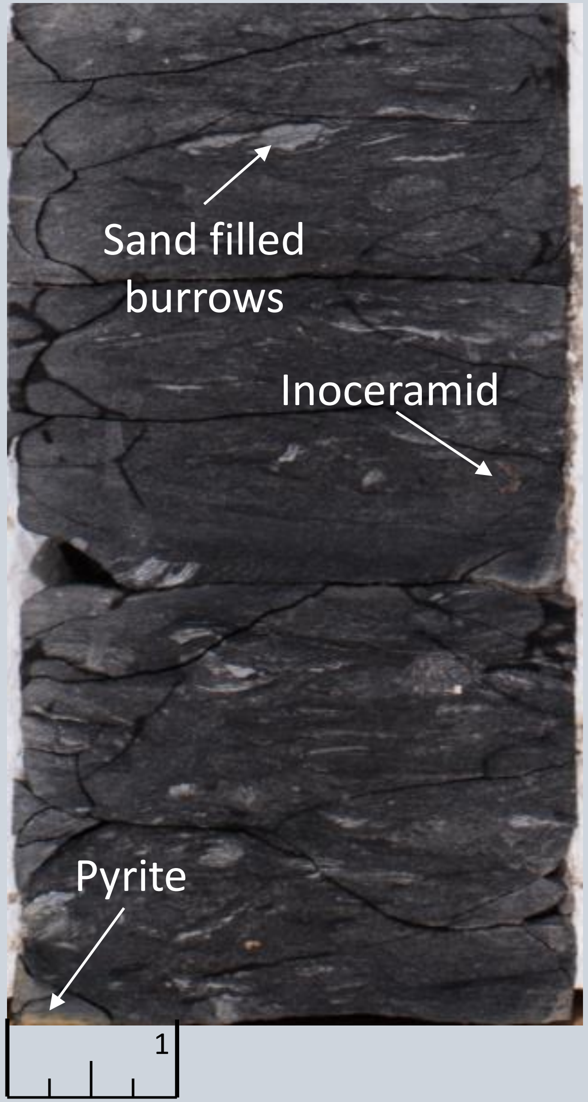

Facies Distribution (Feet)



# Core Facies Description

Facies 1

- Very fine-grained sandy siltstone, poorly sorted, heavily bioturbated, with inoceramid fragments, with pyrite nodules, not oil stained under UV light



# Core Facies Description

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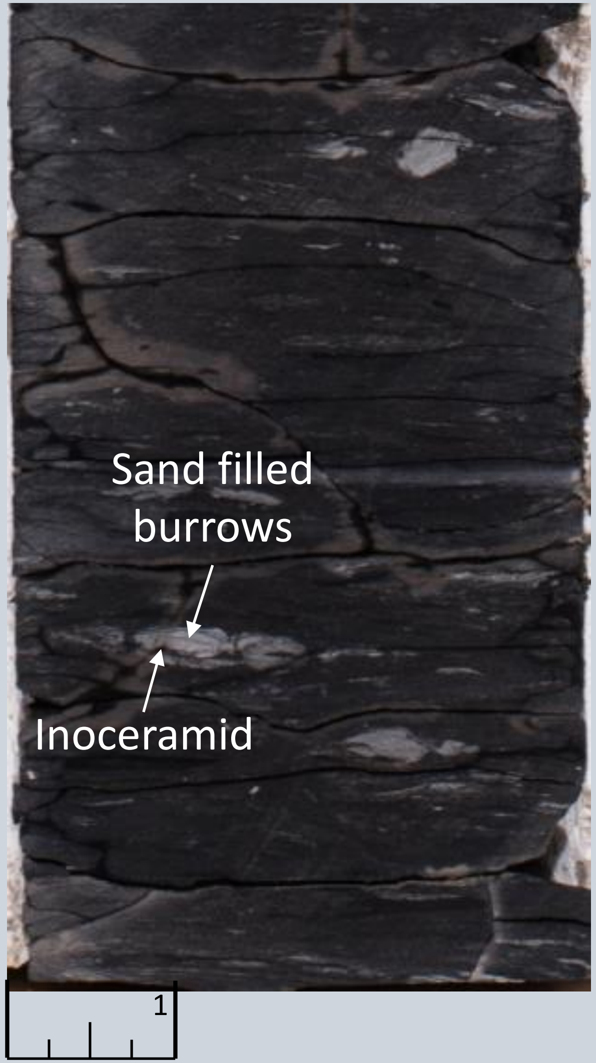
## Facies 2

- Mudrock with mostly clay sized particles, some burrows are filled with very fine sandstone, with vertical fractures

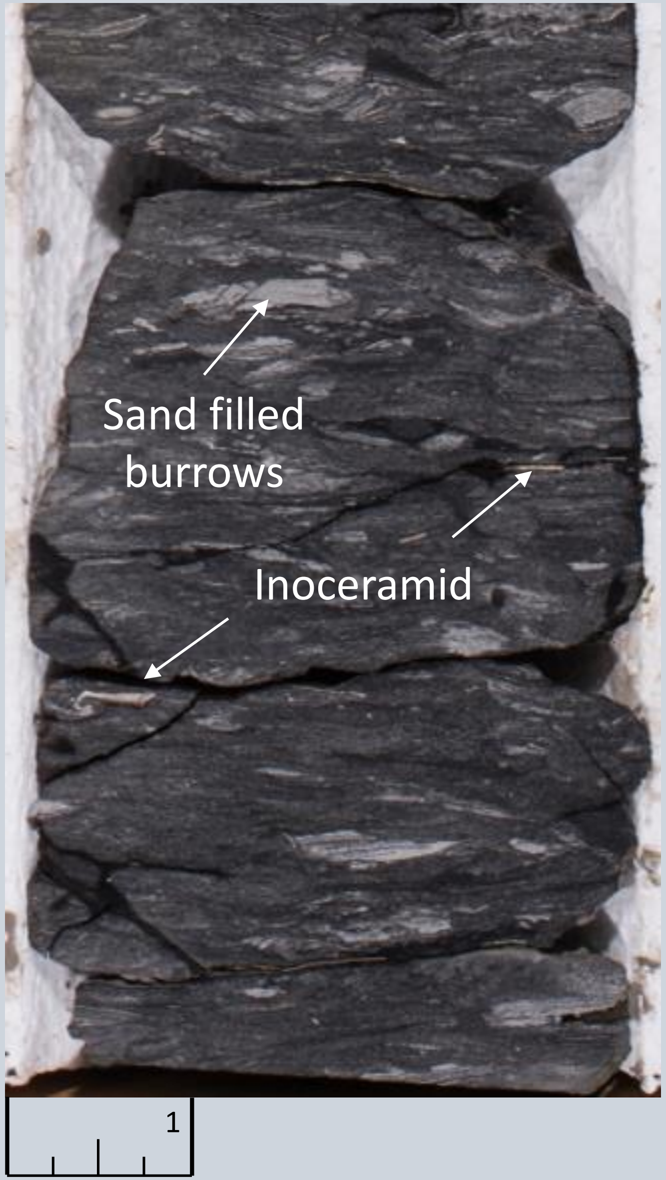


# Core Facies Description



## Facies 3

- Very fine-grained sandy siltstone, poorly sorted, heavily bioturbated, with inoceramid fragments, with pyrite nodules, not oil stained under UV light, higher sand content than Facies 1



# Core Facies Description

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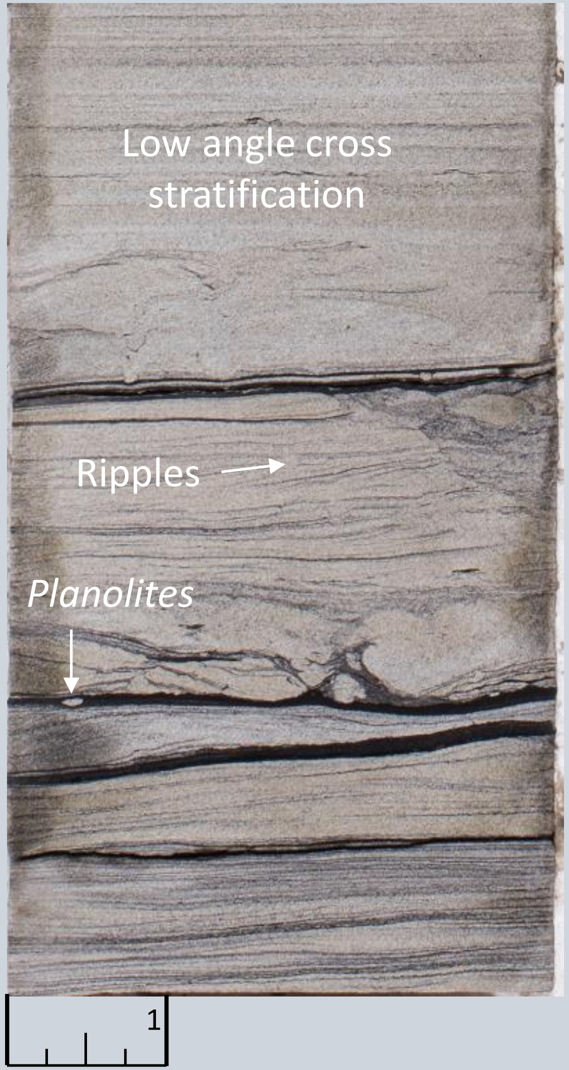
## Facies 4

- Heavily bioturbated, very fine-grained silty sandstone, poorly sorted, with Teichichnus and Skolithos burrows, shows oil staining in core

# Core Facies Description

## Facies 5

- Low angle cross stratified to ripple stratified very fine-grained sandstone, moderate to well-sorted, with organic rich shale beds and mud drapes, with Planolites and Skolithos burrows, shows avid oil staining



# Core Facies Description

## Facies 6

- Very fine-grained silty sandstone, moderately poorly sorted, heavily bioturbated, with a higher sand content than Facies 4, shows heavier oil staining than Facies 4 under UV light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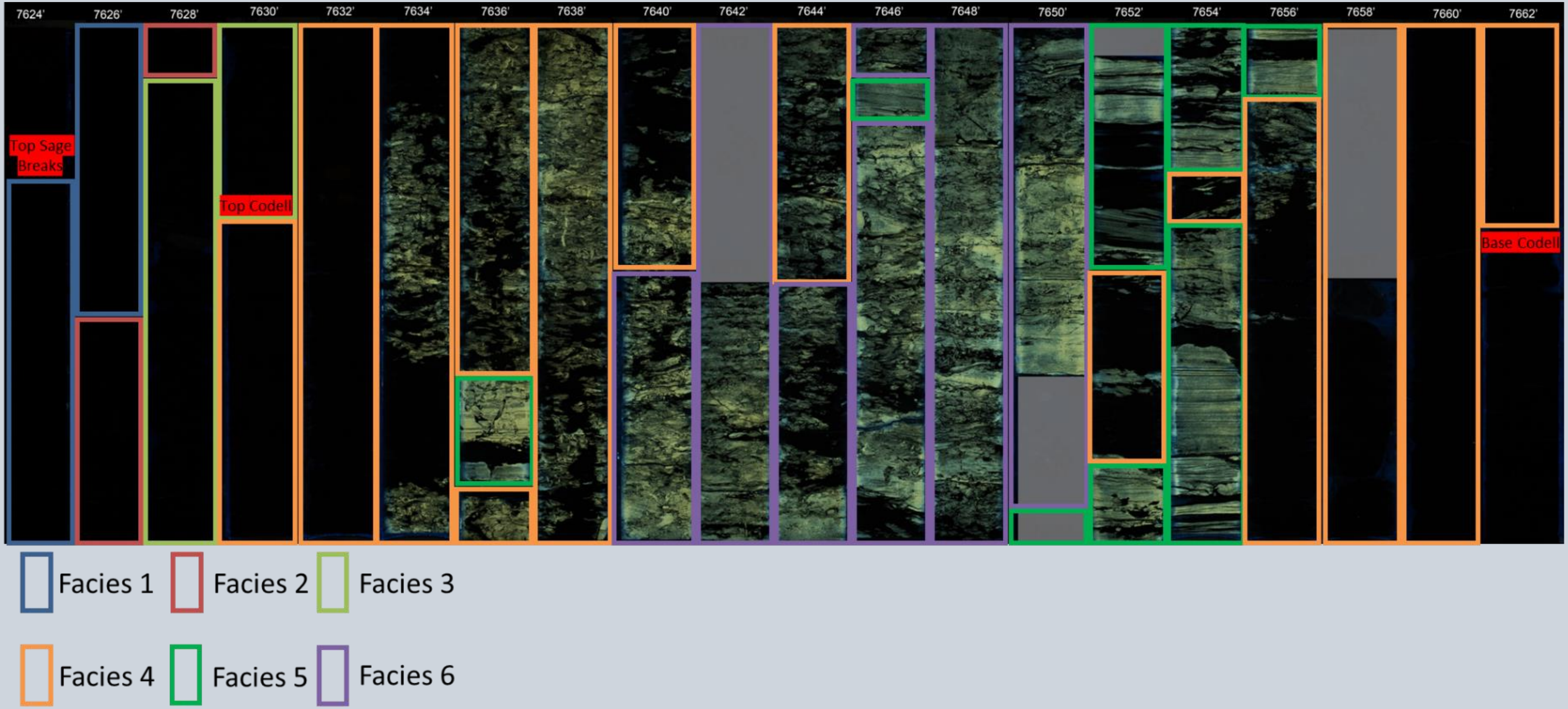
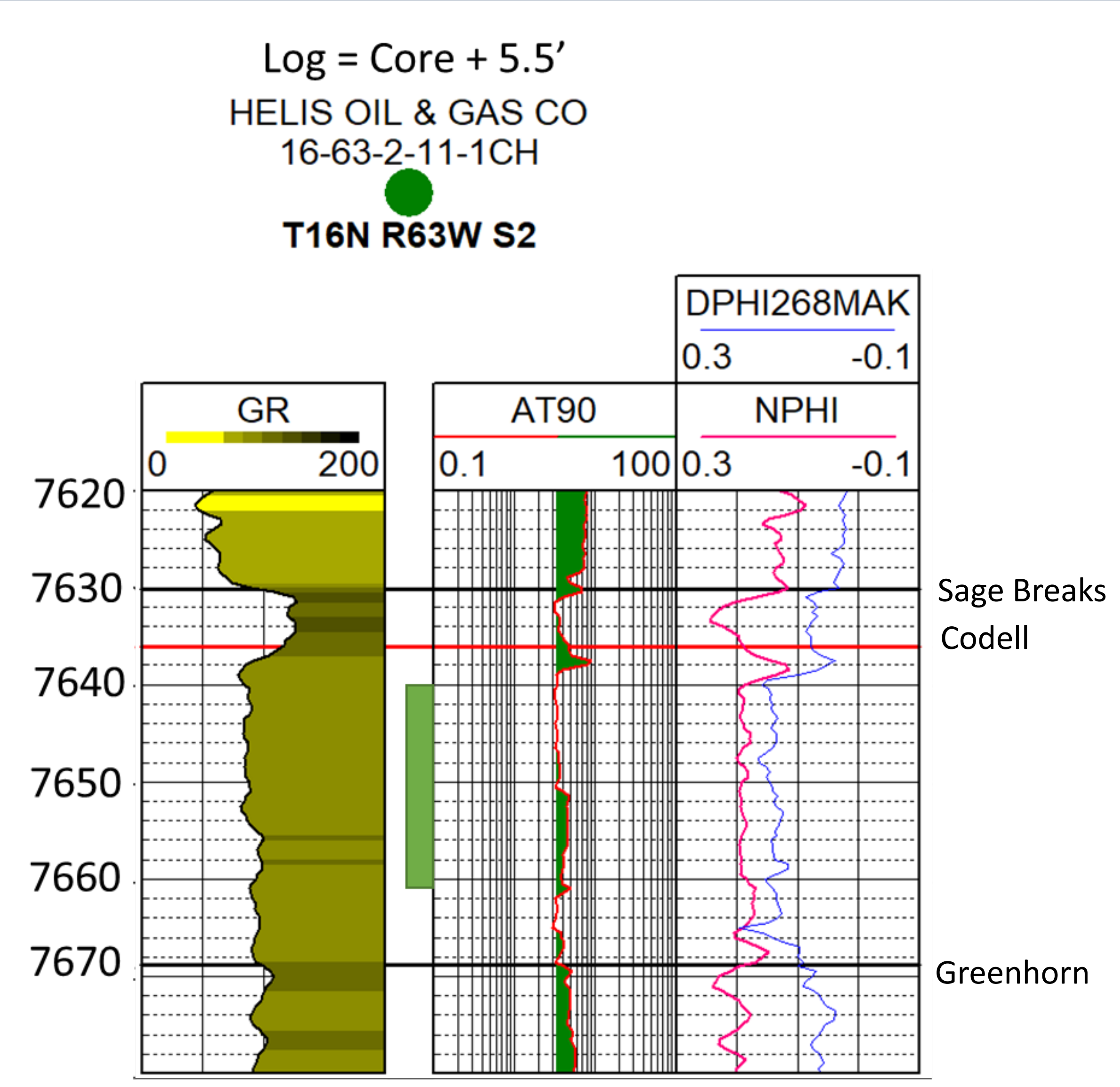
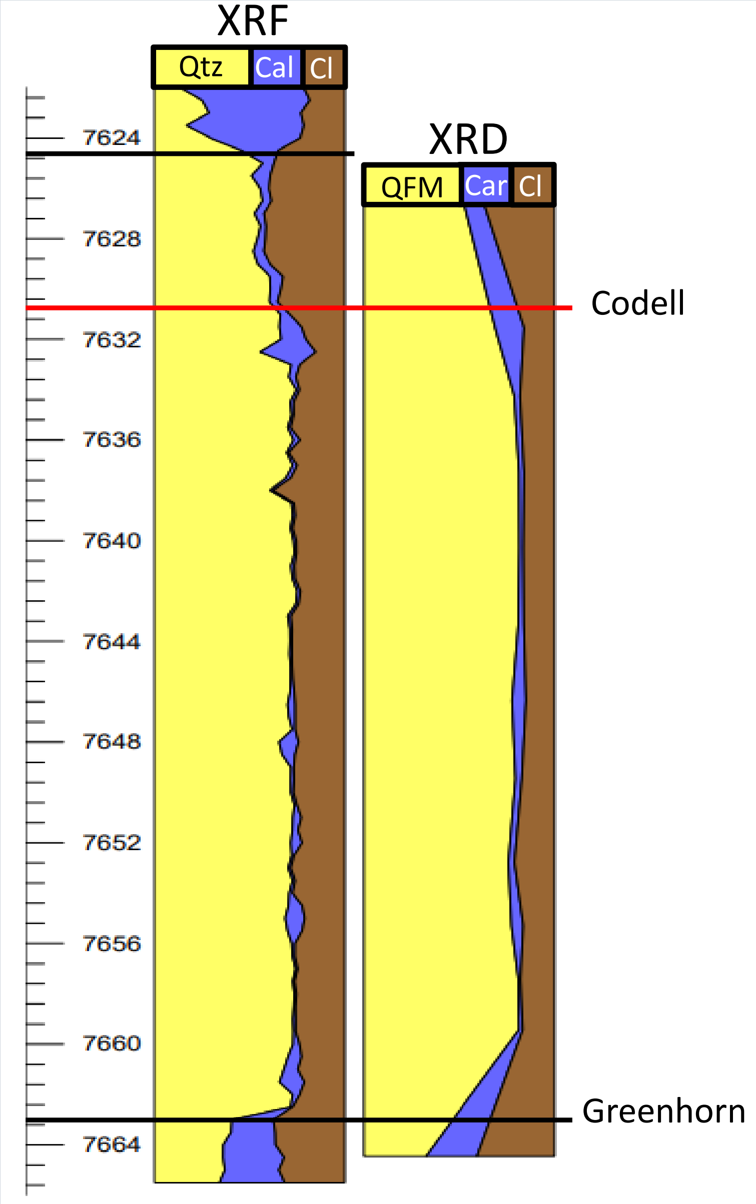
# UV Light Photo – Cain



# Log and XRD/XRF - Cain



# UV Light Photo – Berry Unit 13-9

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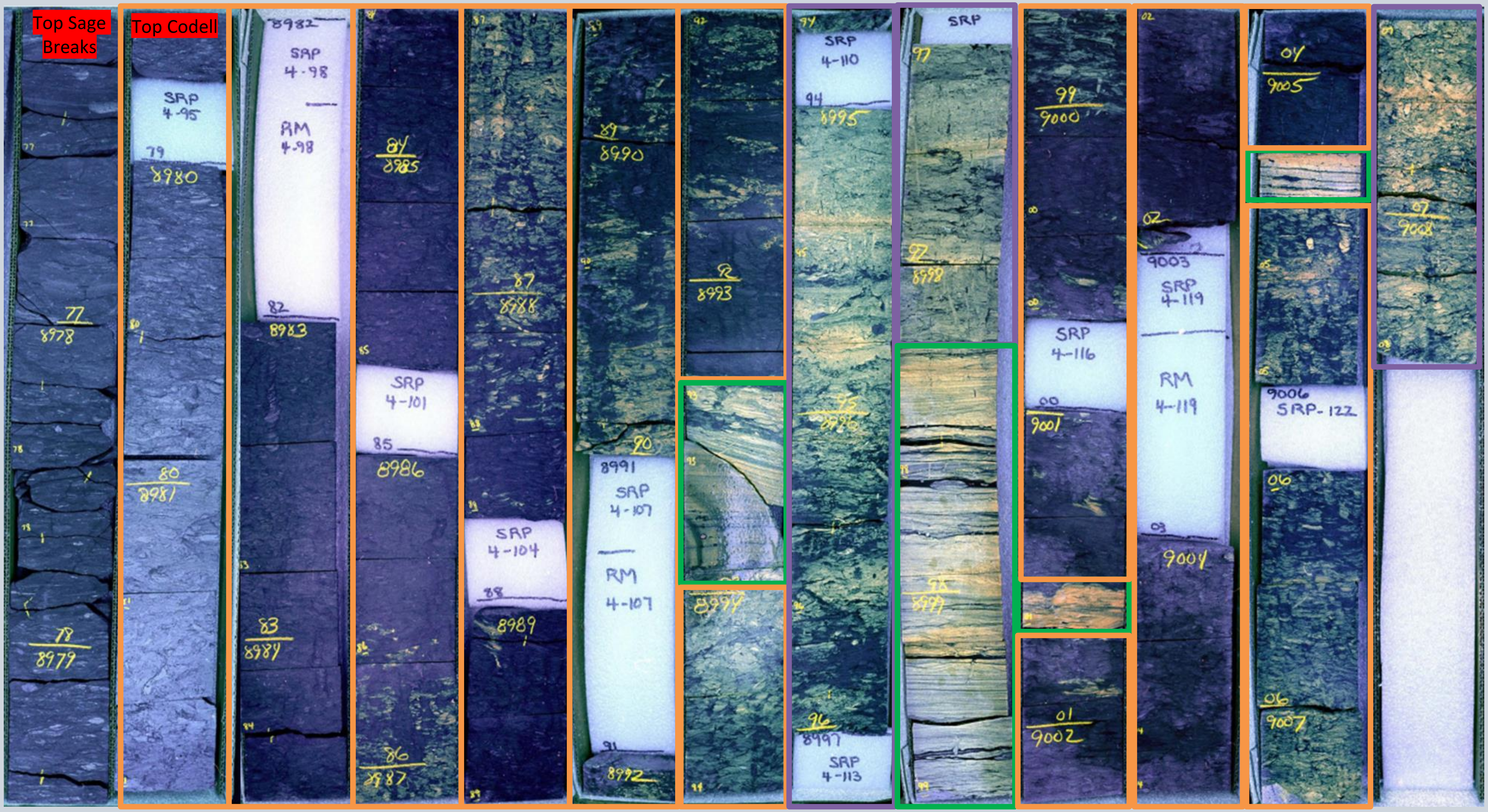
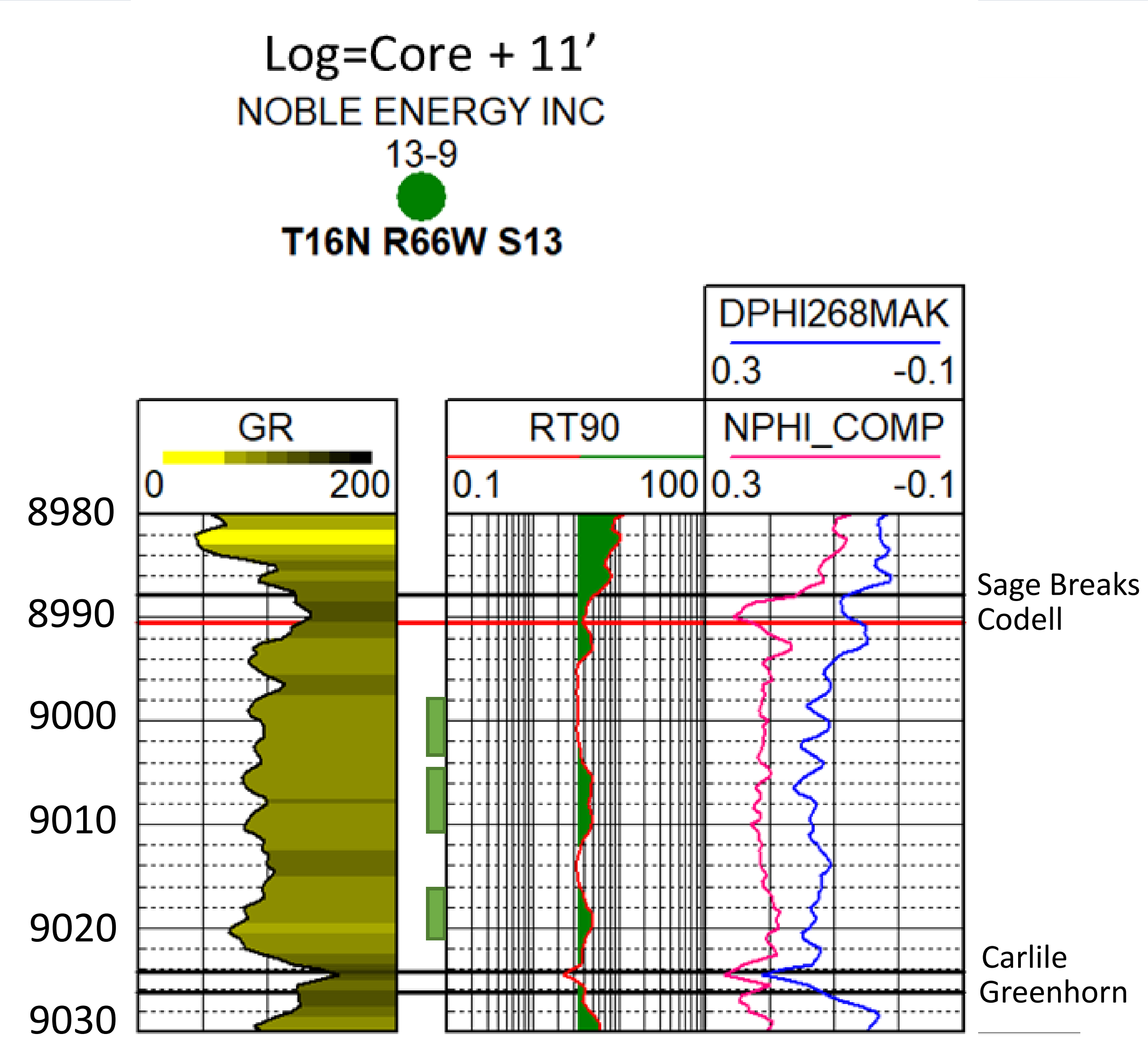
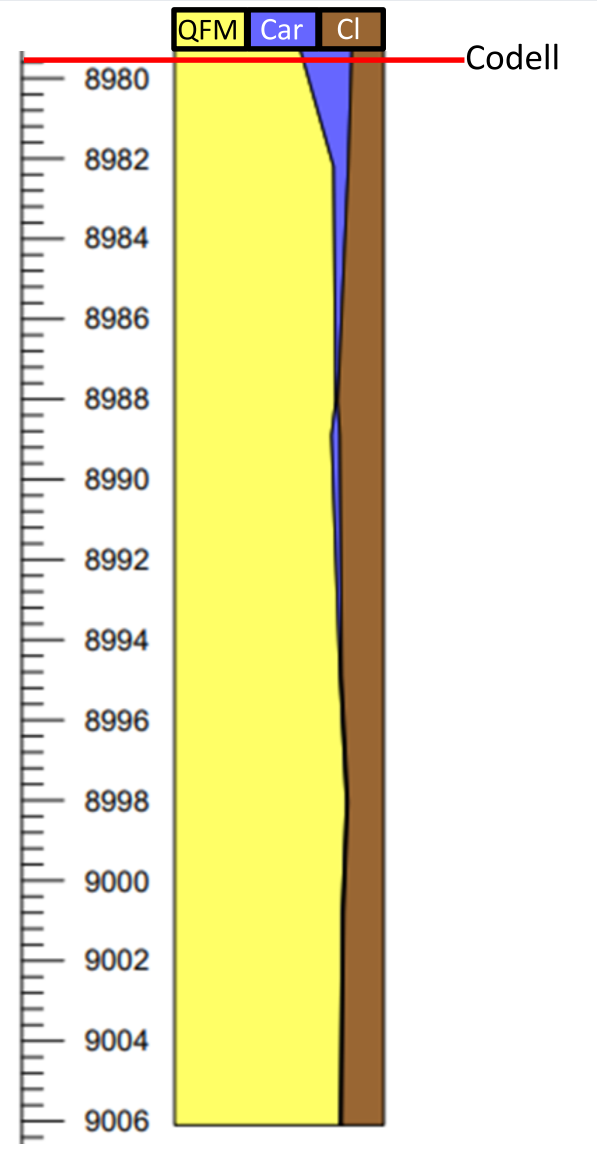
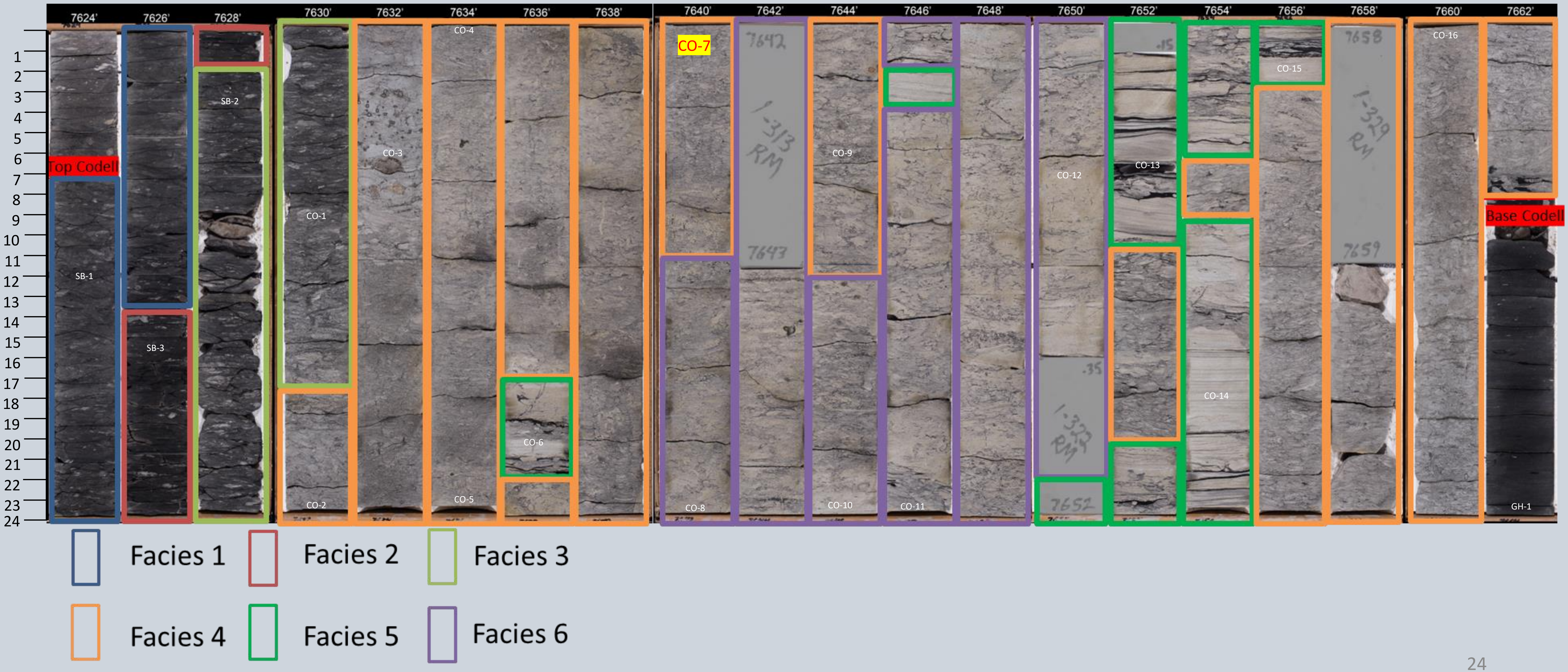


# Log and XRD - Berry

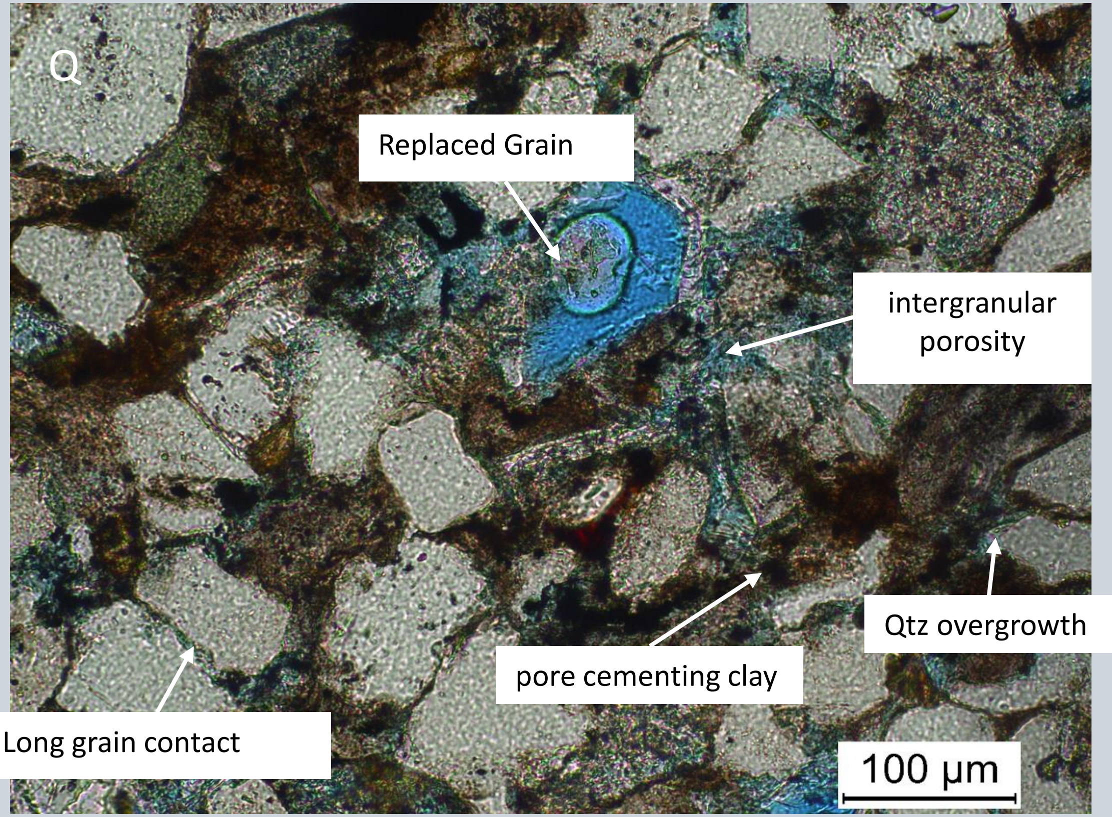


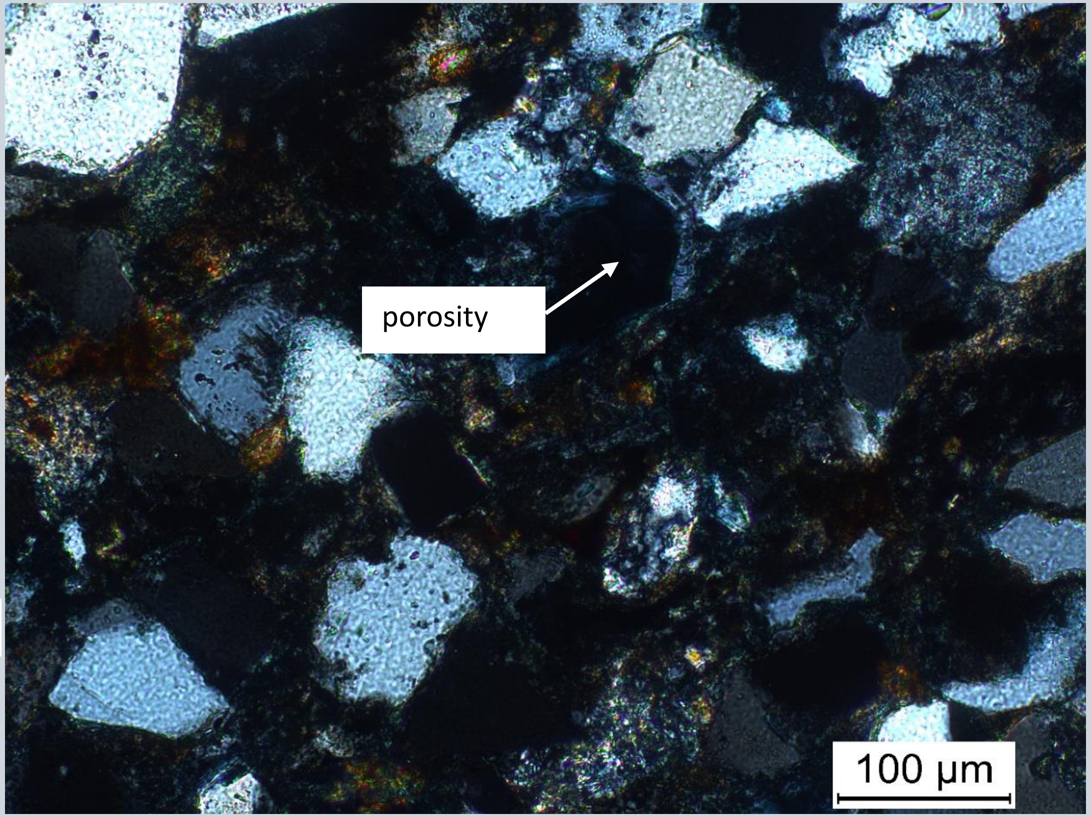



# Thin Sections Facies 4

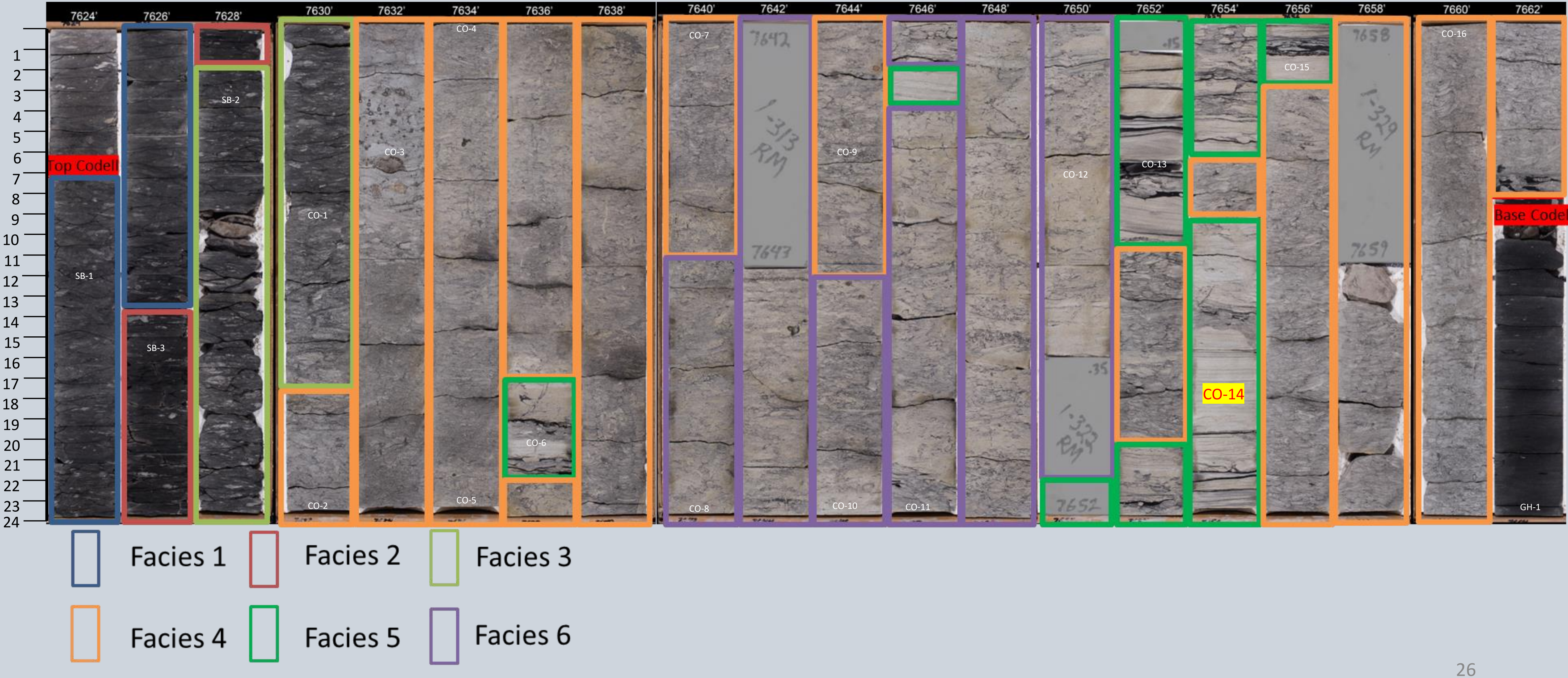


# Thin Section Facies 4

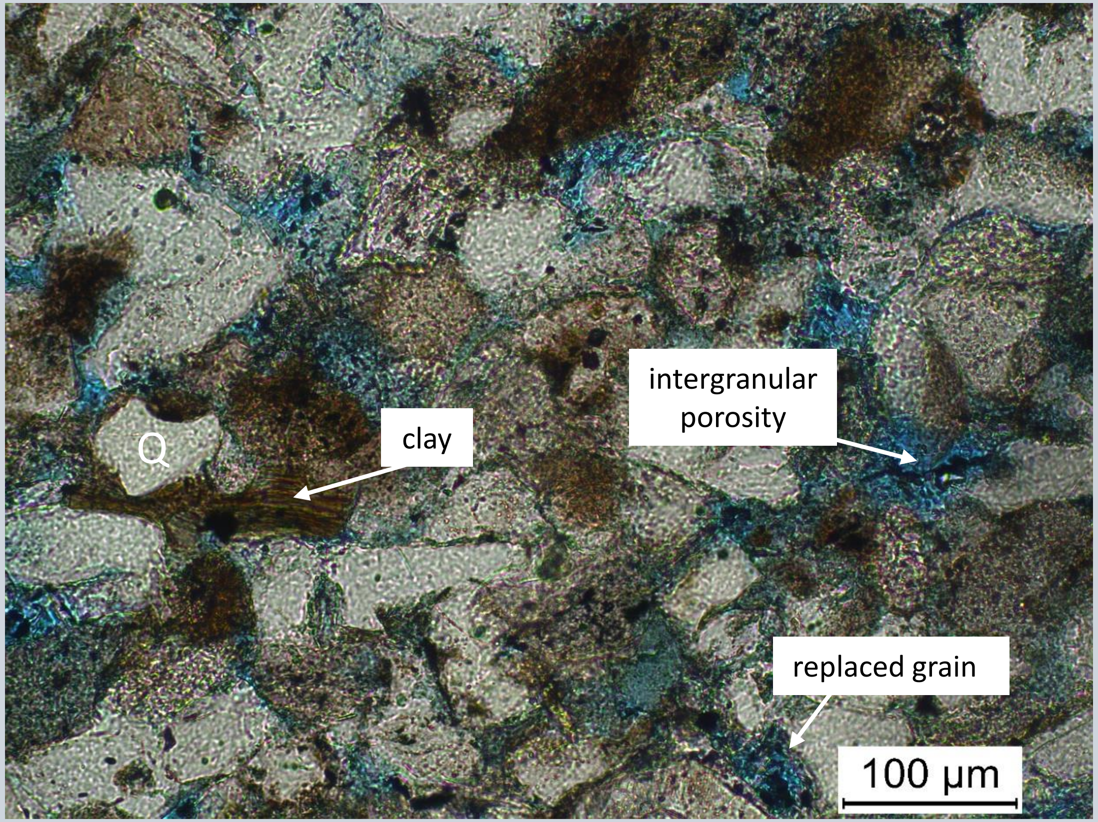


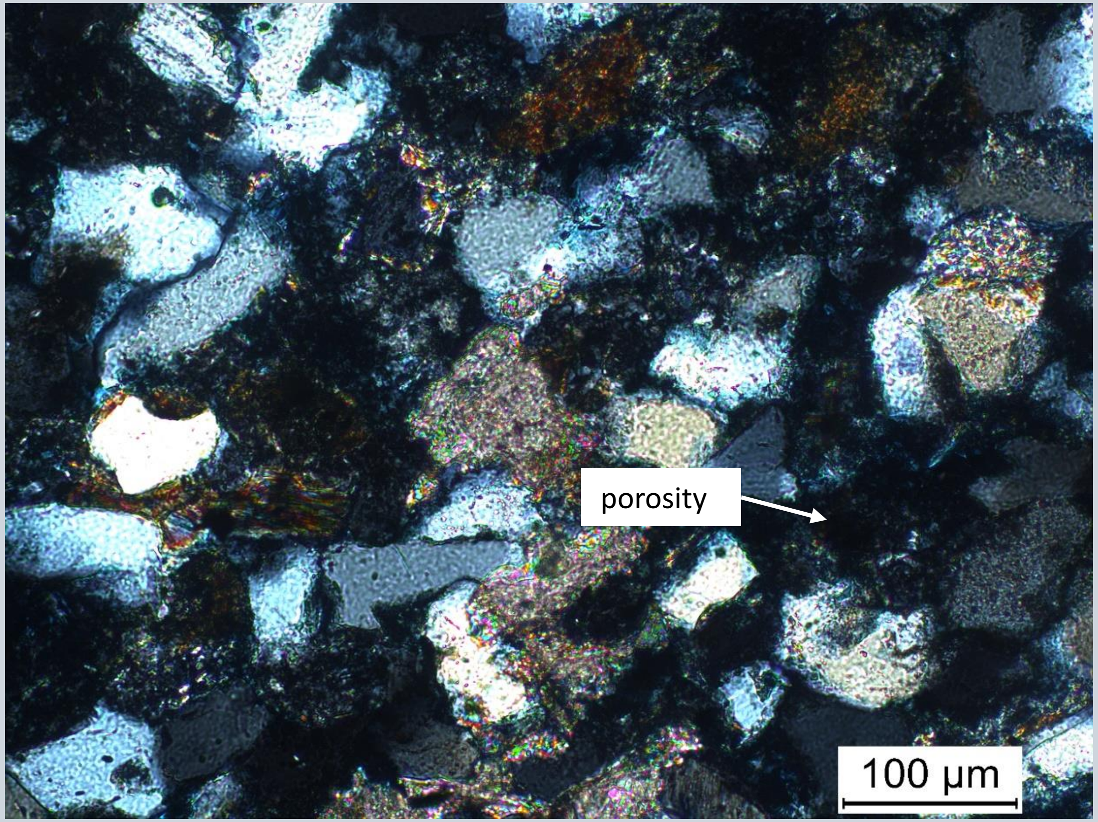



# Thin Section Facies 5



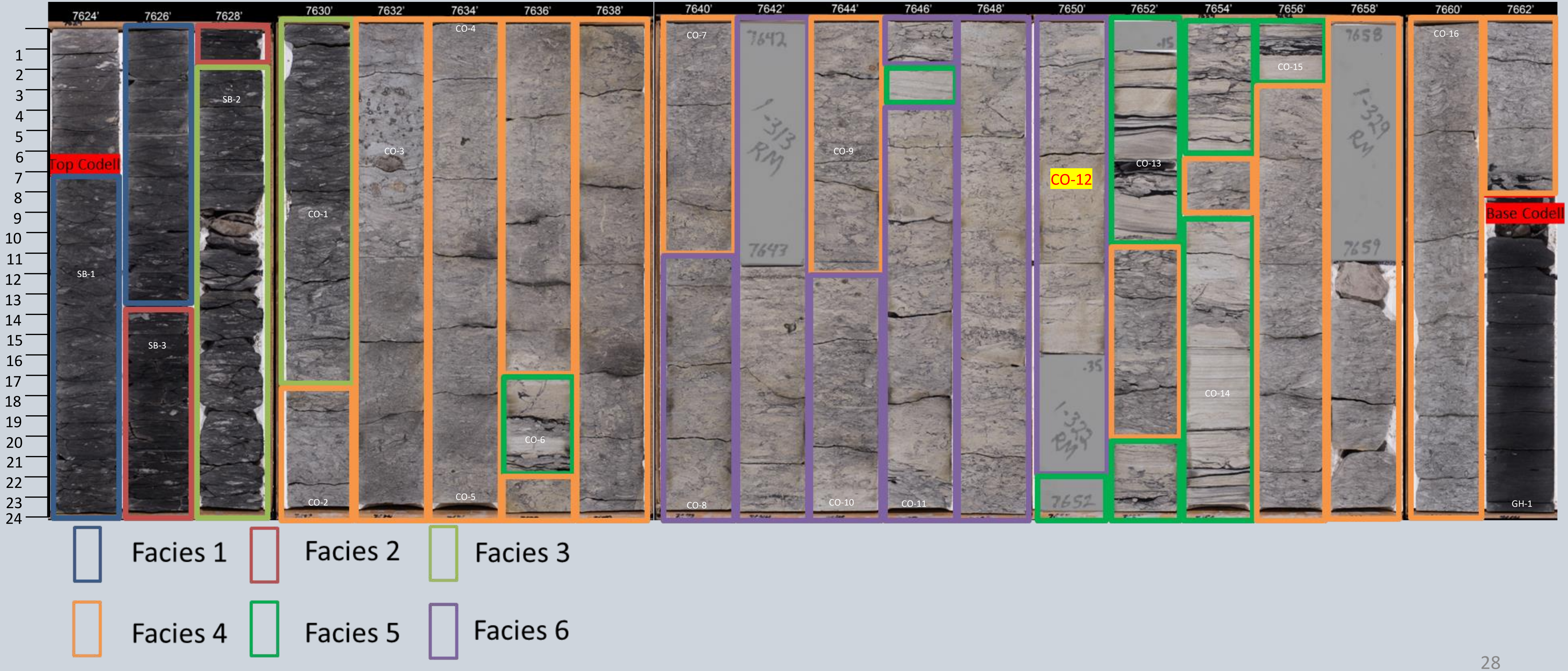
# Thin Section Facies 5



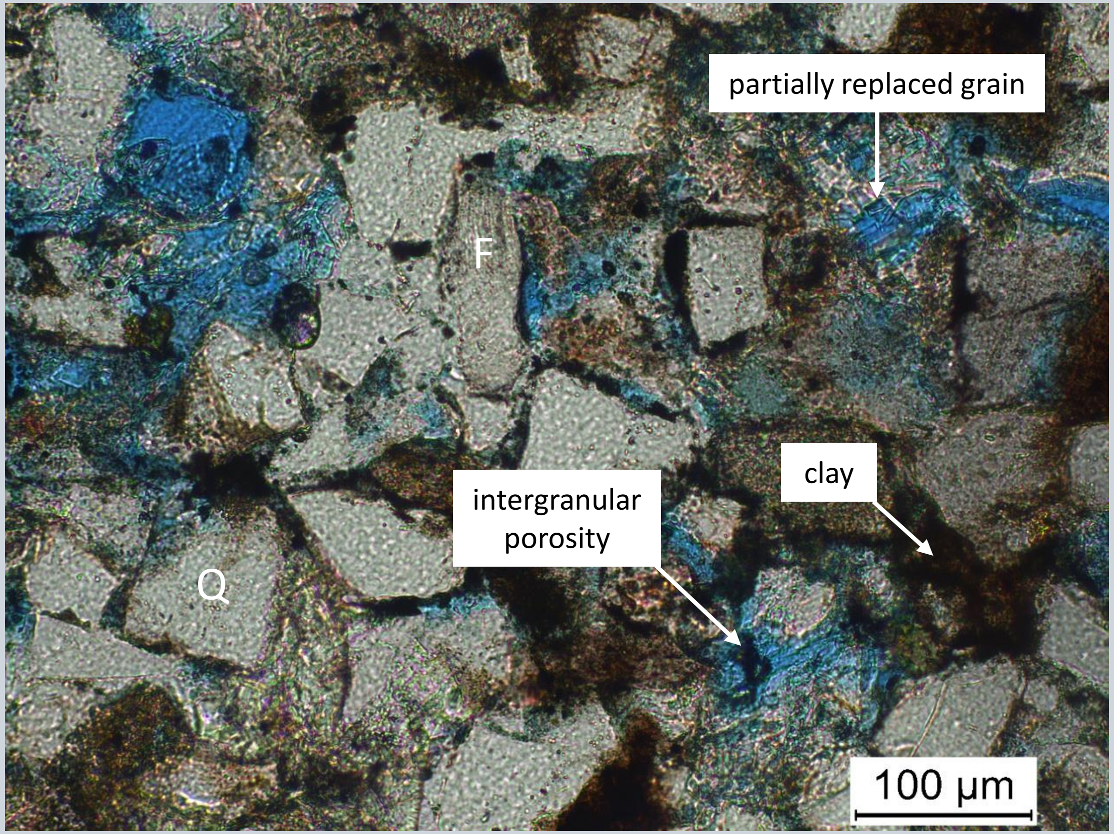



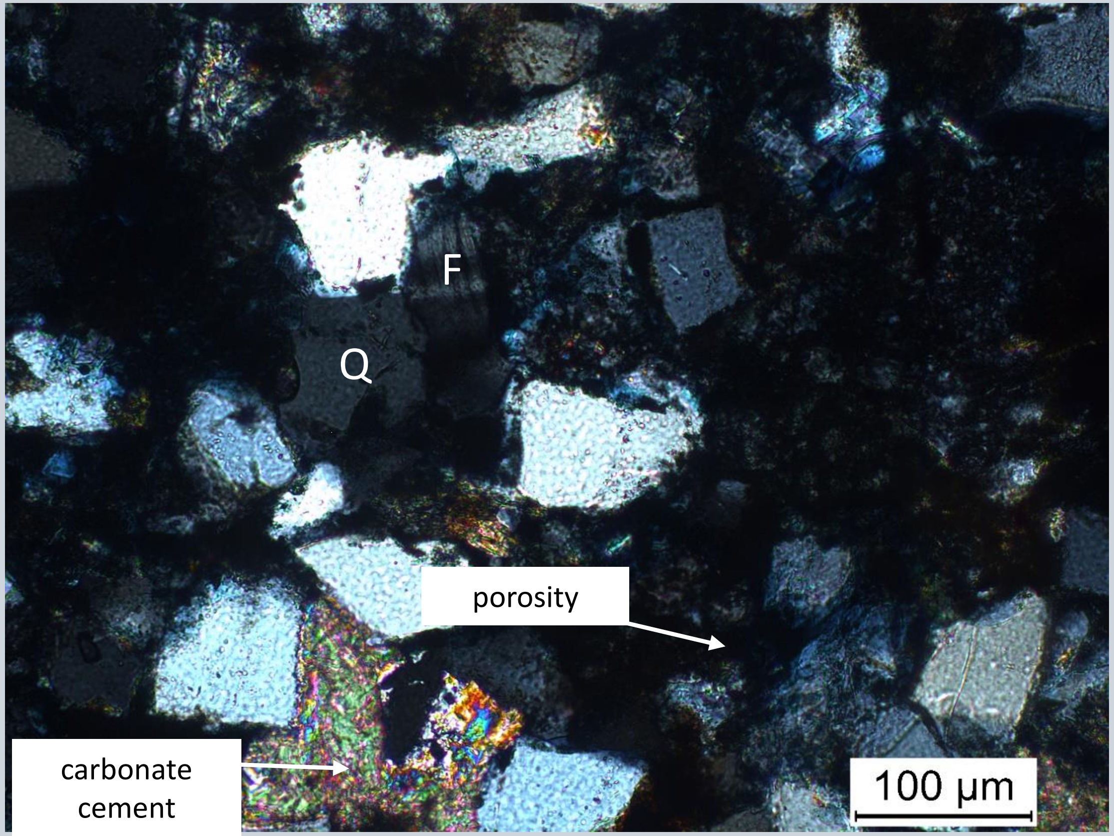
# Thin Section Facies 6



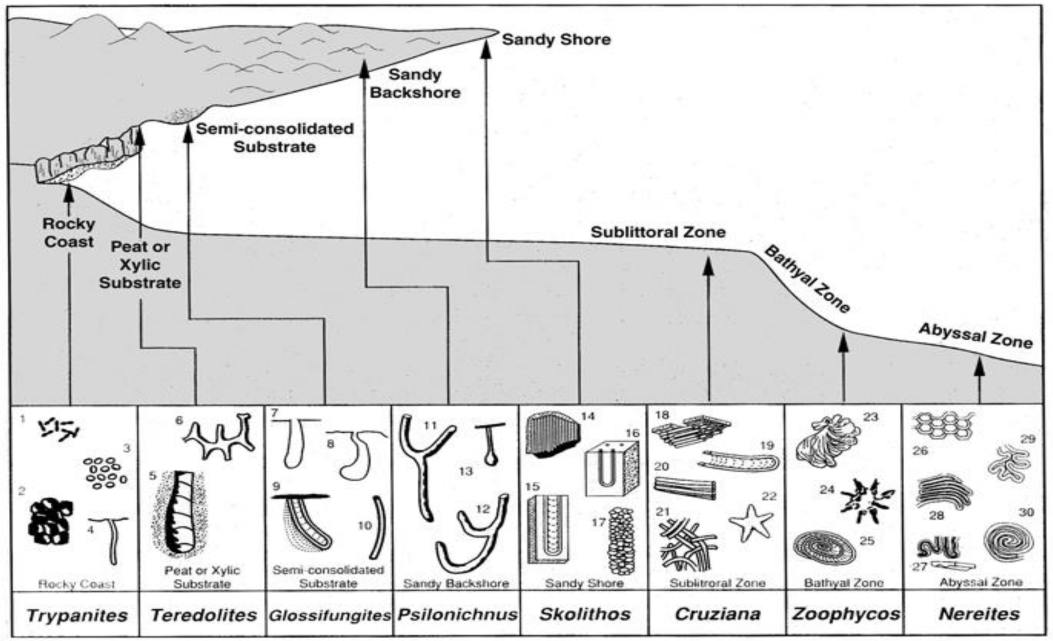


# Thin Section Facies 6



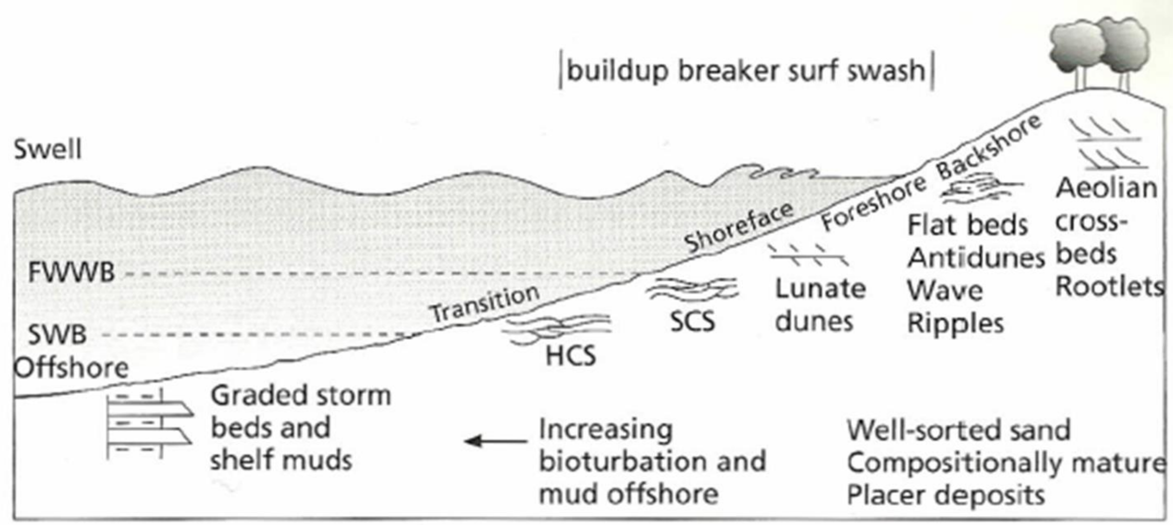
# Depositional Environment




***Distribution of Common Marine Ichnofacies***

Typical trace fossils include: *1) Caulostrepsis; 2) Entobia; 3) echinoid borings; 4) Trypanites; 5) Teredolites; 6) Thalassinoides; 7, 8) Gastrochaenolites or related genera; 9) Diplocraterion (Glossifungites); 10) Skolithos; 11,12) Psilonichnus; 13) Macanopsis; 14) Skolithos; 15) Diplocraterion; 16) Arenicolites; 17) Ophiomorpha; 18) Phycodes; 19) Rhizocorallium; 20) Teichichnus; 21) Planolites; 22) Asteriacites; 23) Zoophycos; 24) Lorenzinia; 25) Zoophycos; 26) Paleodictyon; 27) Taphrhelminthopsis; 28) Helminthoida; 29) Cosmorhaphe; 30) Spirorhaphe.*

Seilacher, 2007

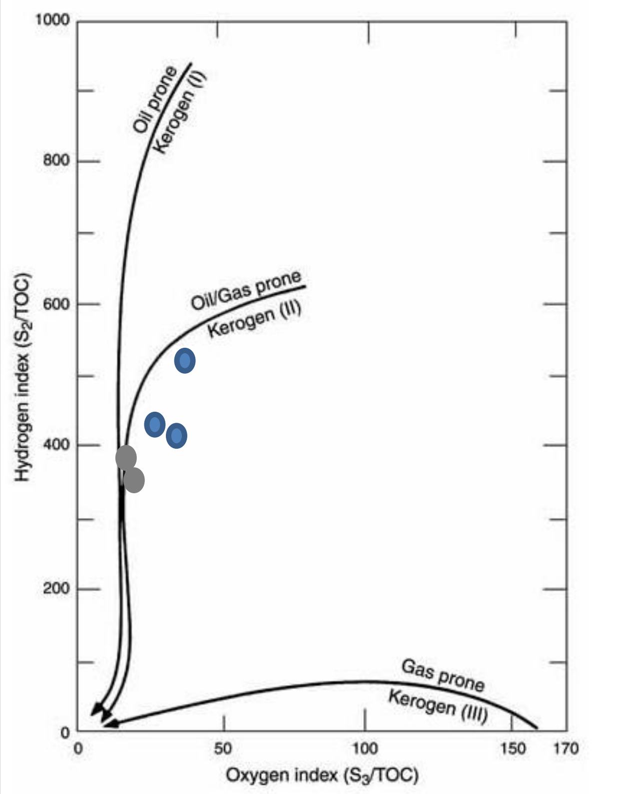



Tucker, 2007

# SRA Niobrara C Marl & Greenhorn Limestone

| Sample ID | | | | | | Source Rock Analyses | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project / Sample ID | Rock ID | Well Name | Formation Name | Upper Depth (ft) | Sample Type | Percent Carbonate (wt%) | Leco TOC (wt%) | HAWK S1 (mg HC/g) | HAWK S2 (mg HC/g) | HAWK S3 (mg CO2/g) | HAWK Tmax (°C) | Calculated %Ro (RE TMAX) | Hydrogen Index (S2x100/TOC) | Oxygen Index (S3x100/TOC) | S2/S3 Conc. (mg HC/mg CO2) | S1/TOC Norm. Oil Content | Production Index (S1/(S1+S2)) |
| RHOG-191001-001 | 1-1 GM | Cain 16-63-2-11-1CH | Niobrara C Marl | 7,475.00 | Core Chunk | 33.59 | 1.79 | 0.48 | 7.77 | 0.35 | 425 | 0.49 | 434 | 20 | 22 | 27 | 0.06 |
| RHOG-191001-002 | 1-2 GM | Cain 16-63-2-11-1CH | Niobrara C Marl | 7,508.30 | Core Chunk | 31.56 | 1.43 | 0.43 | 5.73 | 0.39 | 427 | 0.53 | 401 | 27 | 15 | 30 | 0.07 |
| RHOG-191001-003 | 1-3 GM | Cain 16-63-2-11-1CH | Niobrara C Marl | 7,530.10 | Core Chunk | 54.68 | 1.72 | 0.49 | 8.90 | 0.60 | 425 | 0.49 | 517 | 35 | 15 | 28 | 0.05 |
| RHOG-191001-004 | 1-4 GM | Cain 16-63-2-11-1CH | Codell Sandstone | 7,648.80 | Core Chunk | | | | | | | | | | | | |
| RHOG-191001-005 | 1-5 GM | Cain 16-63-2-11-1CH | Codell Sandstone | 7,654.50 | Core Chunk | | | | | | | | | | | | |
| RHOG-191001-006 | 1-6 GM | Cain 16-63-2-11-1CH | Greenhorn Limestone | 7,677.00 | Core Chunk | 43.92 | 1.80 | 0.75 | 7.06 | 0.26 | 429 | 0.56 | 392 | 14 | 27 | 42 | 0.10 |
| RHOG-191001-007 | 1-7 GM | Cain 16-63-2-11-1CH | Greenhorn Limestone | 7,679.00 | Core Chunk | 50.49 | 1.51 | 0.44 | 5.64 | 0.28 | 428 | 0.54 | 374 | 19 | 20 | 29 | 0.07 |

- Ro values from Niobrara sidewall cores average values near 0.5 - thermally immature
- Ro values from Greenhorn average near 0.55 – thermally immature
- S1 and S2 peaks indicate low levels of free hydrocarbons and high levels of hydrocarbons that formed during pyrolysis indicating high generating potential
- High HI and low OI indicate marine source
- Tmax below 430 (°C) represents immature organic matter

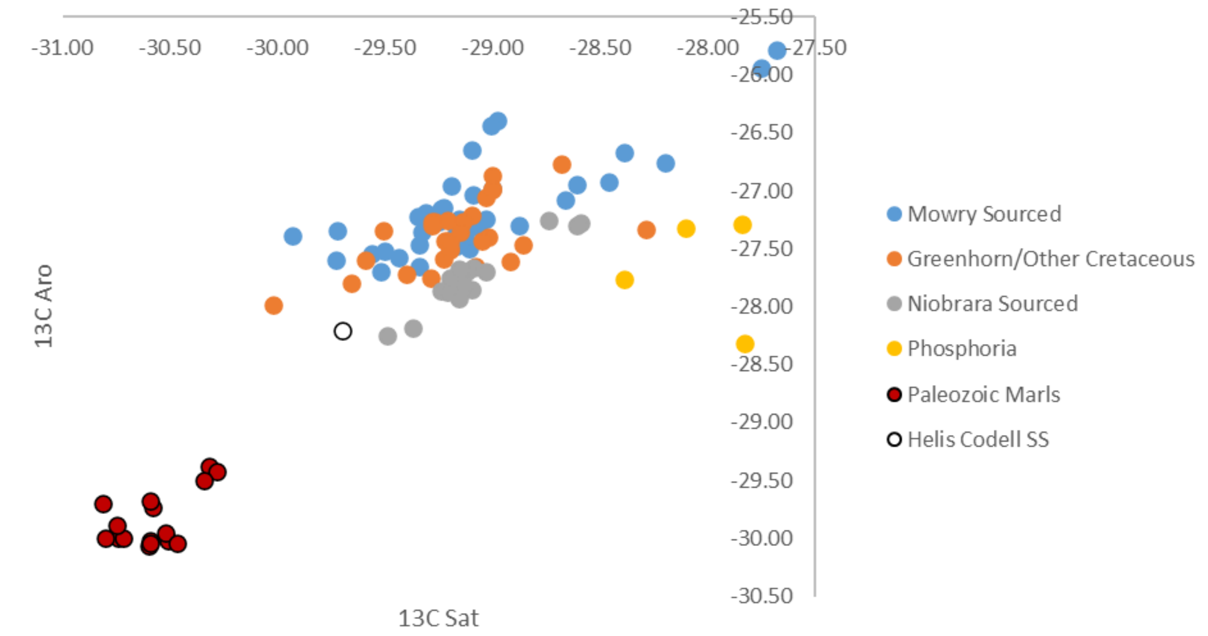


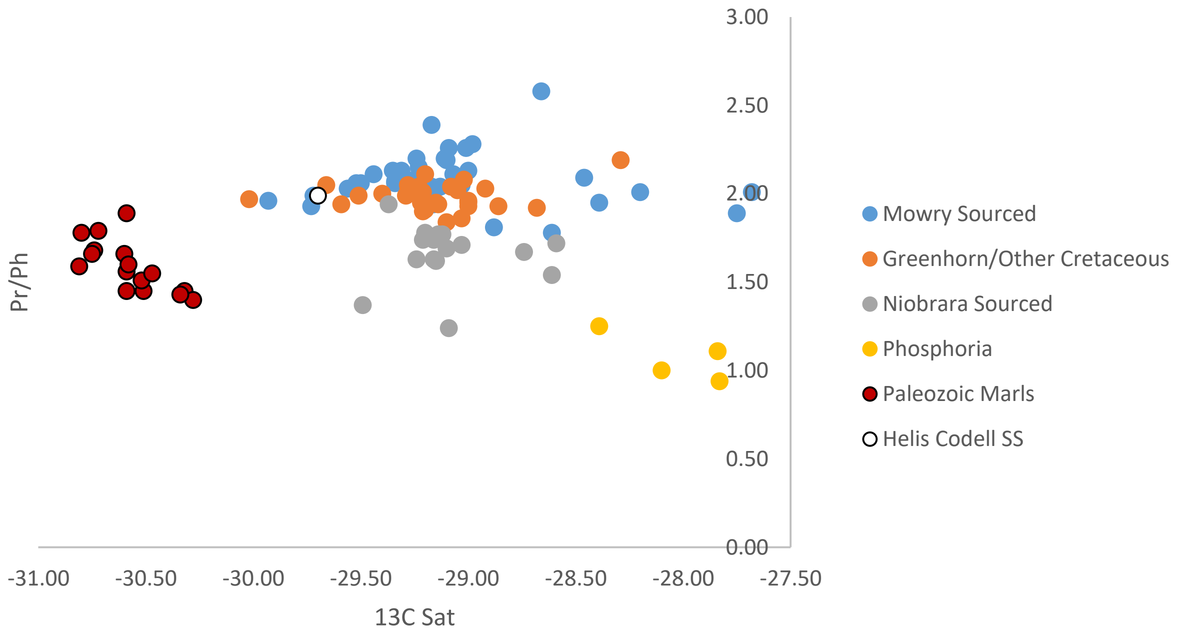

- HI and OI values indicate an oil/gas prone Type II kerogen source
- PI < 0.1 indicates thermally immature

Niobrara
Greenhorn

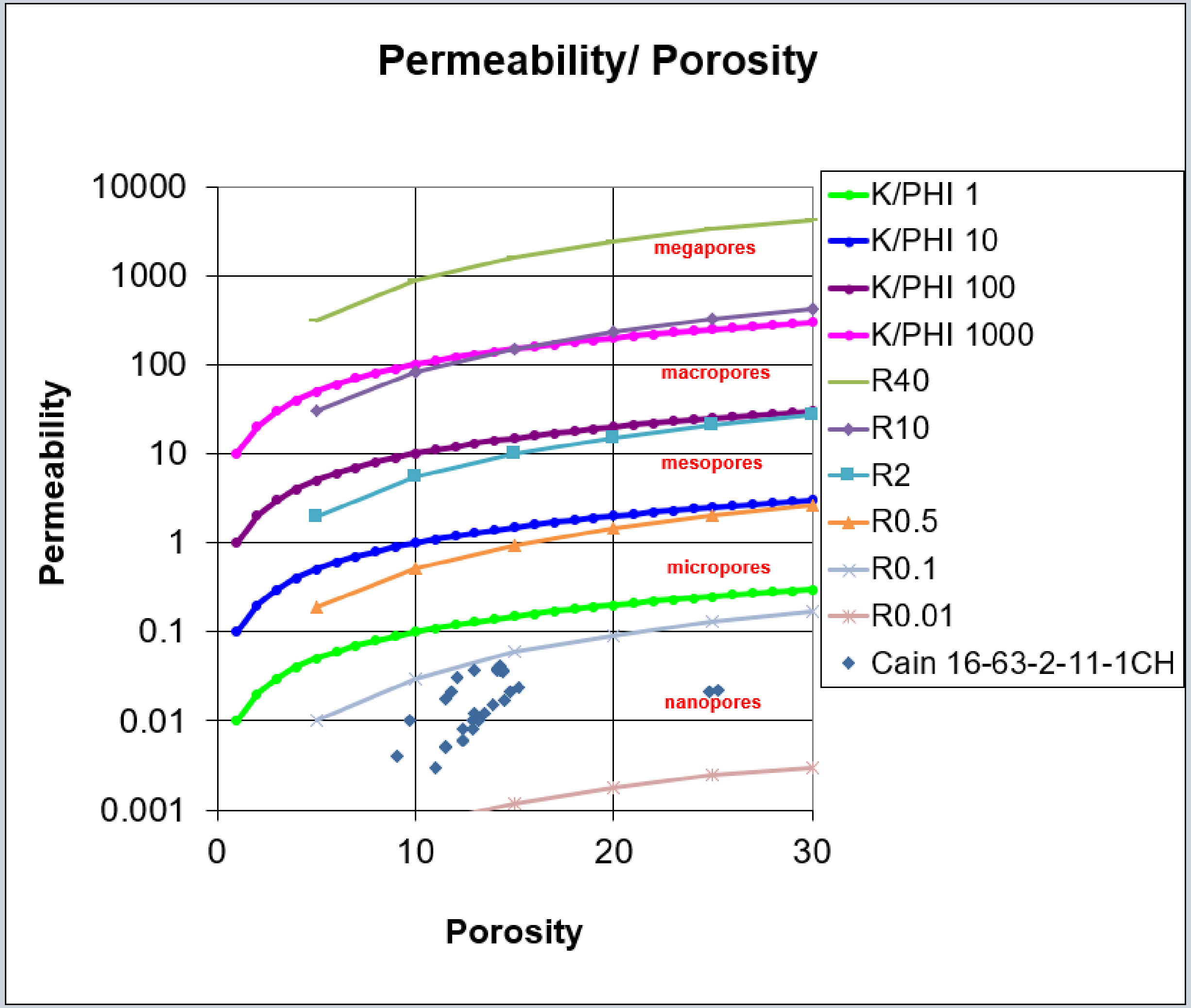
# GeoMark Geochem Analysis

| Oil GC Ratios | Sandberg 16-63-6-31-1CH | Cain 16-32-2-11-1CH | Lerwick 17-63-21-16-1CH |
|---|---|---|---|
| Pristane / Phytane | 1.99 | 2.01 | 1.91 |
| Pristane / n C17 | 0.68 | 0.67 | 0.67 |
| Phytane / n C18 | 0.39 | 0.39 | 0.41 |
| n C18 / (n C18 + n C19) | 0.52 | 0.52 | 0.53 |
| n C17 / (n C17 + n C27) | 0.74 | 0.75 | 0.75 |
| Carbon Preference Index | 1.02 | 1.02 | 1.00 |

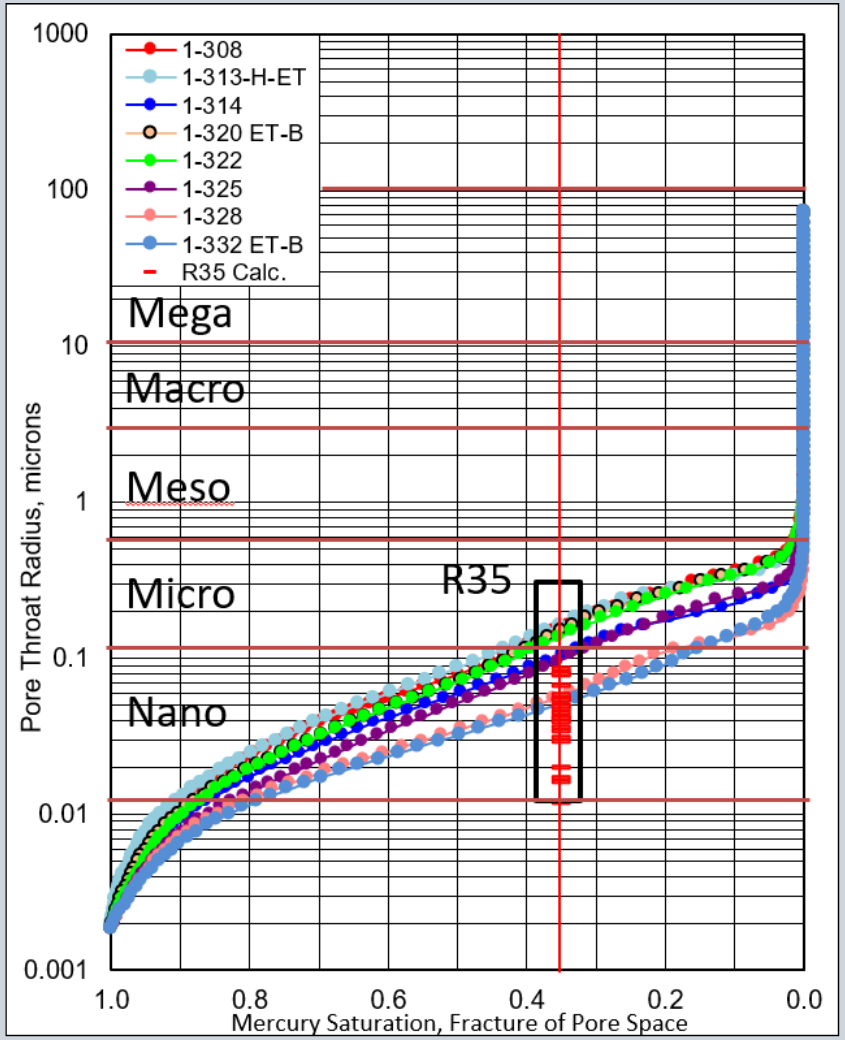


# MICP

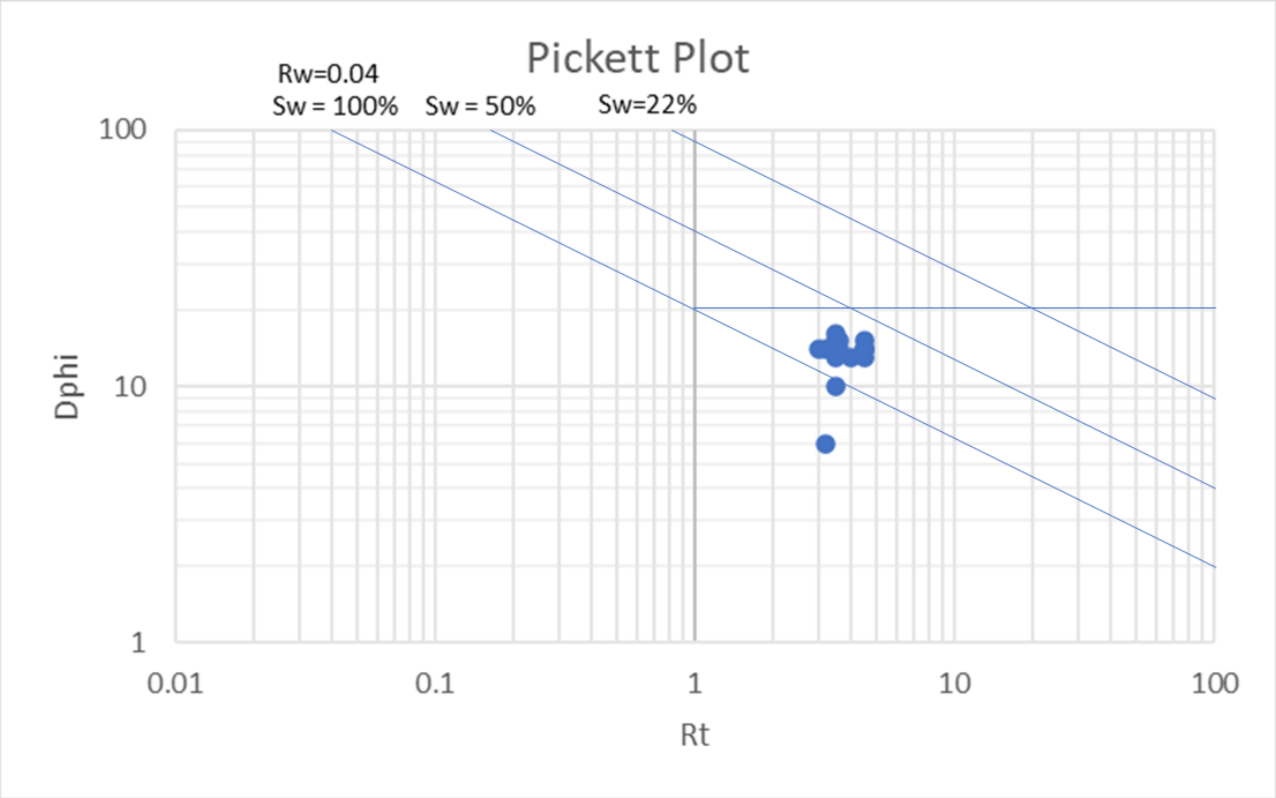


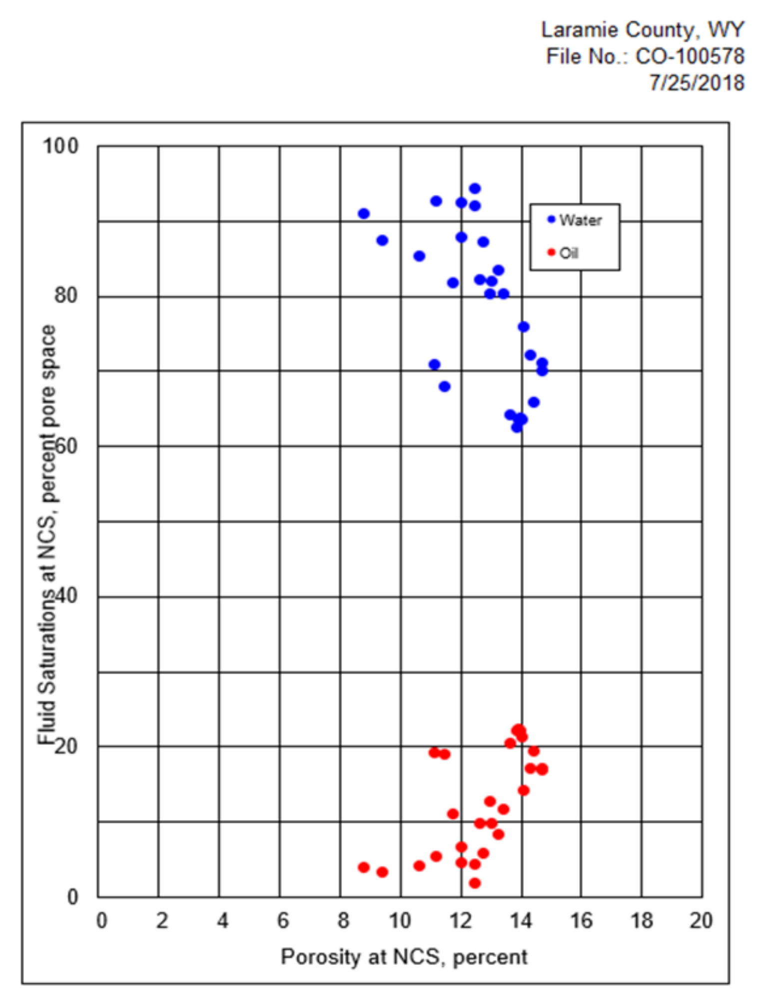
Permeability/ Porosity
Permeability
Porosity
10000
1000
100
10
1
0.1
0.01
0.001
0
10
20
30
megapores
macropores
mesopores
micropores
nanopores
K/PHI 1
K/PHI 10
K/PHI 100
K/PHI 1000
R40
R10
R2
R0.5
R0.1
R0.01
Cain 16-63-2-11-1CH

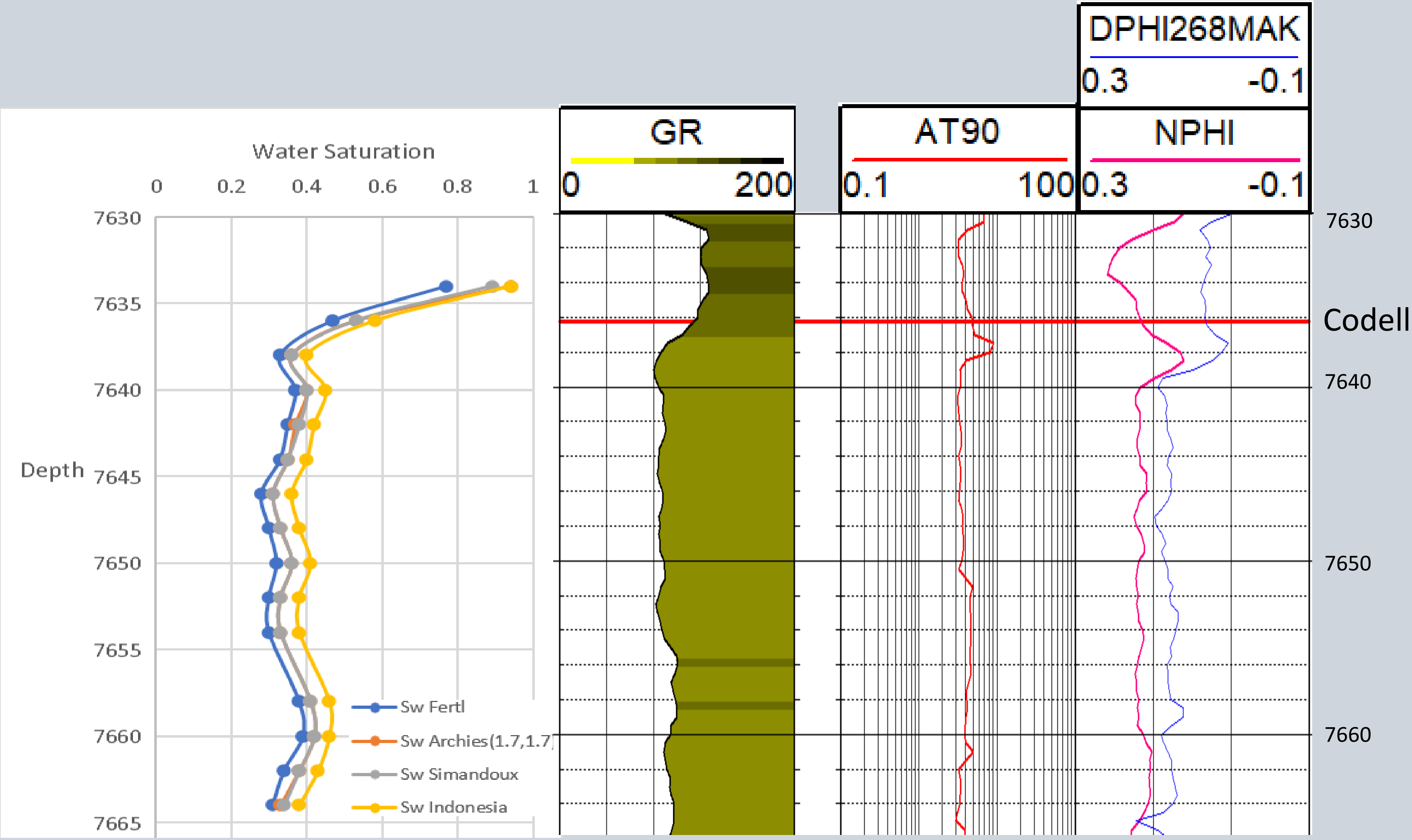
1-308
1-313-H-ET
1-314
1-320 ET-B
1-322
1-325
1-328
1-332 ET-B
R35 Calc.
Mega
Macro
Meso
Micro
Nano
R35
Pore Throat Radius, microns
1000
100
10
1
0.1
0.01
0.001
1.0
0.8
0.6
0.4
0.2
0.0
Mercury Saturation, Fracture of Pore Space

# Water Saturation

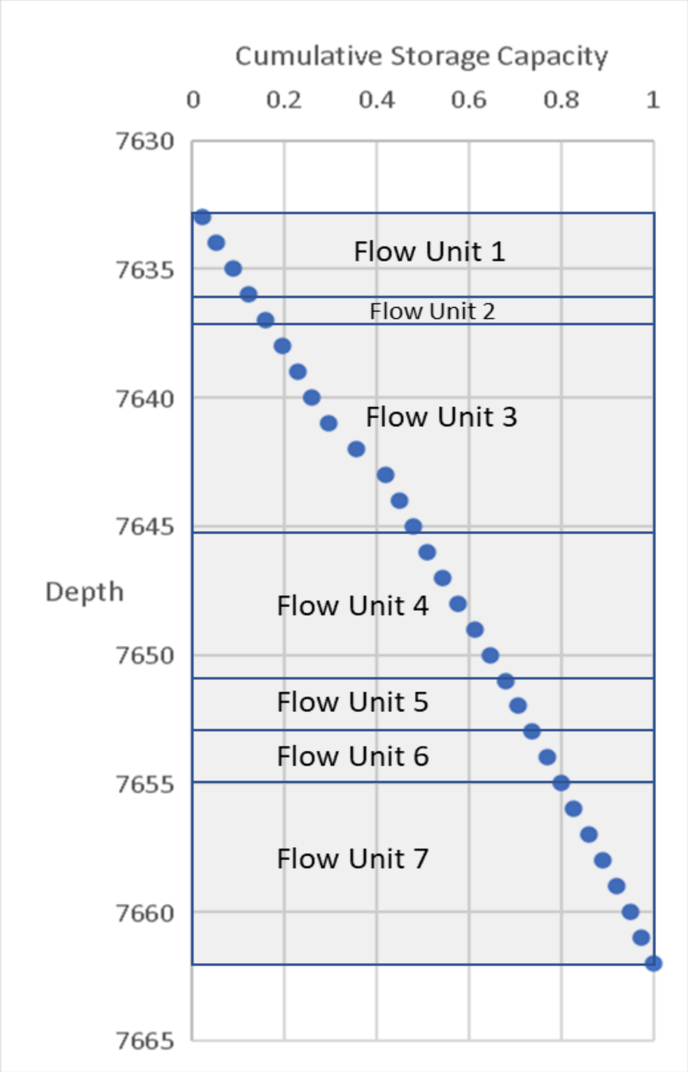


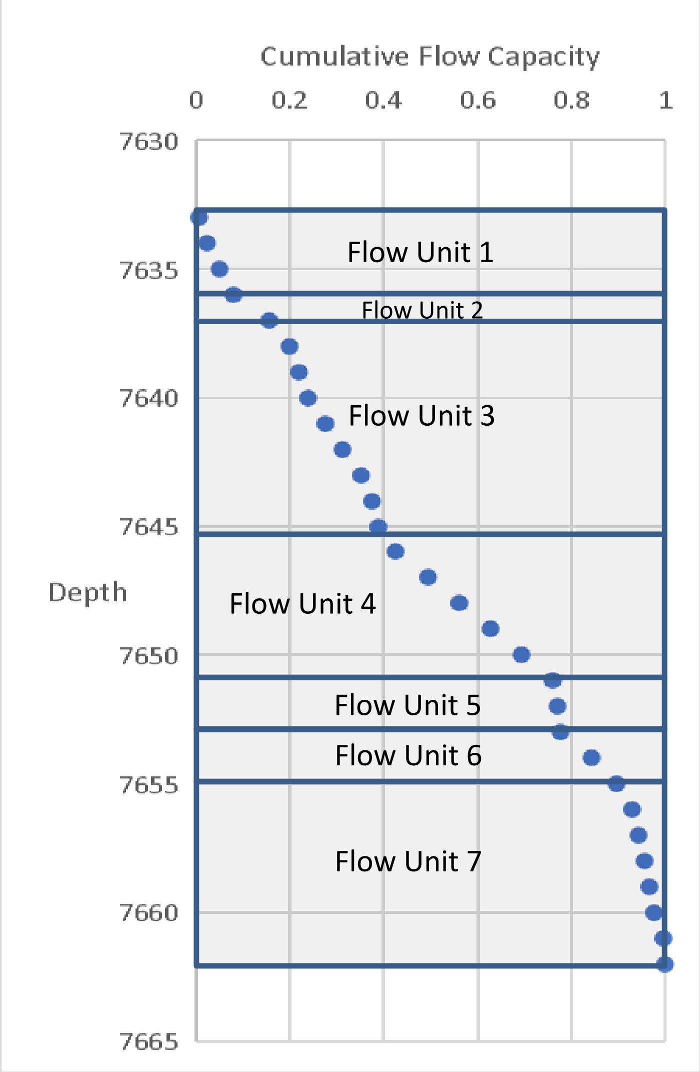



# Water Saturation Calculations

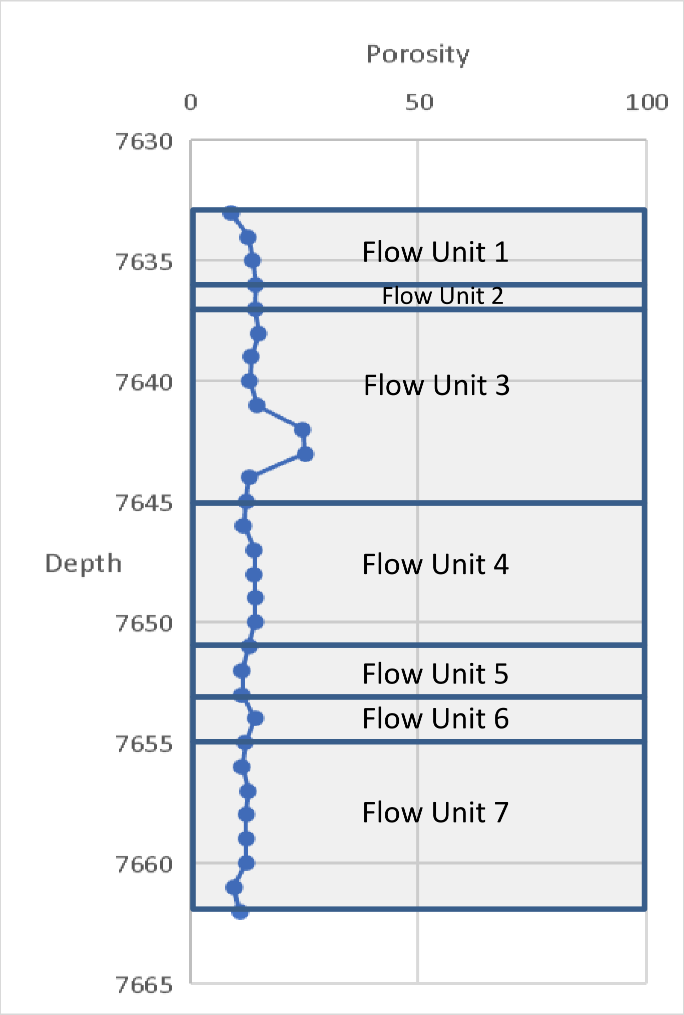


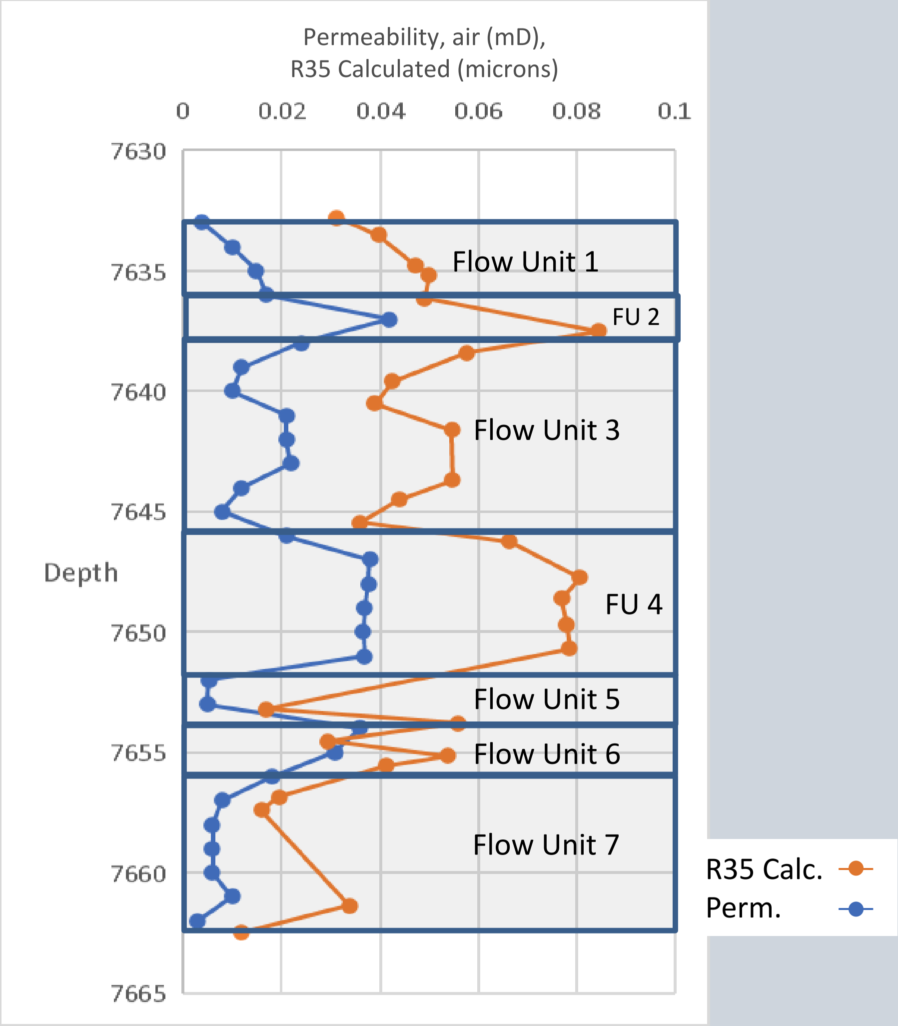
# Flow Capacity and Storage Capacity Vs. Depth



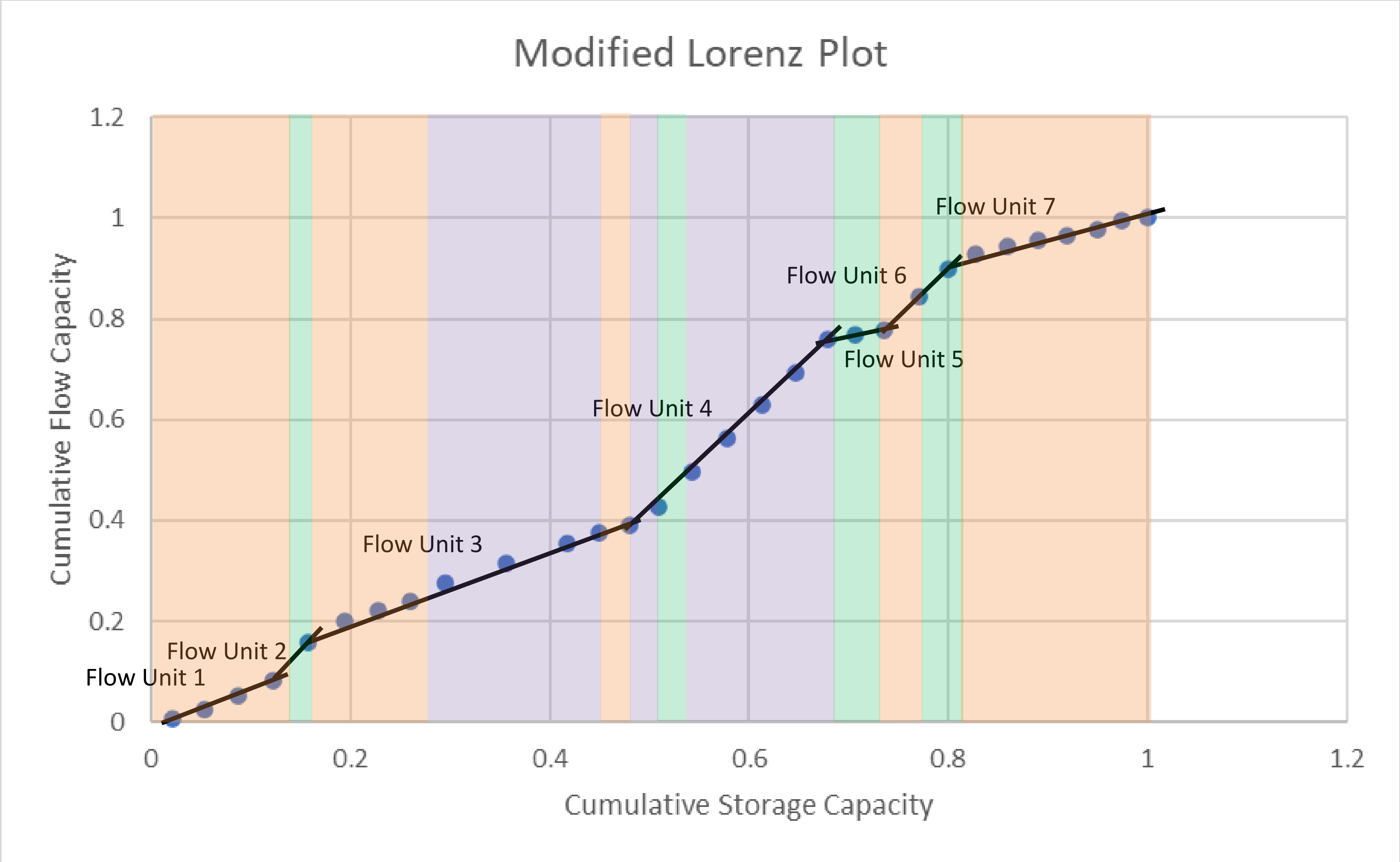



# Porosity and Permeability Vs. Depth



# Flow Units




F4, Sandy Siltstone

F5, Low Angle Cross Strat.

F6, Sandy Siltstone, Higher Sand Content

# Conclusions

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- NE Silo Field shows good production potential based on production data and geologic reservoir characterization techniques.
- Six distinct facies were identified in the Sage Breaks Shale and Codell Sandstone section of the Cain 16-63-2-11-1CH core based on sedimentary structure and differing sand to clay percentages.
- Facies 5 and 6 show the highest amount of intergranular porosity, as well as oil staining.
- Total porosity is consistent through the core; Permeability is the main factor contributing to better flow units.
- Source rock analyses indicate a working petroleum system that is immature in the NE Silo Field area, with oil likely migrating from deeper within the field, with hydrocarbon contributions likely from Niobrara, Greenhorn/other Cretaceous aged source rocks

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