# Reservoir Characteristics and Production Analyses for the Niobrara A Interval at Redtail Field, Weld County, Colorado

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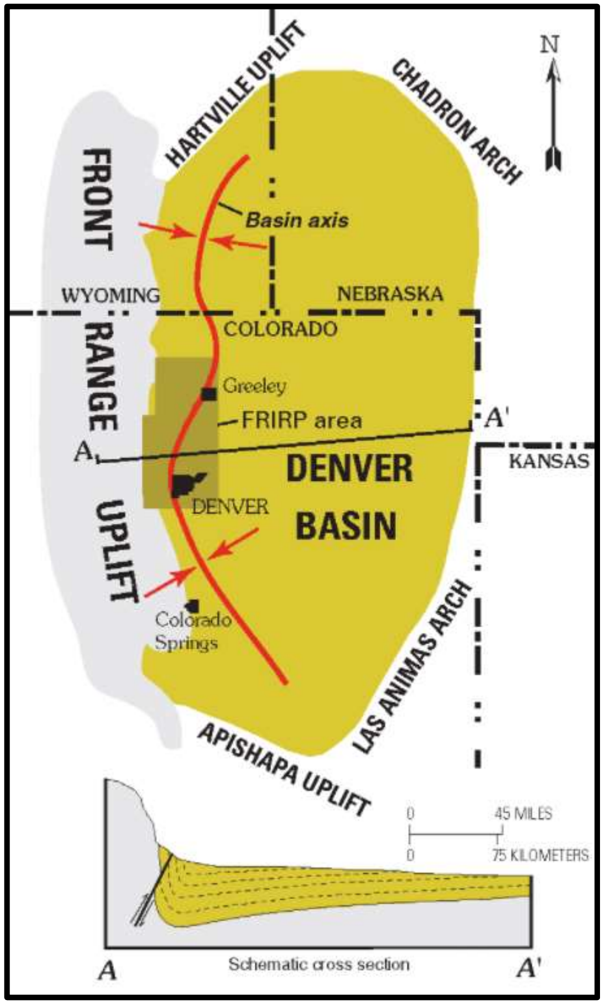
MS Geology

August 2021

# Overview

- Introduction
- Purpose and Objectives
- Research and Methods
- Regional Geology
- Others Previous Work
- Completed Work

# Location and Study Area



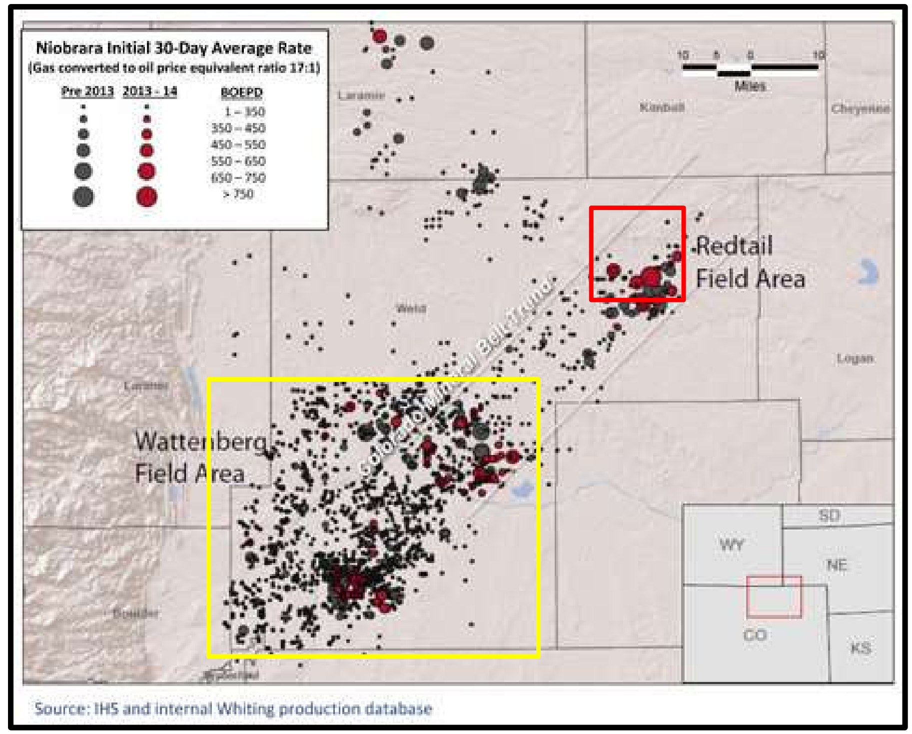

USGS, 2016

Denver Basin bound by:
Hartville Uplift and Chadron Arch to North
North American Craton to East
Apishapa Uplift and Las Animas Arch to South
Front Range Uplift to West

Redtail (and adjacent East Pony Field) are on trend with Wattenberg, but not necessarily continuous.

Why does Redtail Field exist where it is?

Townships: 9N, 10N, 11N
Ranges: 57W, 58W, 59W




Whiting Petroleum, 2014

# Purpose and Objectives

## Purpose:

- Broadly, to summarize the reservoir characteristics and production results of the Niobrara A interval at Redtail Field
  - Lack of understanding of the Niobrara A interval
  - Redtail Field contains nearly all Niobrara A wells in the Denver Basin

## Objectives:

- Better understand the geologic controls on the limits of Redtail Field
- Extend the field model to other areas of the Denver Basin that may be prospective in the Niobrara A

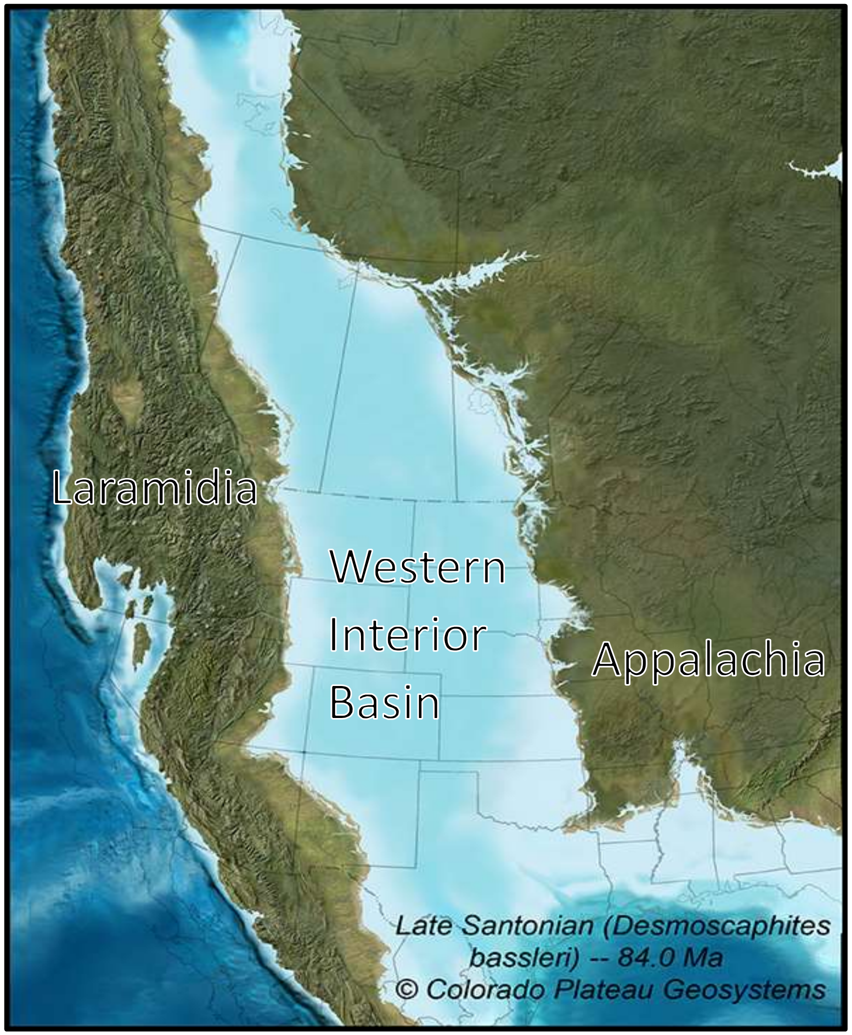
# Research and Methods

- Facies description of the Niobrara A interval in the Razor 25-2514 core
- Core-to-log model in the Razor 25-2514 ($\Phi$, k, $S_o$ and $S_w$, gamma correlations)
- Total organic carbon and pyrolysis analyses to evaluate thermal maturity, kerogen type, and calculate vitrinite reflectance of the Niobrara A interval
- Bottom-hole temperature (BHT) mapping to compare against thermal maturity

# Research and Methods – cont'd

- Calculate OOIP and map values across Redtail
- Calculate EUR values for the Niobrara A interval
- Calculate average recovery factor from current production and total estimated production
- Use EUR values to determine the viability of the Niobrara A interval as a development target

# Regional Geology




- Cretaceous Western Interior Seaway connected Arctic Ocean and Tethys Ocean across the North American continent
- Resultant highstand(s) lasted millions of years
- Inundation allowed carbonate biota to flourish at different times
- Oscillations in water depth and water mixing led to different depositional geometries and environments

Blakey, 2008

# Regional Geology – cont'd


- As Cretaceous Western Interior Seaway withdrew, terrigenous deposition dominated
- Subduction angle transition led to Laramide Orogeny and fracturing of previous Western Interior Basin into smaller basins
- Denver Basin buried to sufficient depth to allow hydrocarbon generation
- Organic-rich mudstones acted as source rocks; chalks acted as reservoirs

Blakey, 2008

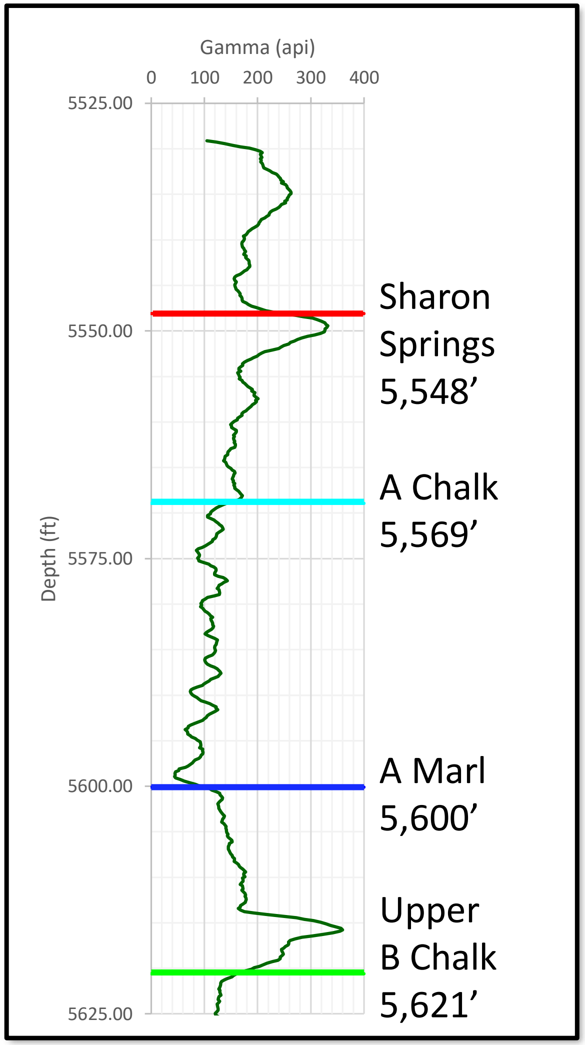
# Others Previous Work

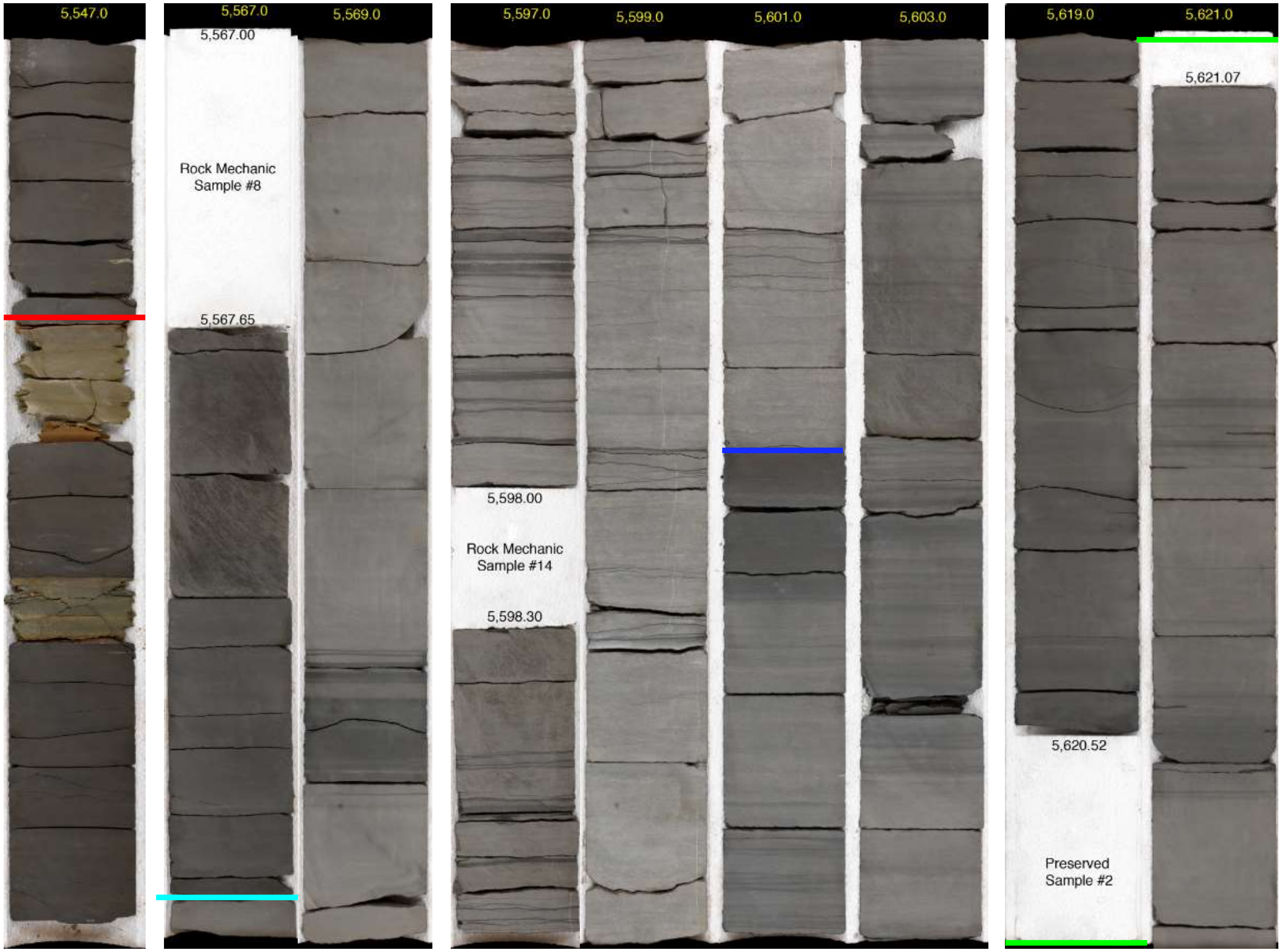
- Niobrara has been studied since the 1950s, publications continue to this day. However, most previous work did not treat the Niobrara A interval, usually due to the interval being non-existent or not having data available
- Pahnke (2014) investigated microporosity in the chalks of the Niobrara Formation, described the types of porosity therein, and explained how porosity changes in relation to burial depth and diagenesis
- ElGhonimy (2015) studied petrophysical, geochemical, mineralogical, and storage capacity of the entire Niobrara Formation and evaluated each bench individually
- Sonnenfeld *et al.* (2015) investigated bentonites within the Niobrara Formation and their impact on proppant placement and effective fracture continuity

# Previous Work – cont'd

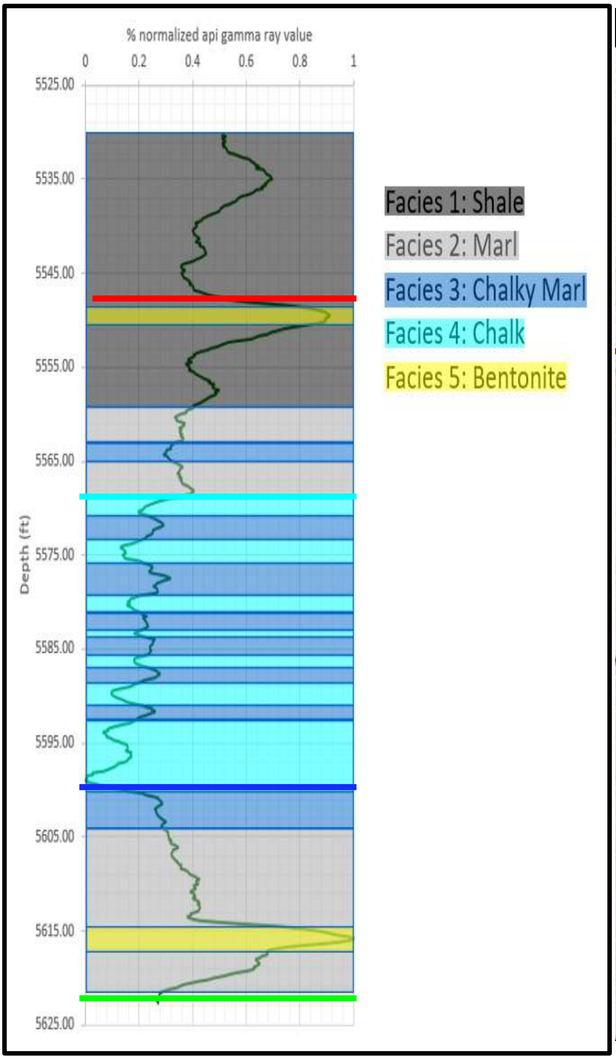
- Zumberge *et al.* (2016) studied hydrocarbon sourcing and movements within the Niobrara Petroleum System
- Aydin (2017) researched the porosity and permeability of each bench of the Niobrara and concluded that the Niobrara A Chalk and A Marl contain the highest porosities and permeabilities of the Niobrara Formation
- Byrnes *et al.* (2017) investigated porosity and permeability in the Niobrara Formation by using digital rock physics to characterize chalk properties
- Deacon and McDonough (2018) studied how producibility of the Niobrara was impacted by depositional and stratigraphic complexities
- Bane (2018) analyzed core and core-associated data, performed geomechanical evaluations in the Niobrara, and evaluated the influence of paleo-high structures on thermal maturity.
- Lopez (2018) characterized peloids and diagenesis exclusively in the Niobrara A Chalk and noted loss of porosity with increased burial depth due to several factors

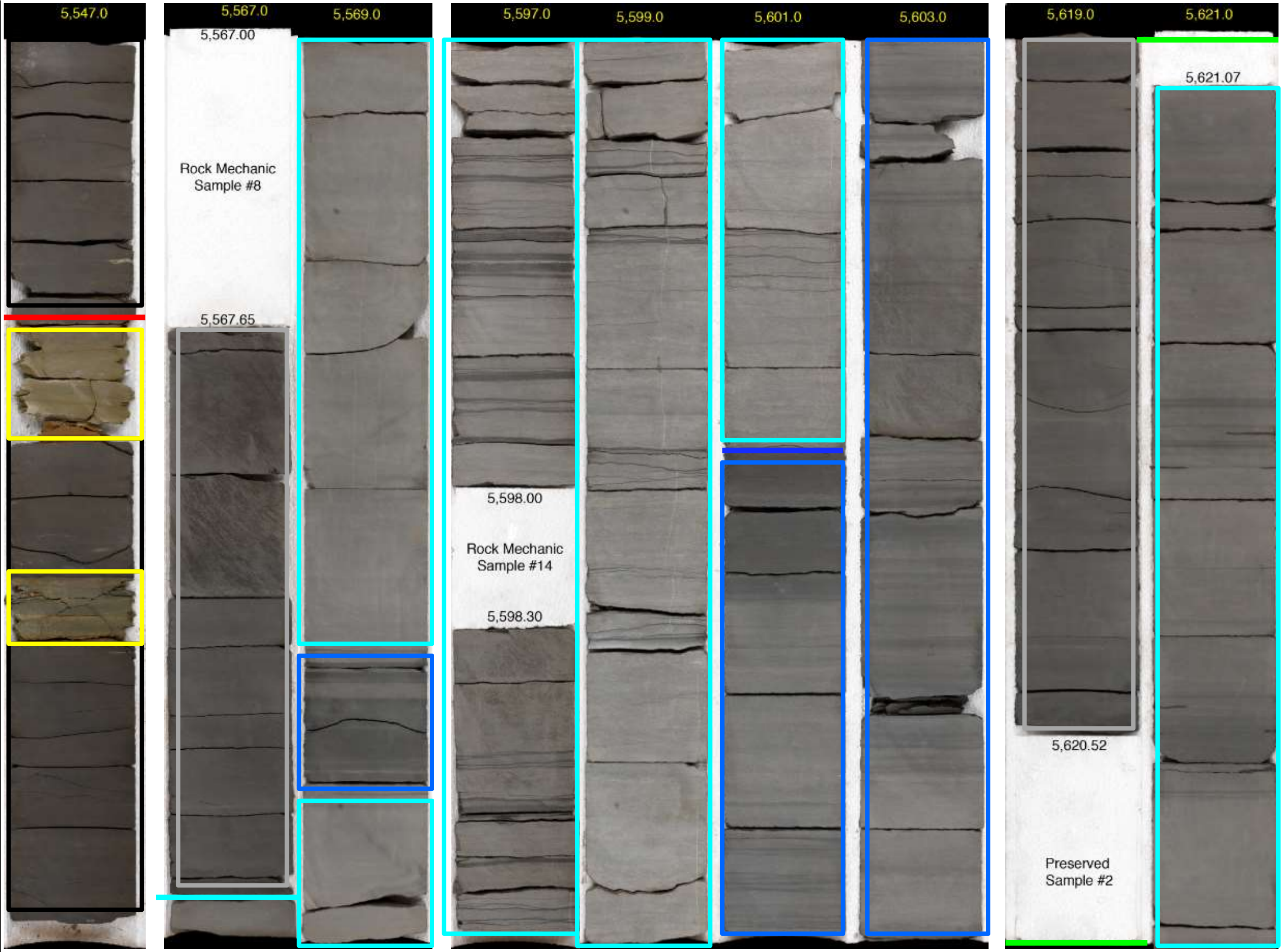
# Type Log and Contacts



# Type Log and Facies Distribution



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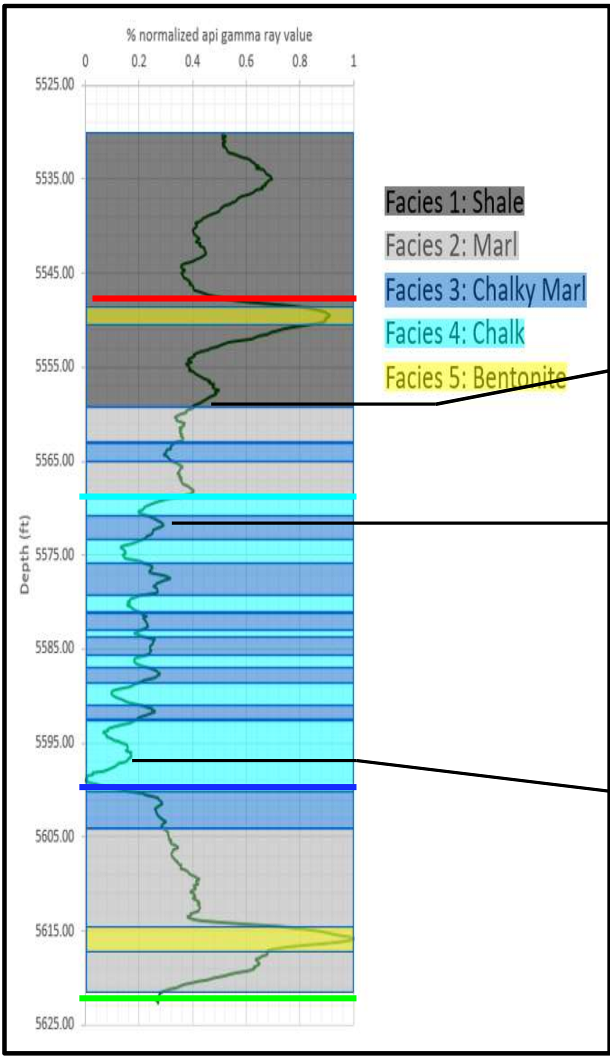
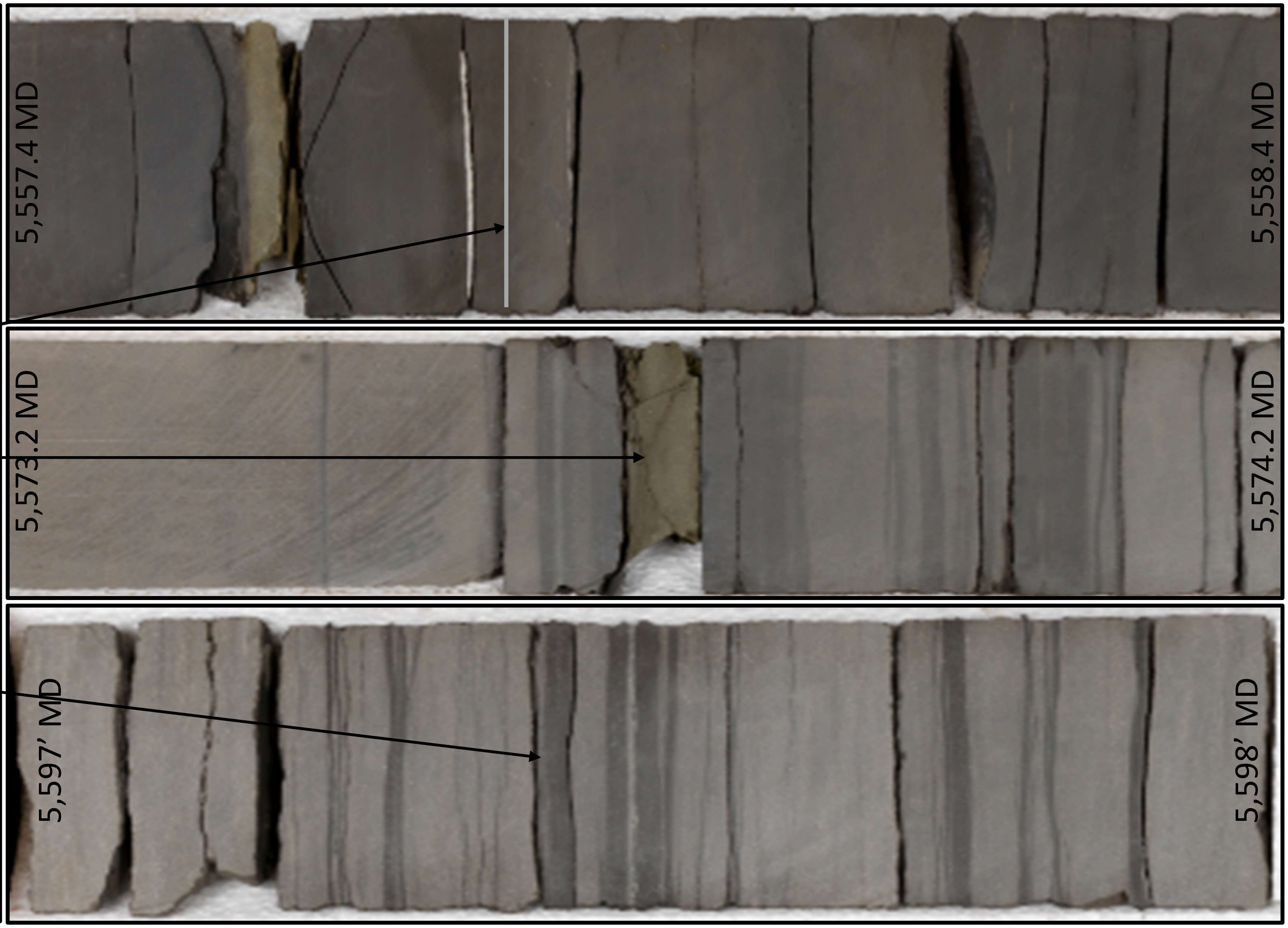
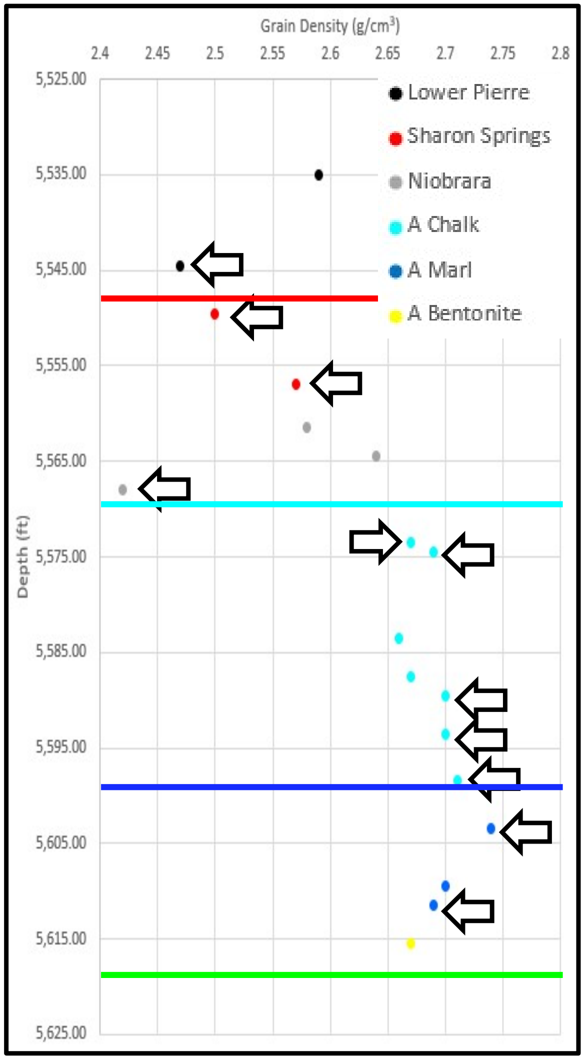
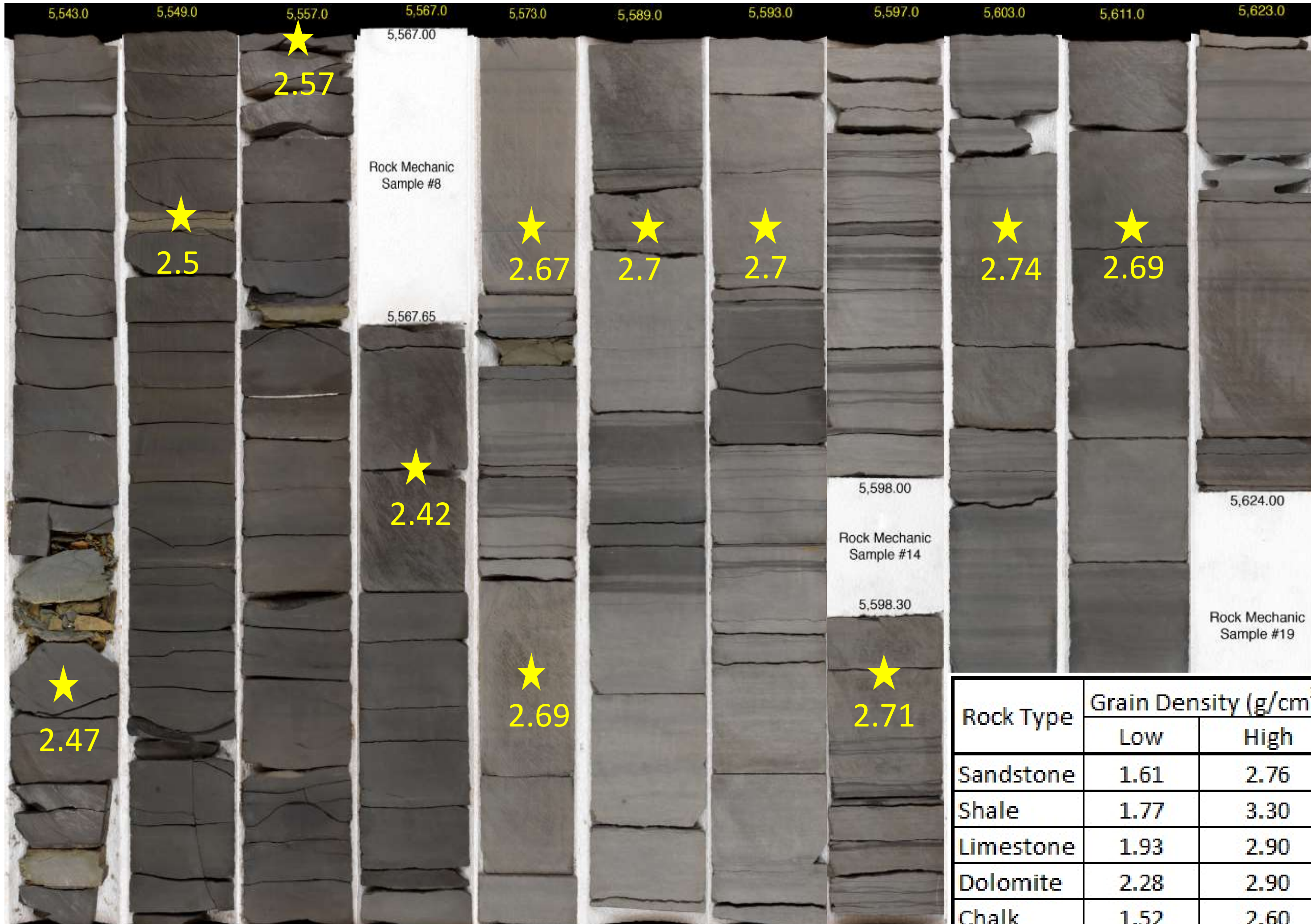


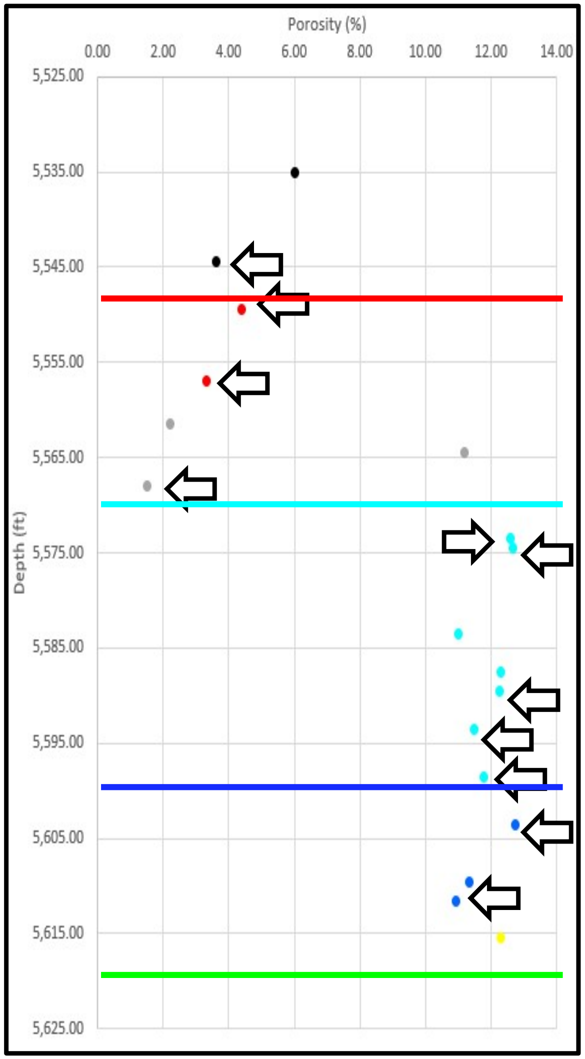
# RCA Sampling – Grain Density

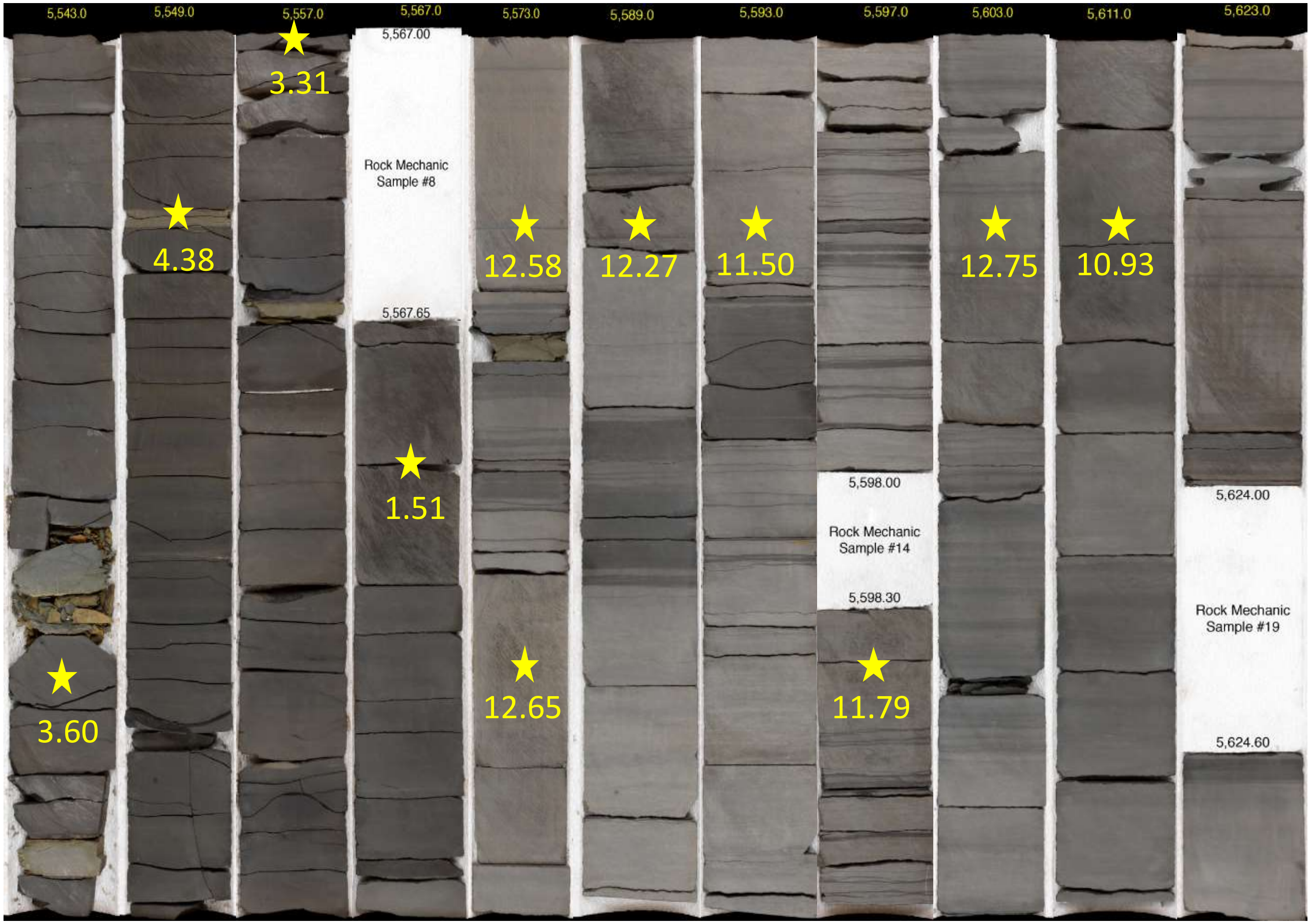


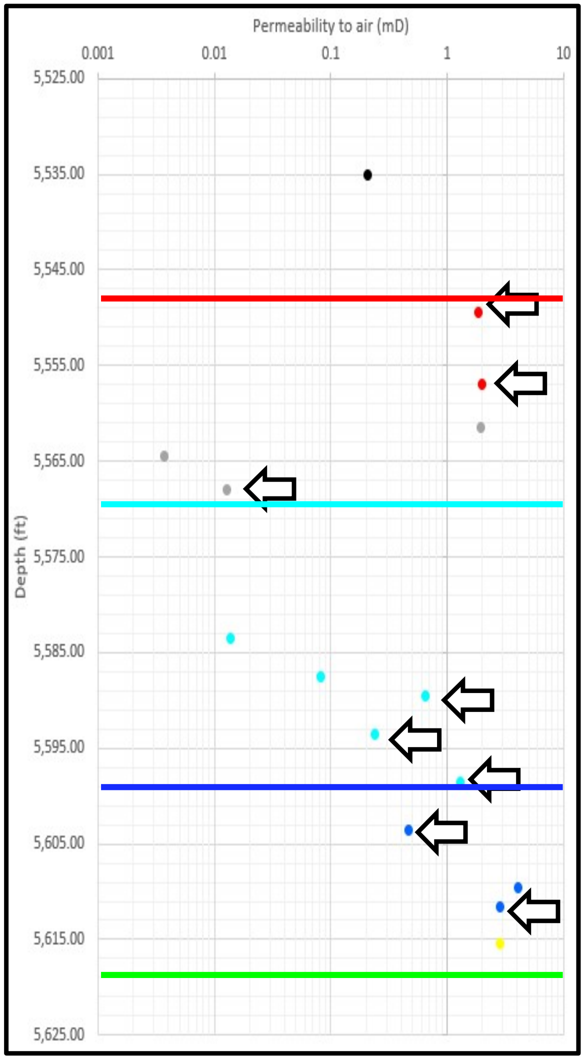

| Rock Type | Grain Density (g/cm³) | |
|---|---|---|
| | Low | High |
| Sandstone | 1.61 | 2.76 |
| Shale | 1.77 | 3.30 |
| Limestone | 1.93 | 2.90 |
| Dolomite | 2.28 | 2.90 |
| Chalk | 1.52 | 2.60 |

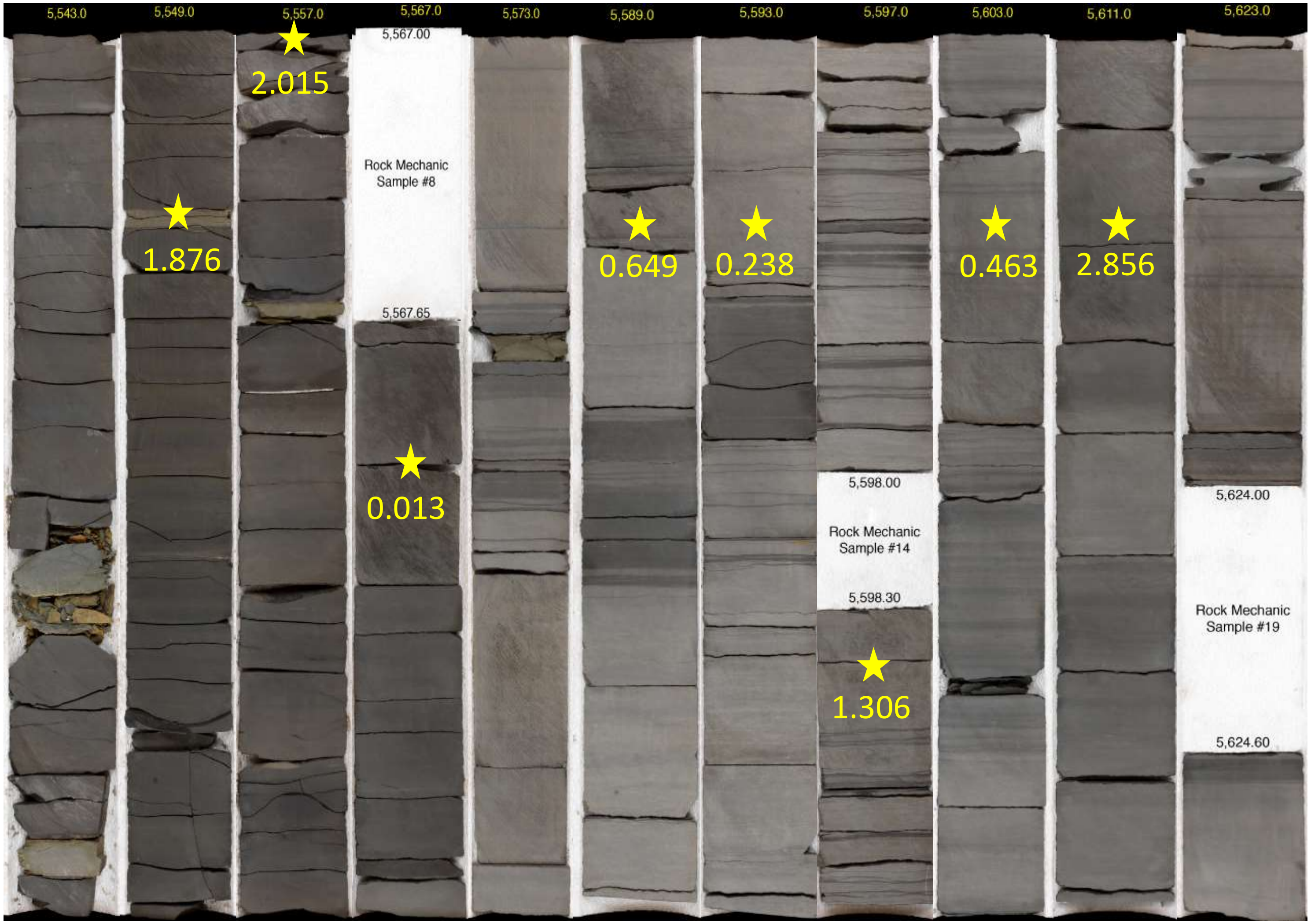
# RCA Sampling – Porosity



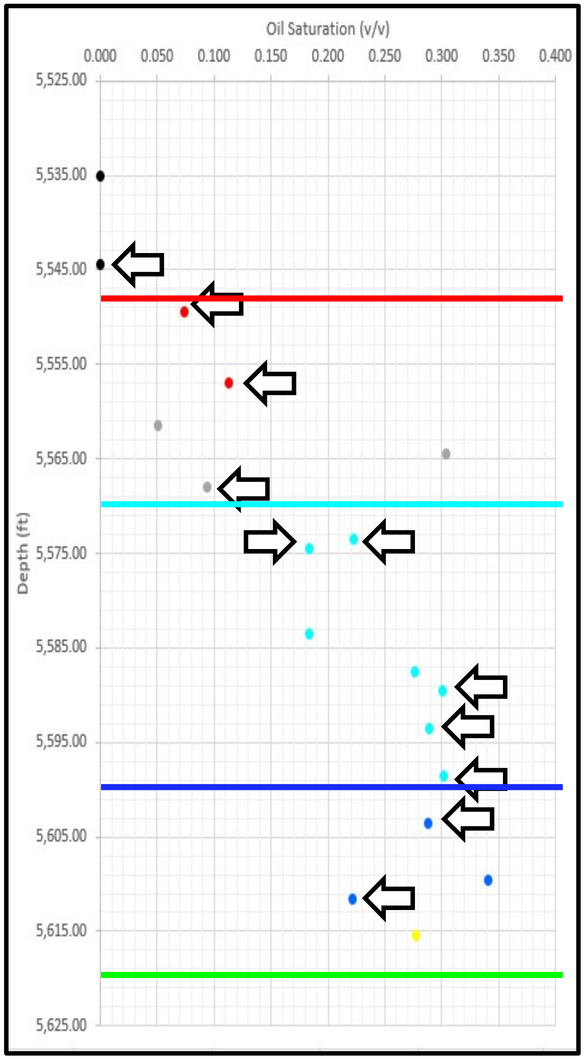



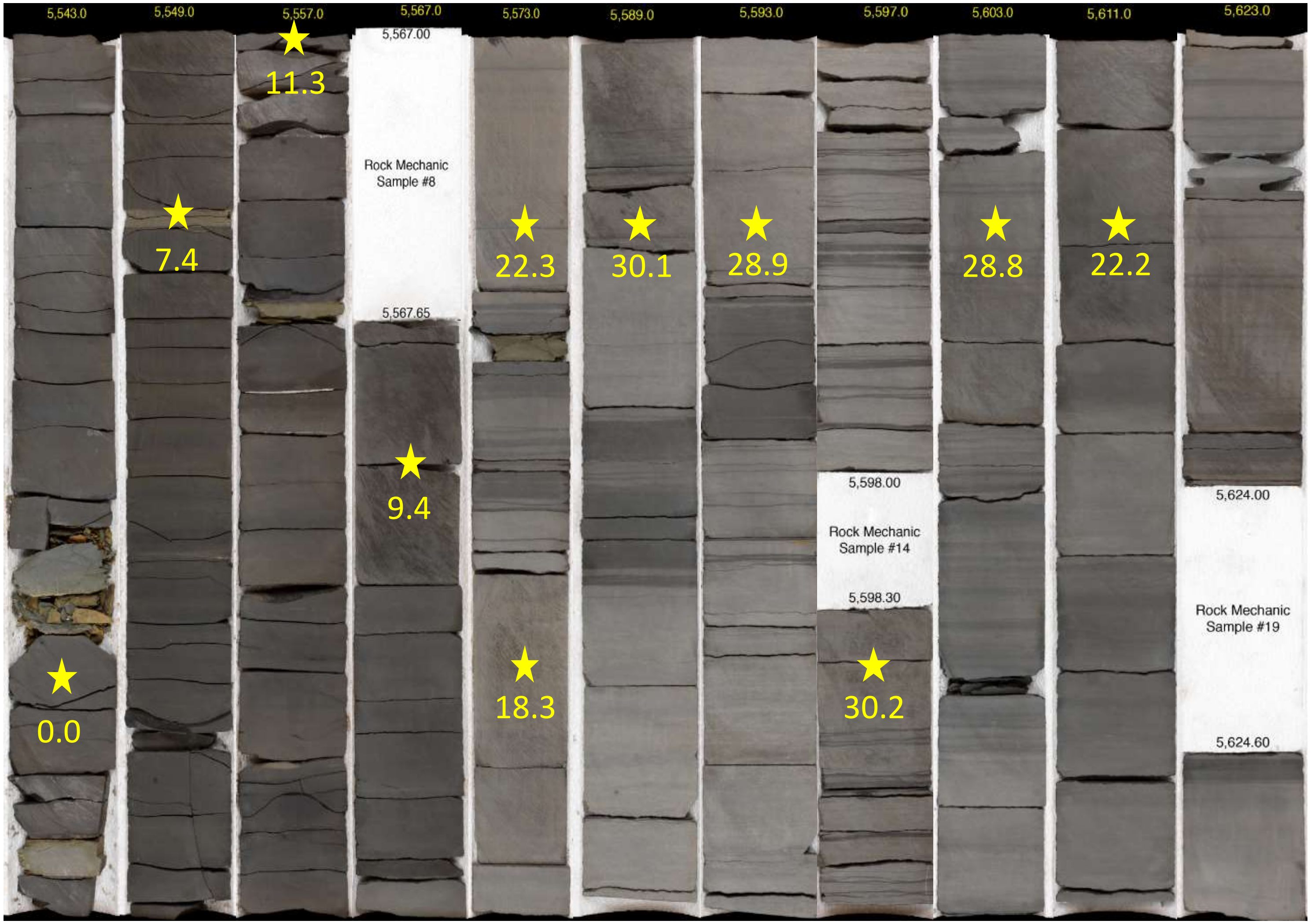
# RCA Sampling – Permeability to air



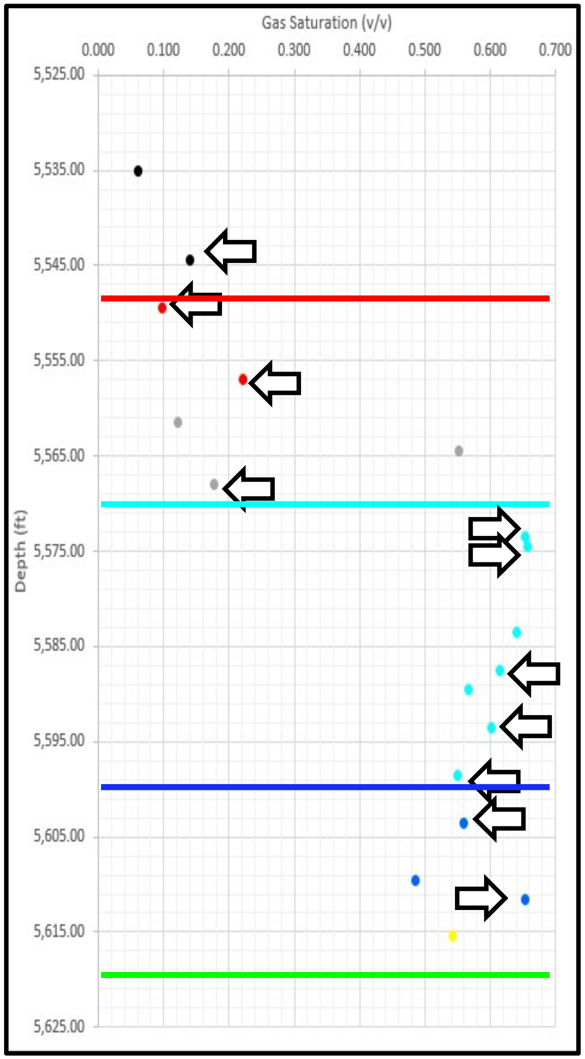



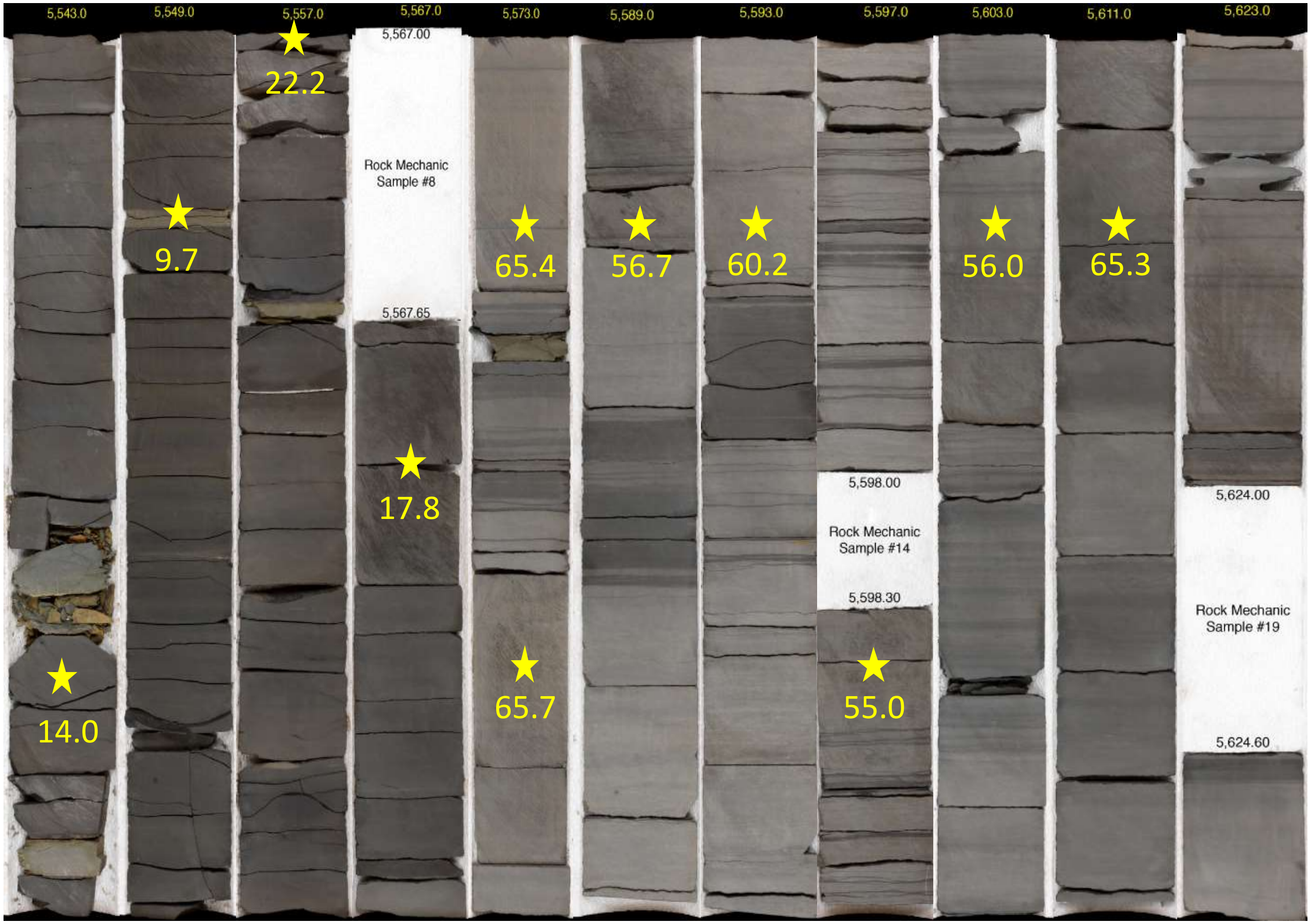
# RCA Sampling – Oil Saturation



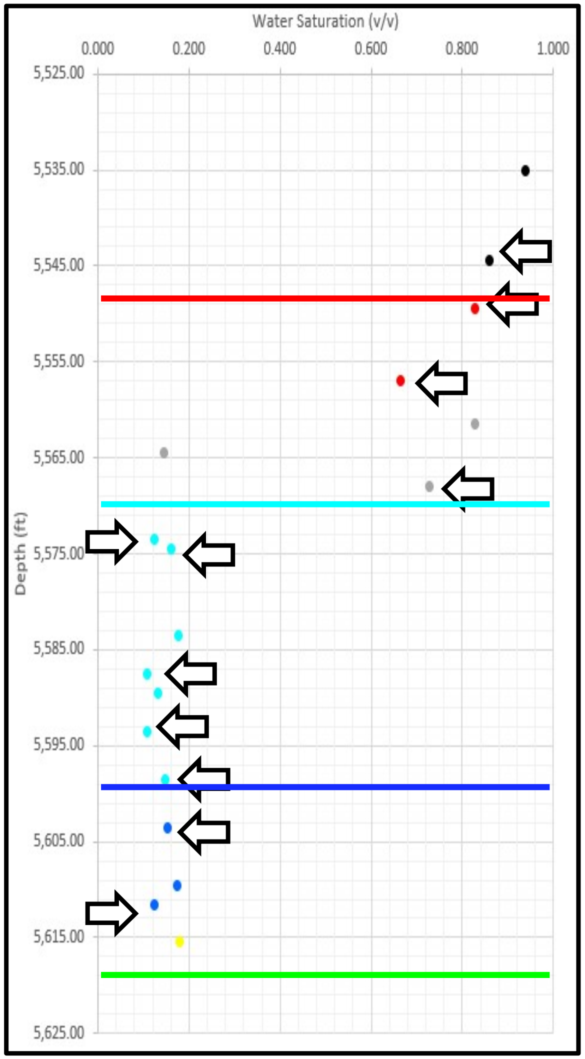



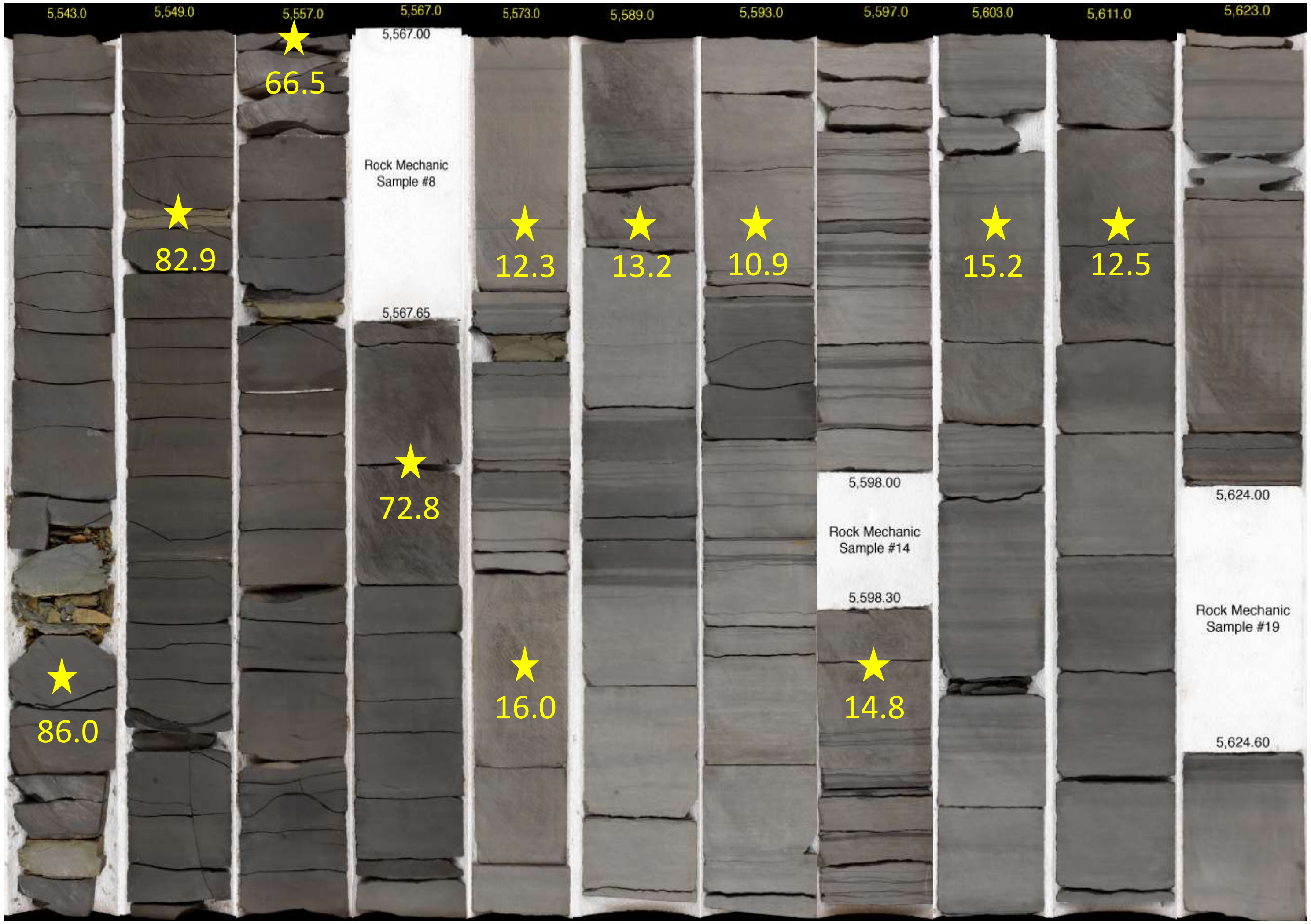
# RCA Sampling – Gas Saturation



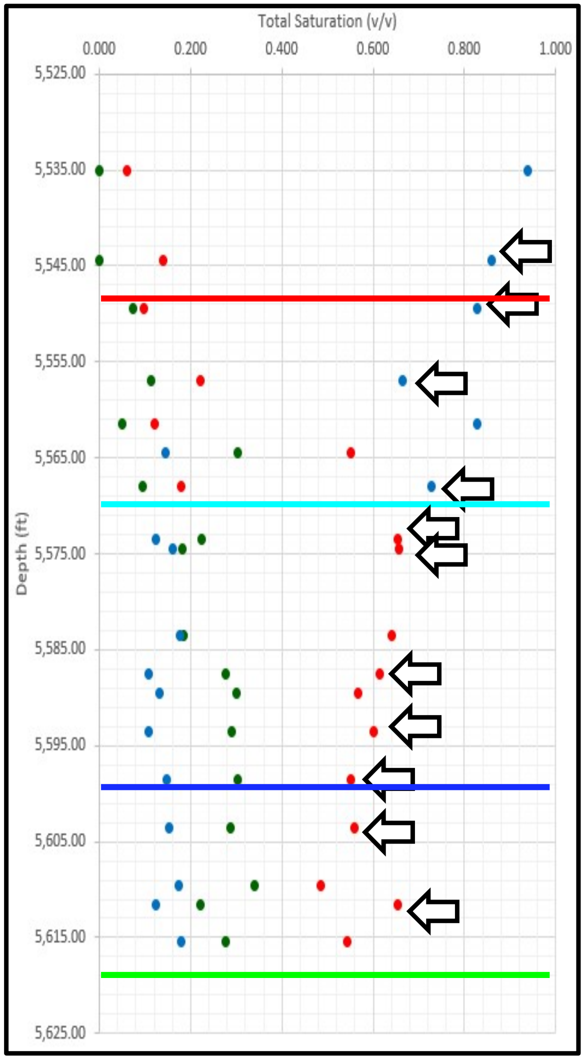



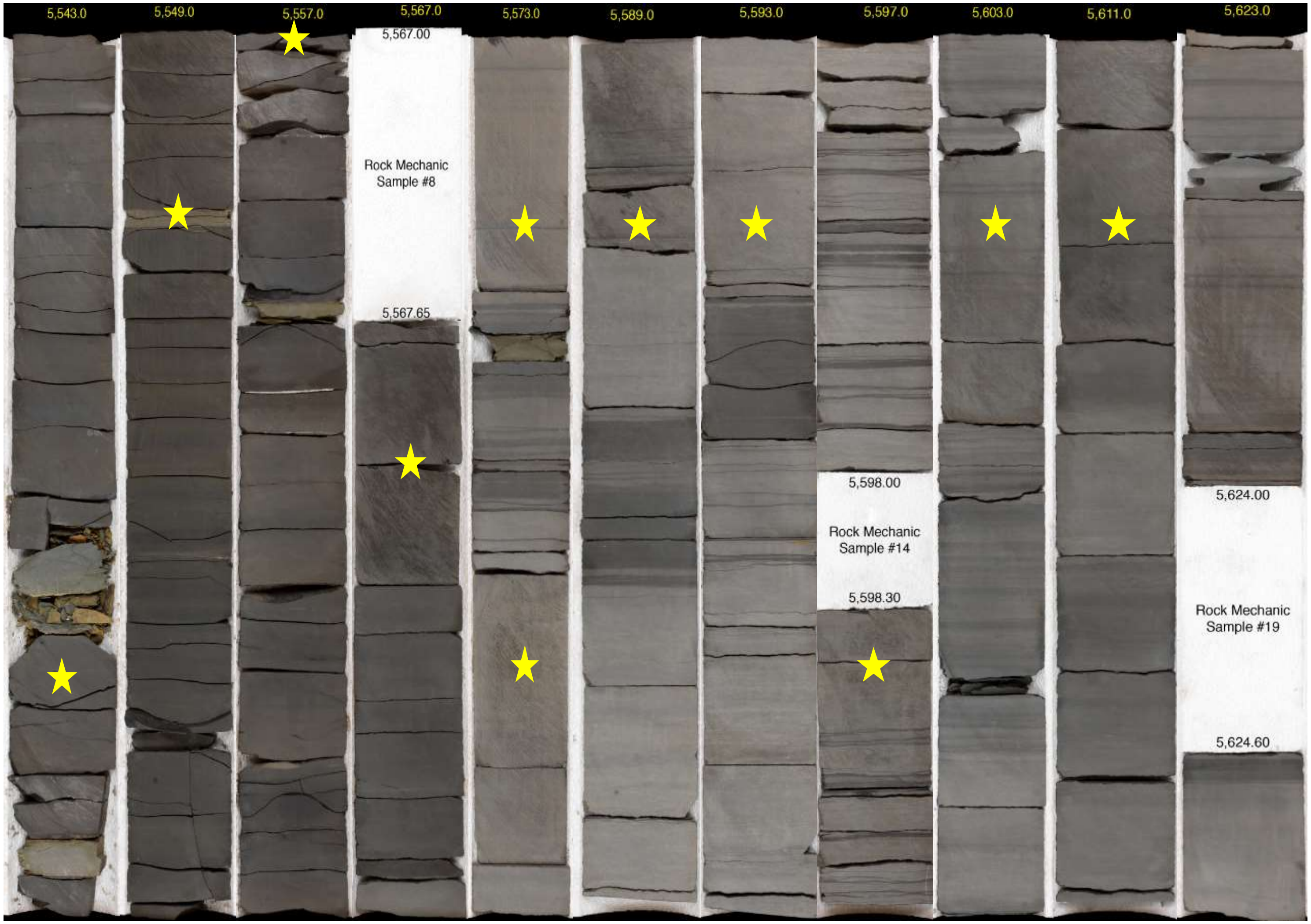
# RCA Sampling – Water Saturation



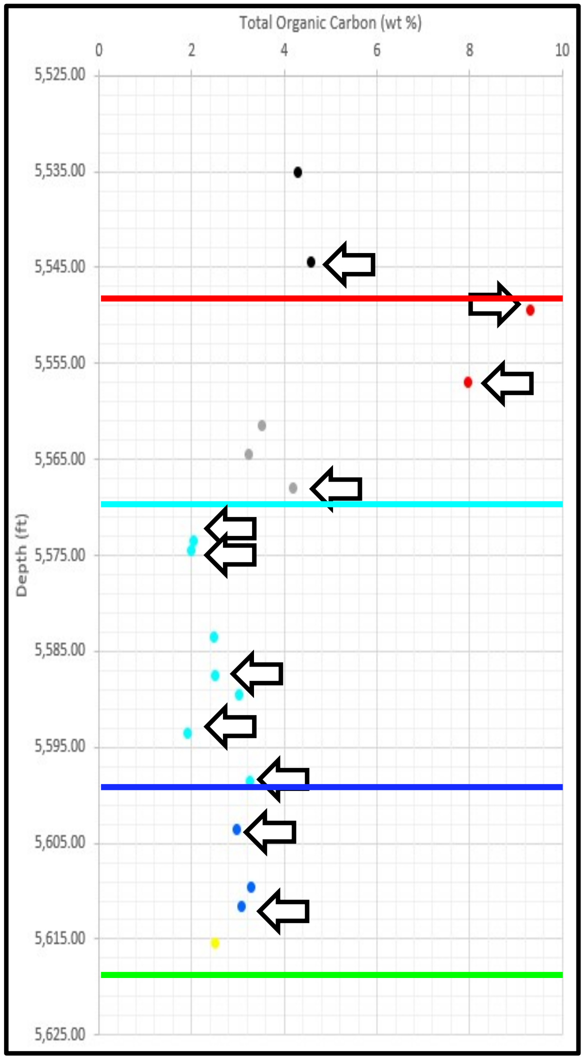



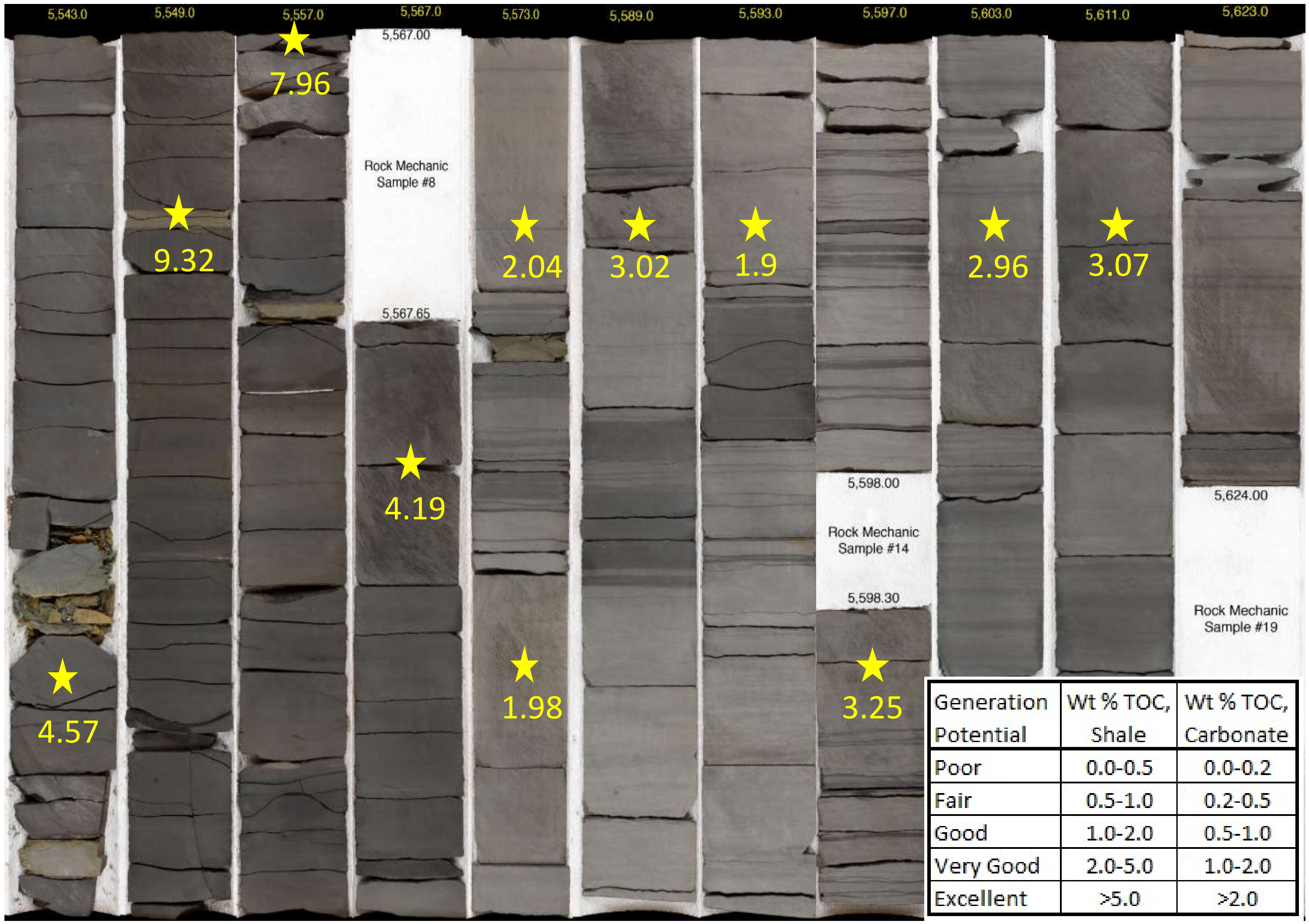
# RCA Sampling – Total Saturations



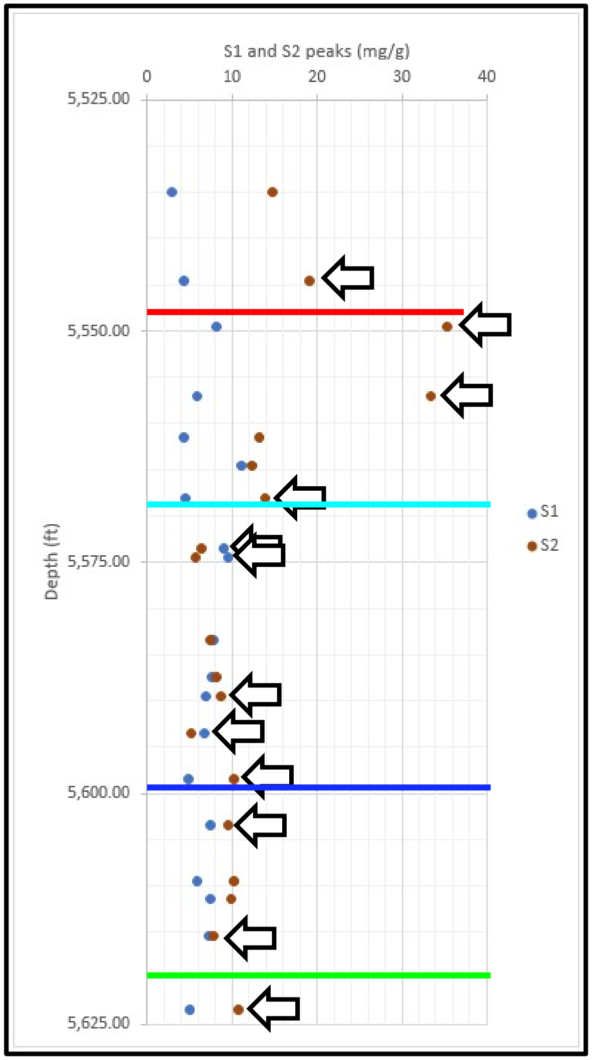
# TOC Samples

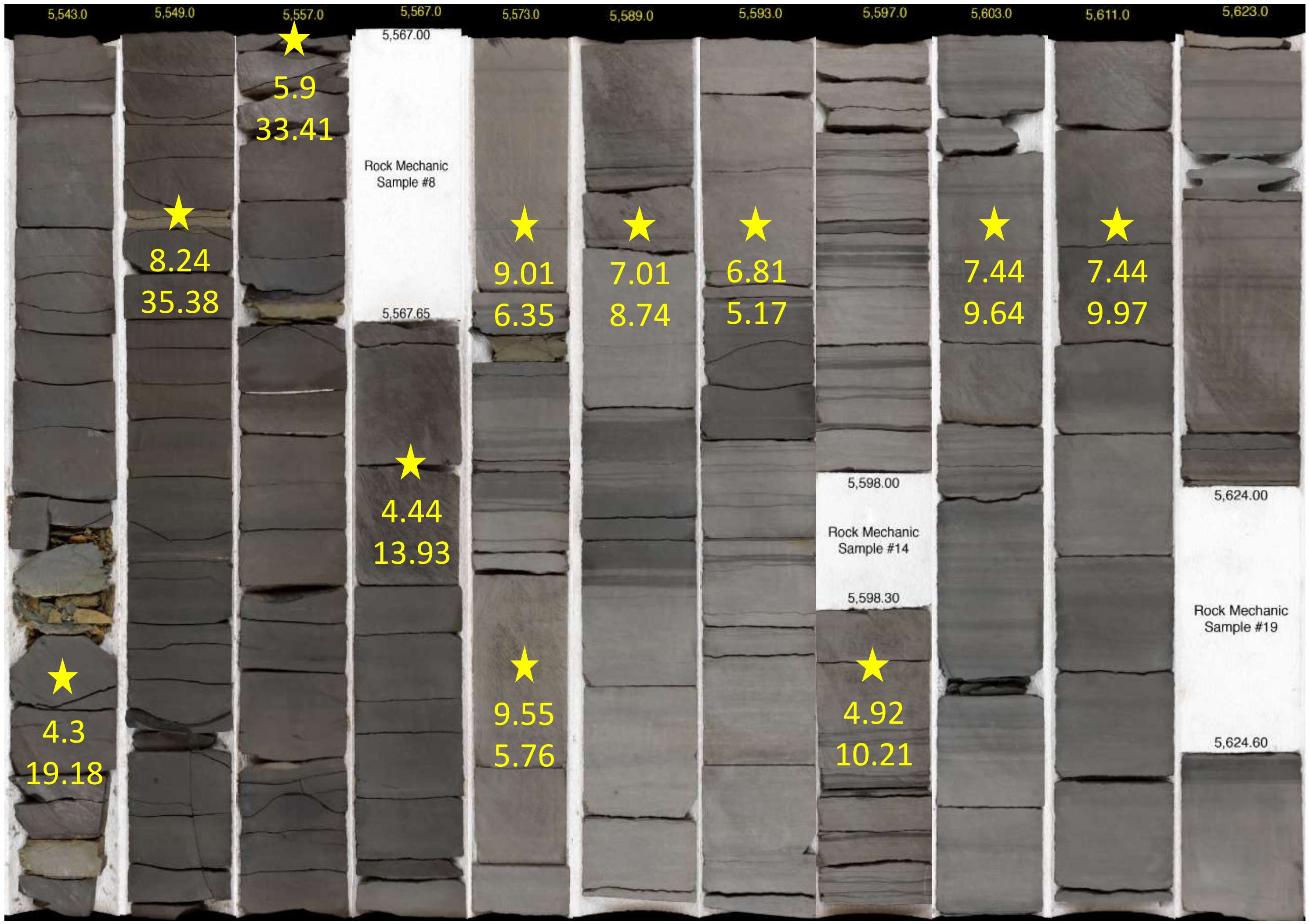


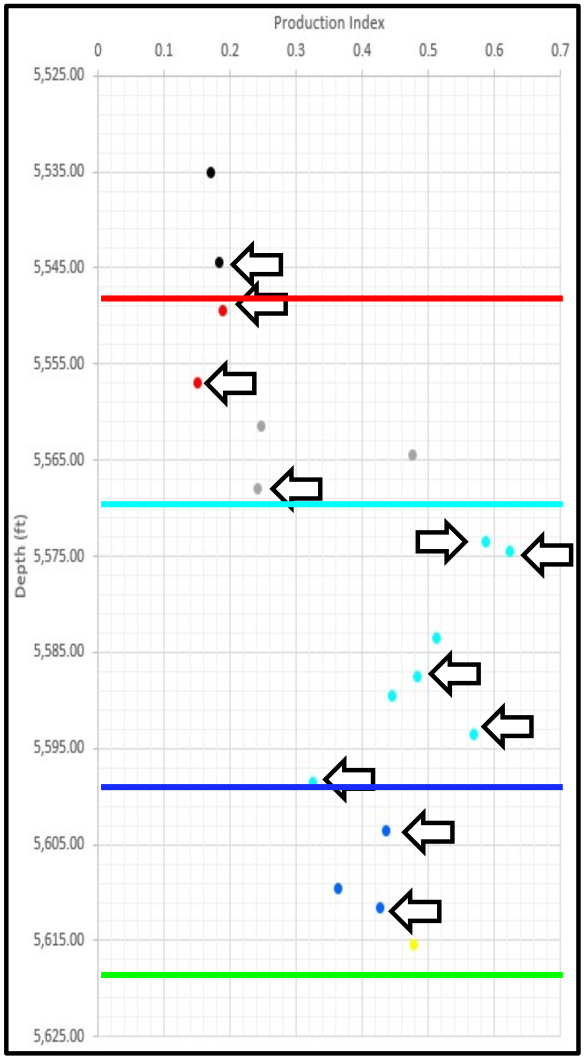

| Generation Potential | Wt % TOC, Shale | Wt % TOC, Carbonate |
|---|---|---|
| Poor | 0.0-0.5 | 0.0-0.2 |
| Fair | 0.5-1.0 | 0.2-0.5 |
| Good | 1.0-2.0 | 0.5-1.0 |
| Very Good | 2.0-5.0 | 1.0-2.0 |
| Excellent | >5.0 | >2.0 |

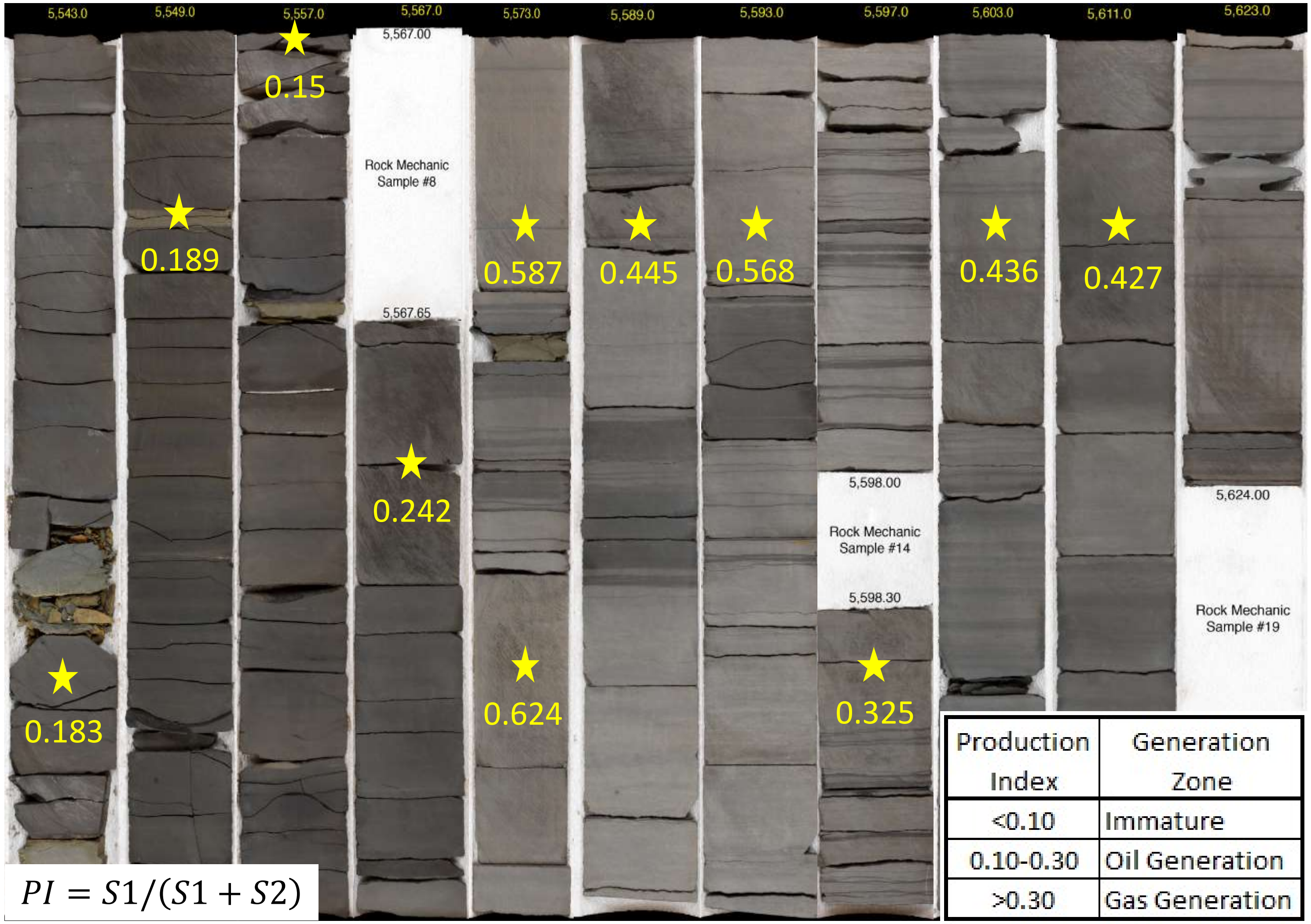
# S1 and S2 Peaks



# Production Index – Evolution Level of Organic Matter

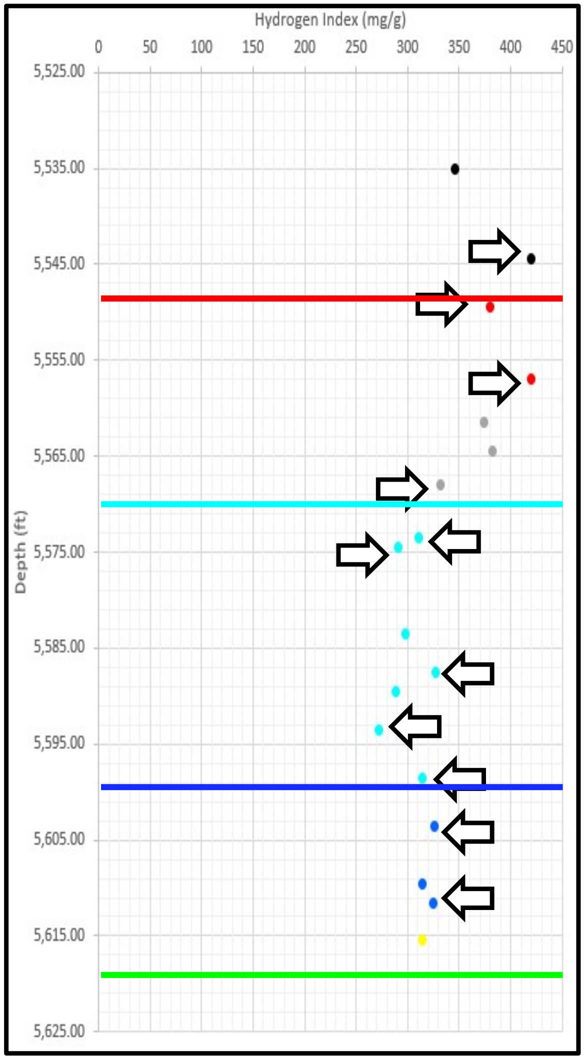


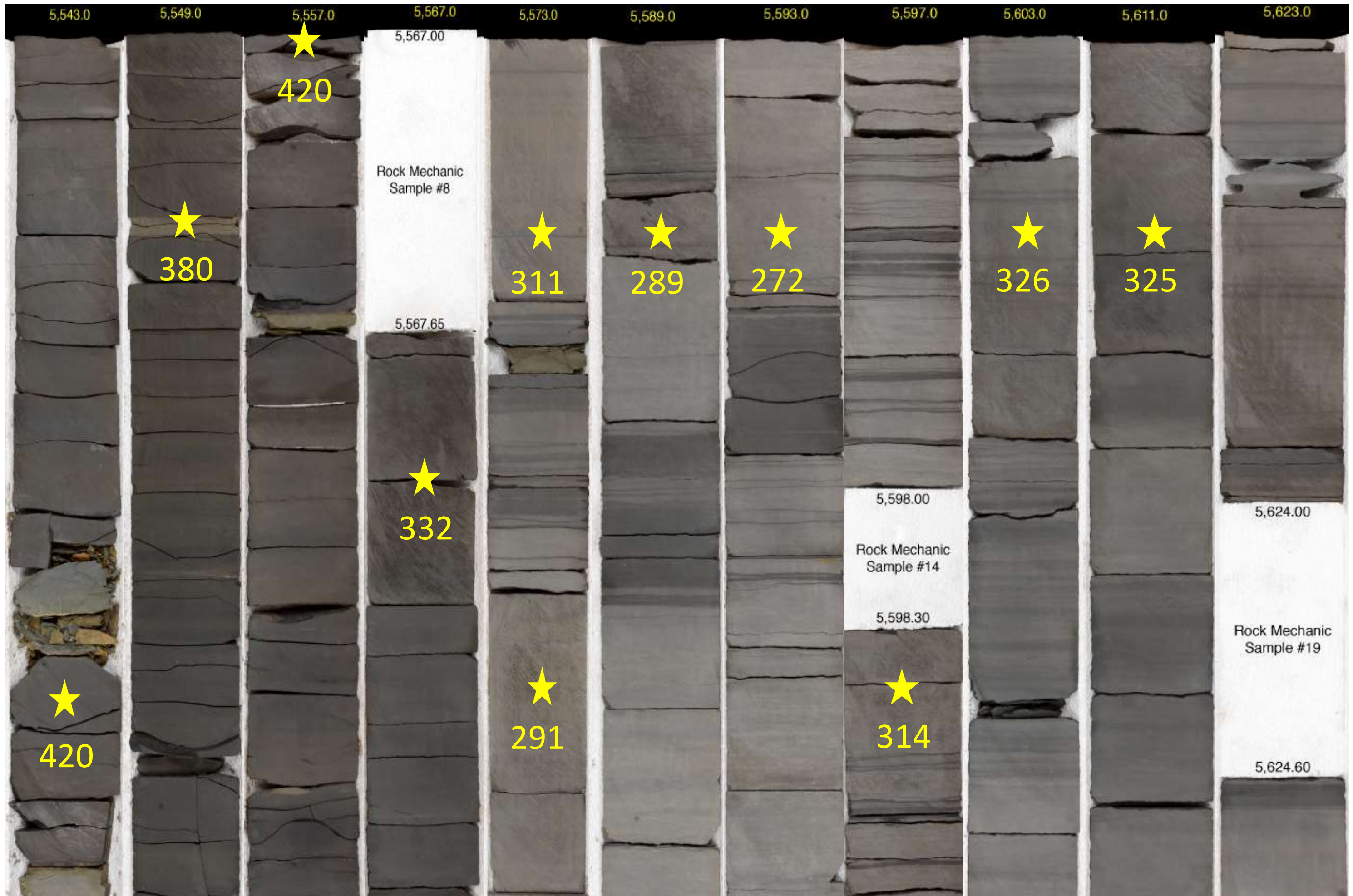




$$PI = S1/(S1 + S2)$$

| Production Index | Generation Zone |
|---|---|
| <0.10 | Immature |
| 0.10-0.30 | Oil Generation |
| >0.30 | Gas Generation |

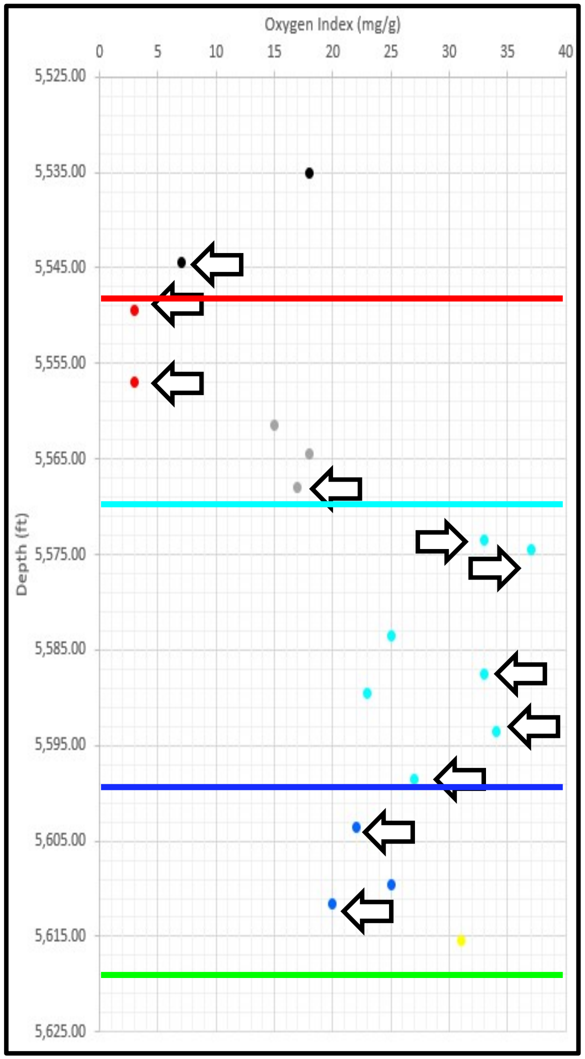
# Hydrogen Index – Hydrogen Relative to Organic Carbon

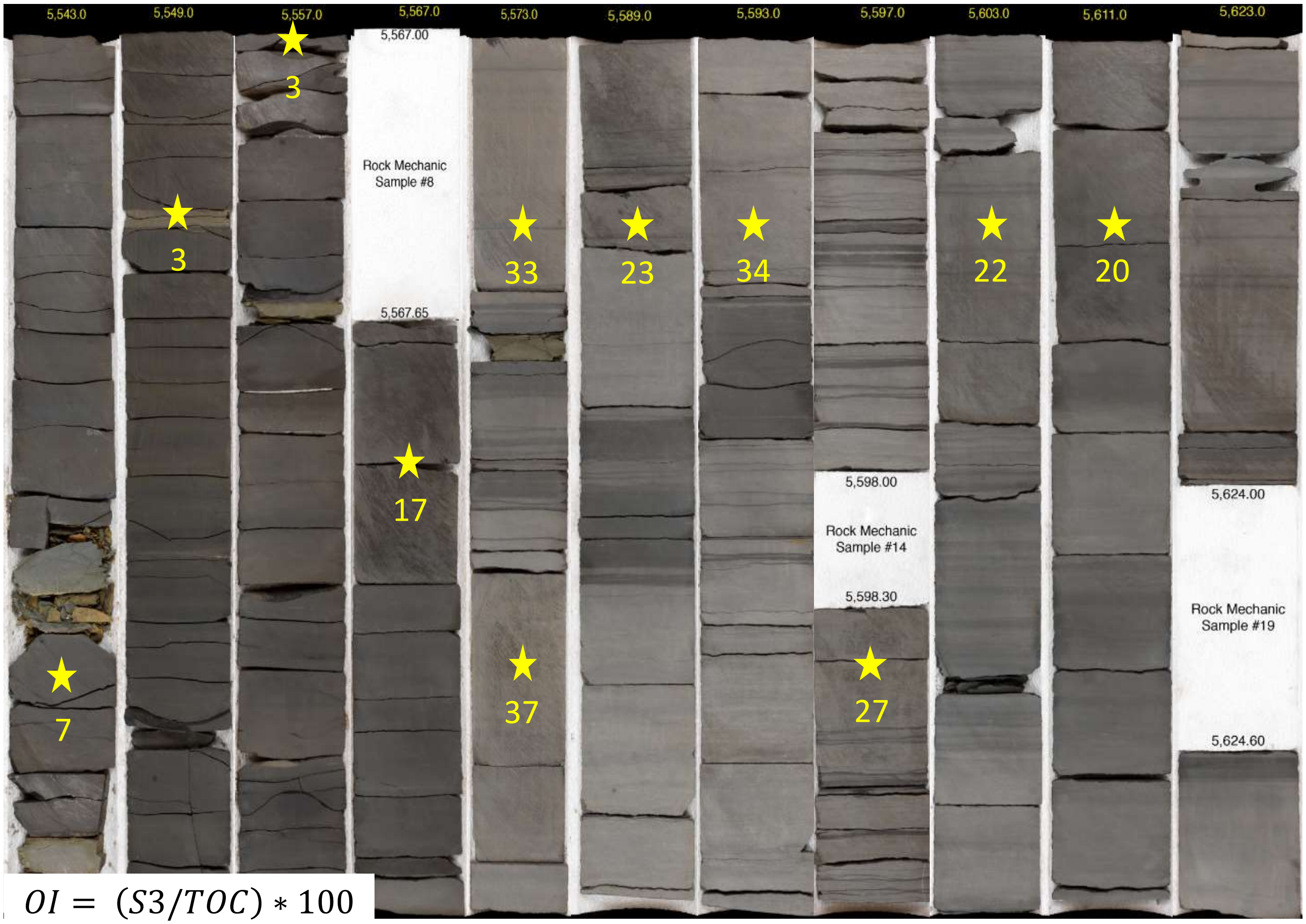



$$HI = (S2/TOC) * 100$$

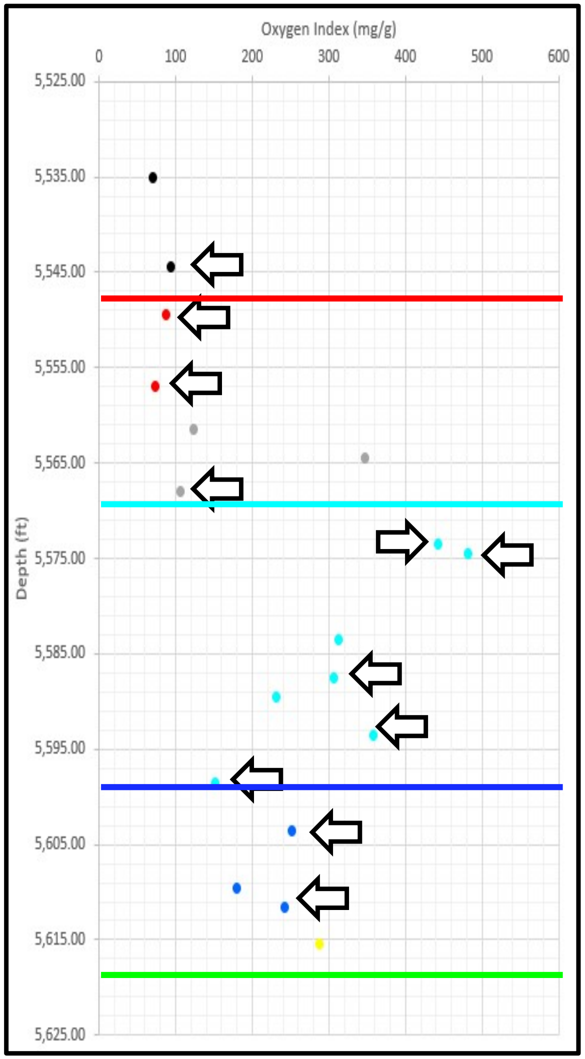
# Oxygen Index – Oxygen Relative to Organic Carbon

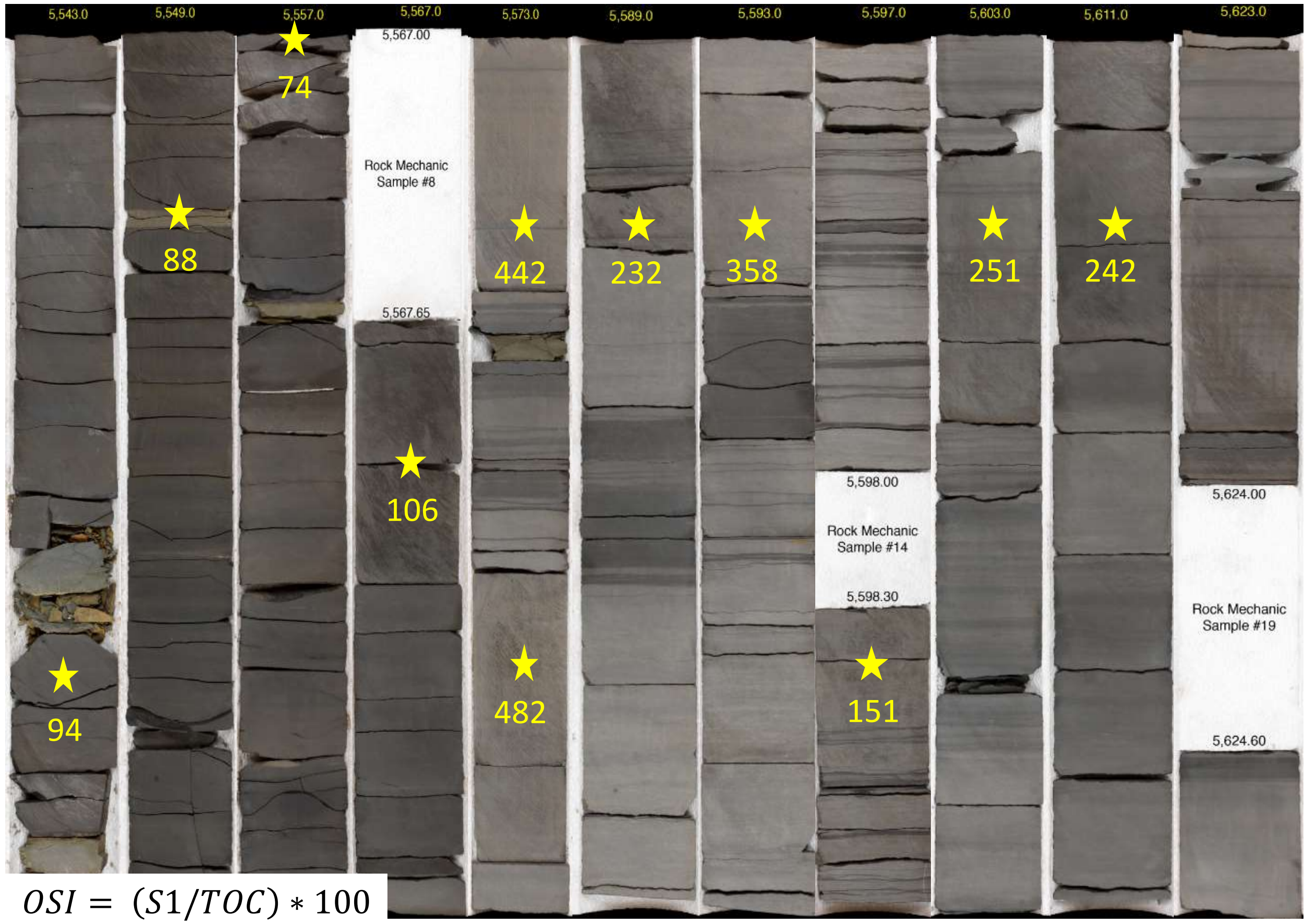



$$OI = (S3/TOC) * 100$$

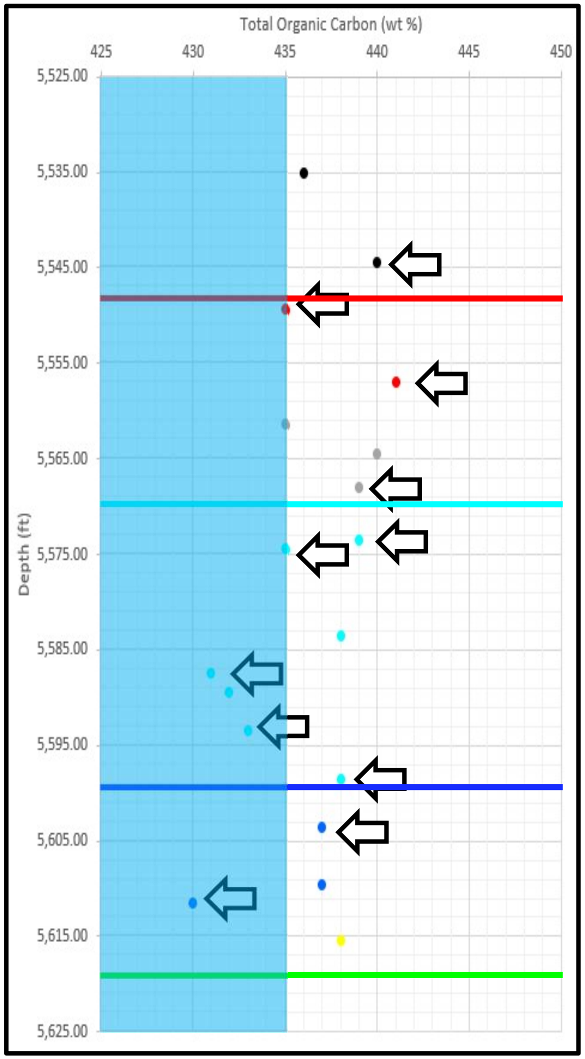
# Oil Saturation Index – Resistance to Oil Expulsion

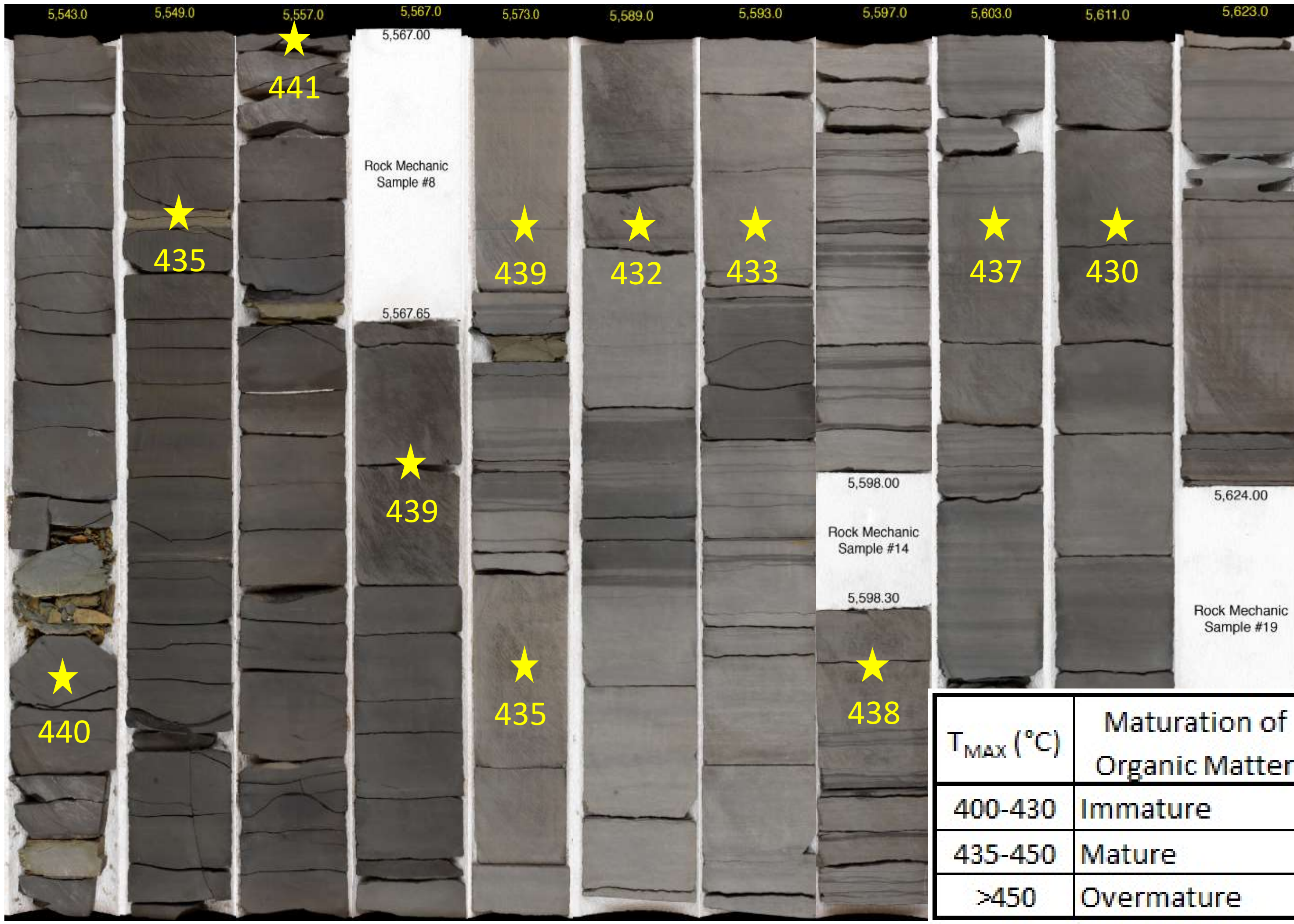



$$OSI = (S1/TOC) * 100$$

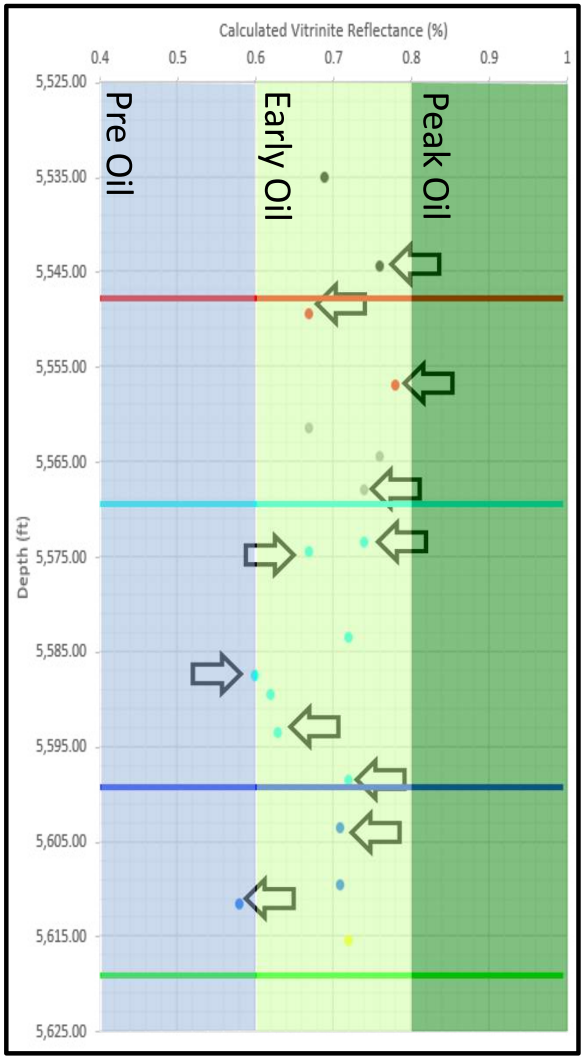
# $T_{MAX}$

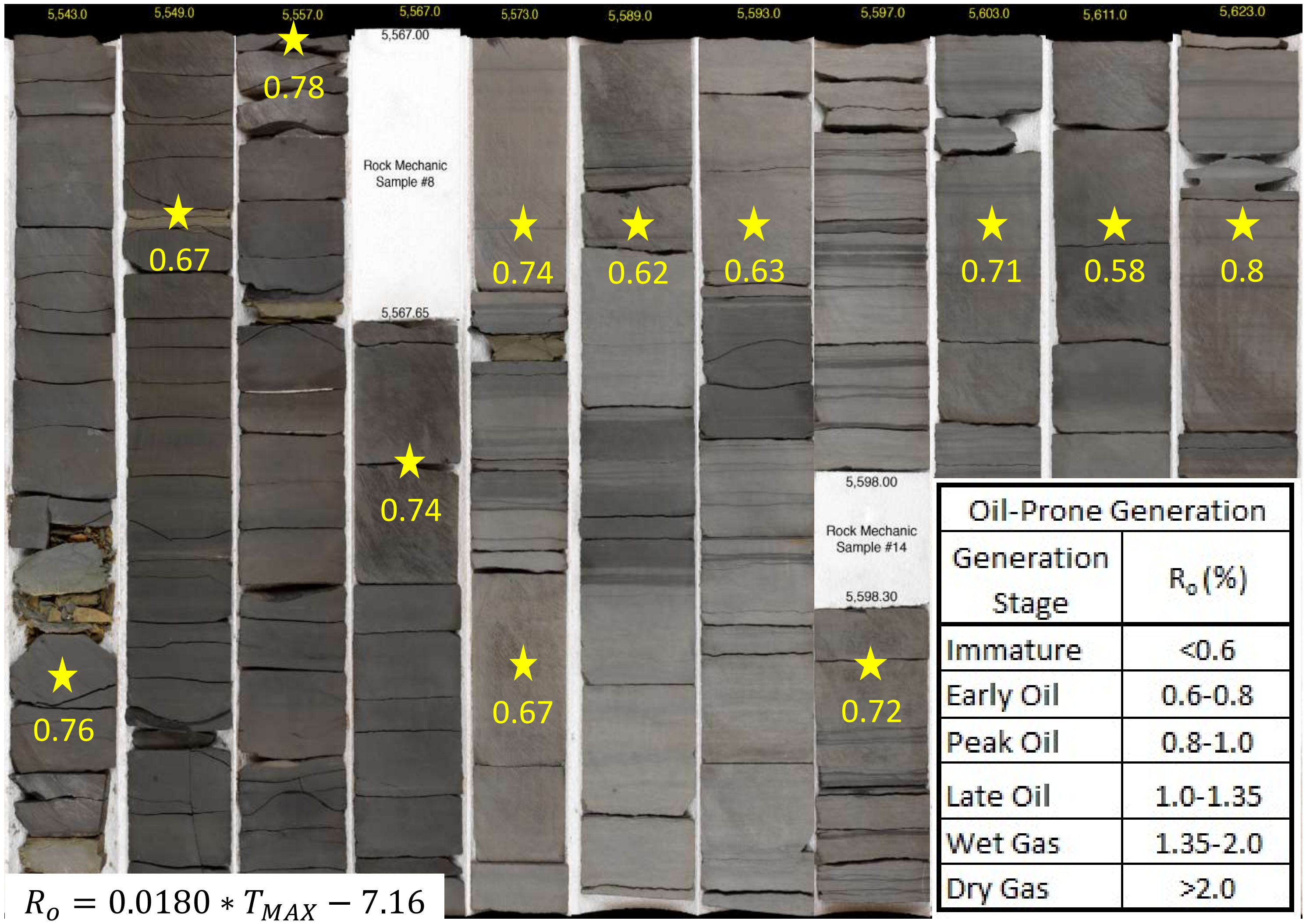



| $T_{MAX}$ (°C) | Maturation of Organic Matter |
|---|---|
| 400-430 | Immature |
| 435-450 | Mature |
| >450 | Overmature |

# Calculated Vitrinite Reflectance

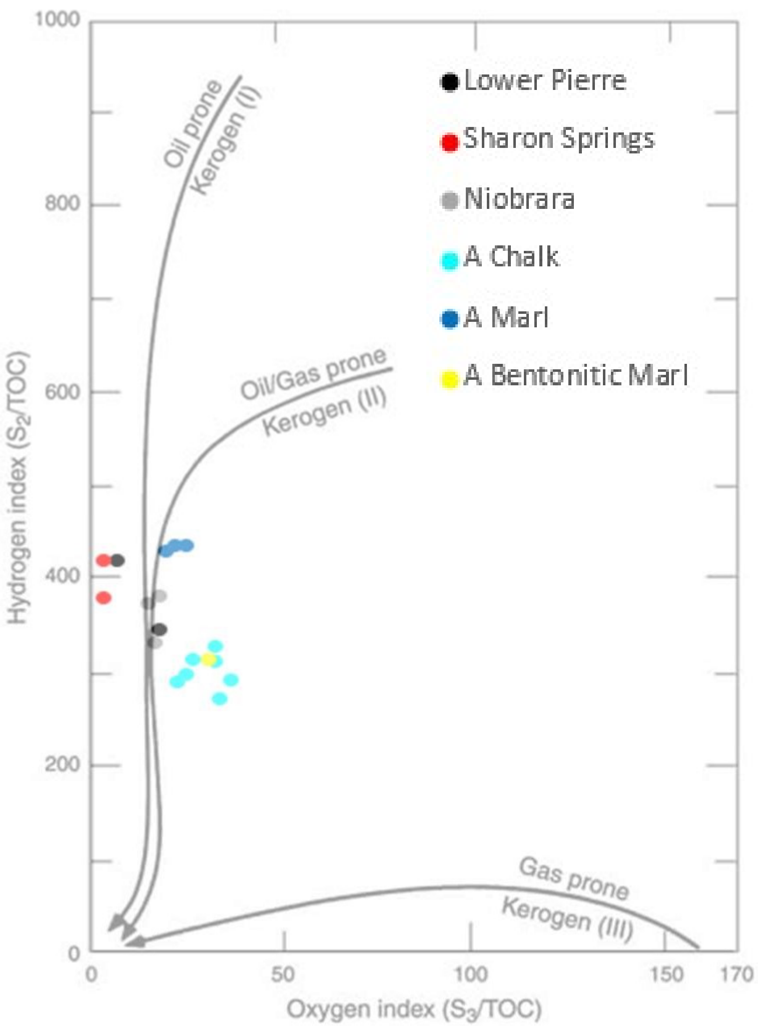



$$R_o = 0.0180 * T_{MAX} - 7.16$$

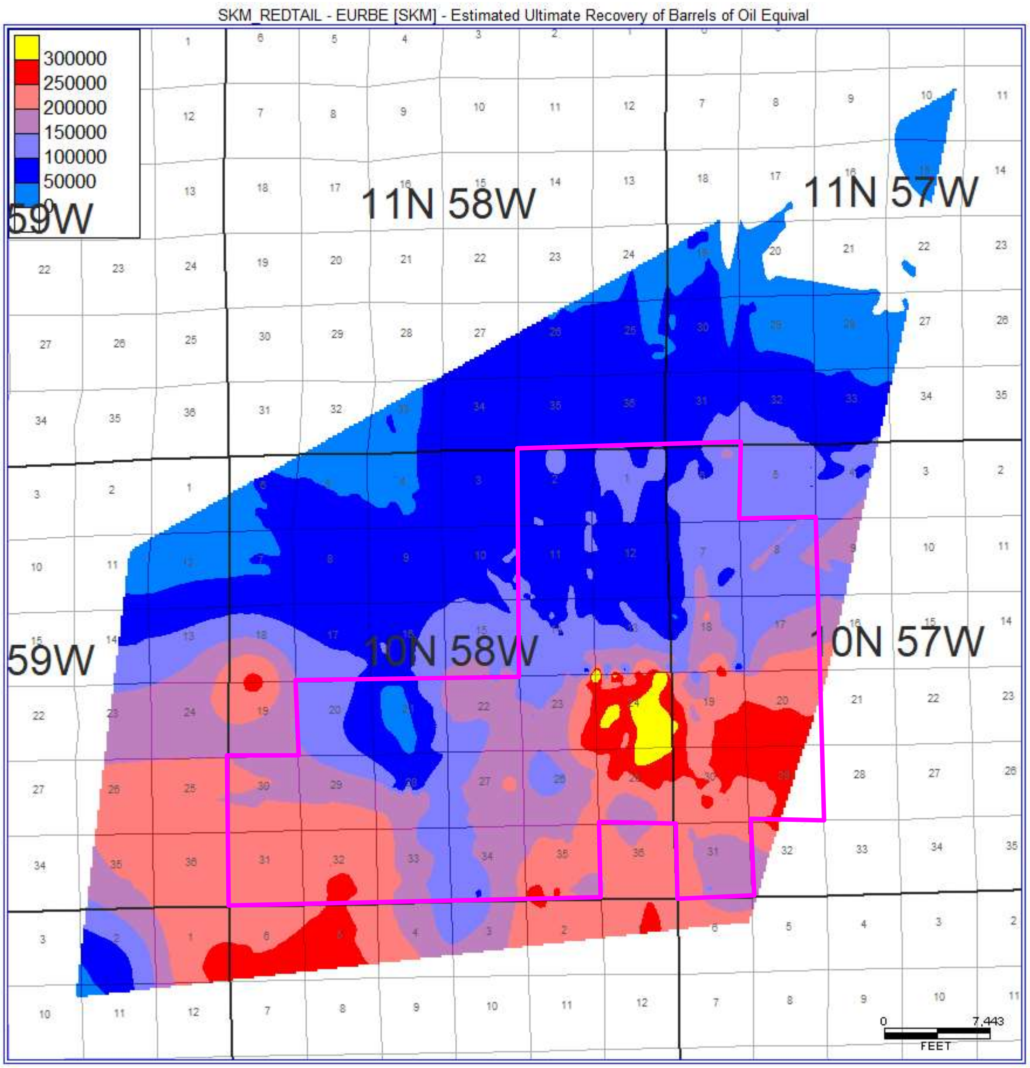
| Oil-Prone Generation | |
|---|---|
| Generation Stage | $R_o$ (%) |
| Immature | <0.6 |
| Early Oil | 0.6-0.8 |
| Peak Oil | 0.8-1.0 |
| Late Oil | 1.0-1.35 |
| Wet Gas | 1.35-2.0 |
| Dry Gas | >2.0 |

# Van Krevelen Diagram



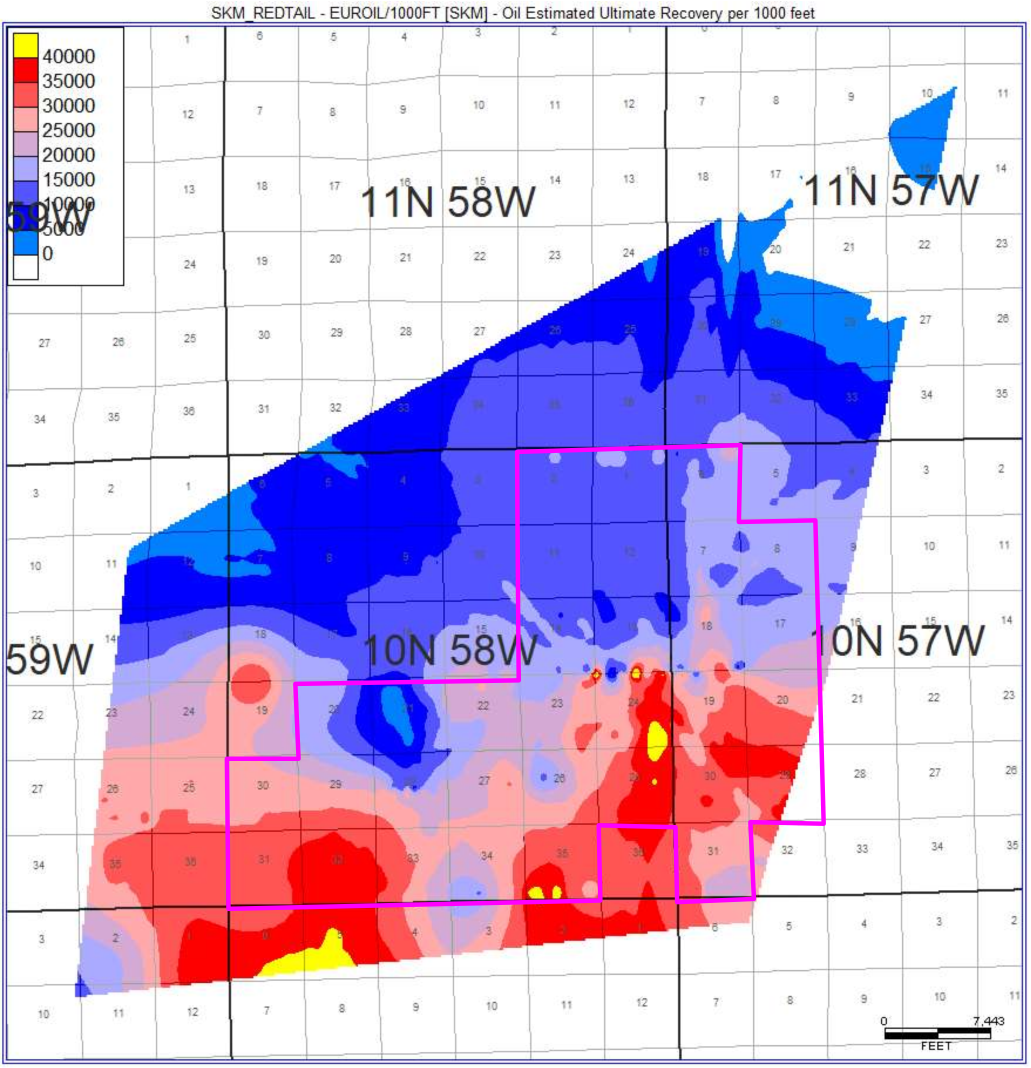

- Samples in the Lower Pierre and Sharon Springs plot to Type I and Type II kerogen
- Samples in the Niobrara plot to Type II and Type III kerogen
- Niobrara A Marl samples contain highest HI; Niobrara A Chalk samples contain highest OI
- Type II is expected for the Niobrara as it is of marine origin

# EUR in Redtail



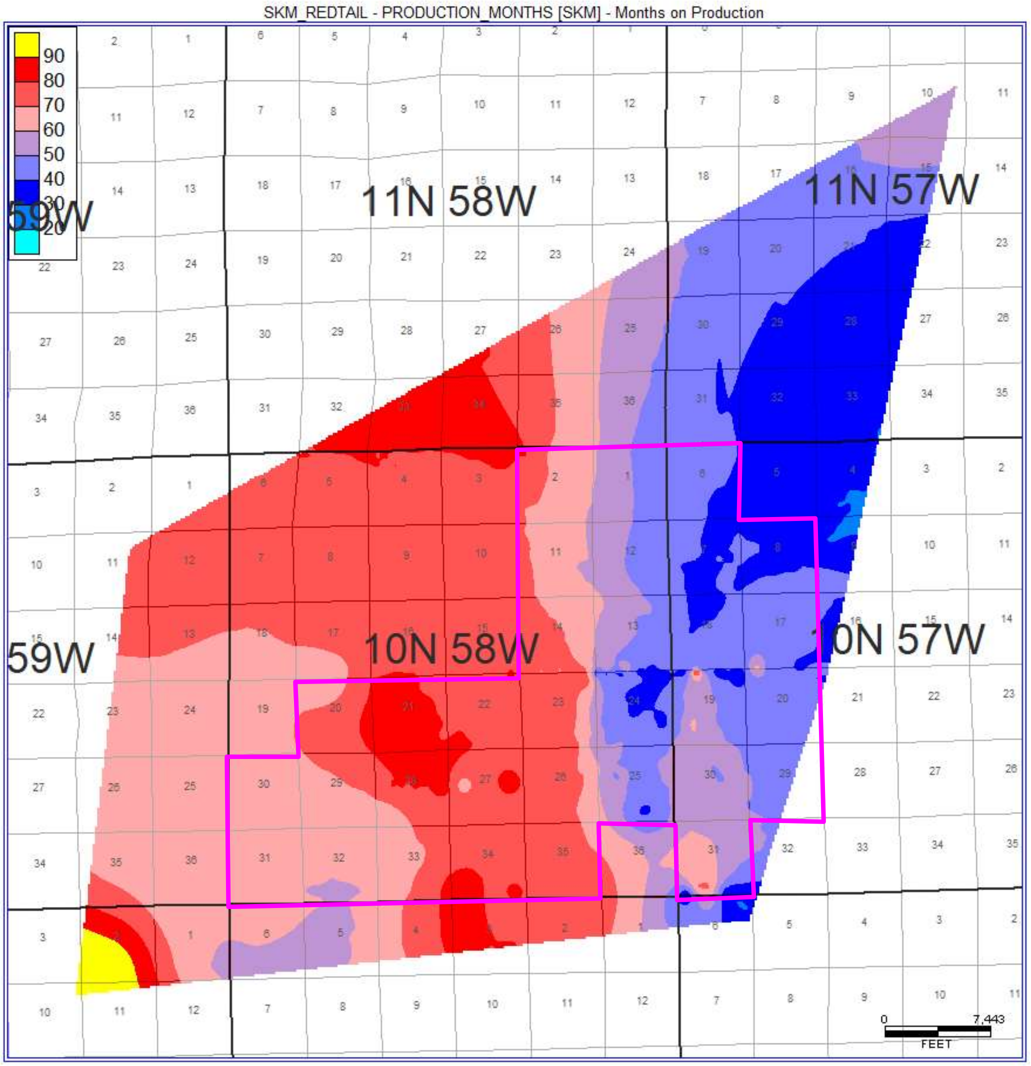

- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Niobrara A wells produce less oil than Niobrara B wells
- Average EUR of 156,215 BOE (low: 16,052; high: 477,881)
- Best EUR in sections 24 and 25 (heart of field)
- Gas to BOE: Gas/6

# EUR/1,000'



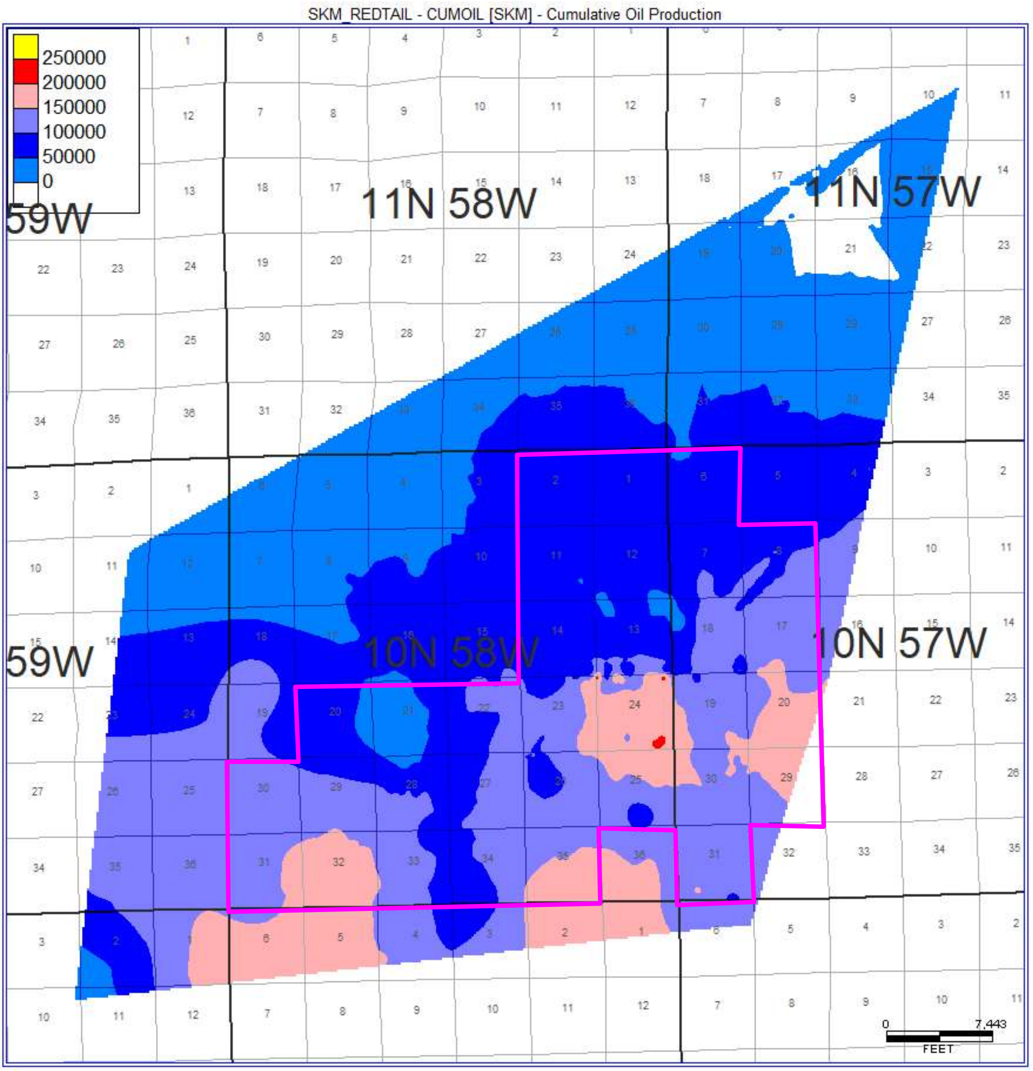

- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Wells normalized per 1,000' of lateral wellbore
- Average wellbore length of 7,276' (low: 3,553; high: 9,925)
- Average EUR/1,000' of 21,332 BOE (low: 2,595; high: 52,290)
- Best EUR in sections 24 and 25

# Months on Production



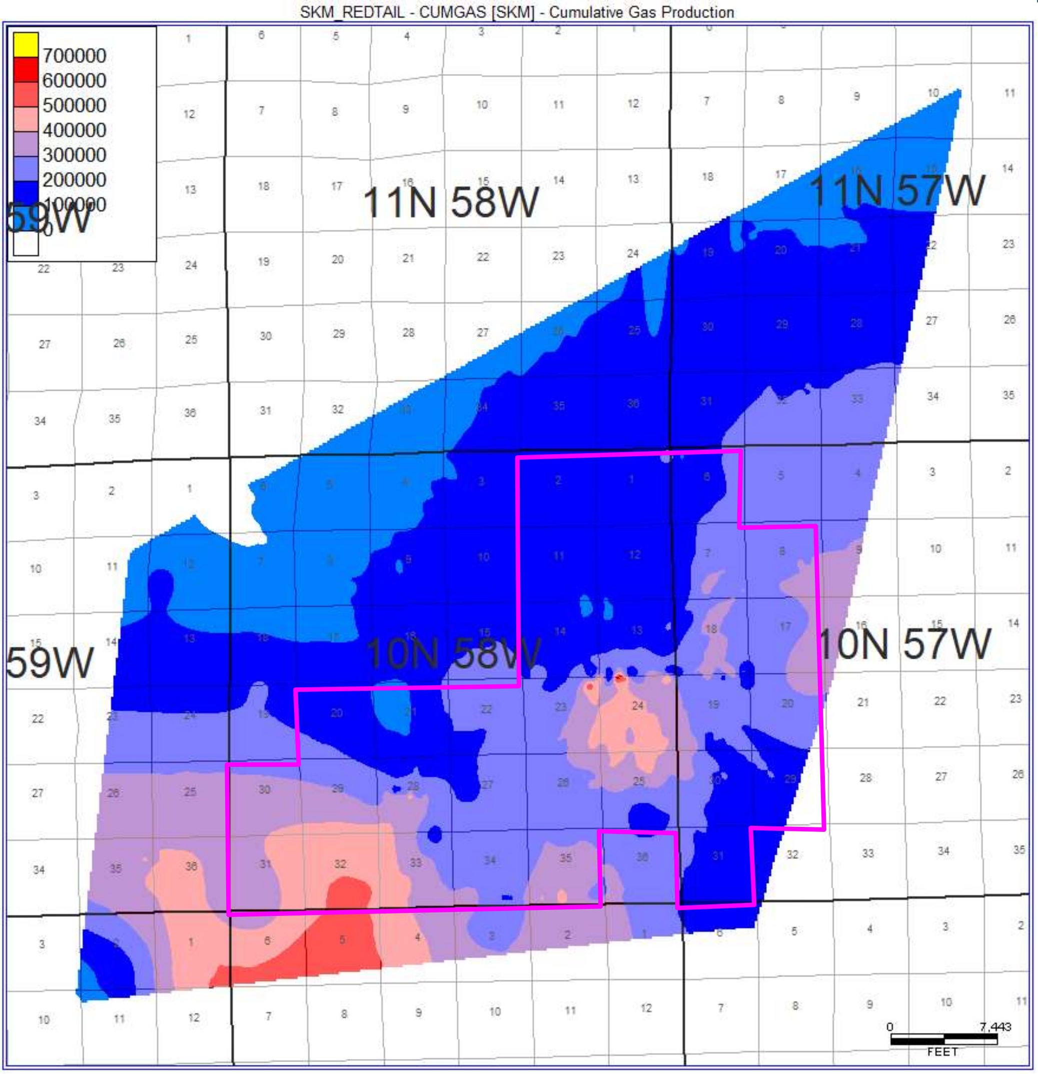

- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Redtail recently passed 100 months of production in oldest Niobrara A well
- Average production time of 63 months (low: 33; high: 100)
- Oldest production through western portion of field

# Cumulative Oil Production



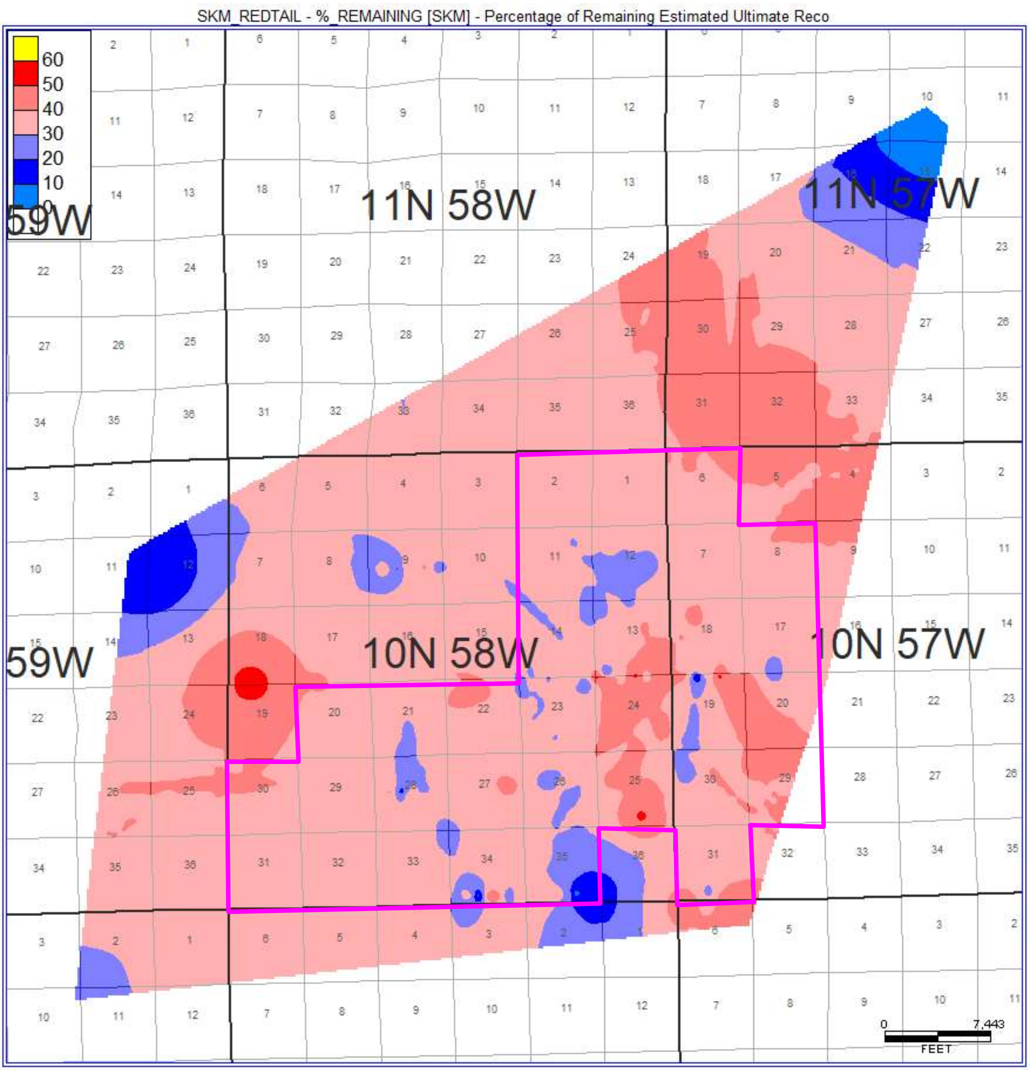

- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Average oil production of 100,055 BO (low: 16,052; high: 237,778)
- Sections 24 and 25 possess highest oil production

# Cumulative Gas Production




- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Average gas production of 231,800 SCF (low: 18,133; high: 679,975)
- Sections 24 and 31 possess highest gas production

# Remaining EUR




- Wells that produce from the Niobrara A only in the Redtail Field area (103 wells)
- Average remaining EUR of 34.14% (low: 0; high: 53.43)
- Sections 24 and 25 possess highest remaining EUR
- Most recently drilled areas have highest remaining EUR

# OOIP Calculation in Section 25

| Interval | A (acres) | h (ft) | Φ (decimal) | $S_w$ (decimal) | $B_{oi}$ | OOIP (STB/section) | Total OOIP (STB/section) |
|---|---|---|---|---|---|---|---|
| Niobrara | 640 | 10.41 | 0.0487 | 0.579 | 1.27 | 834,426 | 15,891,260 |
| Niobrara A Chalk | 640 | 30.11 | 0.1132 | 0.177 | 1.27 | 10,966,879 | |
| Niobrara A Marl | 640 | 10.46 | 0.1185 | 0.156 | 1.27 | 4,089,955 | |

| Interval | Total OOIP (STB/section) | OOIP (STB/section) | Percentage of OOIP by Interval |
|---|---|---|---|
| Niobrara | 15,891,260 | 834,426 | 5.25 |
| Niobrara A Chalk | | 10,966,879 | 69.01 |
| Niobrara A Marl | | 4,089,955 | 25.74 |

$$OOIP = \frac{7758 * A * h * \phi * (1 - S_w)}{B_{oi}}$$

# OOIP Calculation and Recovery Factor in Section 25

| Interval | A (acres) | h (ft) | Φ (decimal) | $S_w$ (decimal) | $B_{oi}$ | OOIP (STB/section) | Total OOIP (STB/section) |
|---|---|---|---|---|---|---|---|
| Niobrara | 640 | 10.41 | 0.0487 | 0.579 | 1.27 | 834,426 | 15,891,260 |
| Niobrara A Chalk | 640 | 30.11 | 0.1132 | 0.177 | 1.27 | 10,966,879 | |
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| Interval | Total OOIP (STB/section) | OOIP (STB/section) | Percentage of OOIP by Interval |
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| Niobrara | 15,891,260 | 834,426 | 5.25 |
| Niobrara A Chalk | | 10,966,879 | 69.01 |
| Niobrara A Marl | | 4,089,955 | 25.74 |

| | |
|---|---|
| Cumulative Oil Production: | 601,497 |
| Cumulative EUR: | 1,094,708.2 |
| OOIP: | 15,891,260 |

| | |
|---|---|
| CumOil Recovery Factor: | 3.79% |
| EUR Recovery Factor: | 6.89% |

Unconventional oil reservoirs typically vary between 2% and 8% recovery factor

# Remaining Work

- Finish writing thesis
- Defend thesis
- Graduate

# MUDTOC Consortium Sponsors
# Spring 2021

## Sponsoring Member Companies

Chevron
Red Willow Production Company
Antero Resources
Crestone Peak Resources
OXY
White Eagle Exploration
EOG Resources
Whiting
Enverus
Helis Oil & Gas
Stratum Reservoir
HighPoint Resources
Cimarex
devon
TGS
GMT Exploration Company LLC

## Supporting Companies

GeoMark
Mike Johnson & Associates
IHS
Schlumberger
MJ Systems
The Energy of Enerplus
PlatteRiver