The Goddard Shale in the Eastern Anadarko Basin: Understanding an Exceptionally Productive Mudrock Reservoir with Fluid Sensitive Clay

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Shale Plays of Oklahoma
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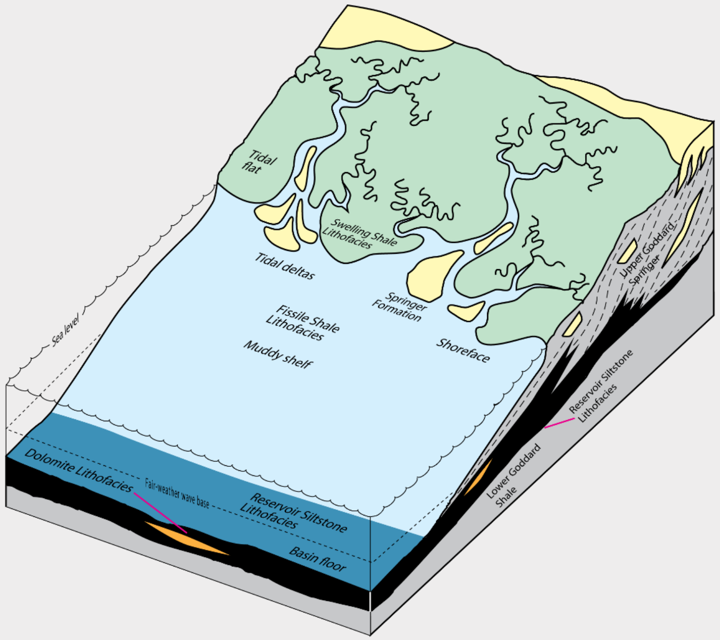


Overview

- Introduction
- Methodology
- Results
- Discussion
- Conclusions

Acknowledgments

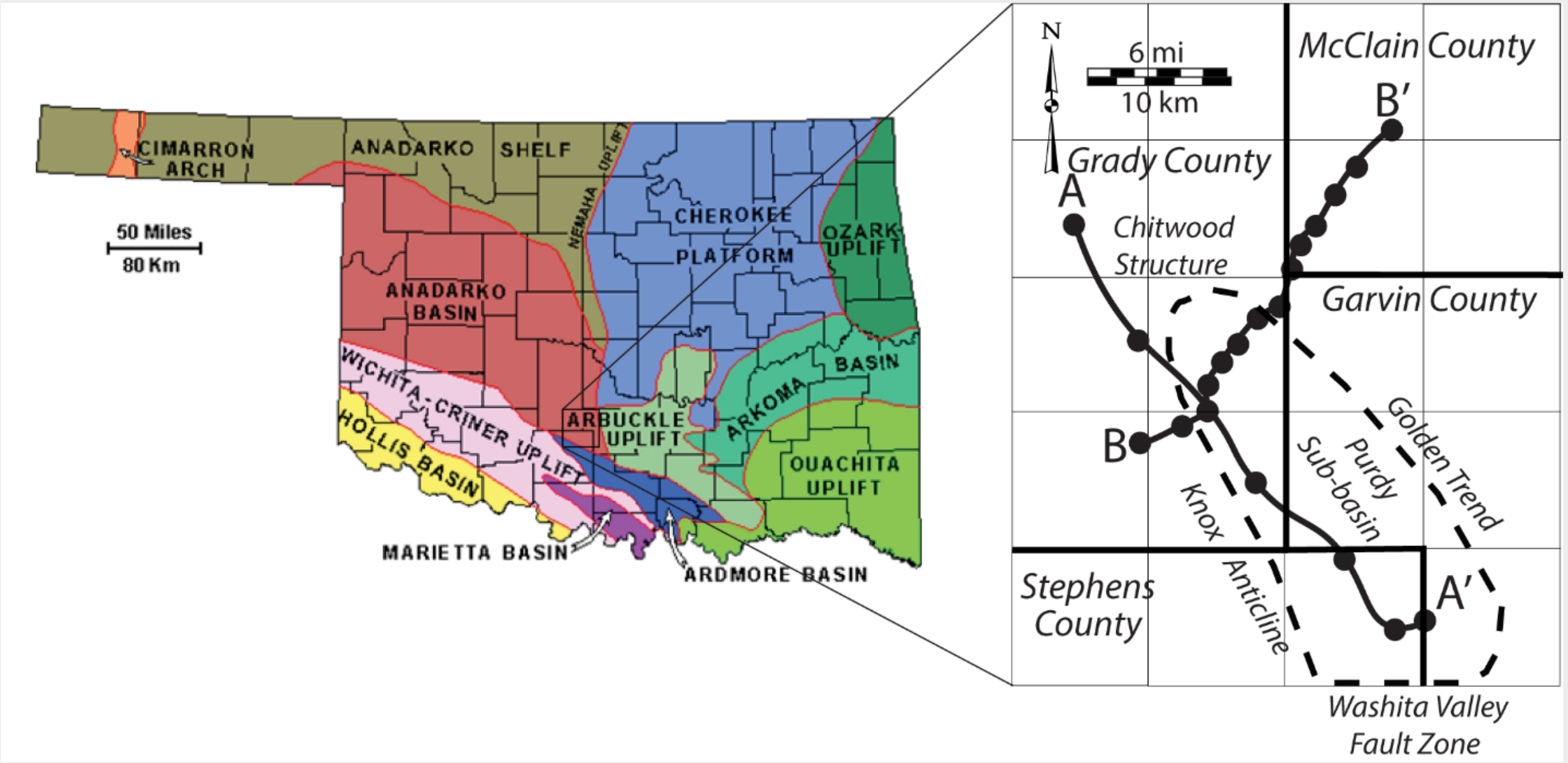
- Rock Wise, LLC
- Weatherford Laboratories

Introduction

- **The Goddard Shale:** A localized, niche shale play in the Anadarko Basin of southwestern Oklahoma.
- **Purpose:** To develop a depositional model of the Goddard Shale and determine what is the primary control on reservoir quality.
- **Hypothesis:**
  - 1 - The Goddard Shale represents depositional environments ranging from shore zone to shelf.
  - 2 - Clay mineralogy is a dominant control on reservoir quality.

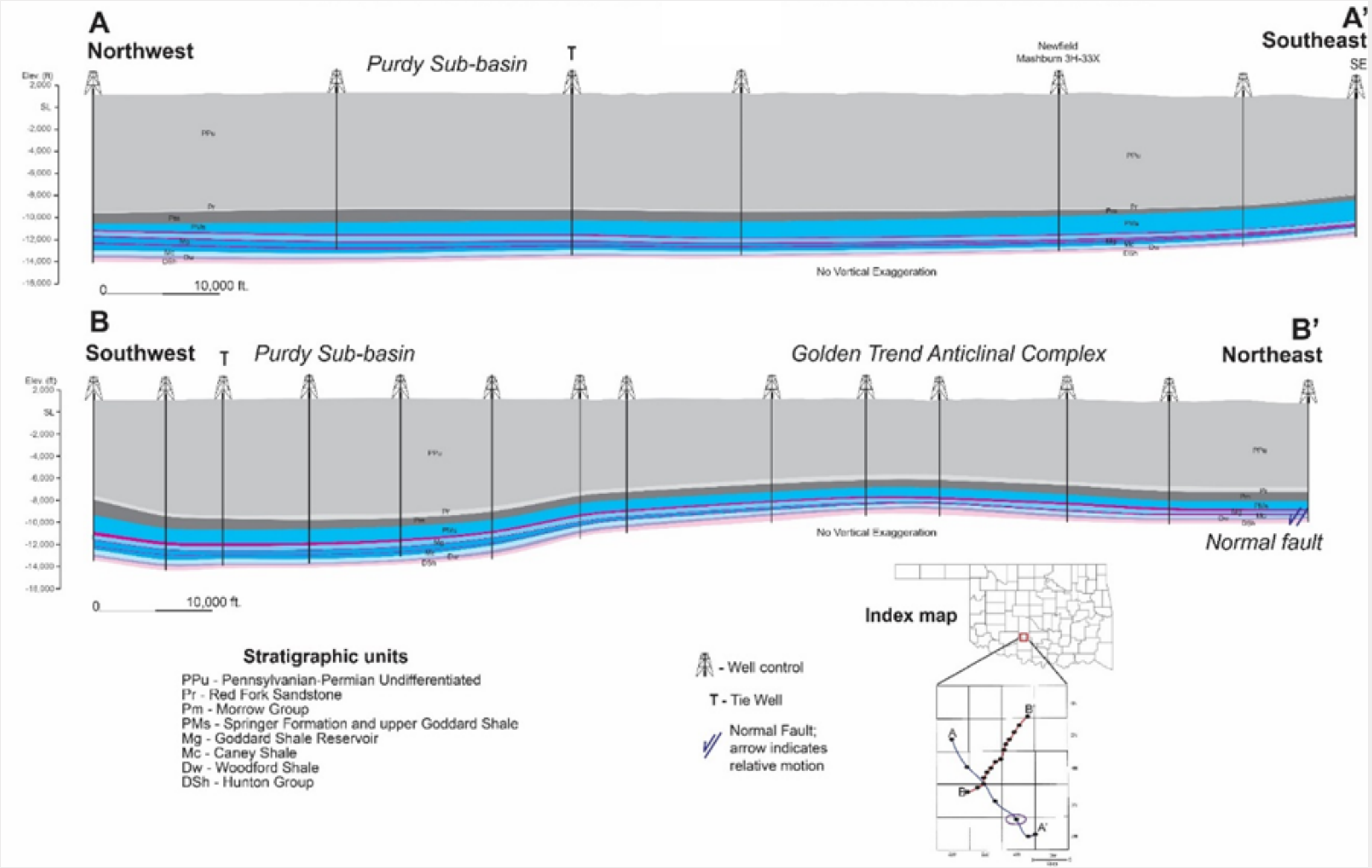
Study Area

- Project focuses on a core from northern Stephens Co.
- Located in the southern Anadarko Basin, north of the Arbuckle Uplift
- Located in the Purdy Sub-basin (Pennsylvanian structure) of the Anadarko Basin
- Used twenty wells to generate strike and dip structural and stratigraphic cross-sections



Modified from Northcutt and Campbell, 1988

Local Structure

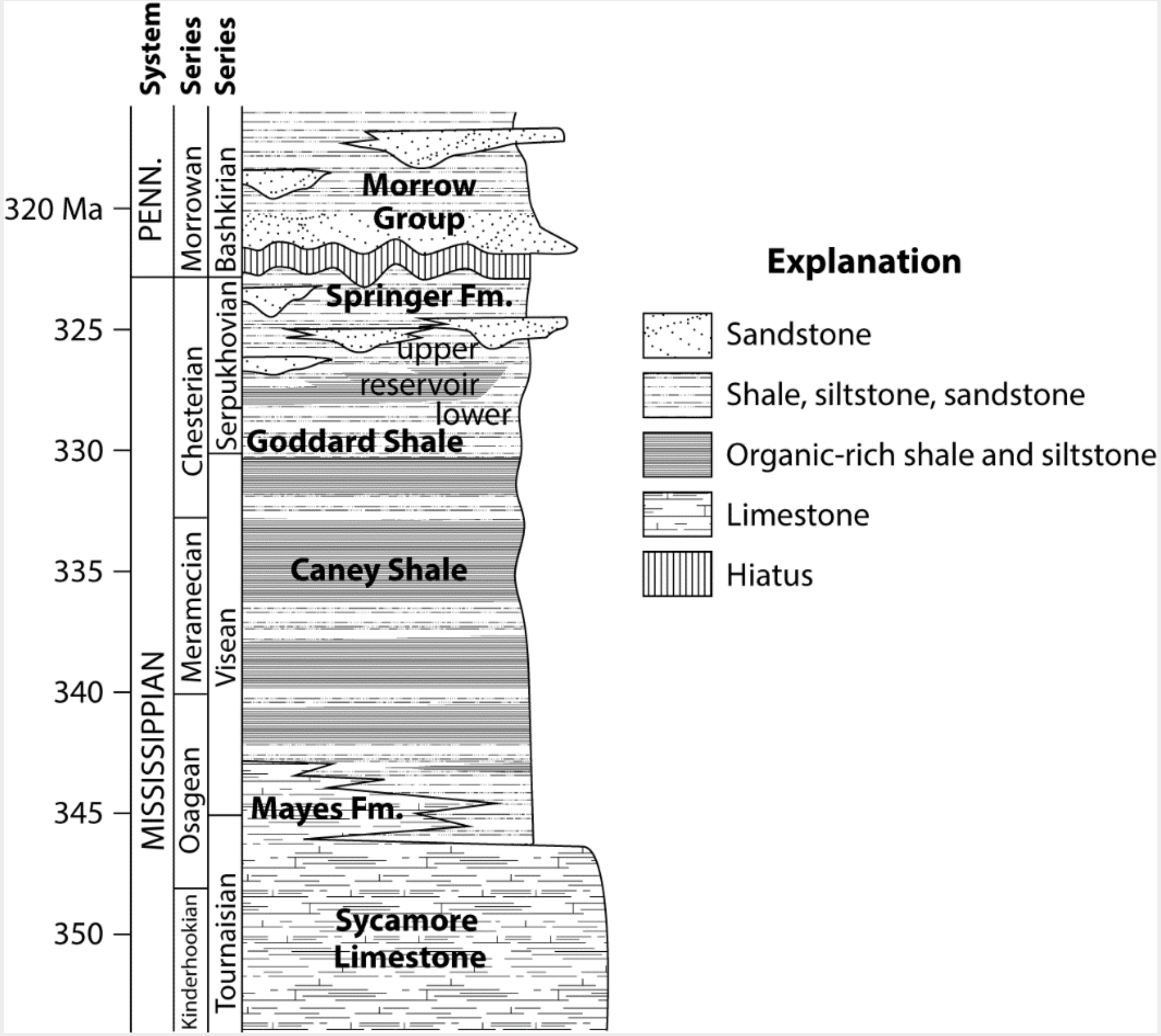


- A-A' traverses the axis of the Purdy Sub-basin (Strike)
- B-B' cross-cuts the axis of the Purdy Sub-basin and includes the Golden Trend anticlinal complex (Dip)

Geologic Background

The Goddard Shale

- Chesterian (Serpukhovian)
- Grey to black shale, siltstone, and dolomite lenses
- Reservoir subcrops, no known outcrops



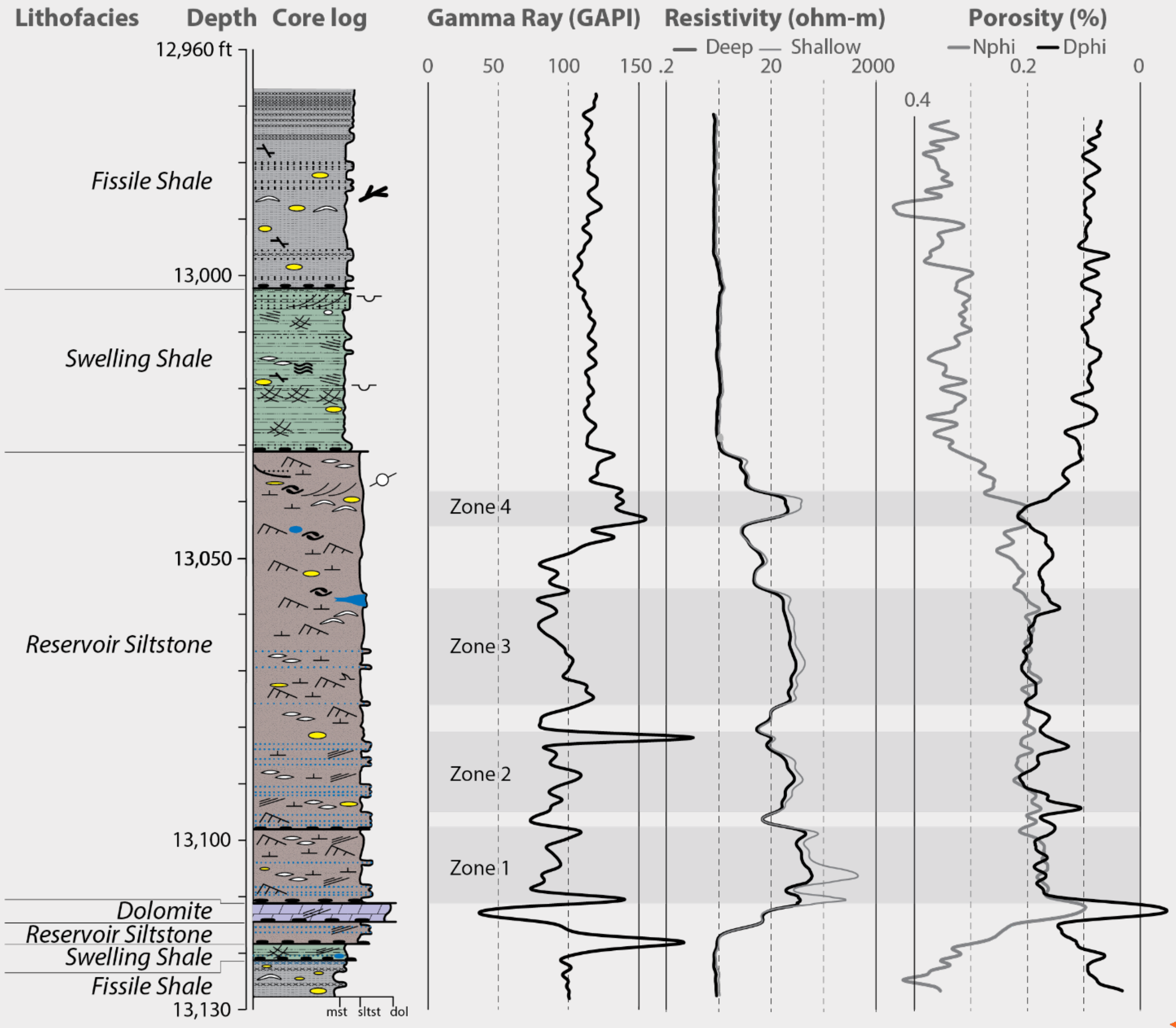
Methodology

Integrated formation evaluation:

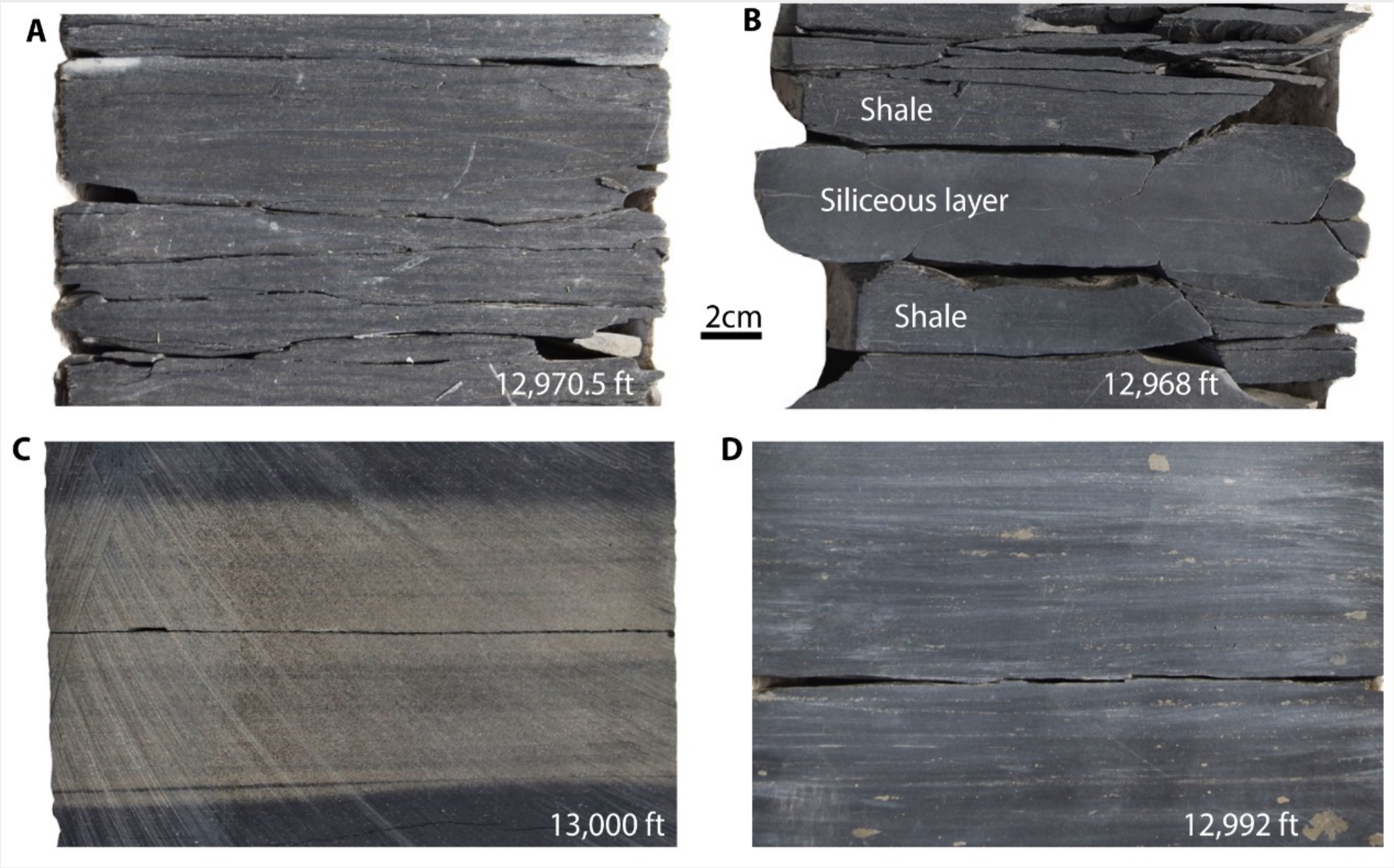
- Core description
- Geophysical and petrophysical log analysis
- Thin section petrology
- Mineralogical and geochemical characterization
- SEM microscopy

Core Description

- Total core length: 162 ft
- Cored complete Goddard Shale reservoir
- Core section divided into 4 lithofacies
  - Fissile Shale
  - Swelling Shale
  - Reservoir Siltstone
  - Dolomite
- Can be simplified into nonreservoir and reservoir strata
  - 4 target zones identified

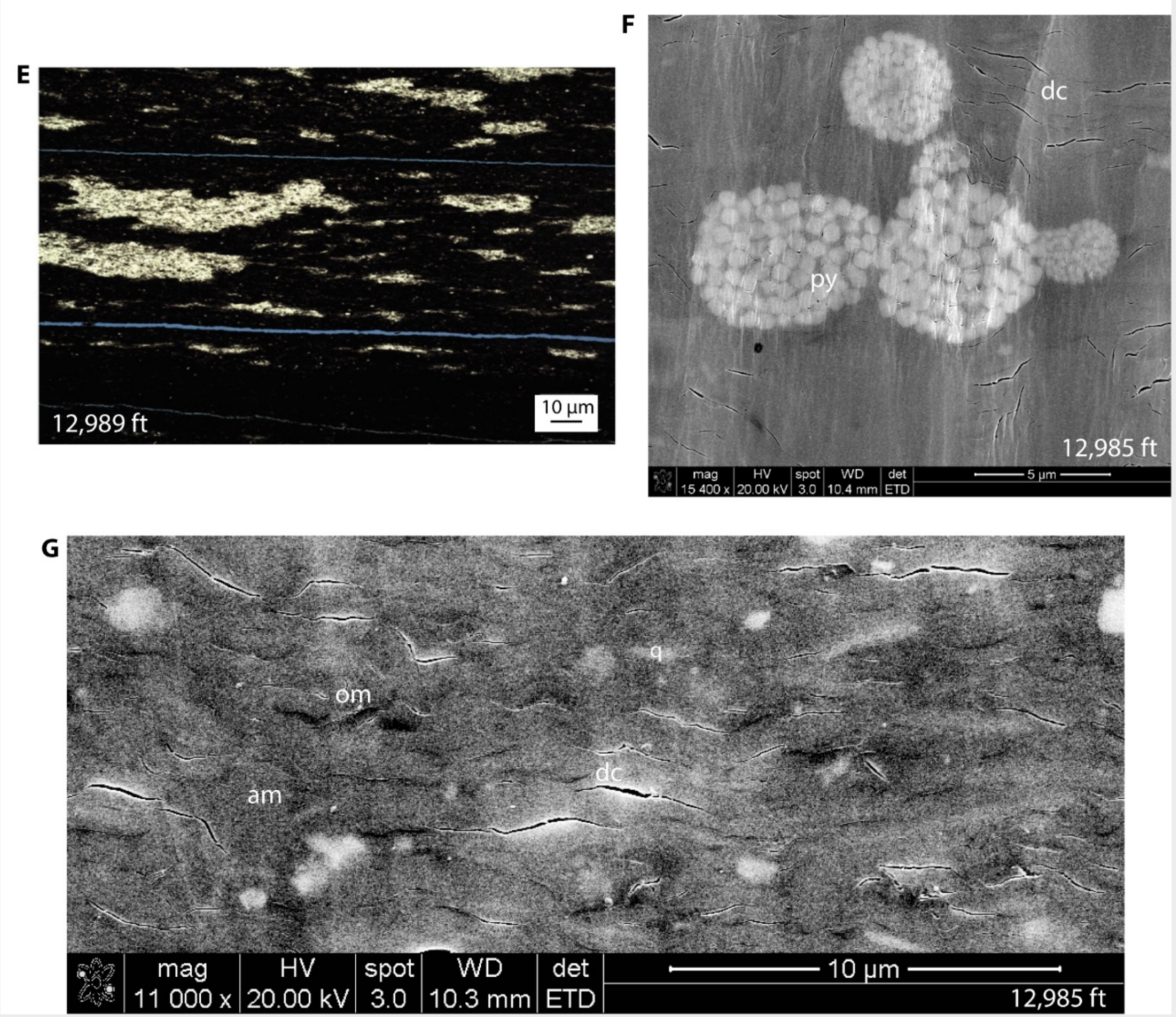


Fissile Shale Lithofacies



A. Fissile shale with horizontal laminae
B. Siliceous layer (common in this facies)
C. Dolomitic siltstone with subhorizontal laminae
D. Disseminated pyrite and nodules of marcasite

Fissile Shale Lithofacies

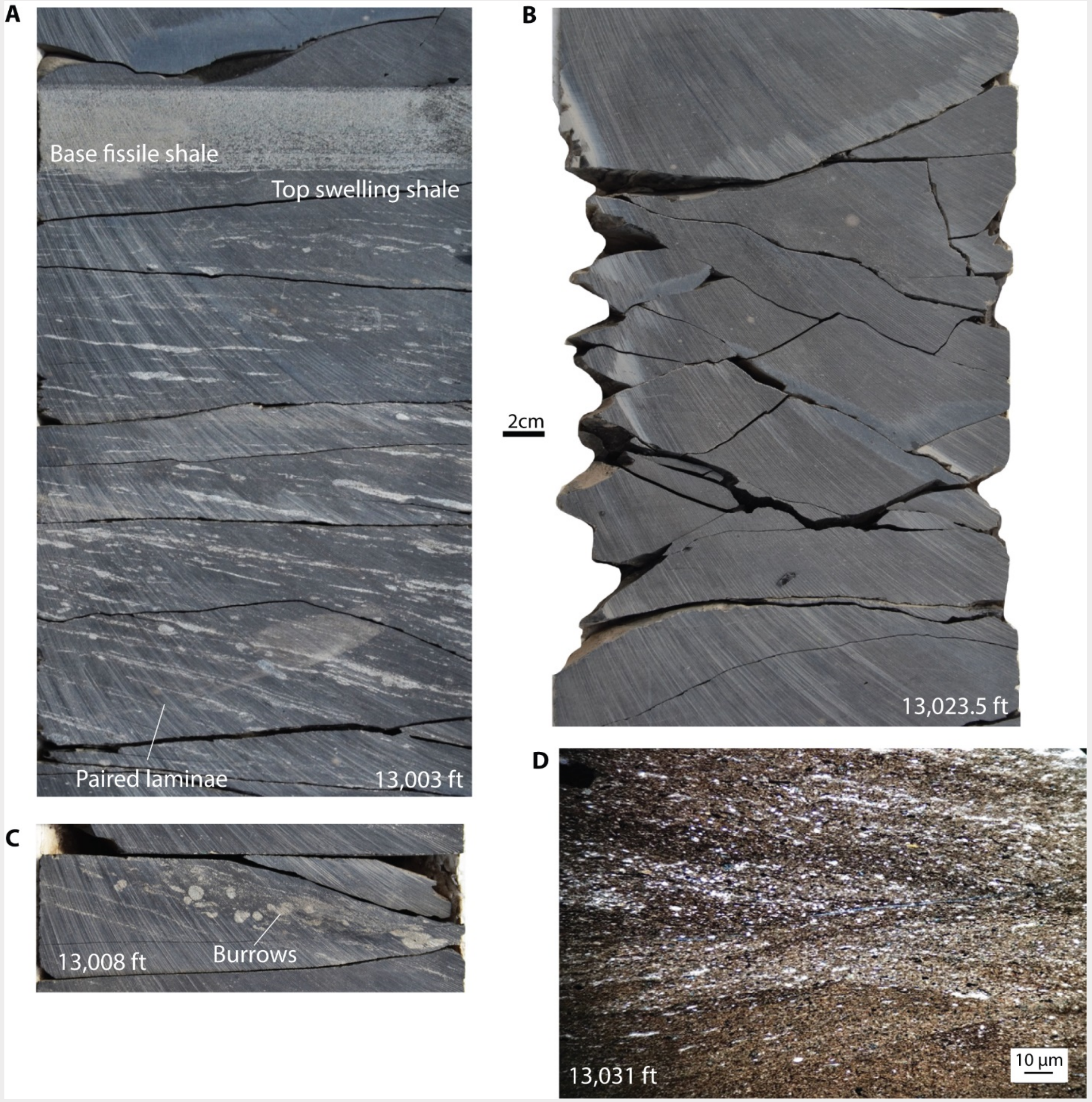


E. Irregular silica lenses, most likely agglutinated foraminifera

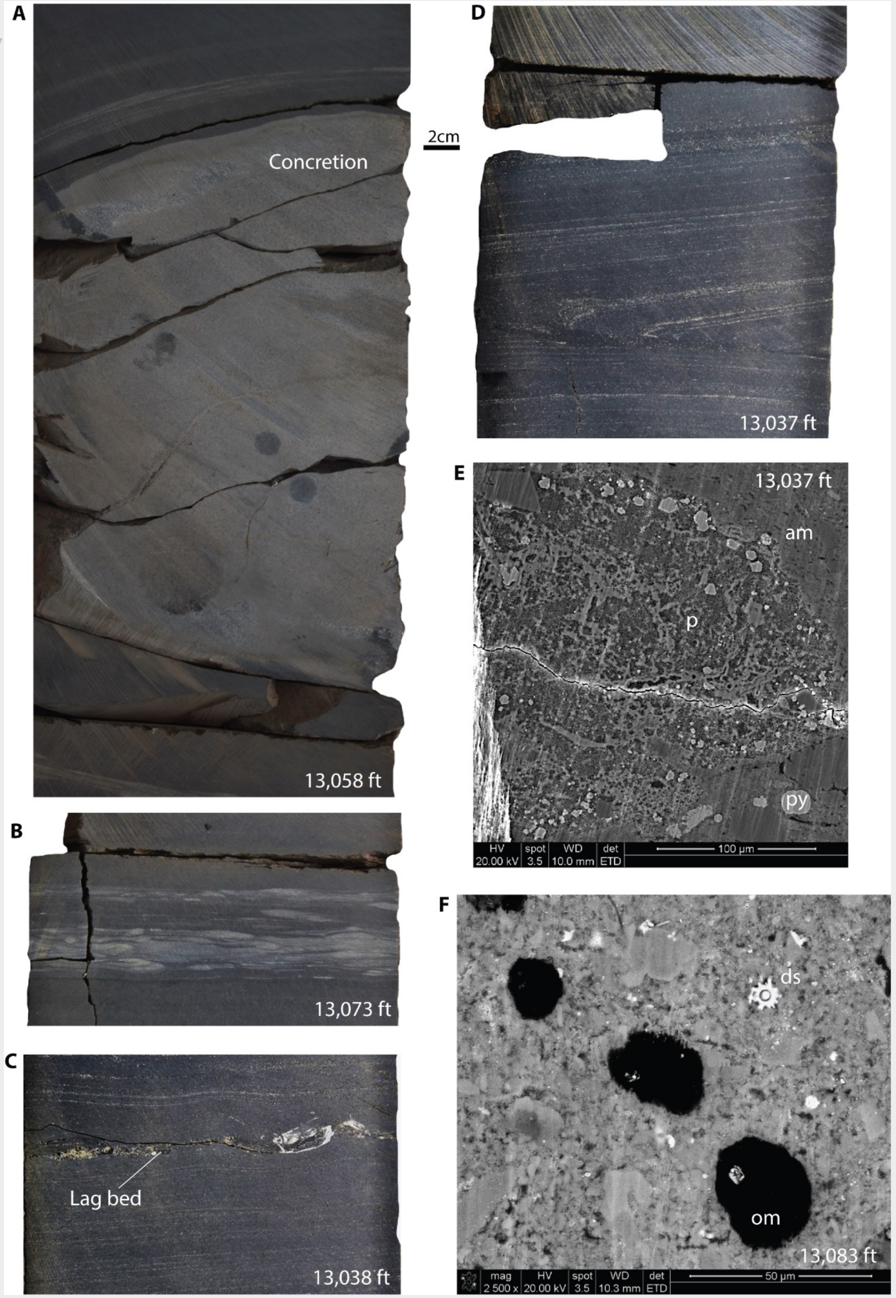
F. Framboidal pyrite (py) and argillaceous matrix with desiccation cracks (dc)

G. Quartz grains (q), fissure pores, argillaceous matrix (am), and organic matter (om)

Swelling Shale Lithofacies



A. Paired pinstripe laminae
B. Slickensided rhombohedral blocks
C. Siltstone filled burrows
D. Silty cross-laminae

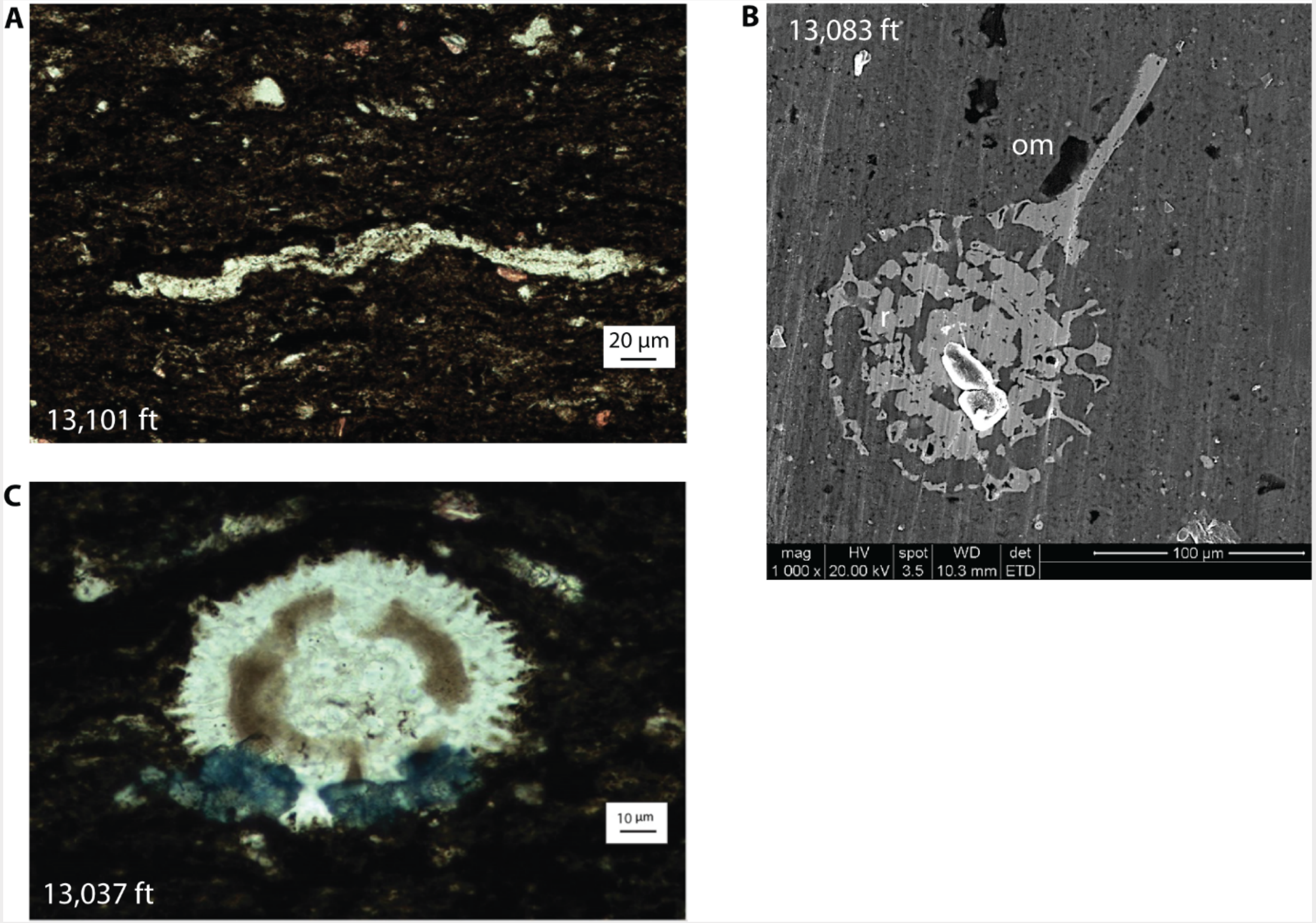


Reservoir Siltstone Lithofacies

A. Dolomite concretion
B. Wavy siltstone bed with ripple cross-laminae and clay drapes
C. Fossil-phosphate lag bed
D. Heterolithic cross-strata with overturned toesets
E. Phosphate particle with peloidal texture (p), argillaceous matrix (am), and pyrite (py)
F. Round bodies of organic matter (om) and demosponge spicule (ds). Note the quartz rich framework

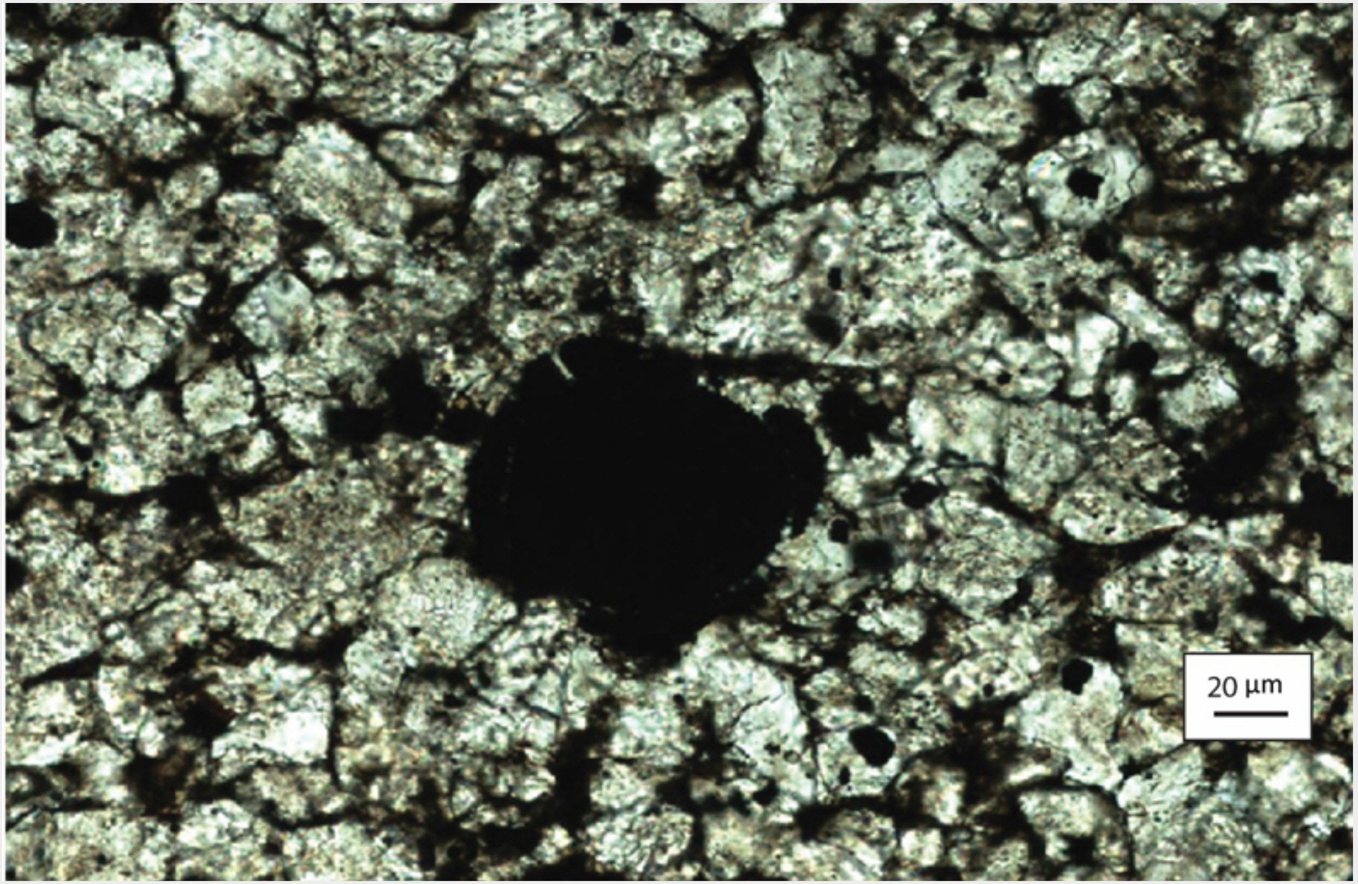
Reservoir Siltstone Lithofacies

A. Agglutinated foraminifera
B. Pyritized spumellarian radiolarian (r) and organic matter (om)
C. Silicified demosponge spicule with ferroan dolomite

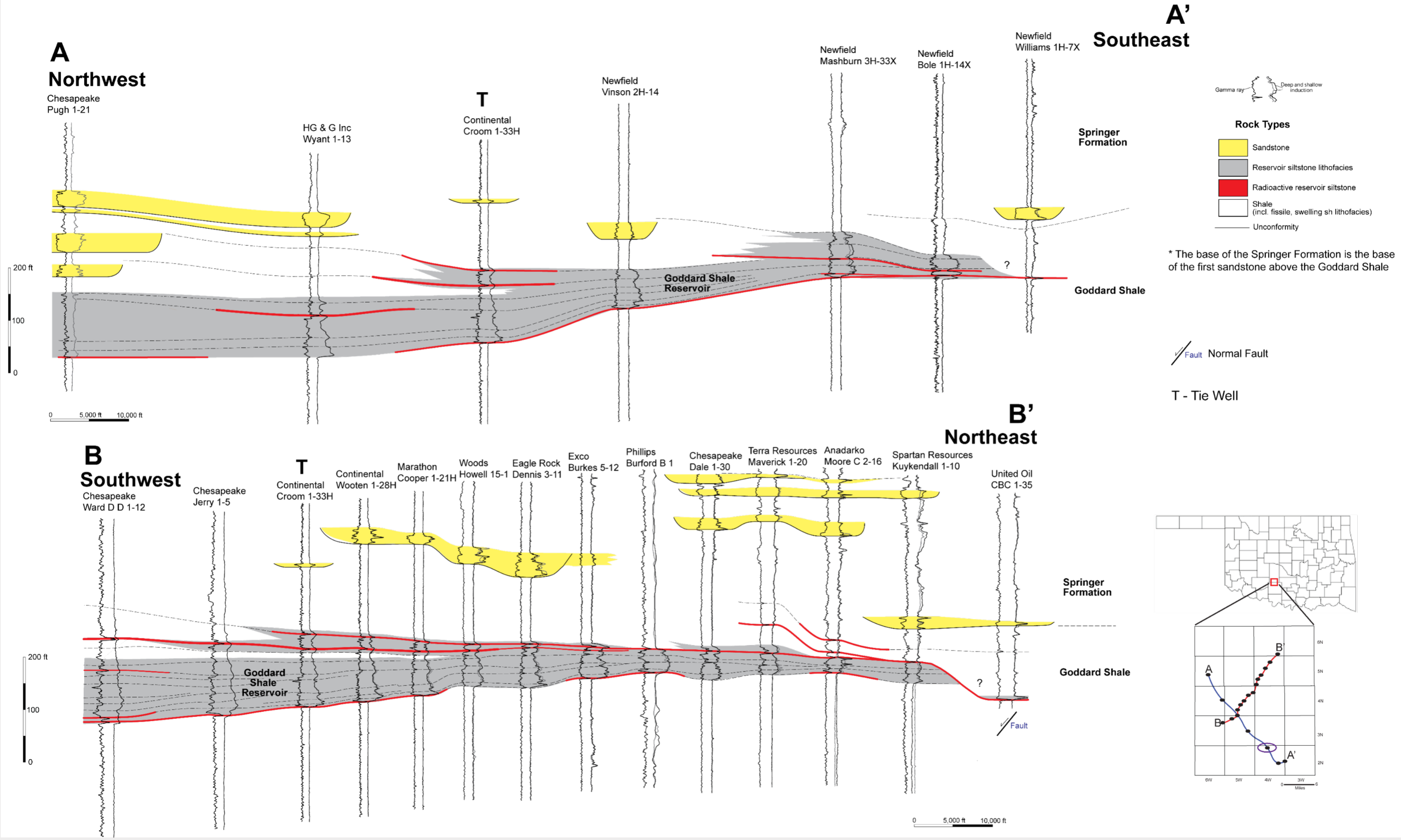


Dolomite Lithofacies

- Right – Graded bedding with dipping laminae and mud chips
- Below – Dolomite crystals and pyrite nodule

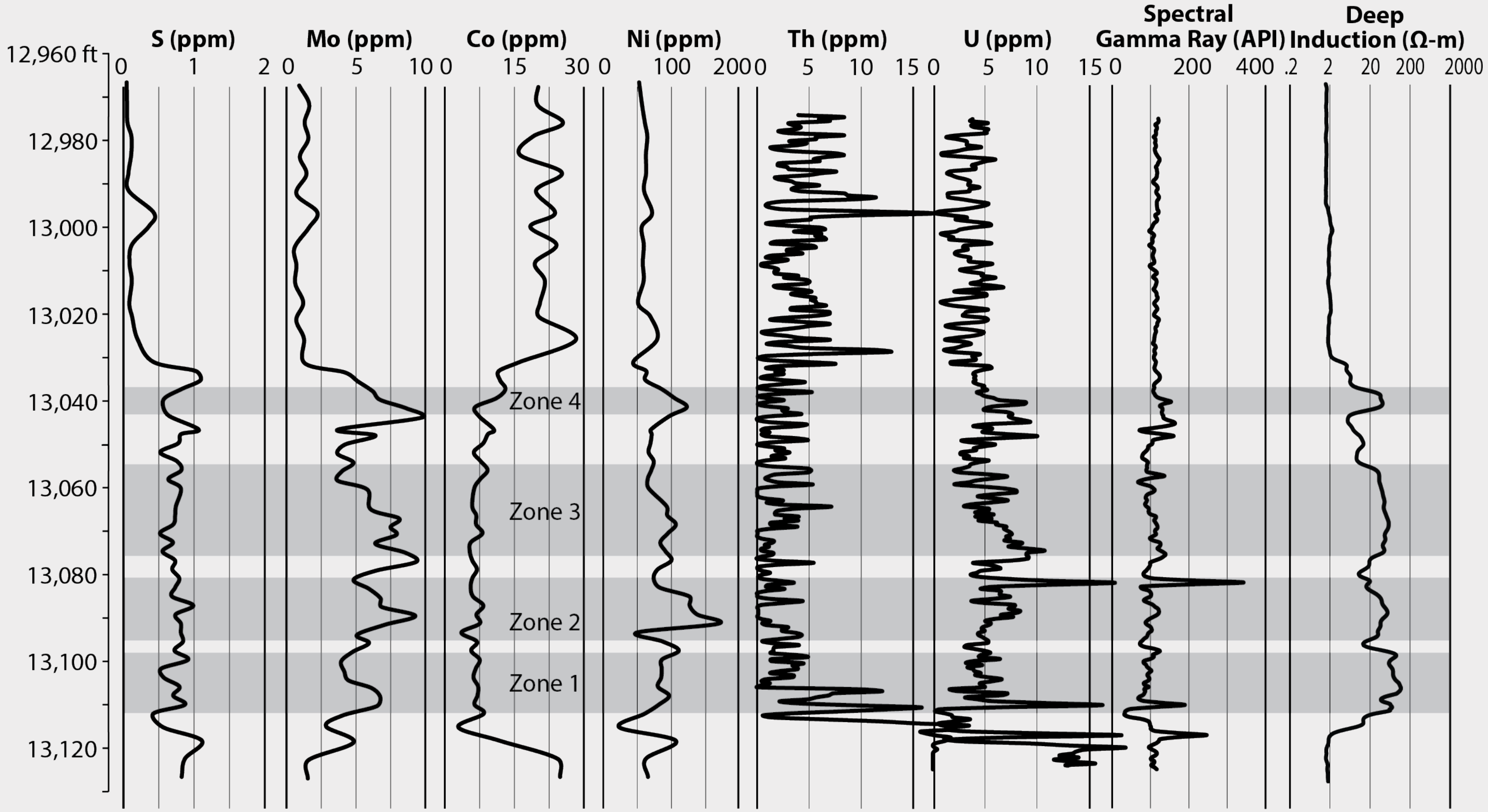


Facies Relationships



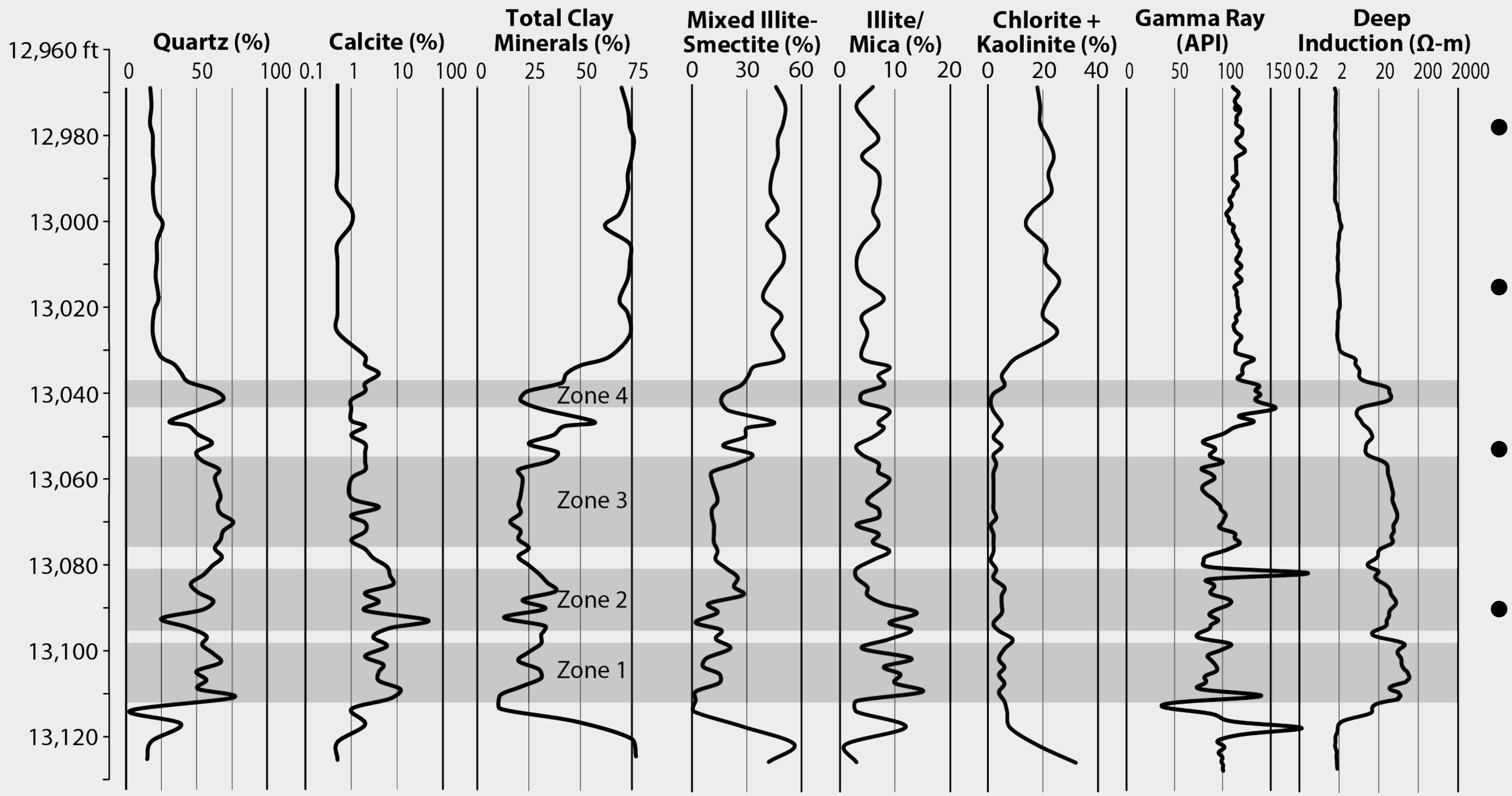
- Prograding clinoforms
- Basal contact of reservoir marks combined lowstand and TSE
- Intertonguing with basal Springer sands defines a progradational highstand
- Higher frequency events may be assignable to Milankovitch cycles

Geochemistry and Clay Mineralogy



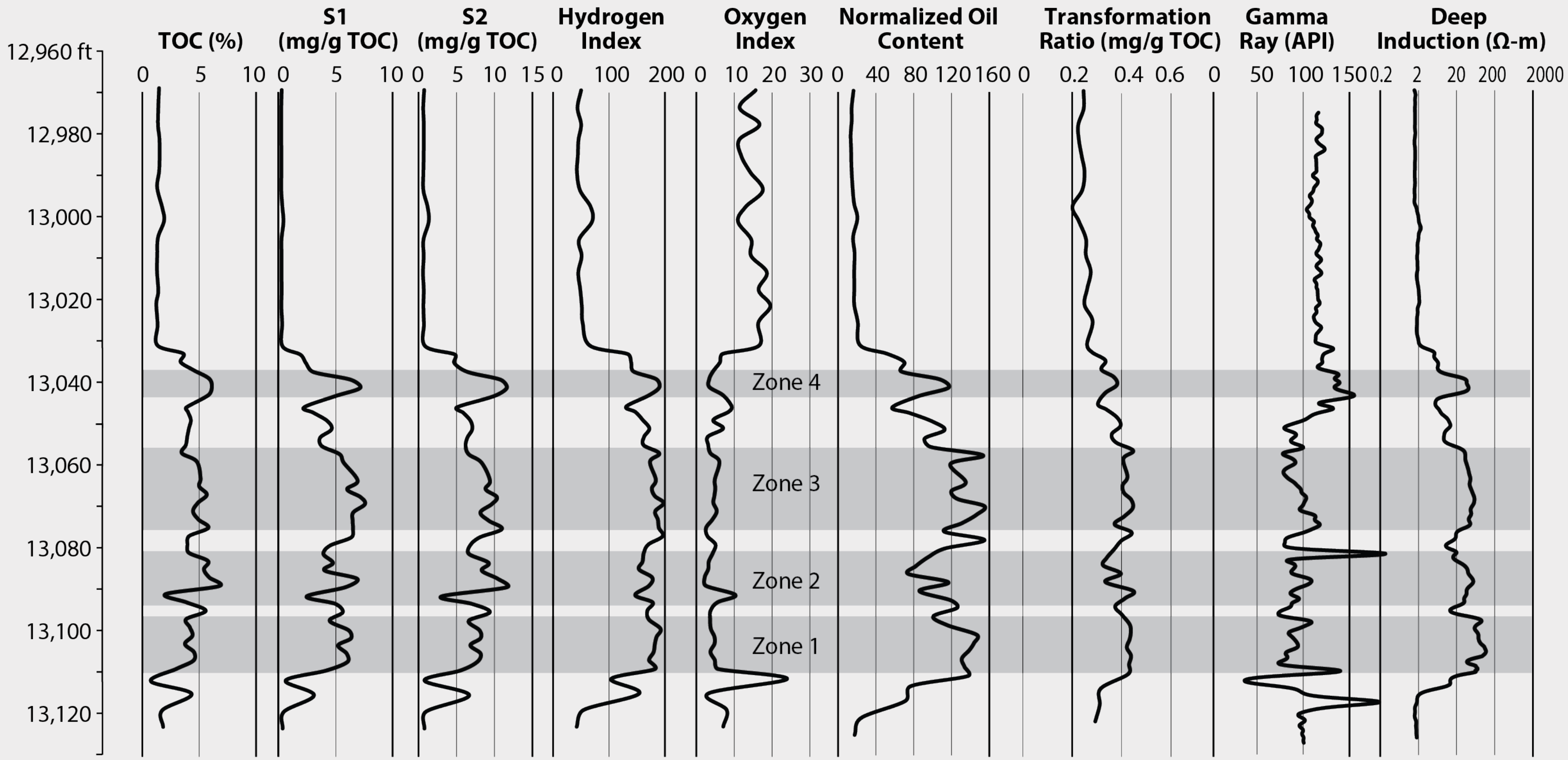
- S: trends 8x higher in reservoir
- Mo: trends much higher in reservoir
- Co: trends much higher in nonreservoir
- Ni: trends slightly higher in reservoir
- Th: elevated in nonreservoir
- U: stark difference between reservoir and nonreservoir
- K: was not plotted and shows little difference between reservoir and nonreservoir

Geochemistry and Clay Mineralogy



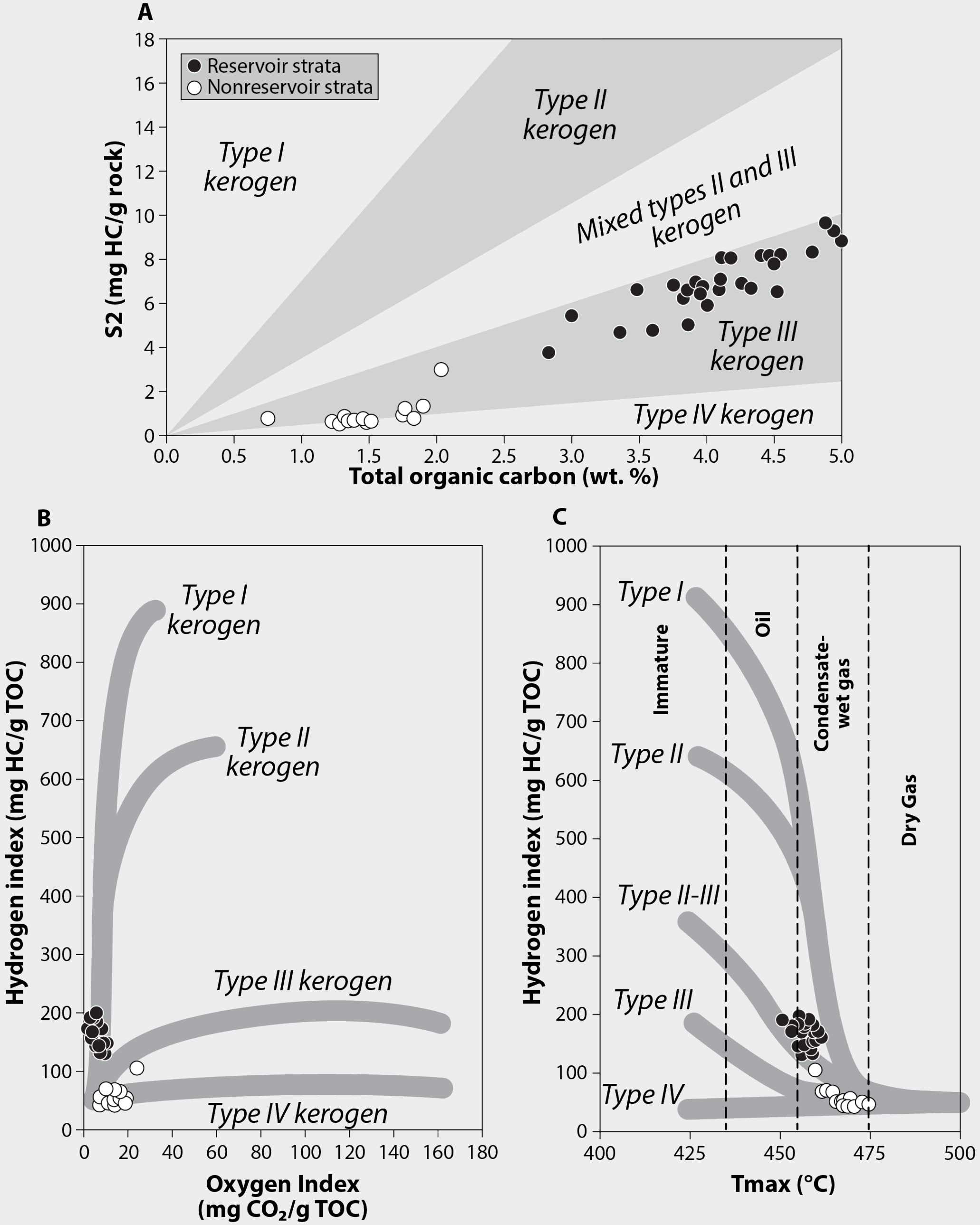
- Quartz: 2x higher in reservoir (56%)
- Calcite: nearly 2x higher in reservoir (5%)
- Total clays: over 2x higher in nonreservoir
- Strong correlation to resistivity curve

Rock-Eval Pyrolysis



- TOC averages 4.6% in the reservoir
- S1 & S2 trend high in the reservoir
- HI is over 3x higher in reservoir
- OI trends low in reservoir
- NOC 6.5x higher in reservoir
- TR trends higher in reservoir
- All curves have a relative trend to resistivity

Rock-Eval Pyrolysis



- Data points define two distinct clusters (reservoir, nonreservoir)

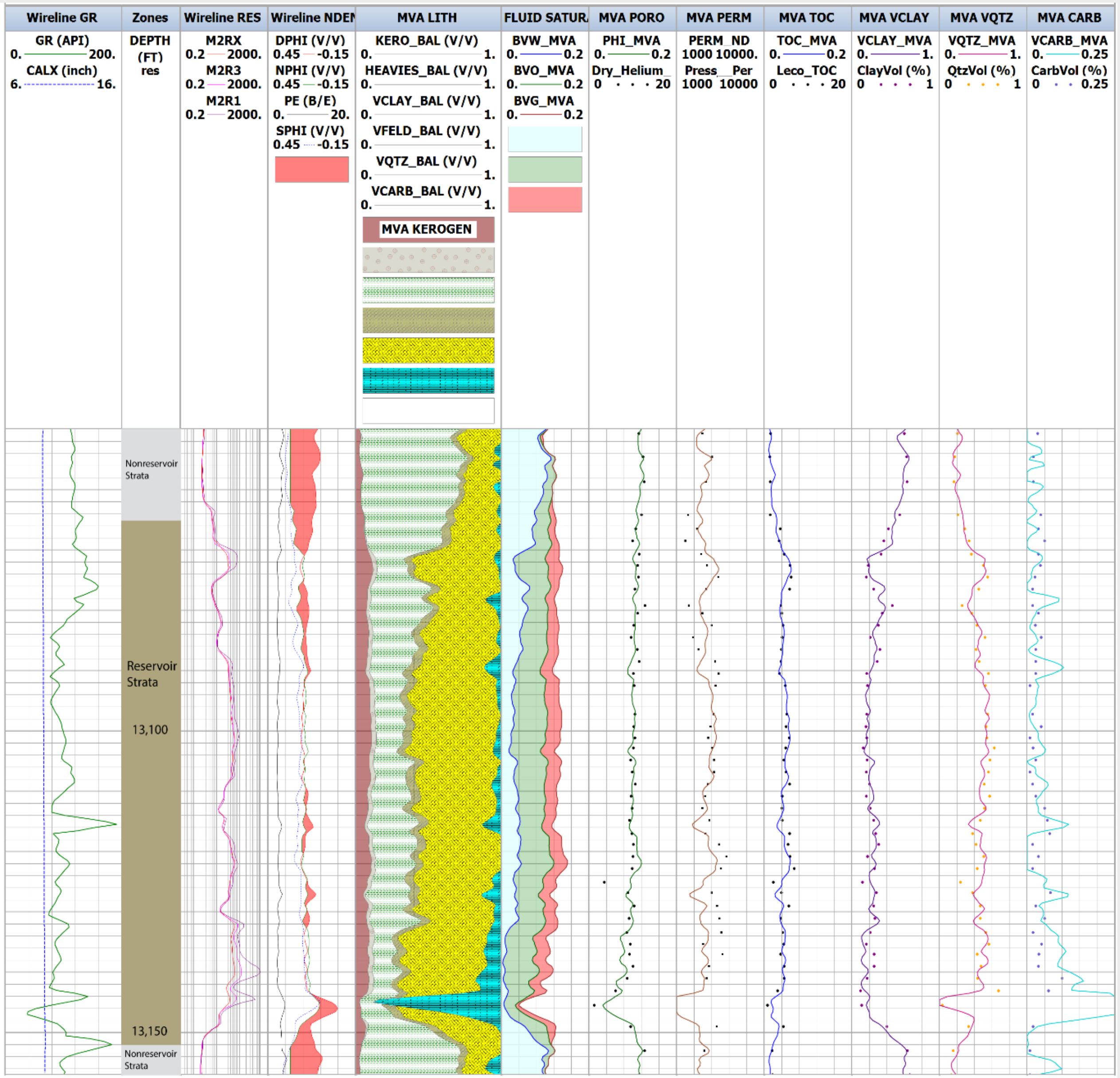
A. Kerogen quality plot

B. Pseudo Van Krevelen plot

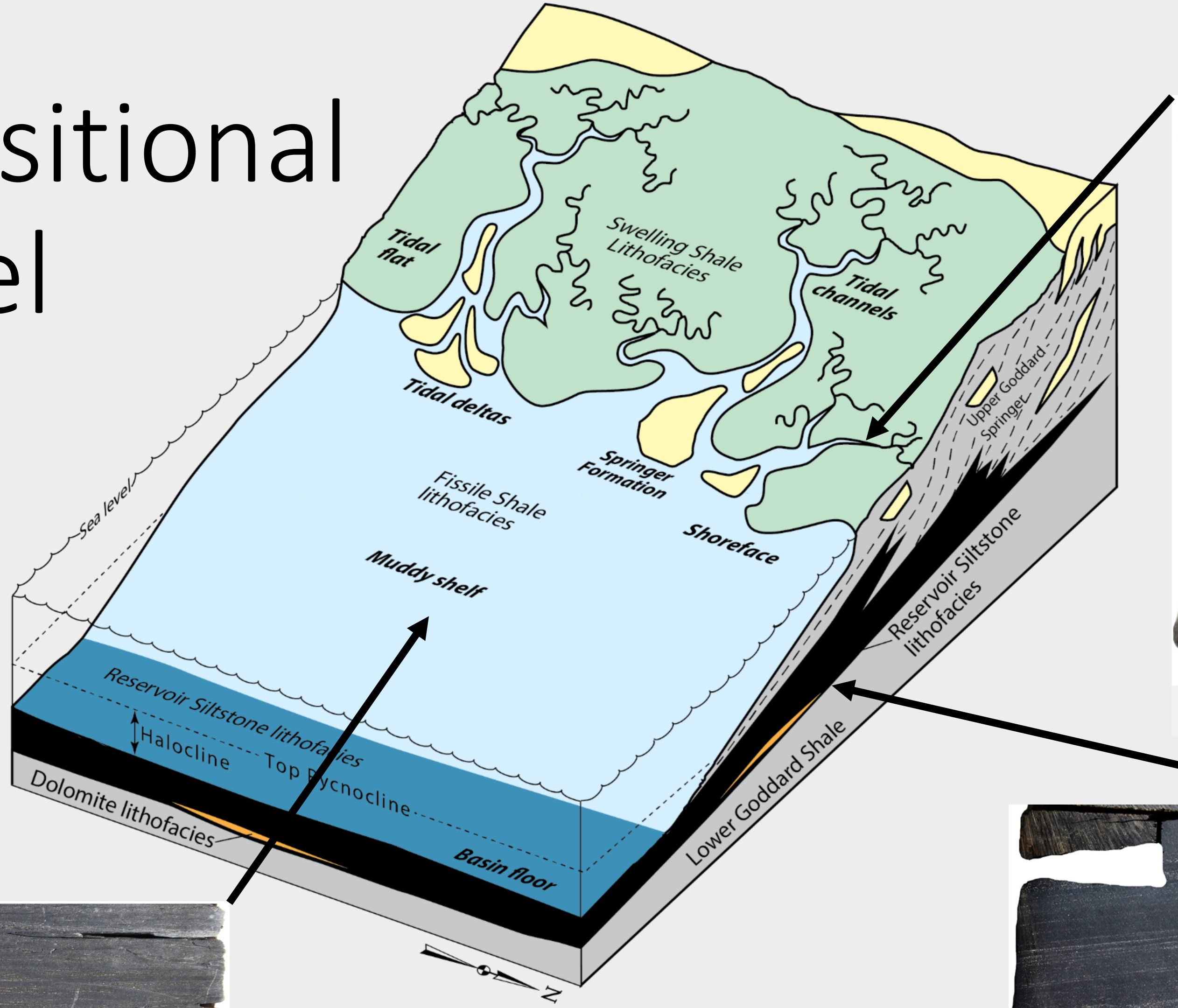
C. Tmax vs. HI

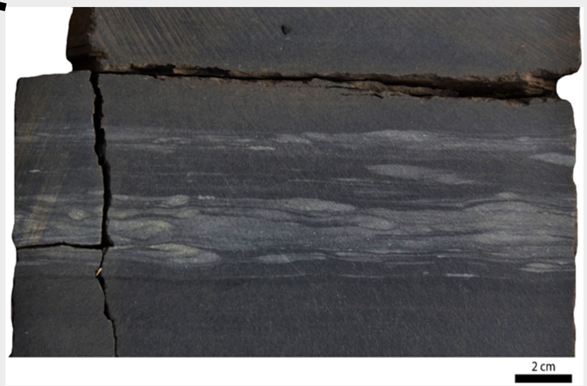
Petrophysical Model

- Porosity increases with Clay, Quartz and TOC presence
- Reservoir Averages:
  - Porosity: 10%
  - TOC: 4 %
  - Oil saturation reaches 50%
  - Natural gas saturation reaches 40%
  - Permeability: 2-5 µD
- Nonreservoir Averages:
  - Porosity: 12%
  - TOC: < 1%
  - Hydrocarbon pore volume: <1%
  - Permeability: ~2.2 µD

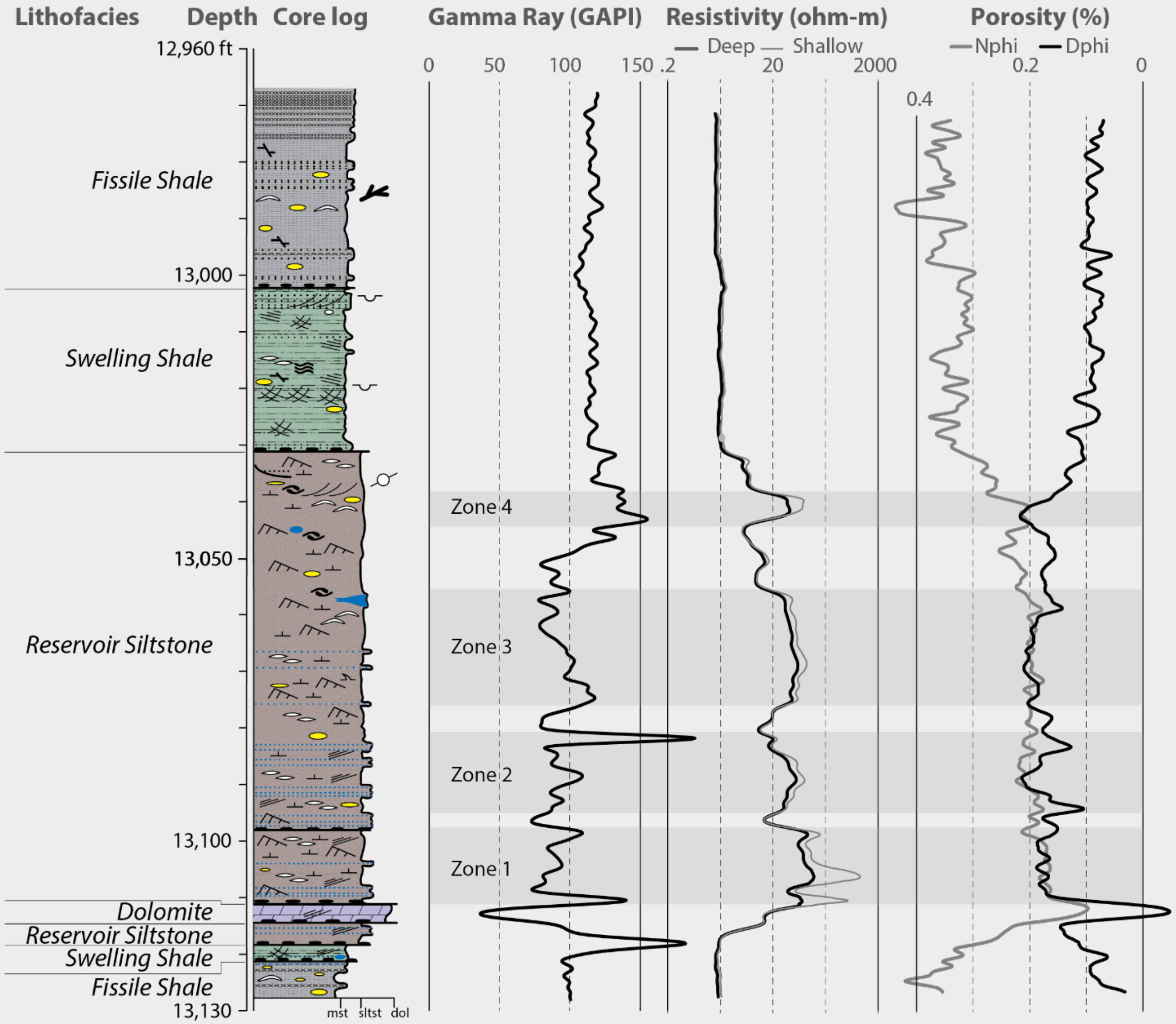


Depositional Model





Reservoir Development



- Clay mineralogy is the primary control on reservoir quality
- 4 target zones were identified for horizontal development
  - As the unit thins, the entire reservoir lithofacies becomes the target
- Resistivity tracks with quartz content, TOC content, and oil saturation, allowing for simple net pay identification with resistivity cut offs
- Overpressured

Conclusions

- Depositional environments range from near shore to distal subtidal
  - Fissile Shale – muddy lagoonal or inner shelf deposit
  - Swelling Shale – tidal flats and immature soils (shore zone deposit)
  - Reservoir Siltstone – distal shelf deposit
  - Dolomite – storm or internal wave deposit that formed near the top of the pycnocline
- Sea level changes contributed to facies heterogeneity and the development of numerous parasequences
- Clay mineralogy is dominant control for reservoir quality
- A simple log resistivity cut off can be used to make an effective map of net pay
  - Quartz, TOC, and oil content have a positive trend
  - Clay volume has a negative trend

Questions!