Sedimentology, Diagenesis, and Lithostratigraphy of the Desmoinesian Upper Fort Scott, Labette Shale, and Lower Pawnee Limestone Formations (Marmaton Group) in Eastern Colorado*

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Search and Discovery Article #30298 (2013)**
Posted November 25, 2013

*Adapted from an oral presentation given at AAPG Mid-Continent Section Meeting, Wichita, Kansas, October 12-15, 2013

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Abstract

Regional gamma ray log cross-sections incorporating outcrop gamma measurements from eastern Kansas aid in delineating Desmoinesian stratigraphy in eastern Colorado and western Kansas by tracing highly radioactive, regionally invariable shale units. A representative type log of the Upper Cherokee and Marmaton groups in eastern Colorado presents the correction of local stratigraphic nomenclature. Sixty-three feet of core (from southeast Colorado) in the Higginsville Limestone Member of the Fort Scott Formation upward through the Myrick Station Limestone Member of the Pawnee Formation were studied to determine sedimentological and diagenetic controls on reservoir development.

Higginsville rocks are composed of subtidal to peritidal lime mudstone cycles overlain by a peloidal grainstone reservoir. Original porosity was occluded by calcite and later dolomite cements, precipitated from fluids moving through fracture systems. Secondary porosity was later created by mesogenetic dissolution proximal to stylolites and fractures. Rapid eustatic drowning caused the deposition of the Labette Shale Formation and the overlying Anna Shale Member of the Pawnee Formation. Carbonate turbidites in the Anna Shale were sourced by higher-energy facies along the Las Animas Arch. Myrick Station rocks are low-energy phylloid algal wackestones overlain by a Chaetetes reef. A combination of subsurface mapping and well log analysis is sufficient to predict reservoir facies in the Myrick Station Limestone. However, mesogenetic dissolution porosity such as that found in the Higginsville Limestone often proves impossible to predict with satisfactory success.

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“Sedimentology, Diagenesis, and Lithostratigraphy of the Desmoinesian Upper Fort Scott, Labette Shale, and Lower Pawnee Limestone Formations (Marmaton Group) in Eastern Colorado”

Andrew (Toby) Eck

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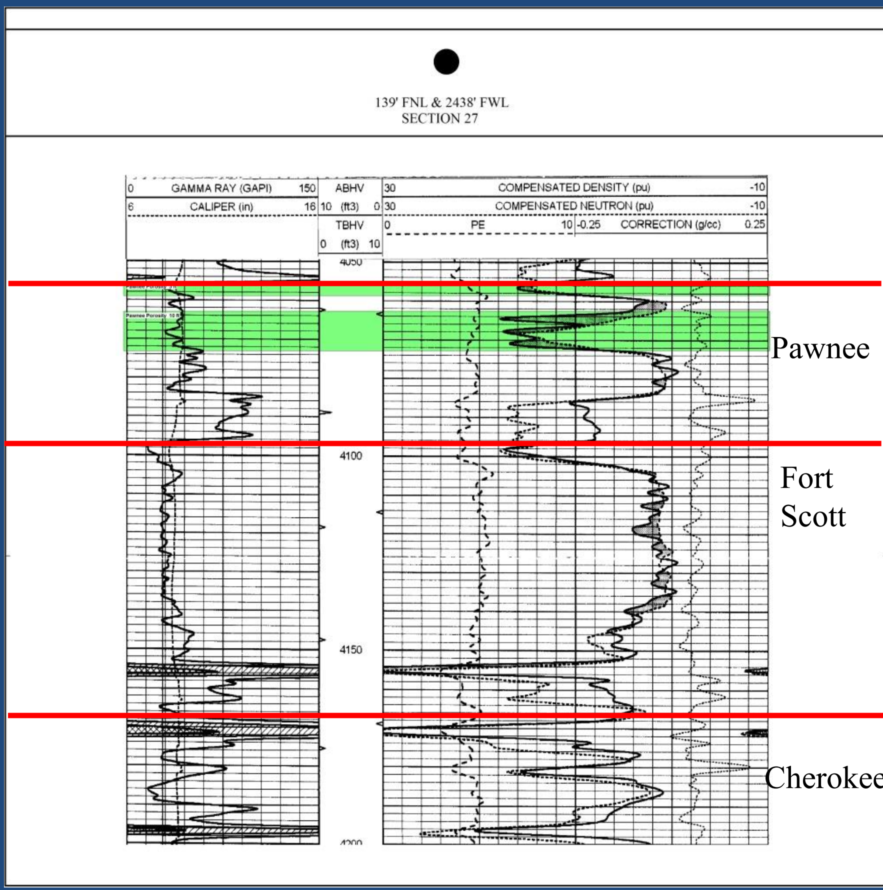
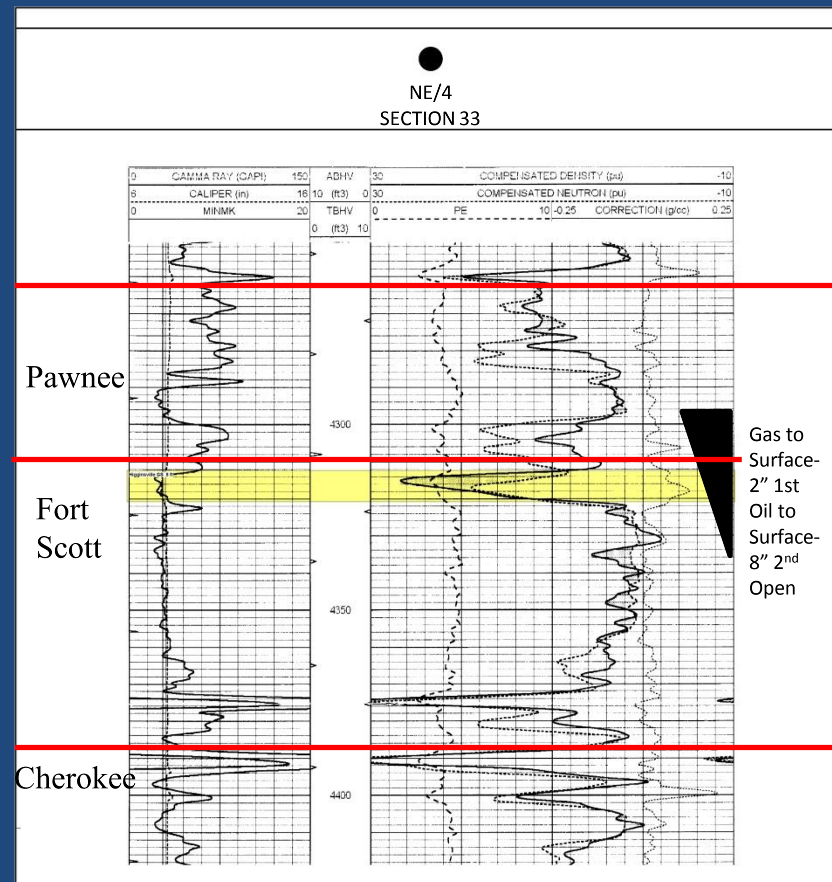
MULL DRILLING COMPANY, INC.
WICHITA, KANSAS

Introduction

Higginsville Limestone and Myrick Station Limestone Reservoirs in Eastern Colorado
Purpose of the Study



Initial Daily Production: 99 Barrels of Oil and 15 Barrels of Water.



Initial Natrual Daily Production: 80 Barrels of Oil (No Wtr.)

Introduction

Higginsville Limestone and Myrick Station Limestone Reservoirs in Eastern Colorado

- **Myrick Station Limestone Reservoir**
  - Best Known Reserves (1 well)- 60 MBO
  - Thickness- 0-15'
  - Porosity- Negligible to >20%
  - Pressure-depletion Drive
  - Associated Water
  - Often Associated Gas

- **Higginsville Limestone Reservoir**
  - Best Known Reserves (1 well)- 130 MBO
  - Thickness- 0-15'
  - Porosity- Negligible to >30%
  - Pressure-depletion Drive
  - Associated Water
  - Often Associated Gas

Good Bailout zones, but predictions are difficult

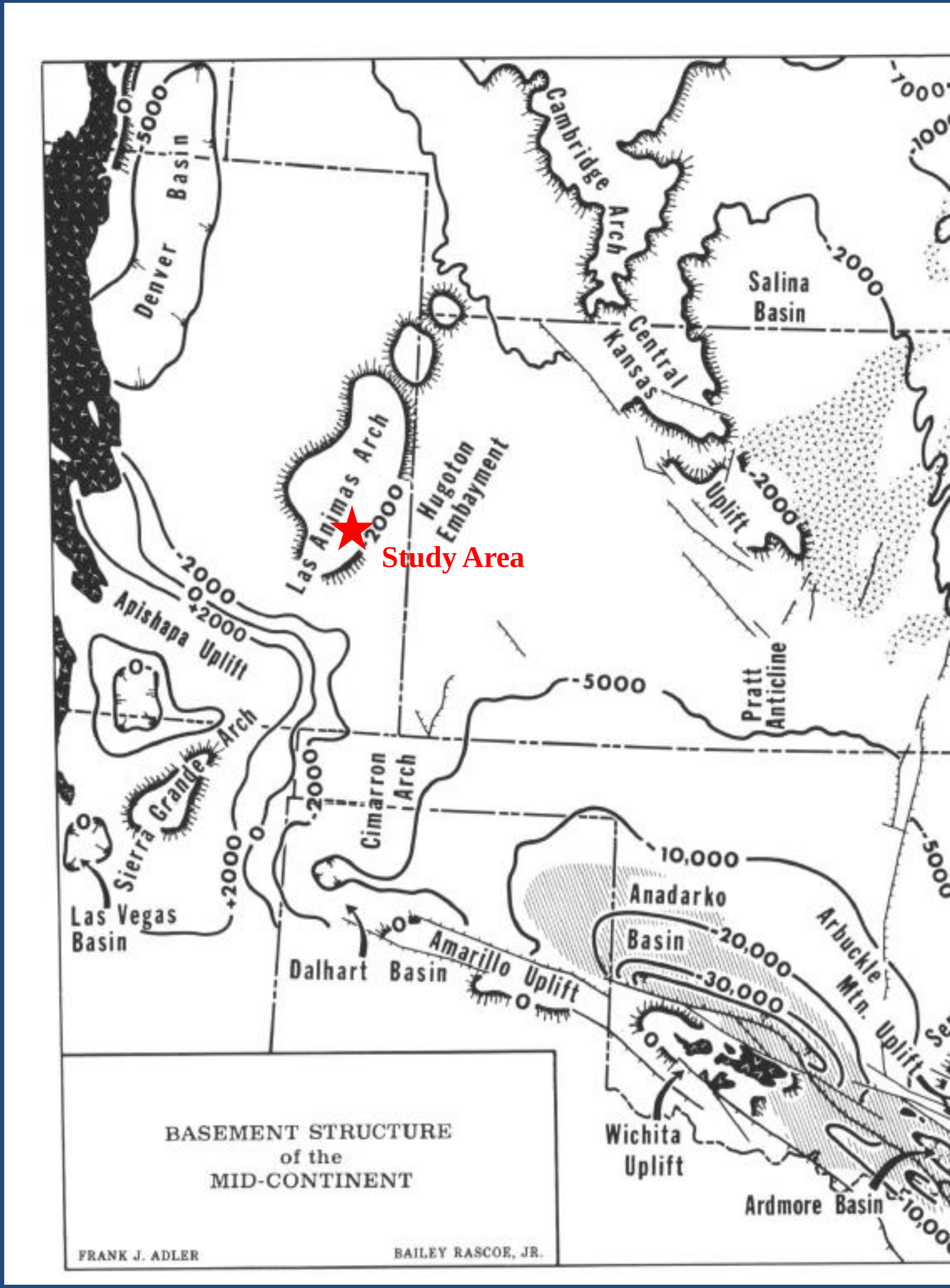
OUTLINE

- Regional Overview/Study Area
- Lithostratigraphy
- Core Study
  - Sedimentology
  - Diagenesis/Thin section petrography
- Exploration implications

Study Area

-Structures and Basins

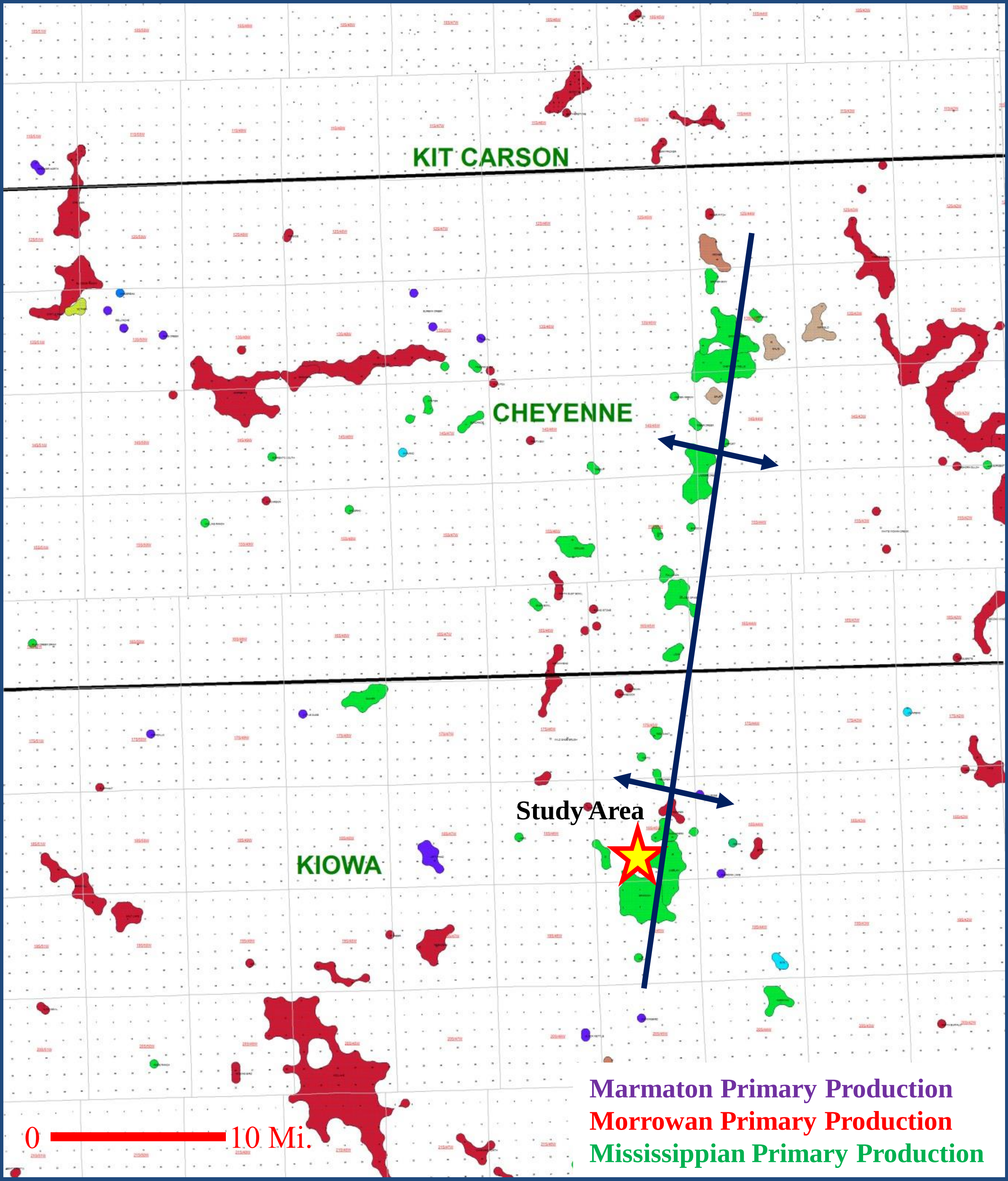
- Las Animas Arch
  - Positive Structure during Precambrian
  - Present-day structure acquired during Laramide
- Apishapa Uplift
  - Wichita Orogeny



Modified from Rascoe and Adler, 1983

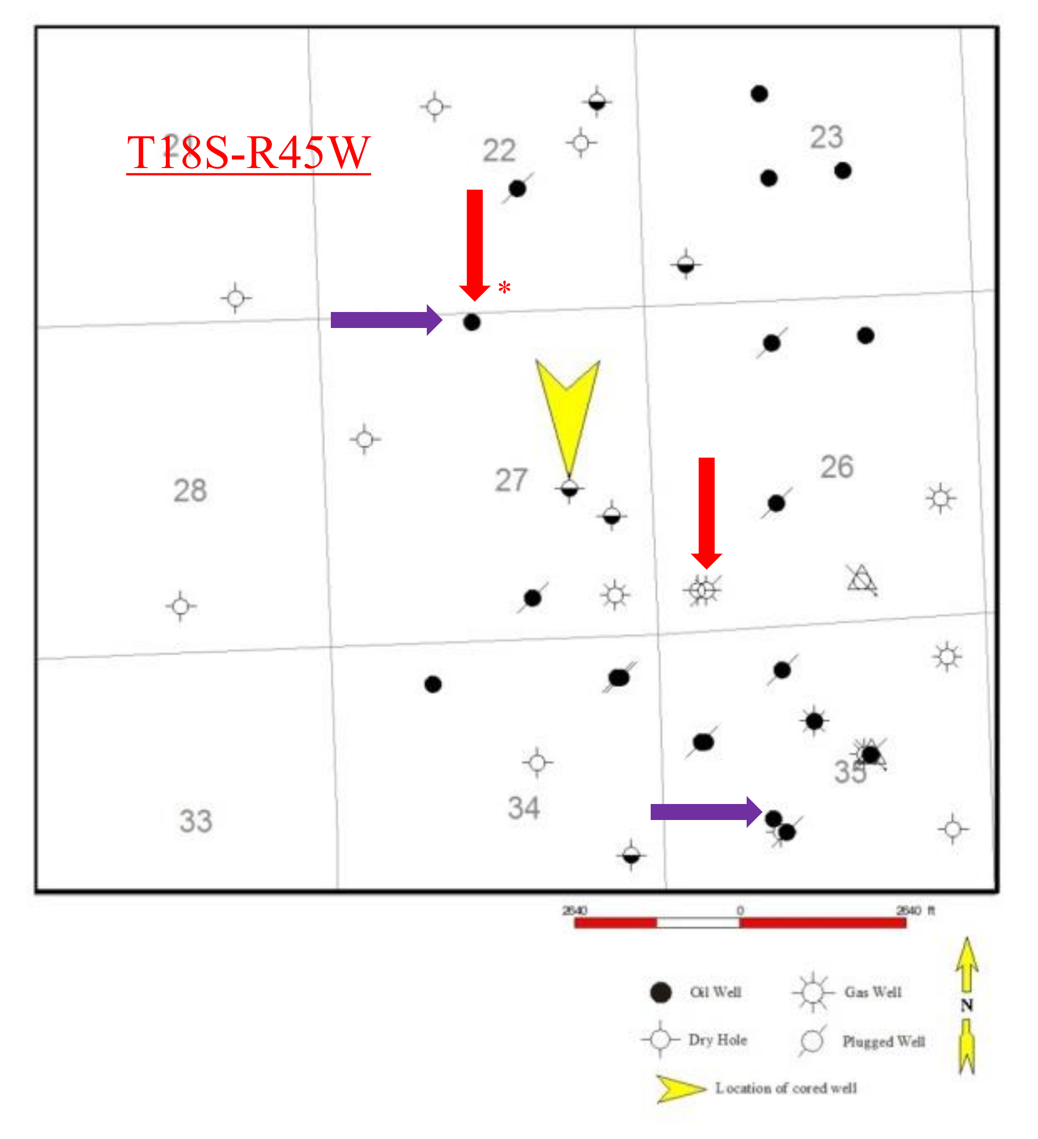
Study Area

- Overlies the Brandon Axis of the Las Animas Arch
- Overlies the Cavalry Oil Field (primarily Mississippian production)



Study Area

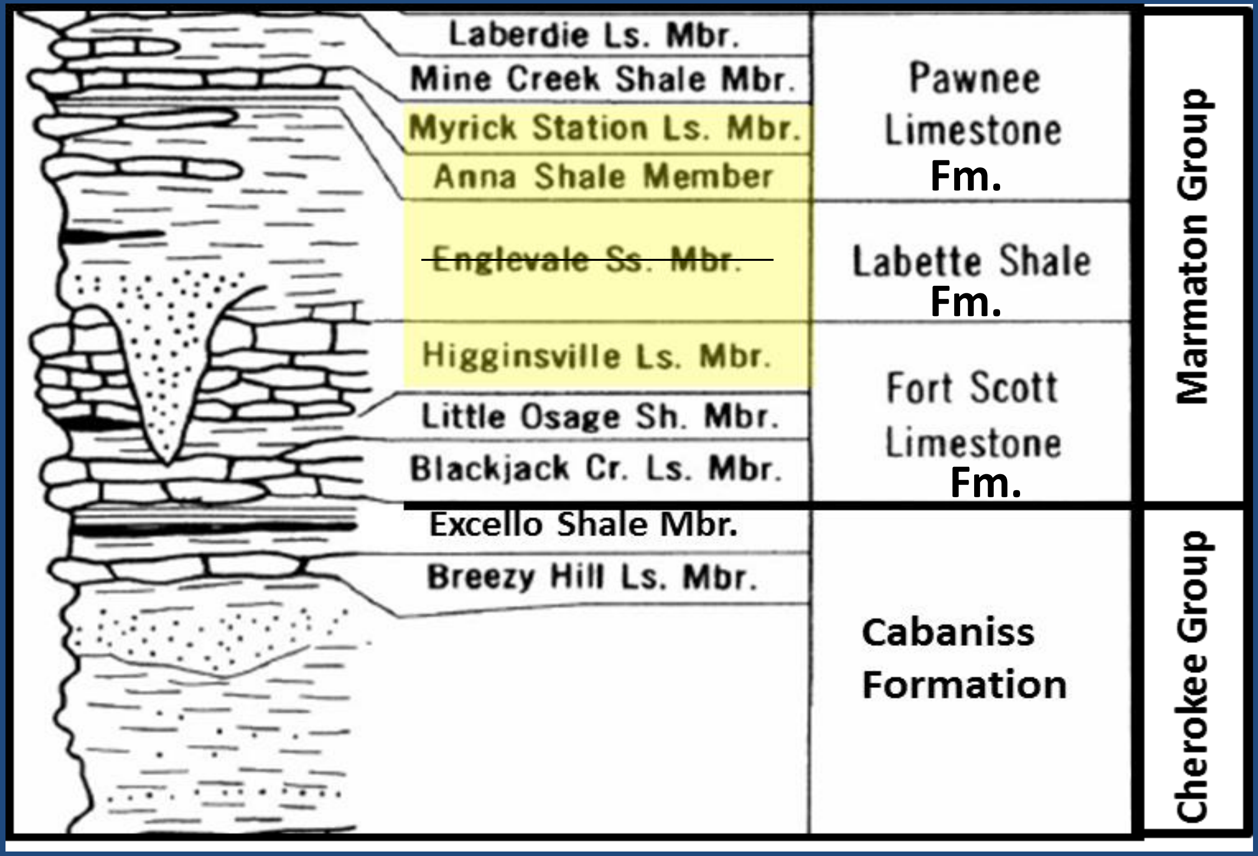
- ~5,000 acres
- Approximately 35 Exploratory Wells
  - Available Logs, Completion, Drill-Stem Test
- One available core
- Myrick Station Production (Purple)
- Higginsville Production (Red)



Stratigraphy

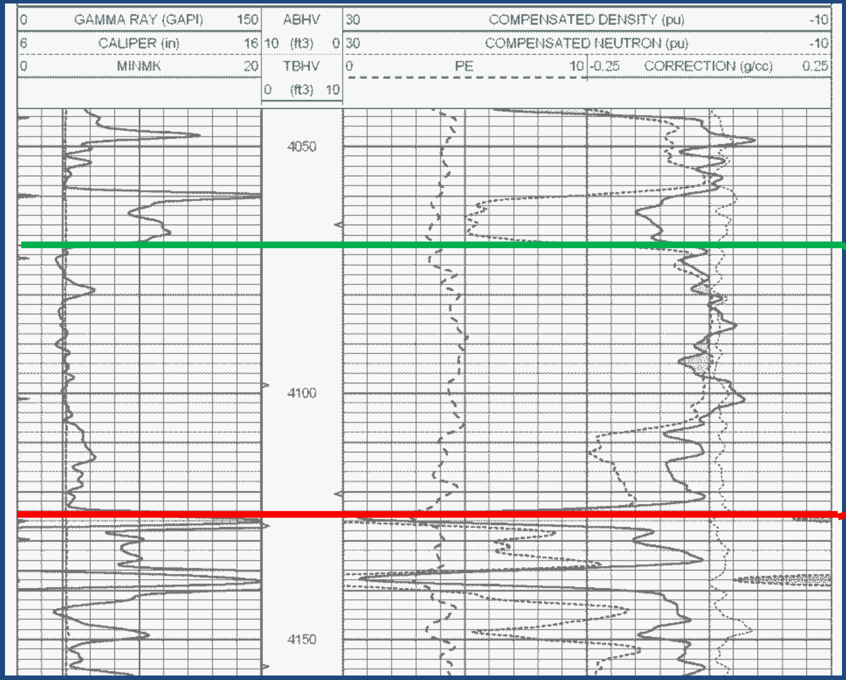
Merriam (1941)

- Lower Pawnee Formation
  - Myrick Station Lst. Mbr.
  - Anna Shale Mbr.
- Labette Shale Formation
- Fort Scott Formation
  - Higginsville Lst. Mbr.
  - Little Osage Shale Mbr.
  - Blackjack Creek Lst. Mbr.

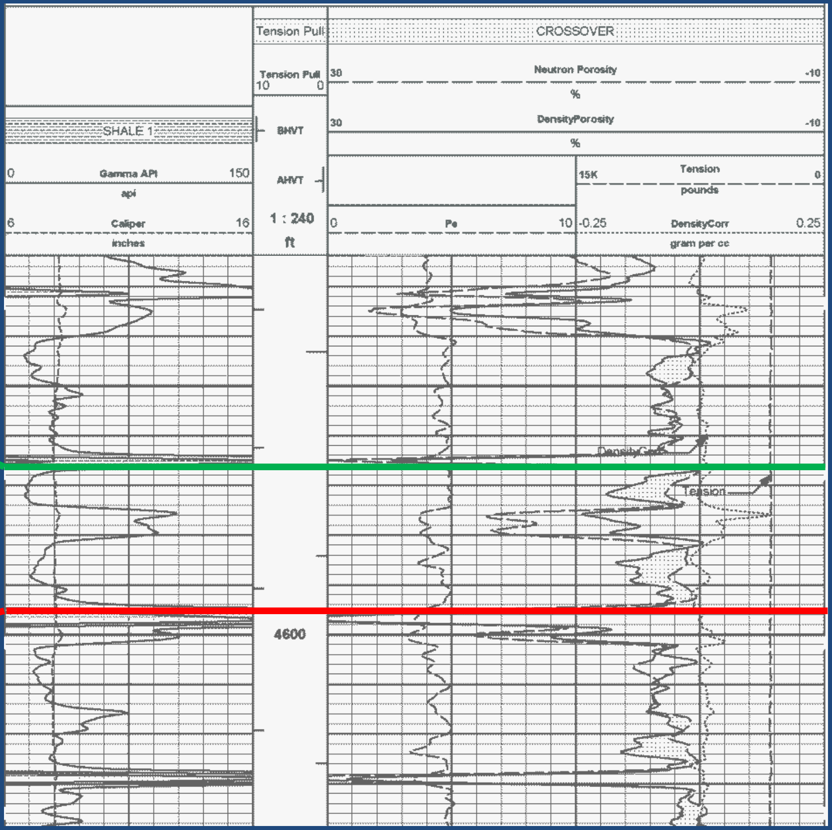


Stratigraphic Nomenclature

Eastern Colorado Nomenclature



Western Kansas Nomenclature



?

Fort Scott

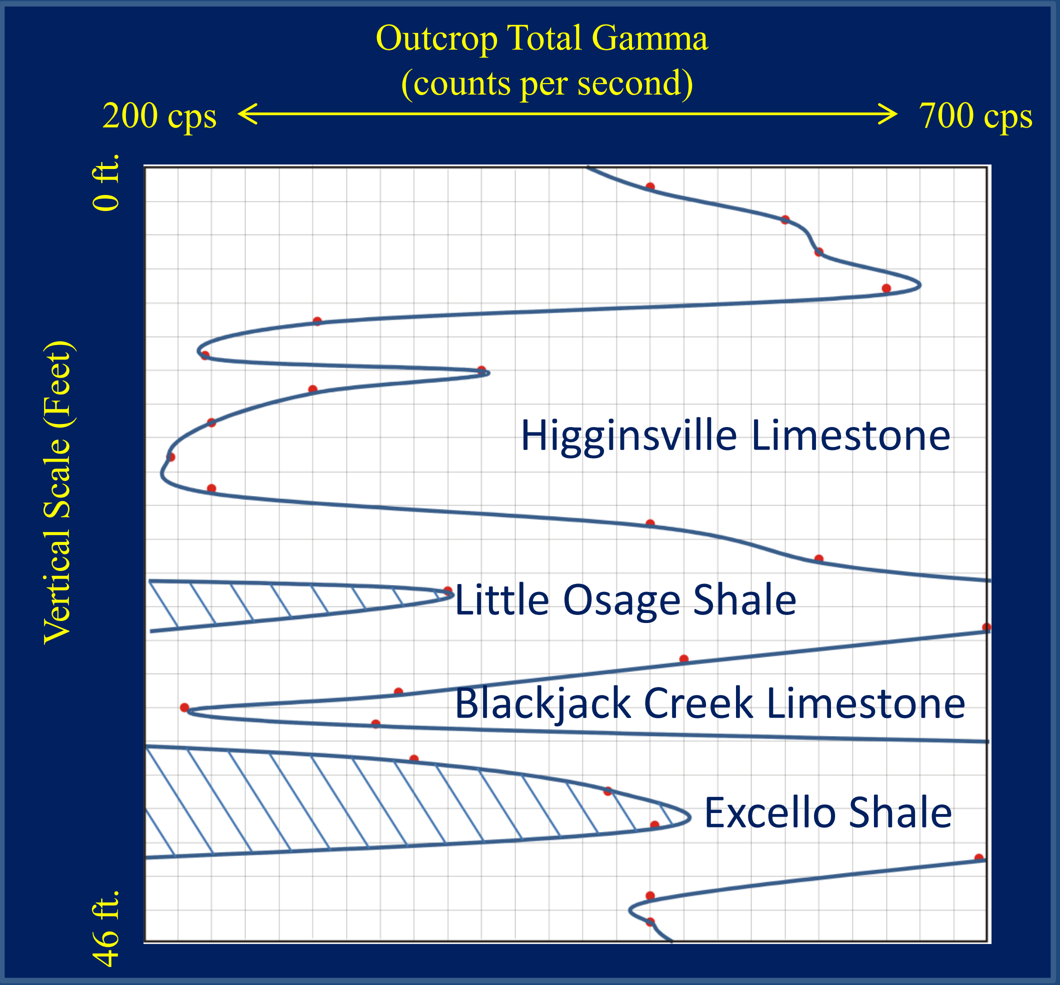
Cherokee

~37 miles

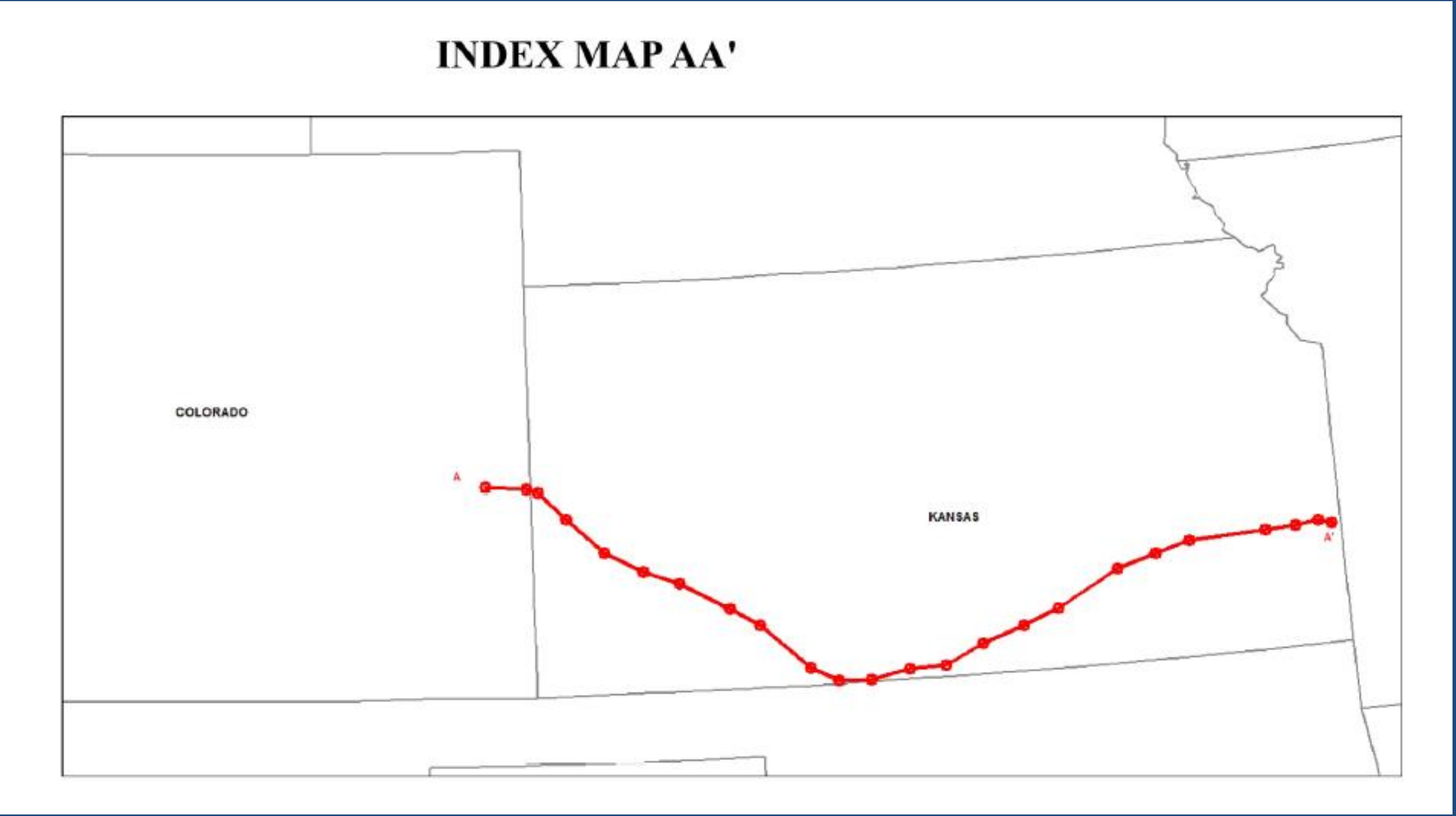
Regional Maps?

Lithostratigraphy

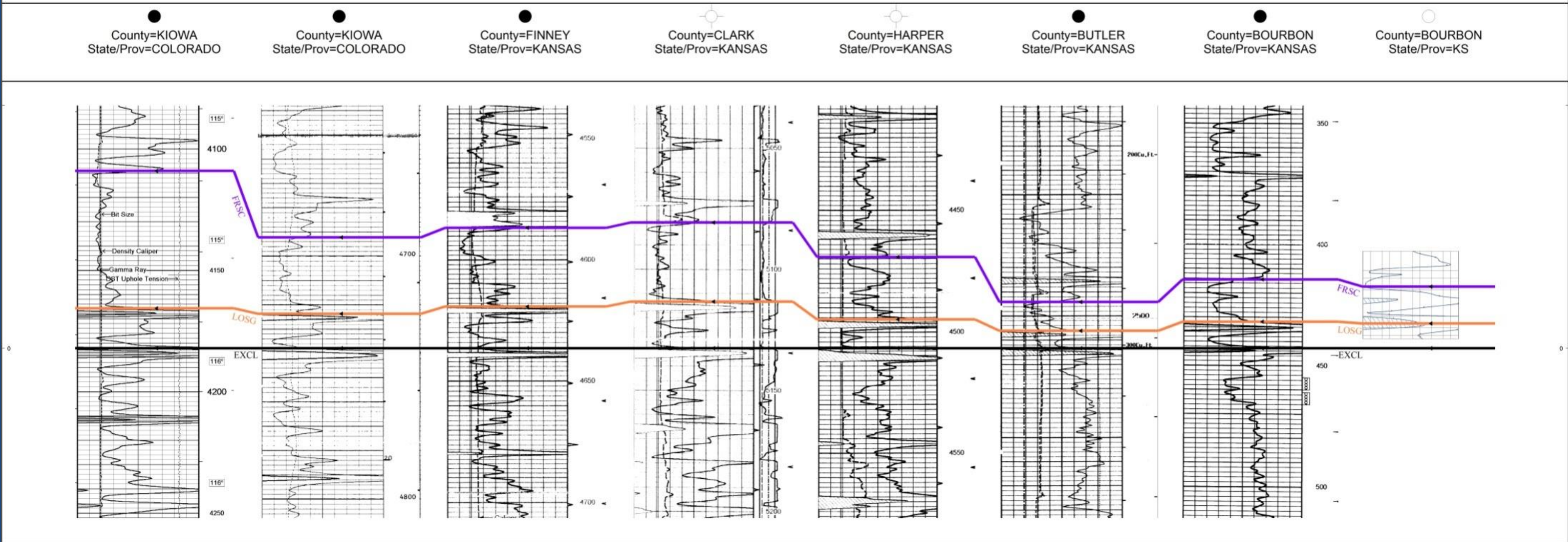
- Bob Slamal's Correlations
  - Gamma Ray Log
  - Desmoinesian carbonates are too variable for long-distance correlations
  - Hot Shales are key
- Outcrop Gamma
  - Fort Scott Type Locality (Merriam, 1941) NE/4 19-25S-25E
- ~80-well cross-section
  - Excello & Little Osage Shales



Representative Cross-Section

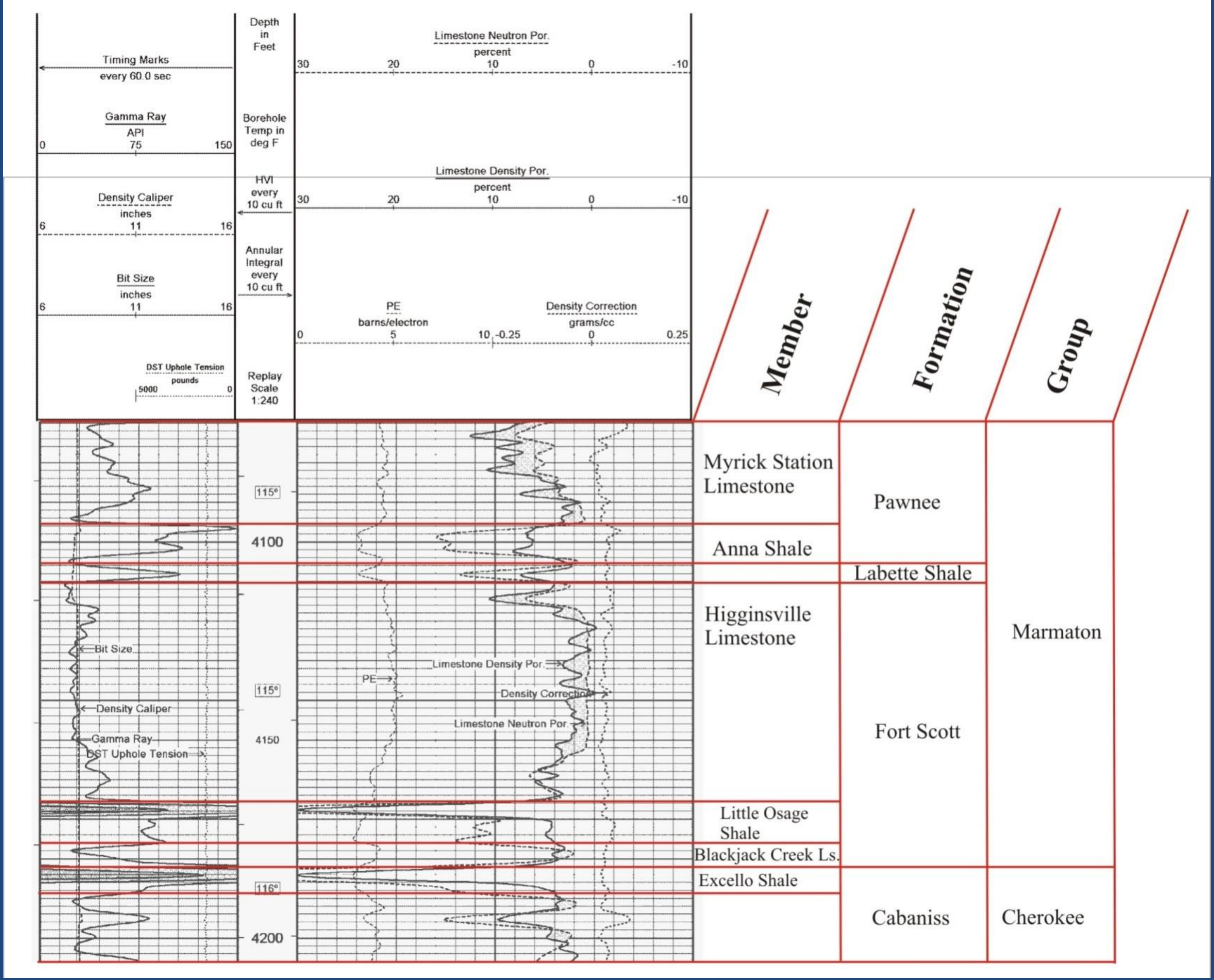


Eastern Colorado Study Area to Fort Scott Type Locality
(Bourbon County, KS)
AA'



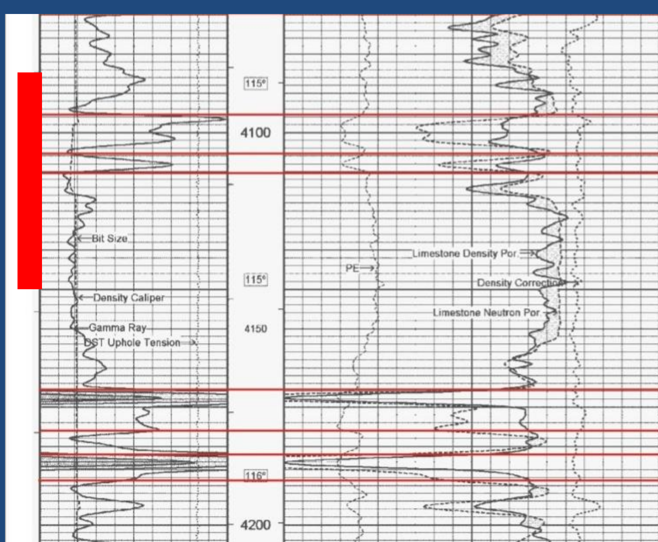
Lithostratigraphy

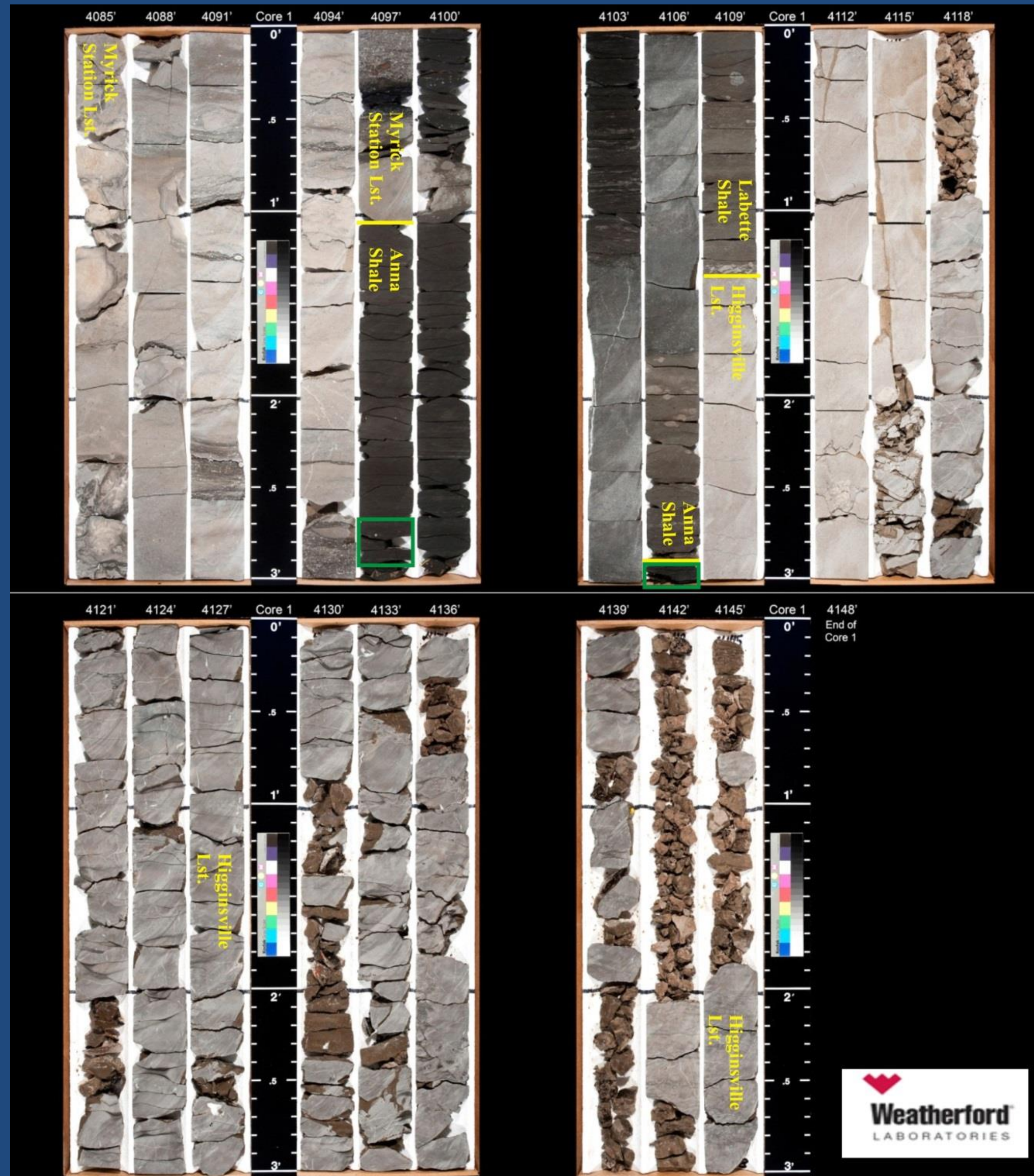
Eastern Colorado Type Log



Sedimentology

- Cored Interval
  - ~13’ Myrick Station Limestone
  - ~10.5’ Anna Shale
  - ~2’ Labette Shale
  - 37.5’ Higginsville Limestone



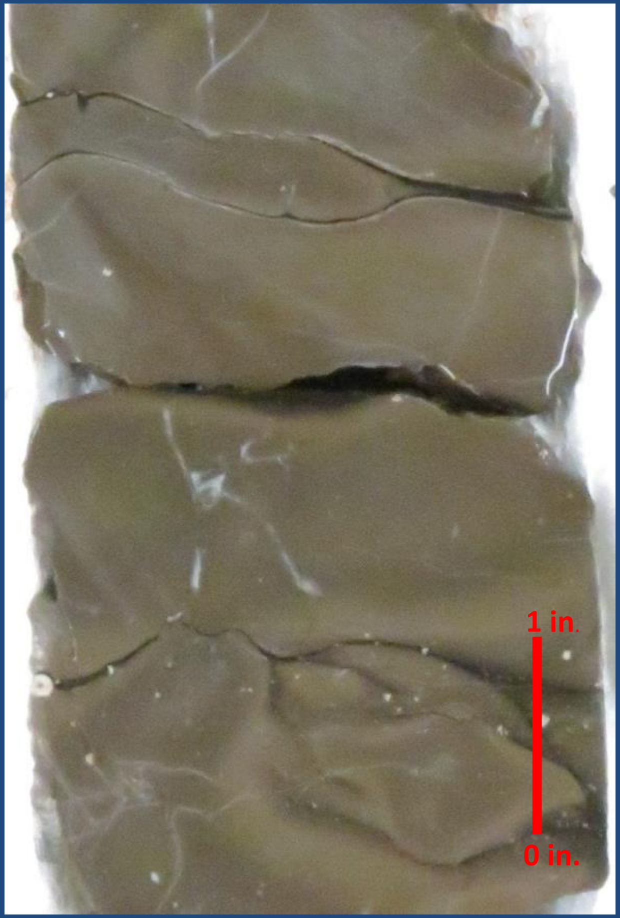


Sedimentology

Core Depth:~4146’

Higginsville Limestone Mbr. of the Fort Scott Formation (37.5’)

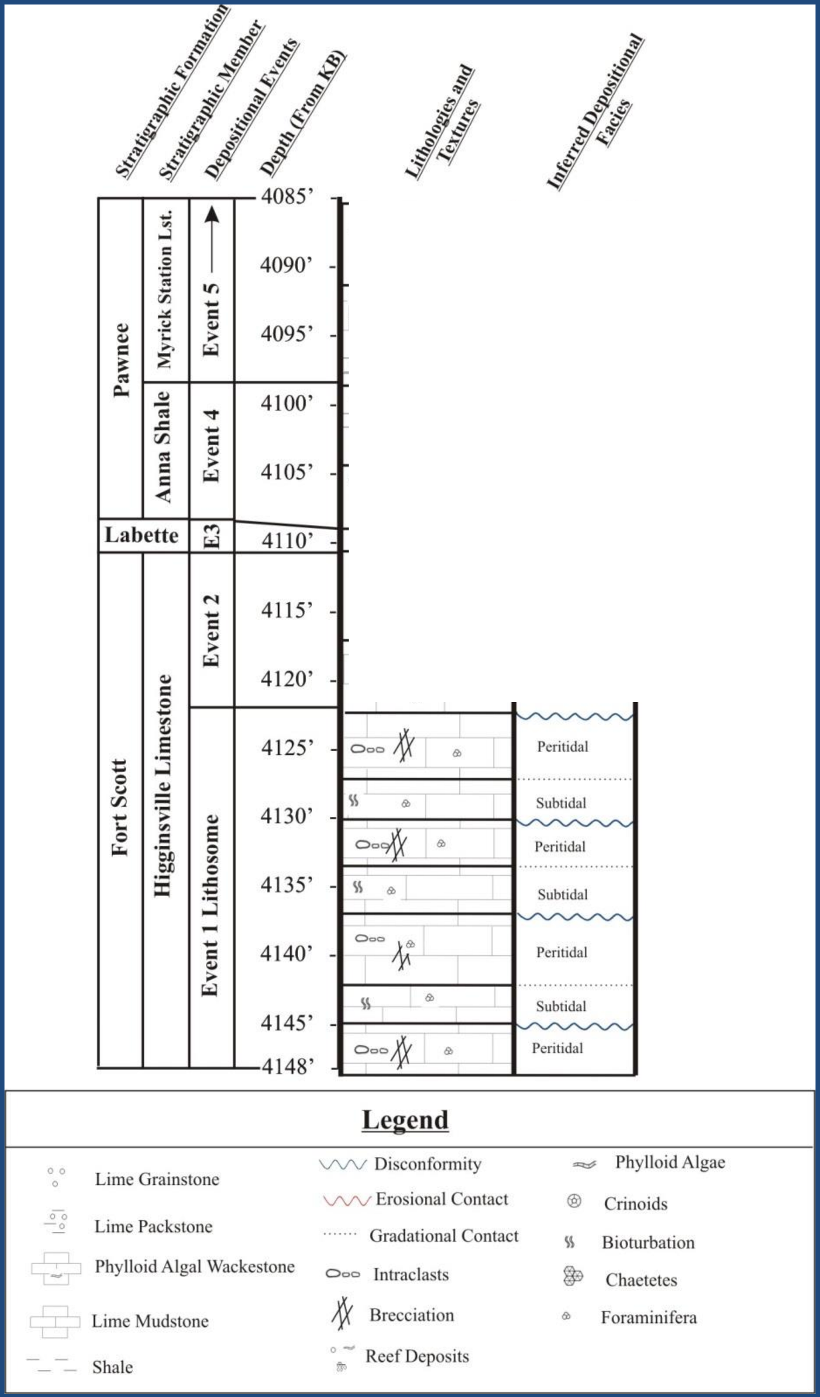
LOWER 26’



Core Depth:~4144’

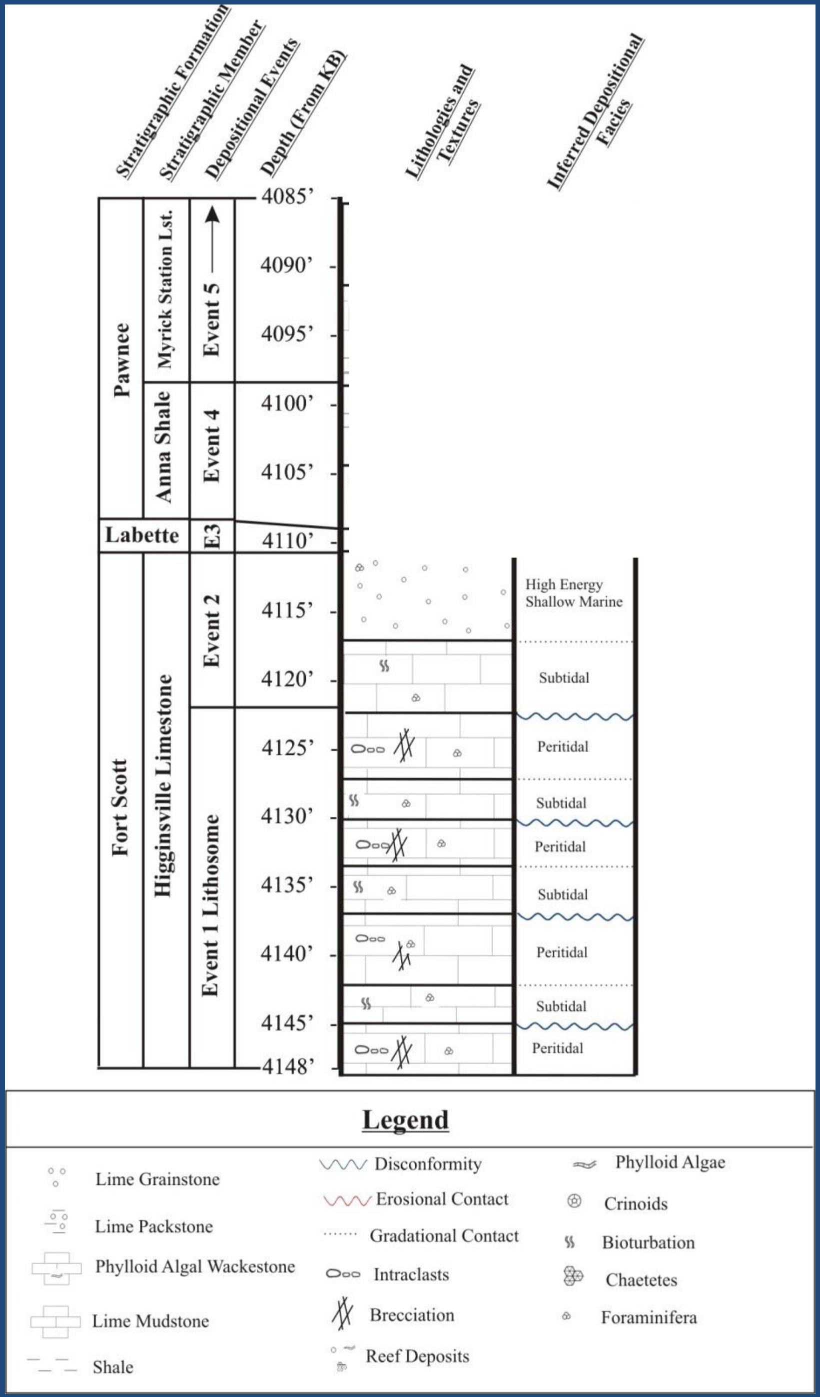
Wilson (1969); Shinn (1983)

Matter (1967); Roehl (1967)



- Subtidal
- Peritidal

- Rapid, gradational contacts from subtidal to peritidal
- Capped by Disconformities

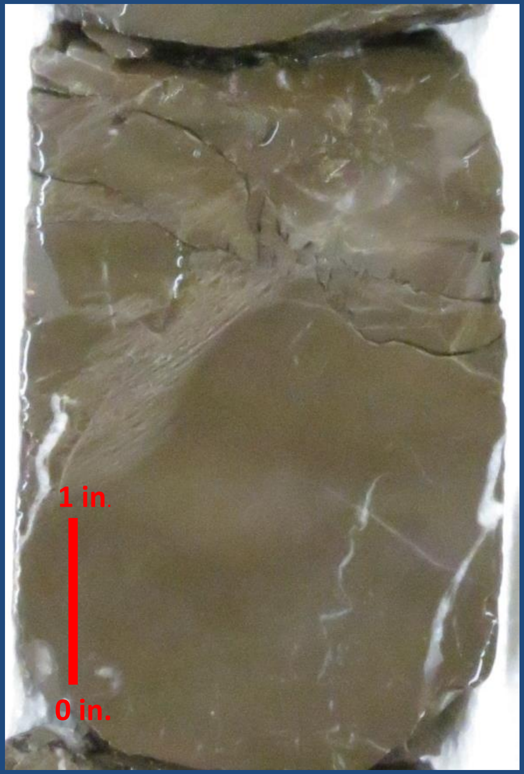


- Overlain by 5’ LMS
- ~6’ grainstone
  - (Reservoir Objective)

Sedimentology

Higginsville Limestone Mbr. of the Fort Scott Formation (37.5')

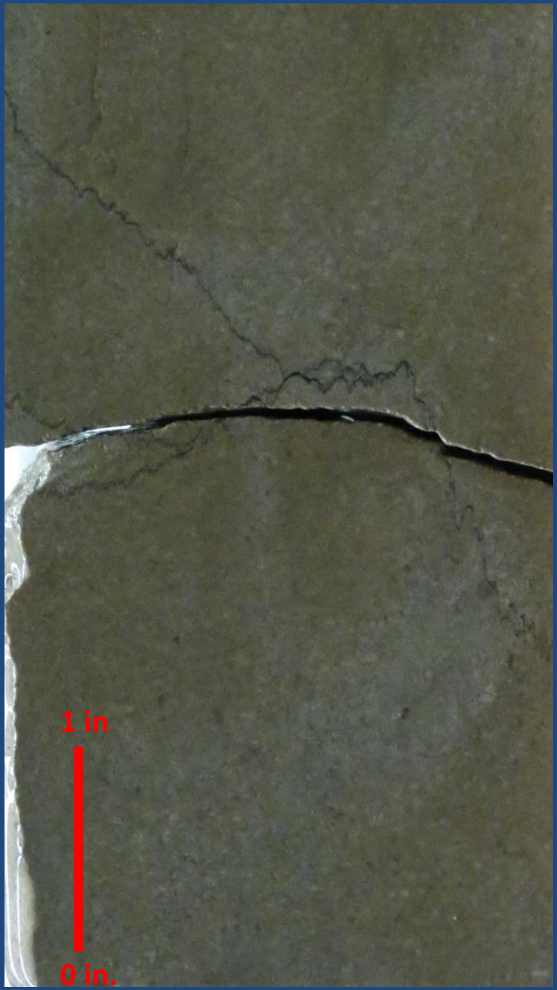
UPPER ~11.5'



Sedimentology

Higginsville Limestone Mbr. of the Fort Scott Formation (37.5’)

UPPER ~11.5’



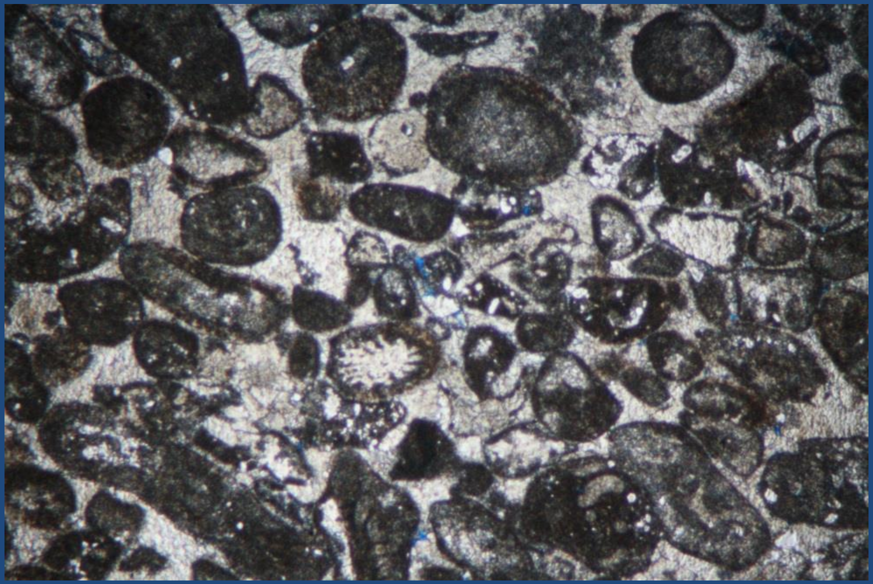
Core Depth: ~4115’

Core Depth: ~4113’

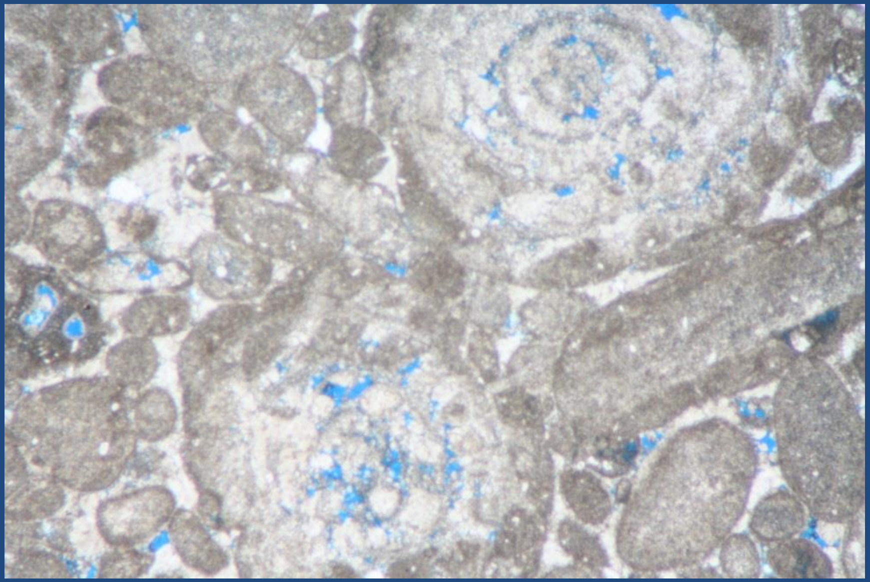
Sedimentology

Higginsville Limestone Mbr. of the Fort Scott Formation (37.5')

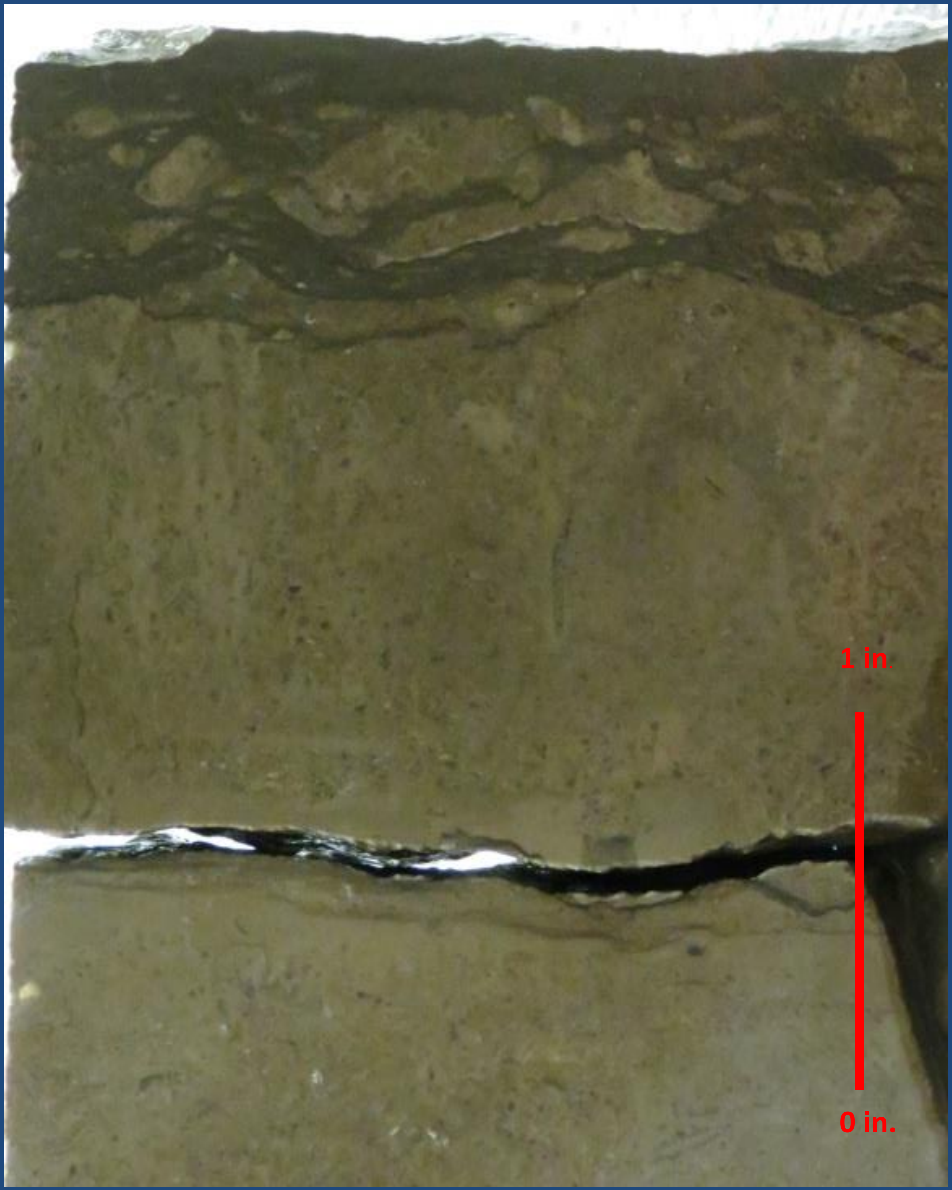
UPPER ~11.5'



Core Depth: ~4115'
Plane Light, 20X



Core Depth: ~4112'
Plane Light, 20X

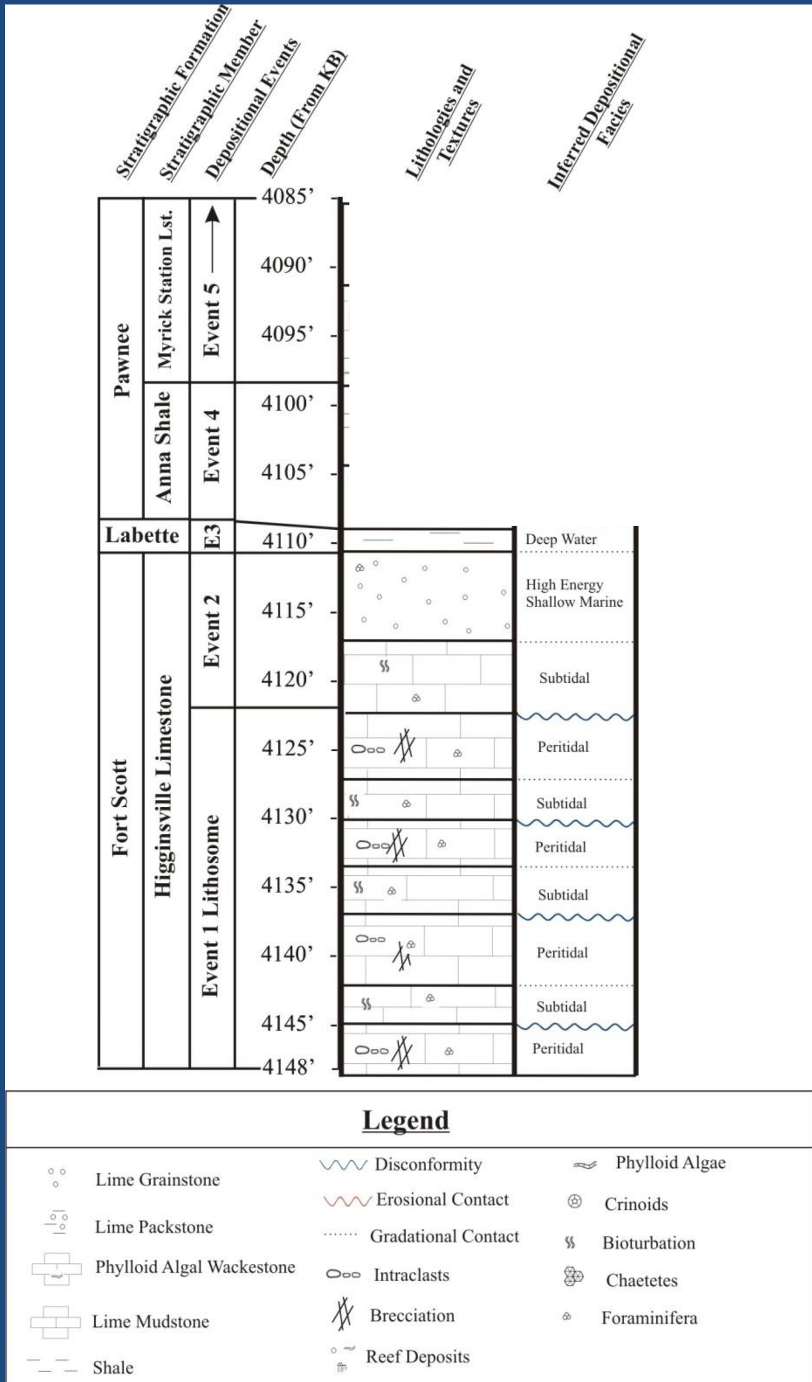


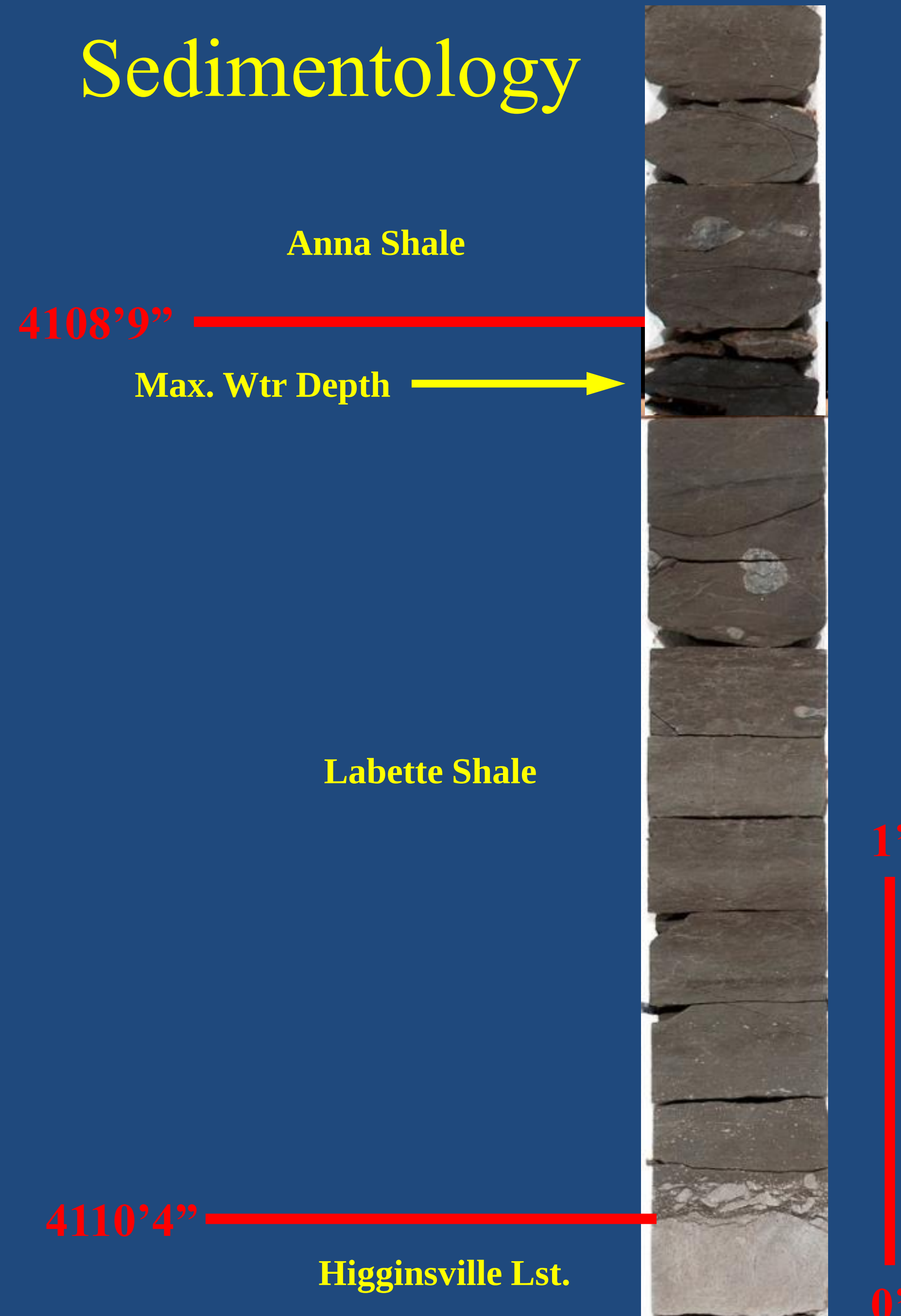
Core Depth: ~4110'

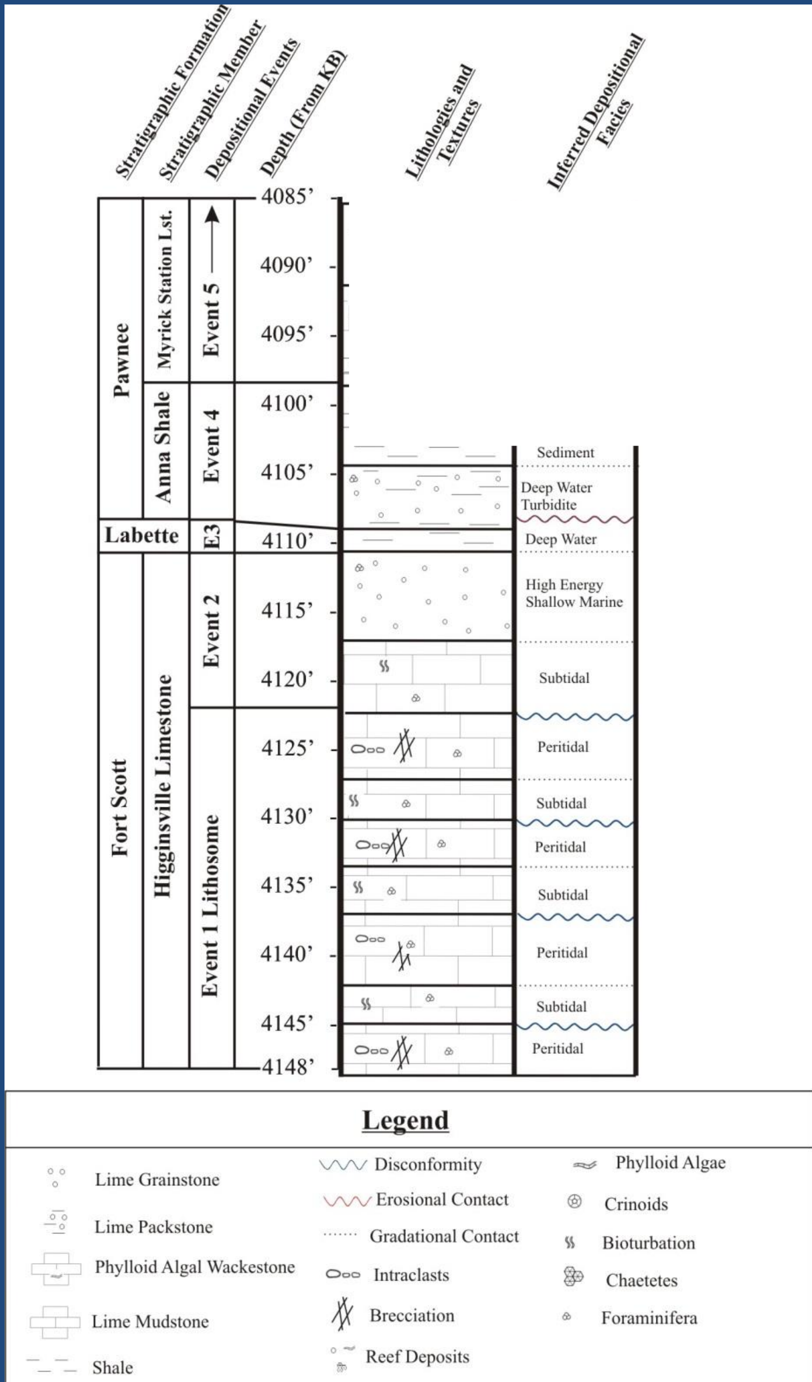
Hardground

Marine calcite cement
Broken and incorporated into shale above during drowning.
(e.g. Wilkinson, 1982)

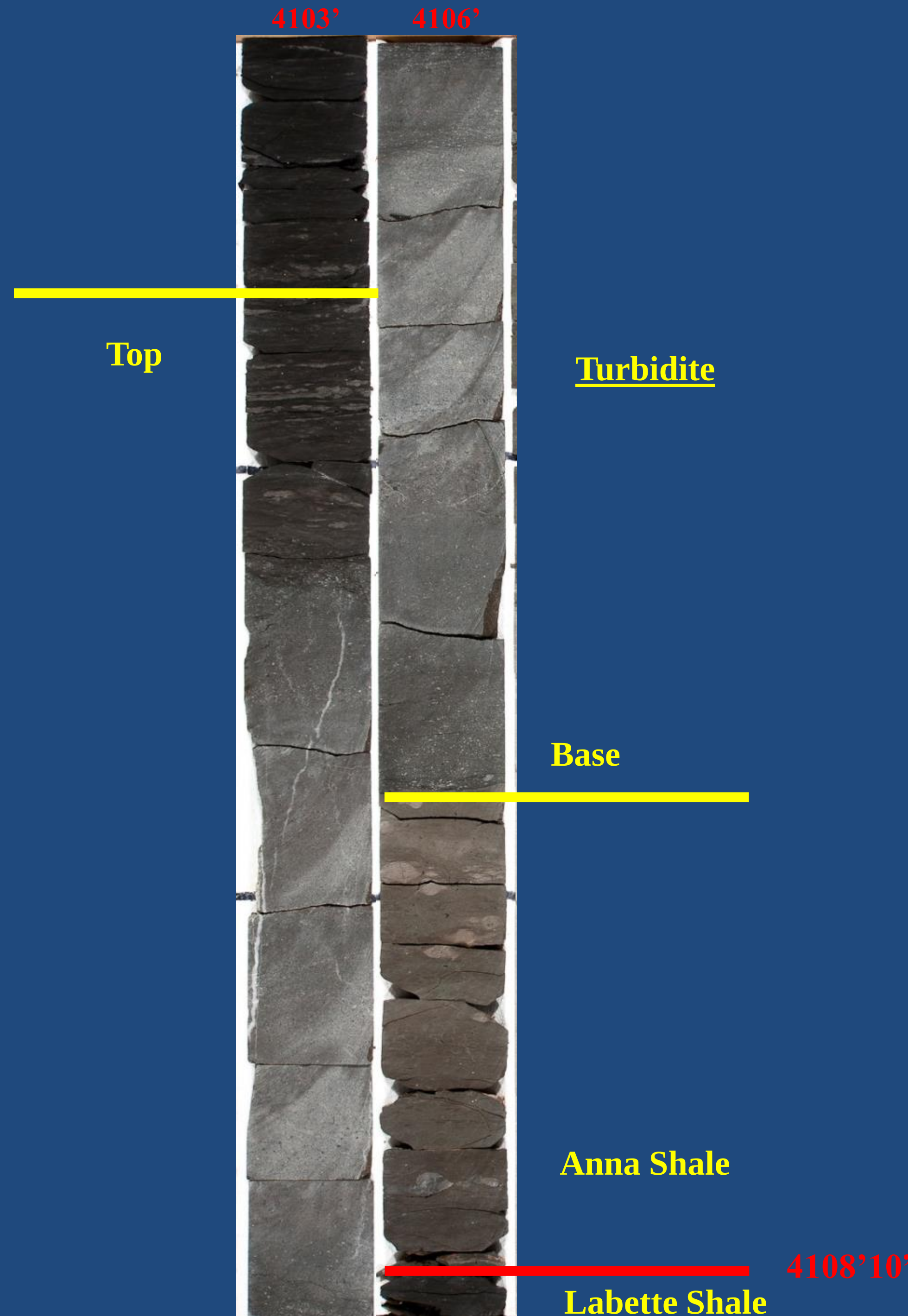
Sedimentology







Stratigraphic Formation
Stratigraphic Member
Depositional Events
Depth (From KB)
Lithologies and Textures
Inferred Depositional Facies
Pawnee
Myrick Station Lst.
Anna Shale
Labette
Fort Scott
Higginsville Limestone
Event 5
Event 4
E3
Event 2
Event 1 Lithosome
4085'
4090'
4095'
4100'
4105'
4110'
4115'
4120'
4125'
4130'
4135'
4140'
4145'
4148'
Sediment
Deep Water Turbidite
Deep Water
High Energy Shallow Marine
Subtidal
Peritidal
Subtidal
Peritidal
Subtidal
Peritidal
Subtidal
Peritidal
Legend
Lime Grainstone
Lime Packstone
Phylloid Algal Wackestone
Lime Mudstone
Shale
Disconformity
Erosional Contact
Gradational Contact
Intraclasts
Brecciation
Reef Deposits
Phylloid Algae
Crinoids
Bioturbation
Chaetetes
Foraminifera



4103'
4106'
Top
Turbidite
Base
Anna Shale
4108'10"
Labette Shale

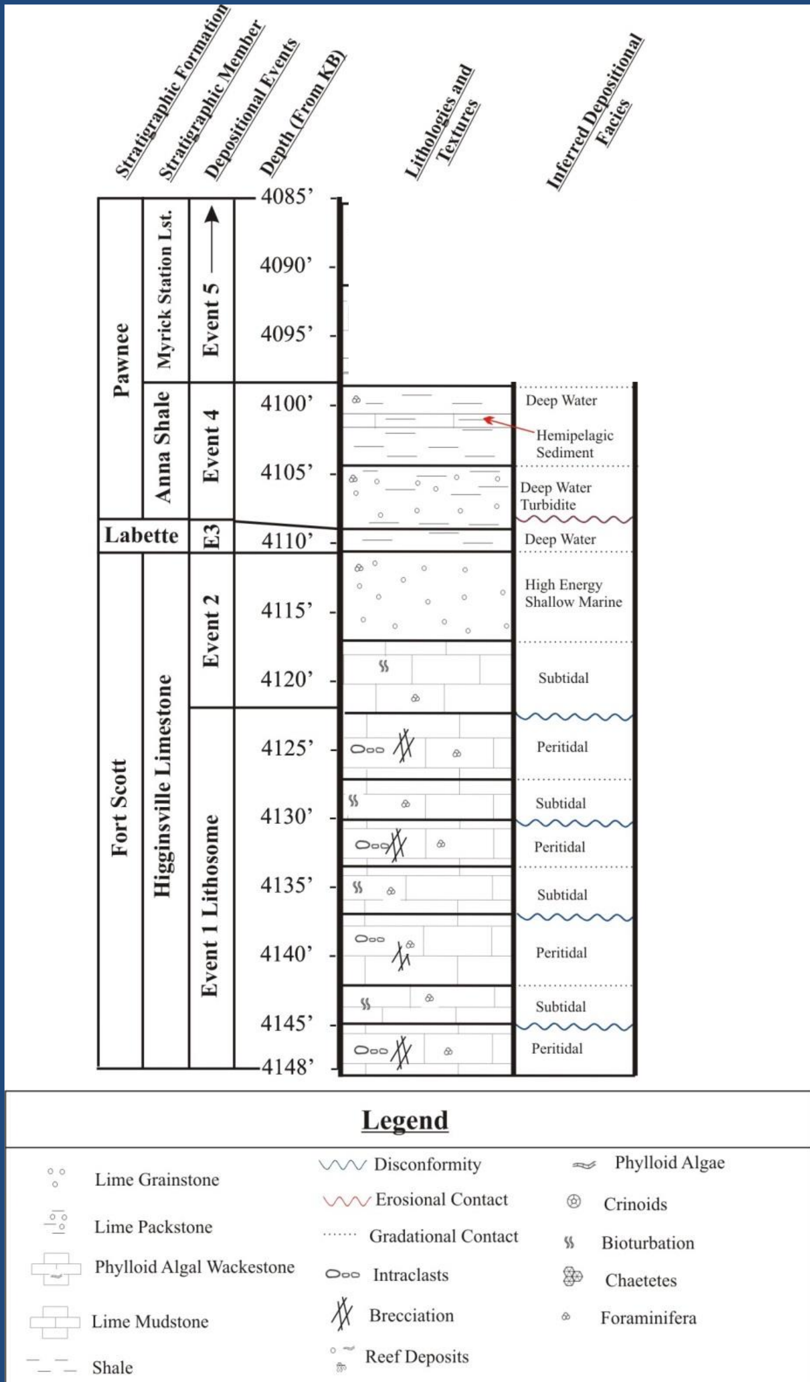
4107’9”

4106’6”

4104’3”

1”
0”

4104’7”



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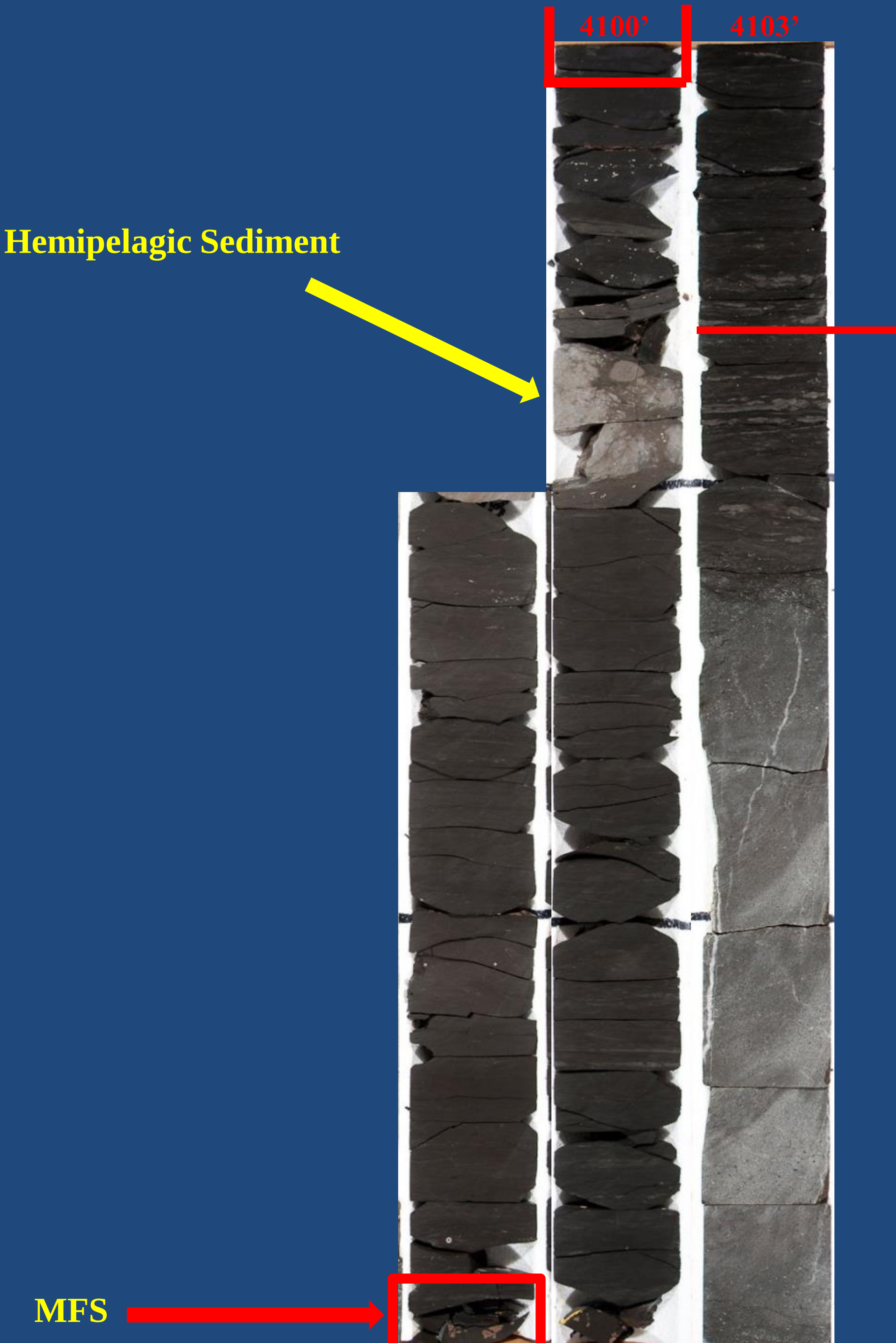
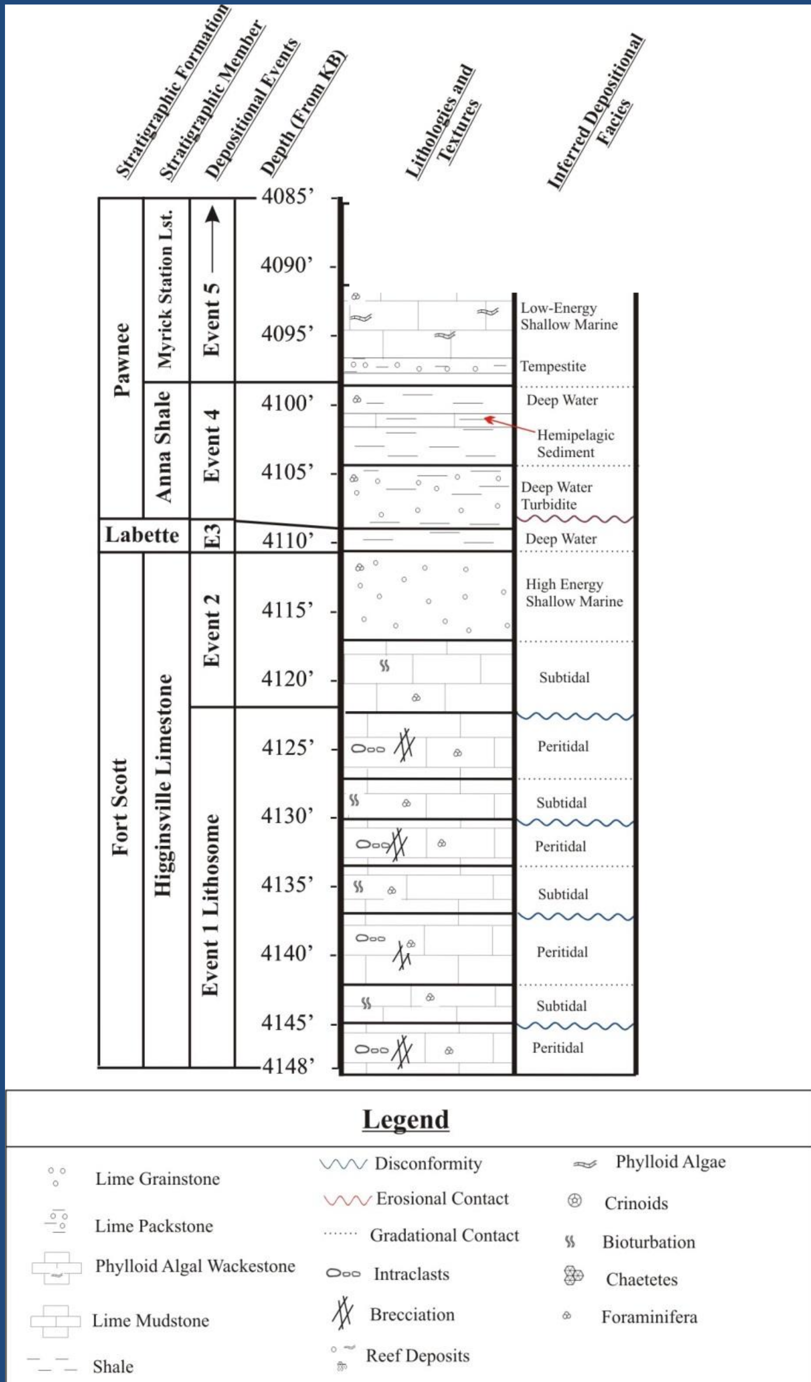
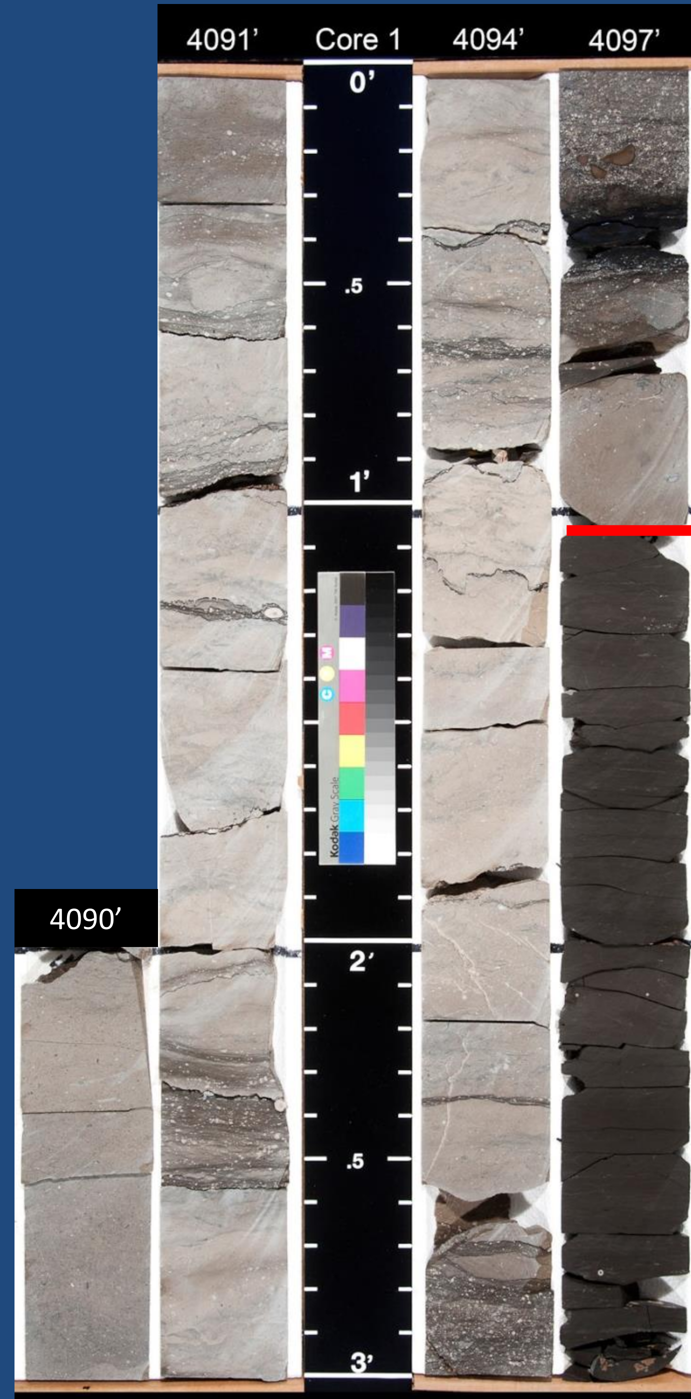
Chaetetes
Foraminifera



4100'
4103'
Hemipelagic Sediment
MFS





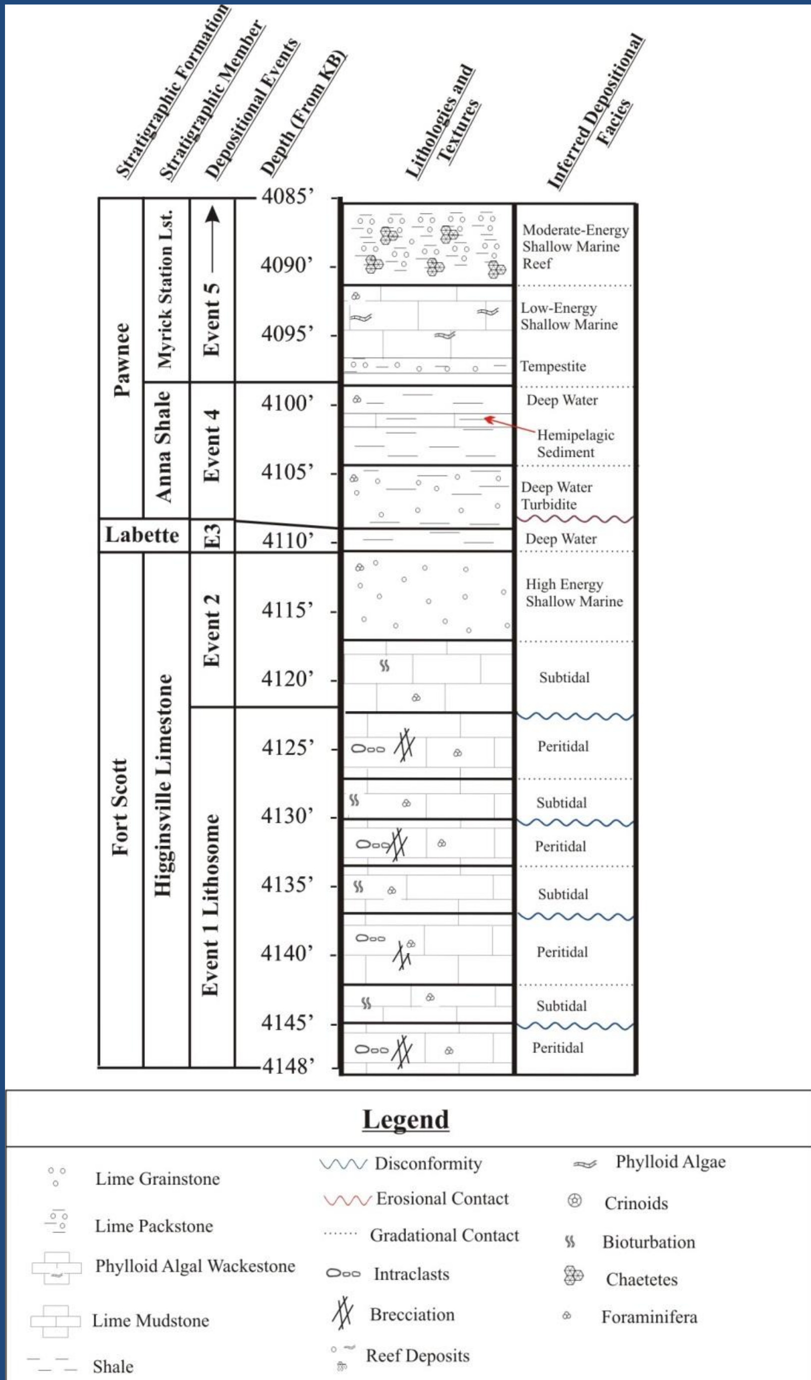
Myrick Station Lst.

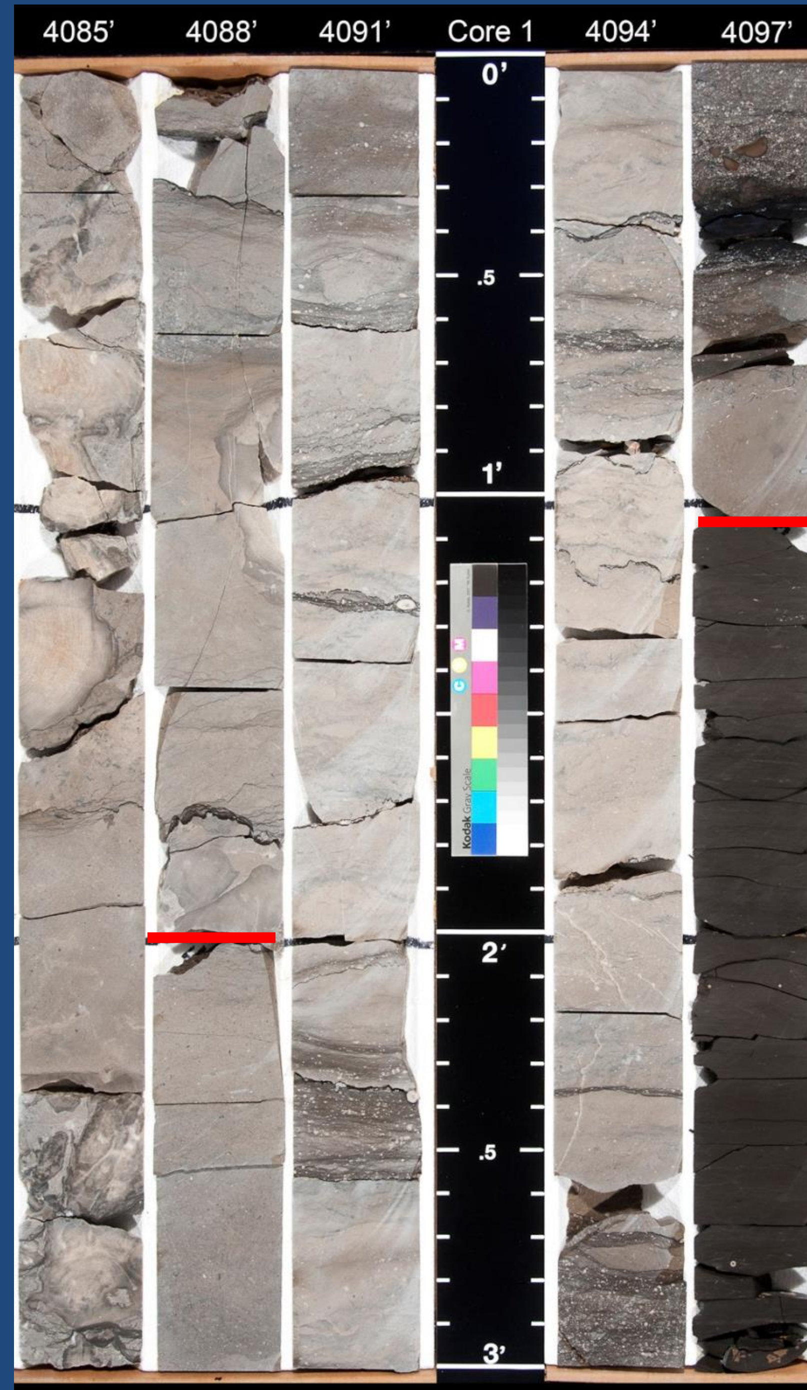
Anna Shale

Tempestites

Similar to Canyon (Middle Penn., West Texas) Limestones (Saller et al., 1993)

Storm Deposits

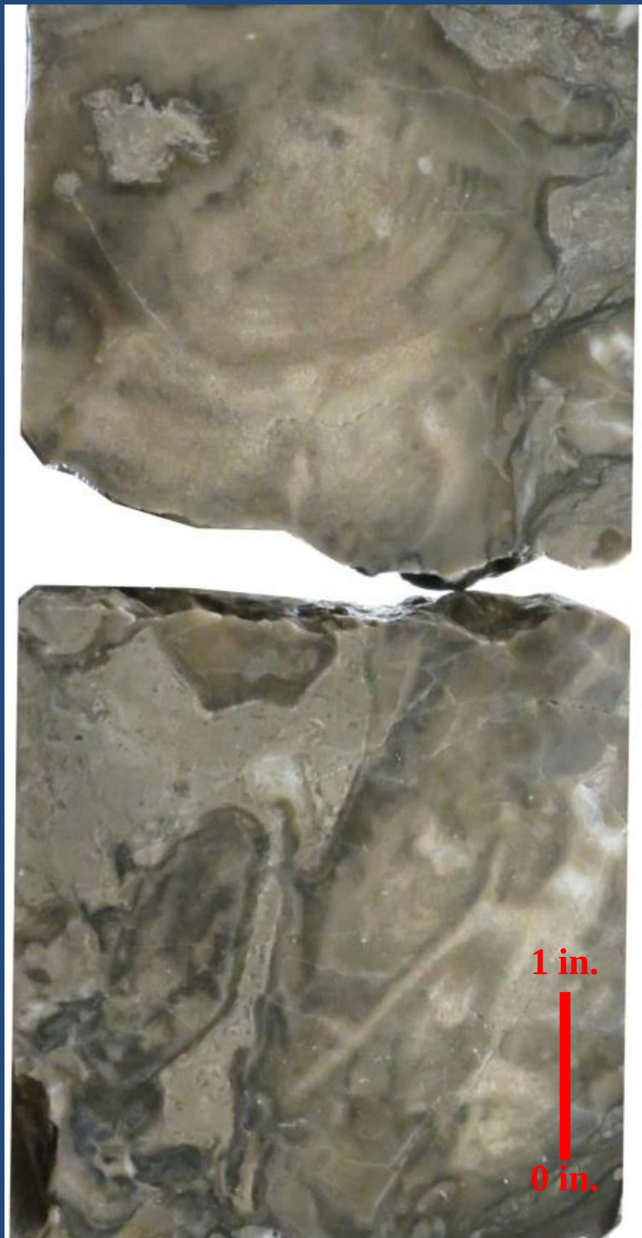




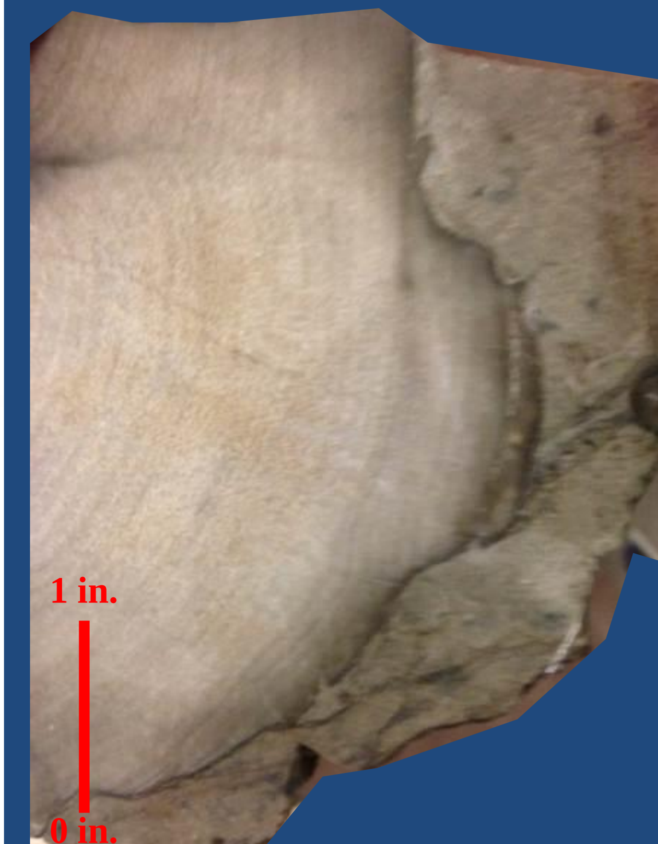
Myrick Station Lst.

Anna Shale

Growth Form



4087-4088’



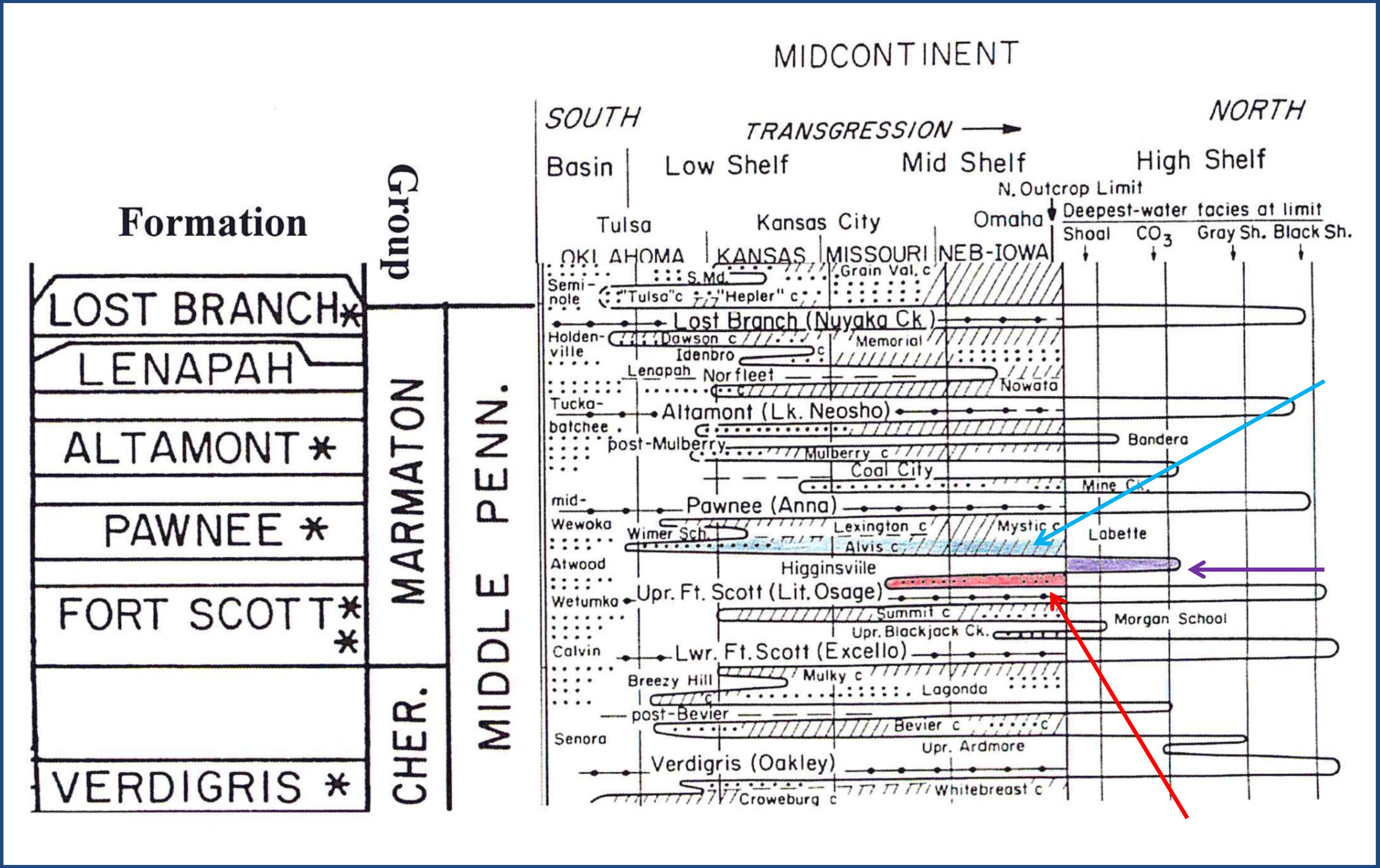
4086’
Overturned

- Connolly et al., 1989
- Suchy and West, 2001

Chaetetes Substratum

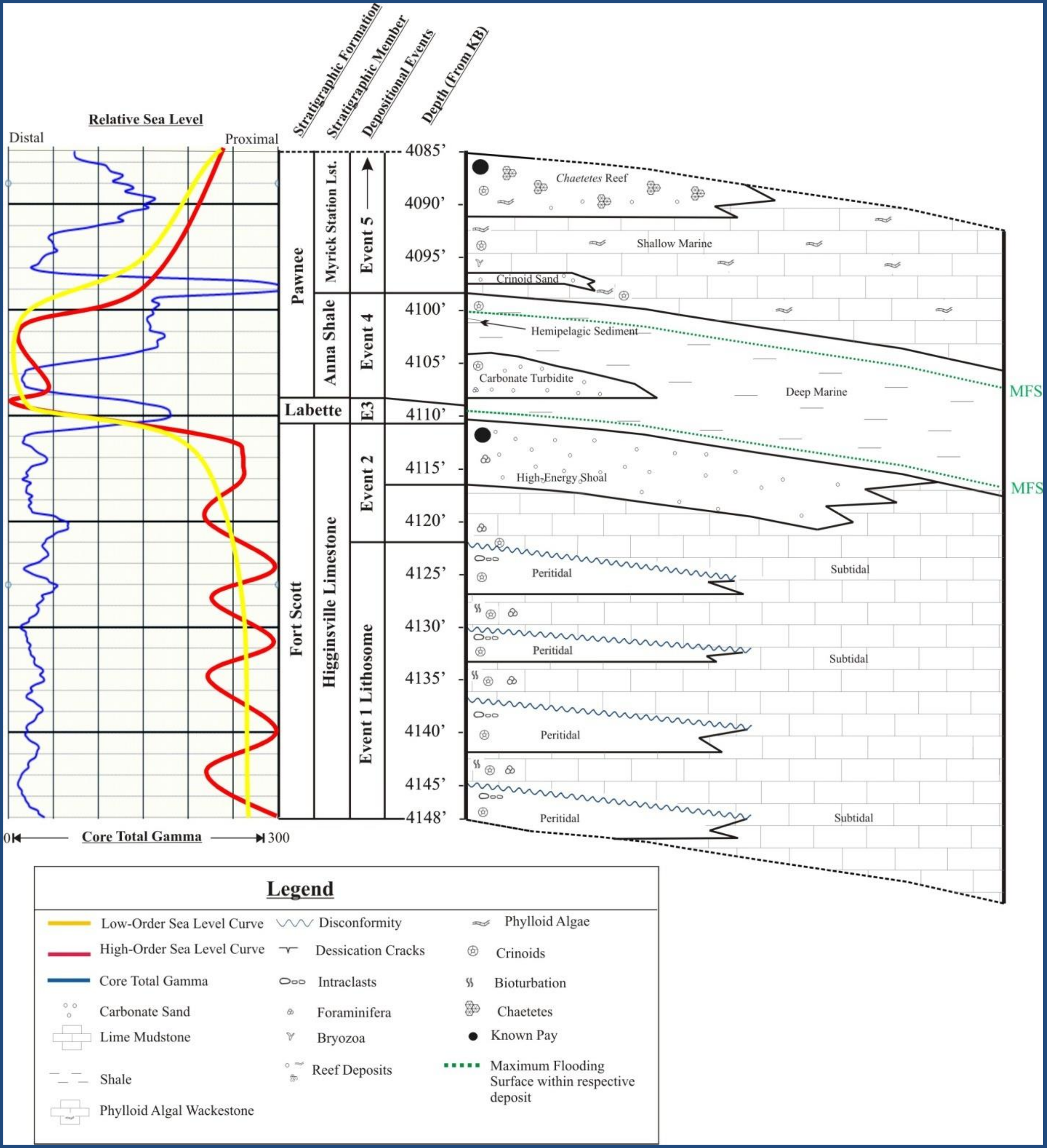
- Moderate Energy
- Often perpendicular to prevailing winds
- Draped over low-relief structures or flanking larger structures.

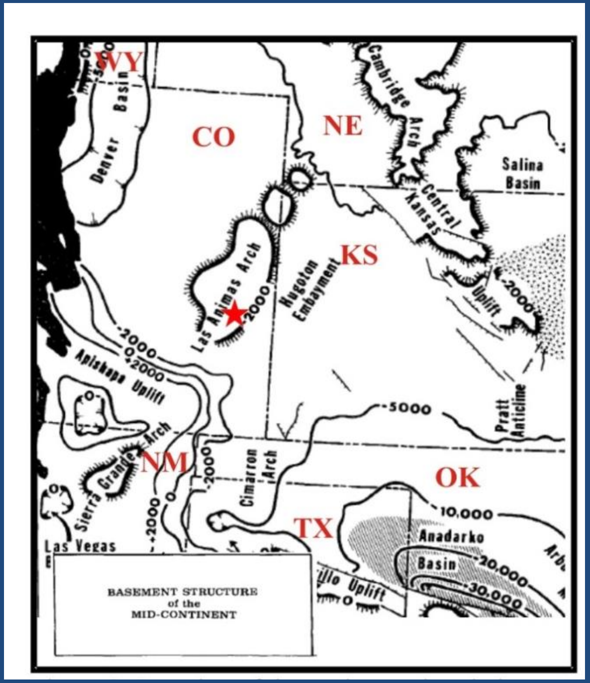
Cyclicity



Modified from Heckel and Boardman (1989)

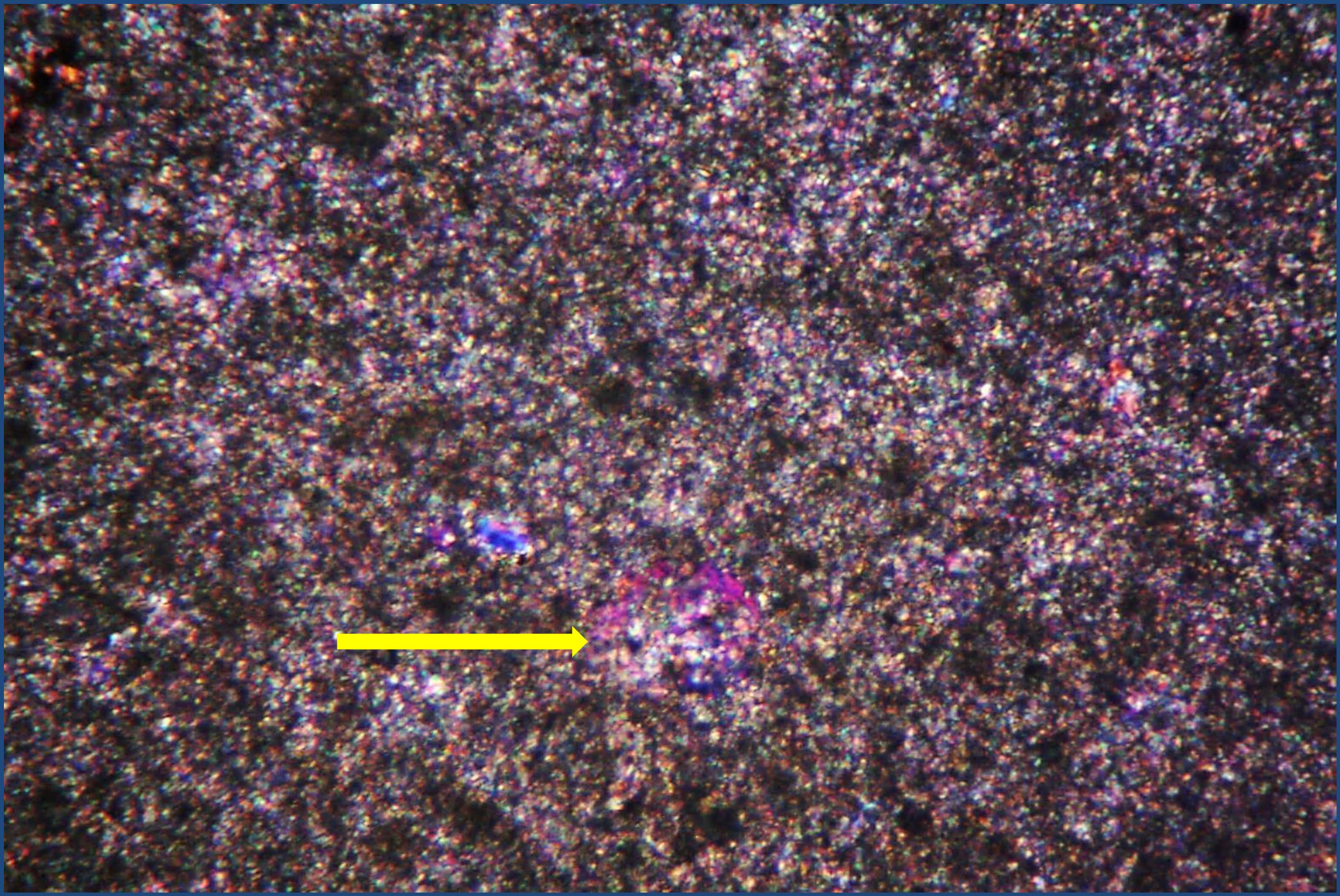
Eustatic vs. Local or Regional Changes in relative sea level.





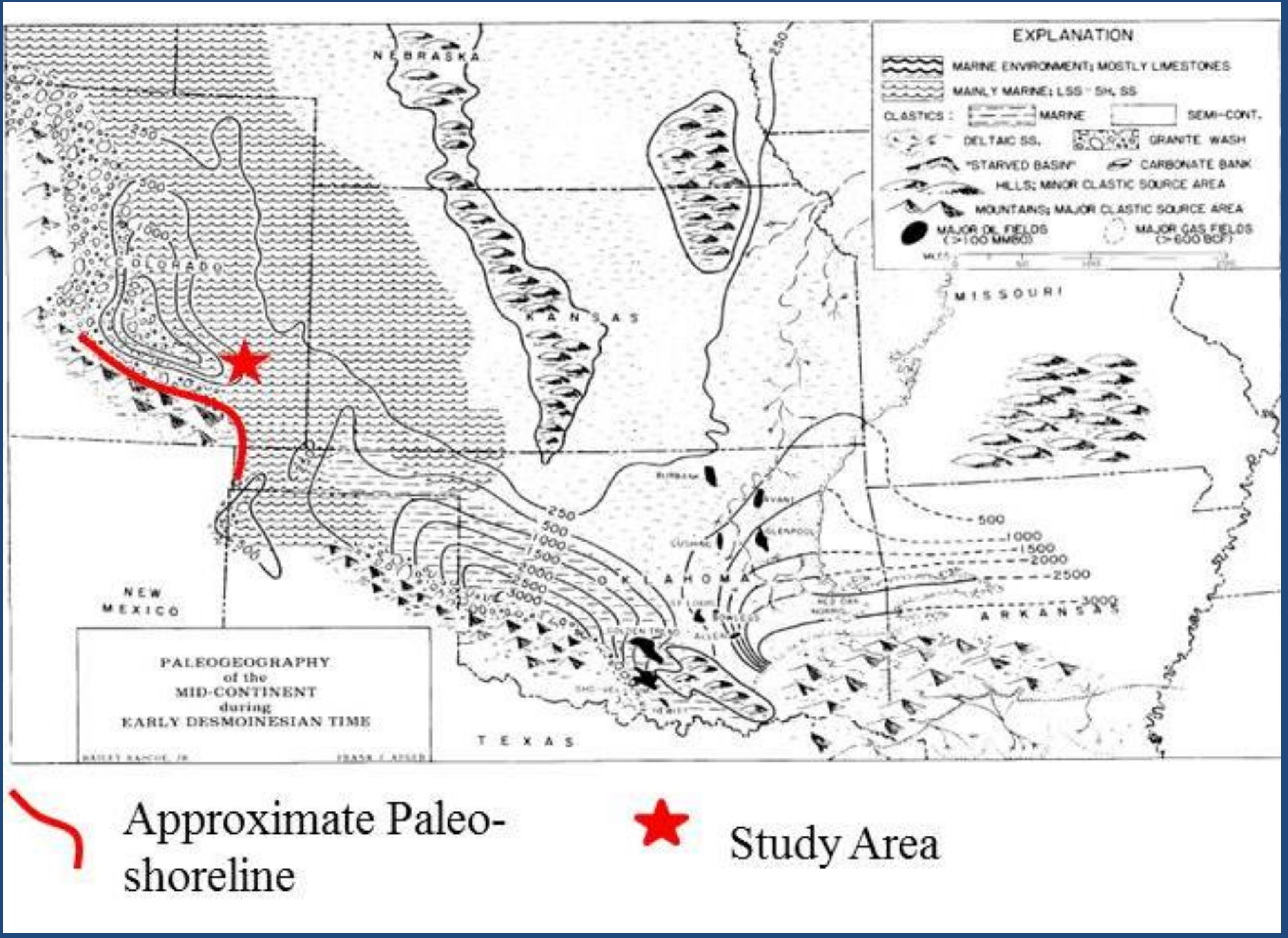
Modified from Rascoe and Adler, (1983)

Thin Section Petrography and Diagenesis



Quartzo-feldspathic silt
Detrital quartz= source for authogenic silica

Cross-nicols; 80X

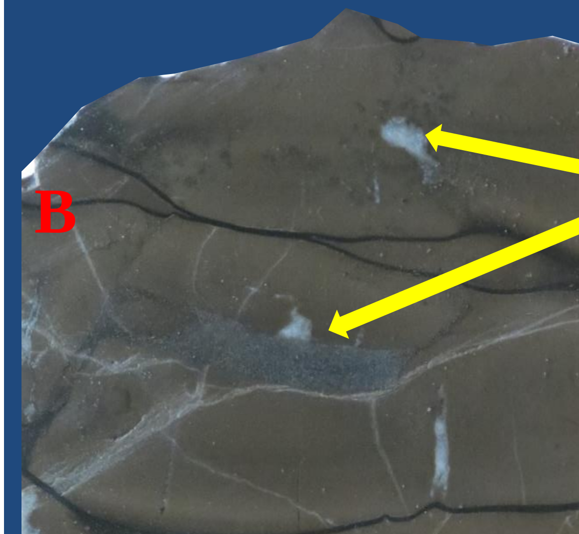


- Approximate distance from study area to Apishapa Uplift: 60 miles.
- Apishapa Uplift: Wichita Orogeny

Modified from Rascoe and Adler, (1983)

Higginsville Lime Mudstone

Stylolites, Fractures, Cements



Dissolution Pores

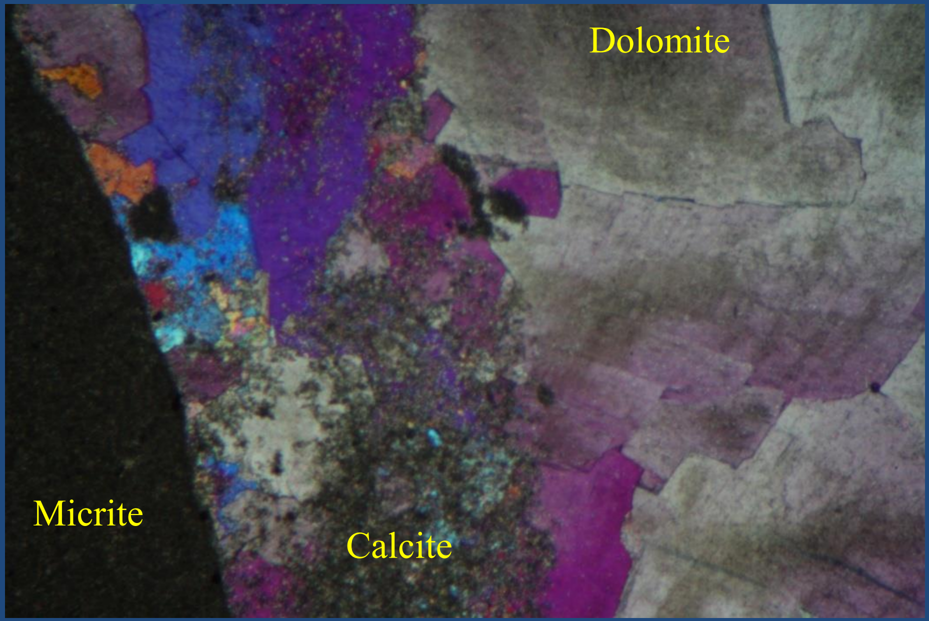
1 in.

0 in.

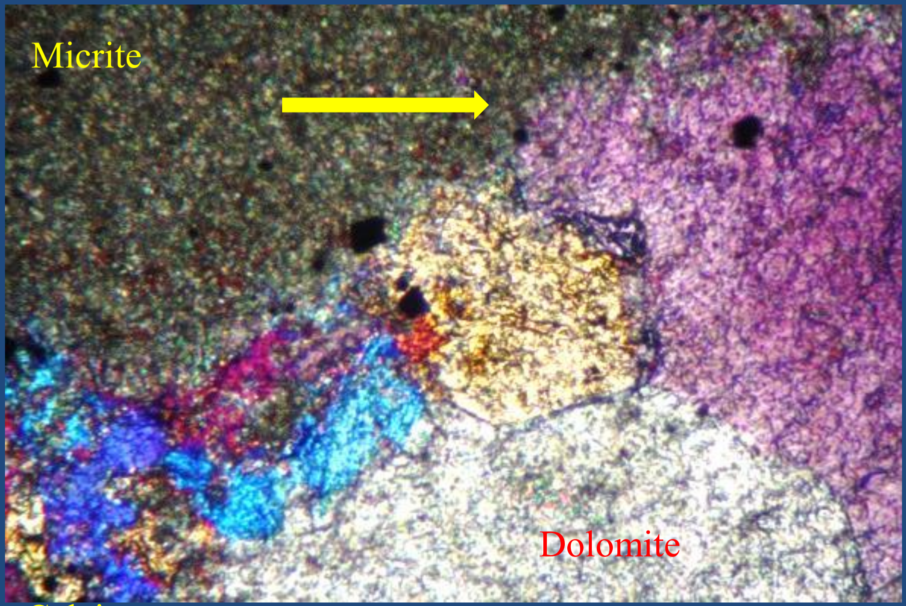
1 in.

0 in.

1.) Fractures and dissolution
2.) Calcite Cement
3.) Stylolitization w/ gash fractures
4.) Further fracturing
4.) Dolomite Cement



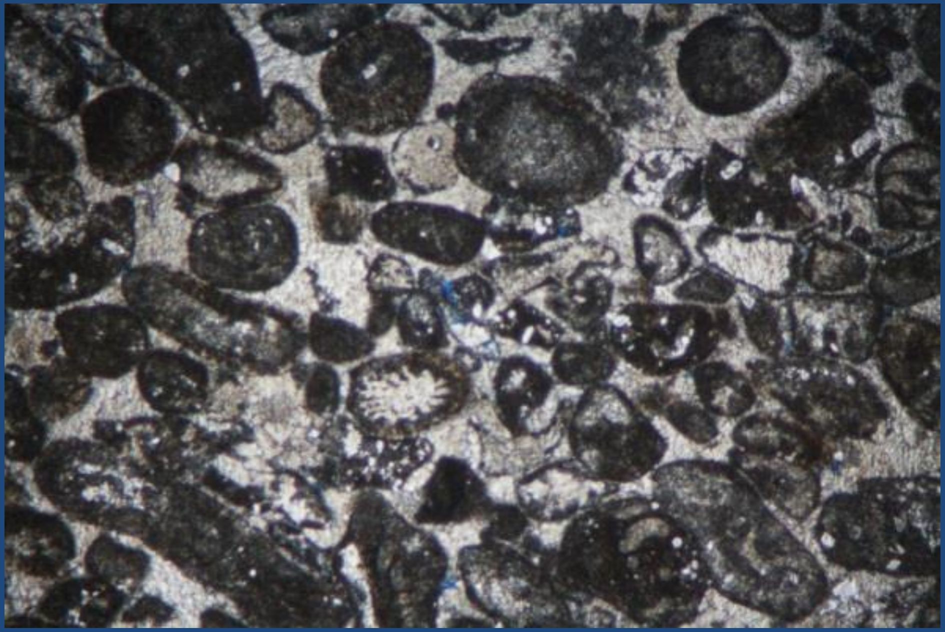
Cross-nicols
20X



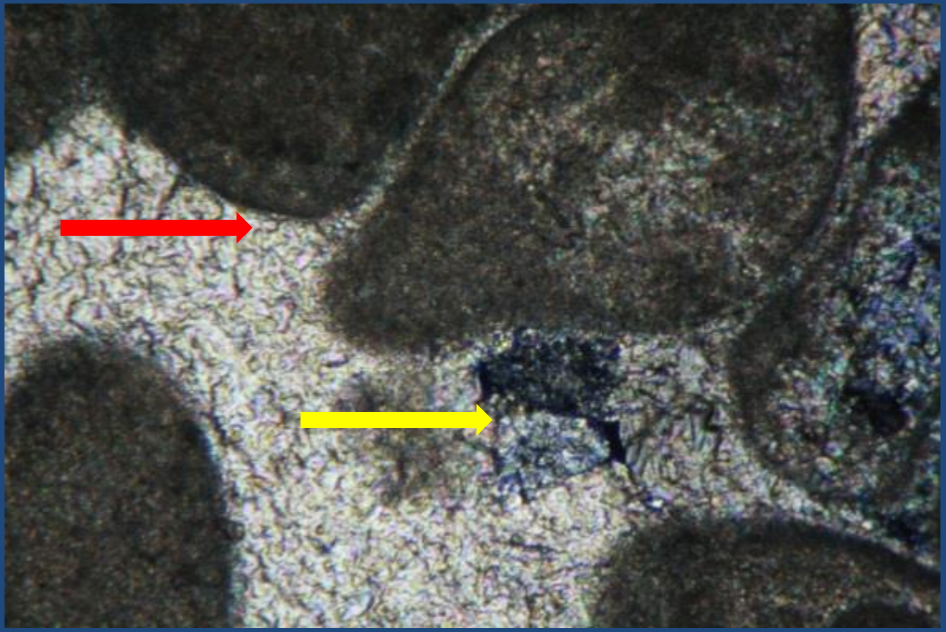
Calcite

Cross-nicols
80X
Stained with Alizarin red-S

- Curved cleavage extinction= saddle dolomite (e.g. Radke and Mathis, 1980)
    - Mesogenetic Process

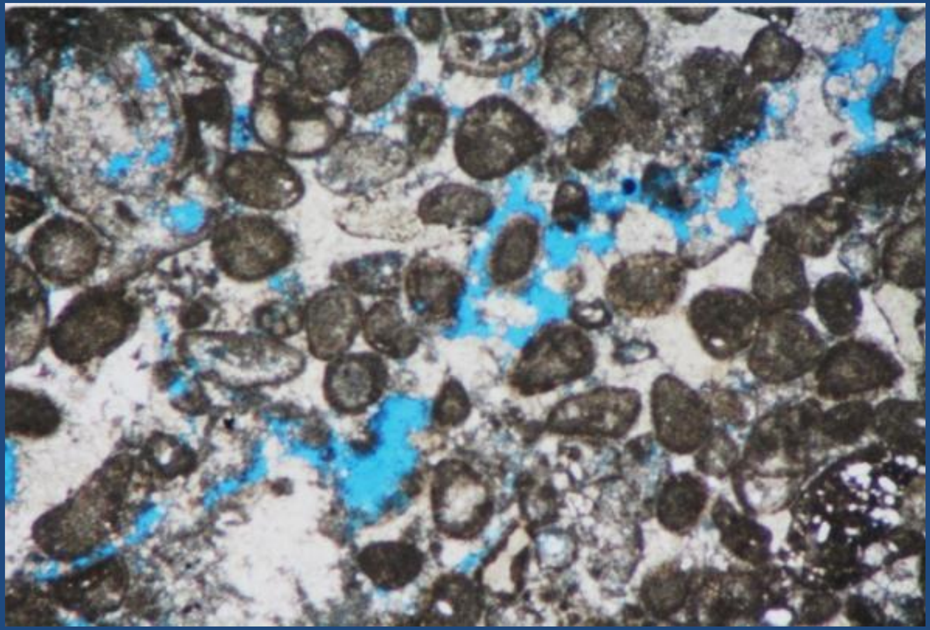


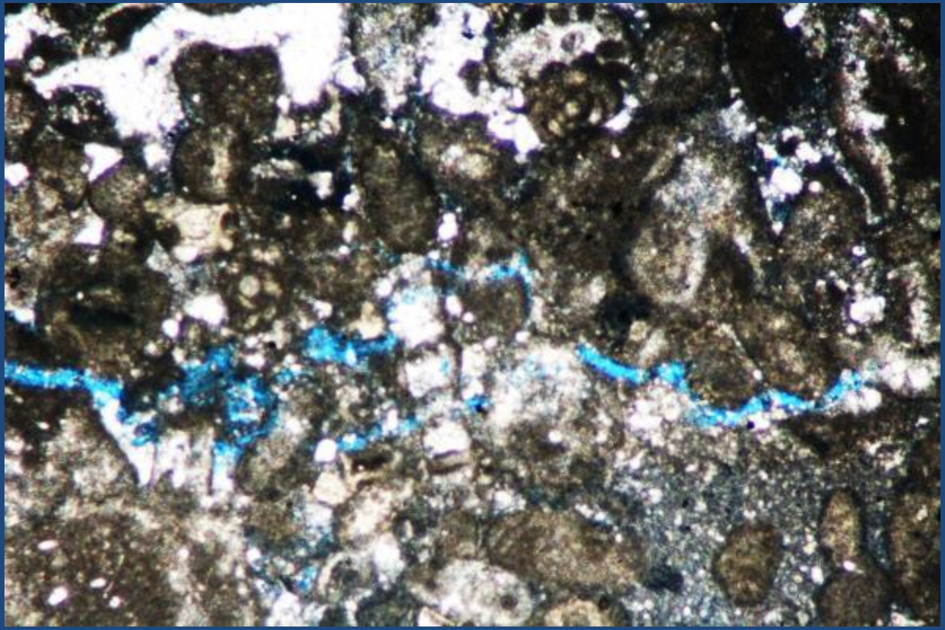
Calcite porosity occlusion in Higginsville Grainstone
20X, plain light

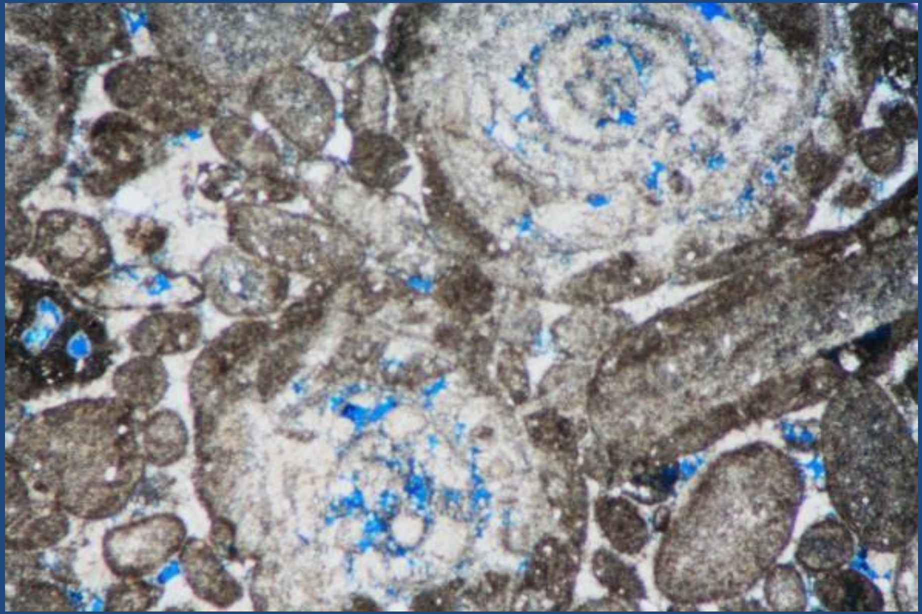


"Bathurst's rule"
80X, cross-nicols

"Bathurst's rule"- Indicative of Phreatic calcite cement







ALL: Plain Light; 20X

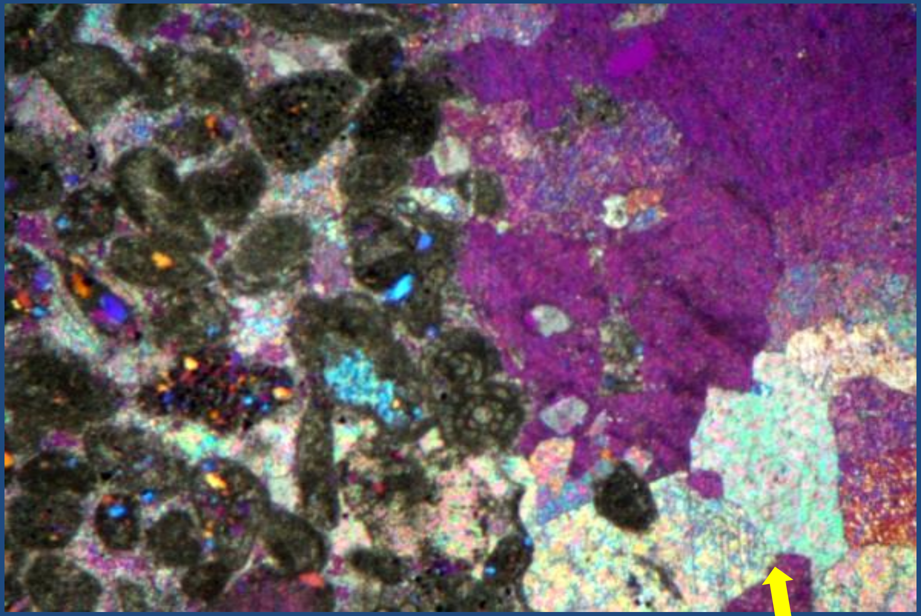
Thin section taken from a late fracture at 4115’

Diagenetic sequence of the Higginsville Limestone

- Minor fractures and dissolution
- Precipitation of meteoric calcite
- Stylolitization
  - Gash fractures
- Saddle Dolomite
- Minor mesogenetic dissolution
  - Interparticle and intraparticle porosity proximal to stylolites and fractures

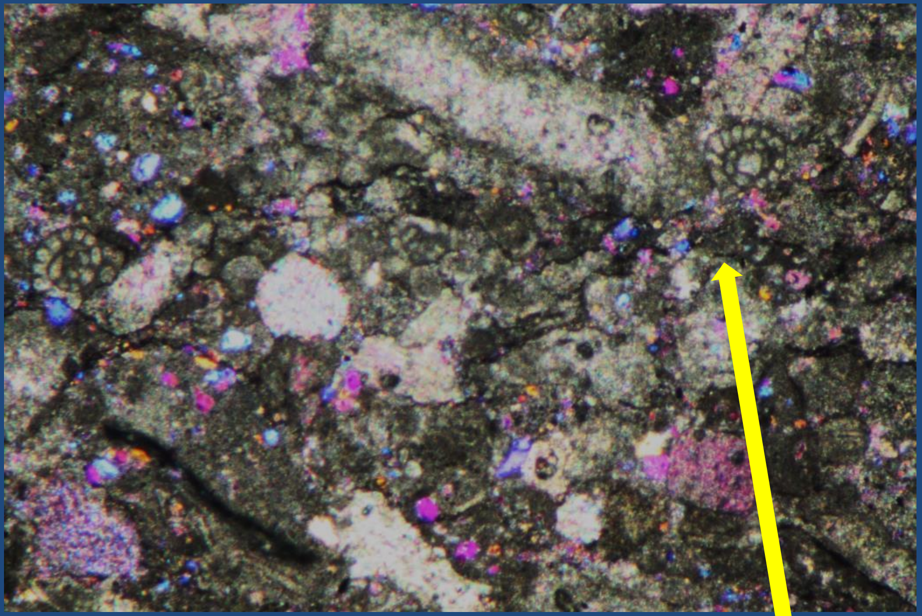
Anna Limestones (Inferred turbidite)

Grainstone



Cross-nicols; 20X

Packstone

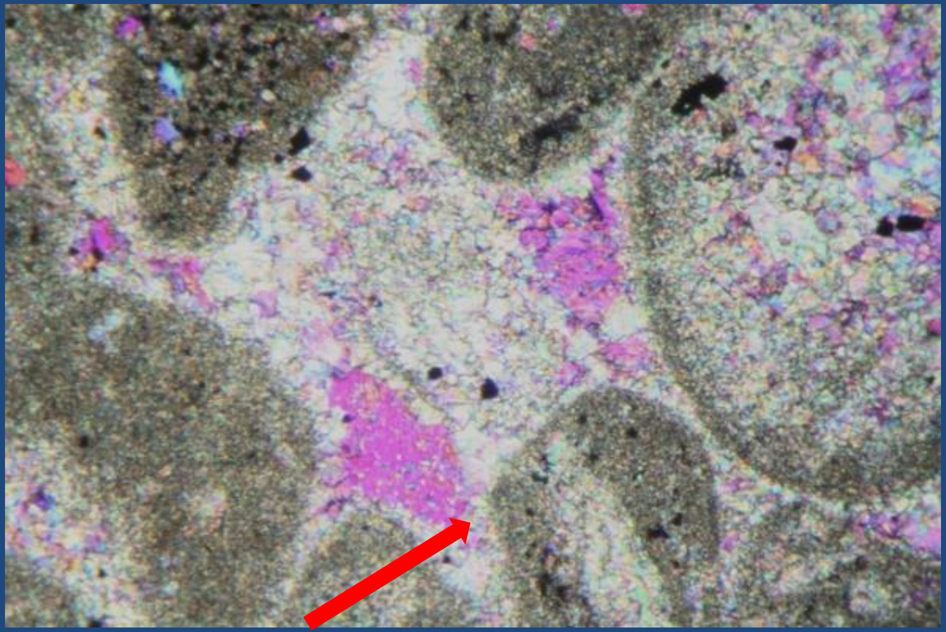


Cross-nicols; 20X

Stylolitized

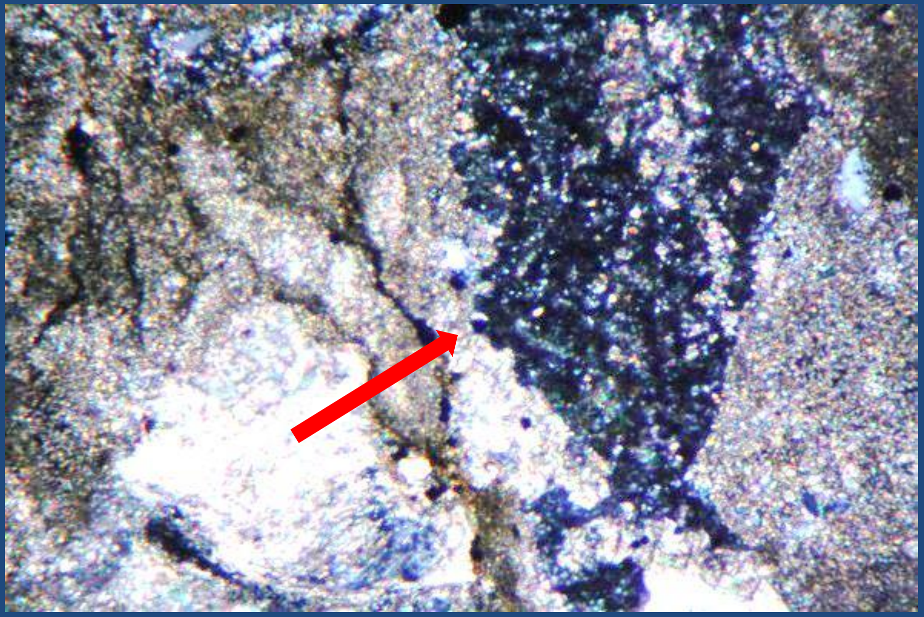
Calcite-filled fracture

“Bathurst’s Rule”



Cross-nicols; 80X

Neomorphic Overgrowth



Cross-nicols; 80X

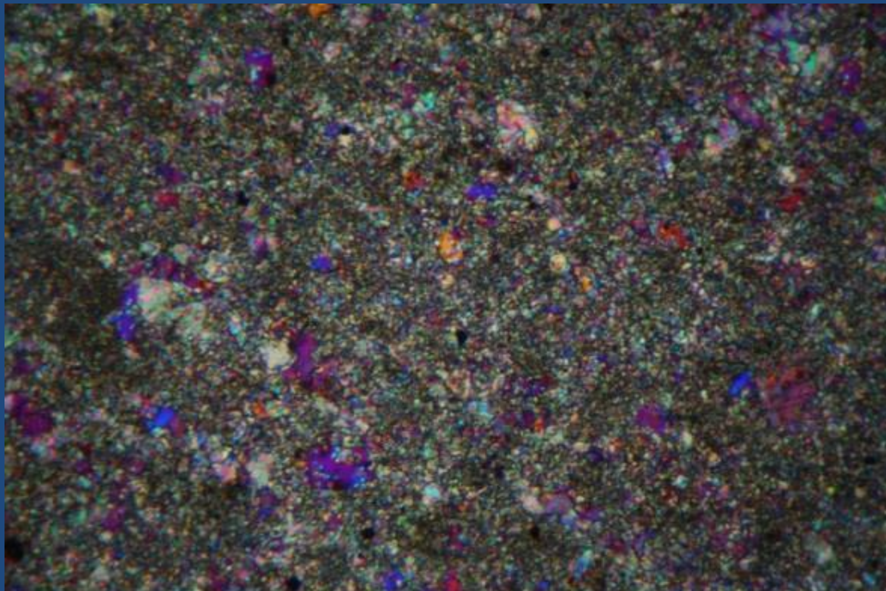
Crinoids: single calcite crystal

Crinoid overgrowth happens very quickly

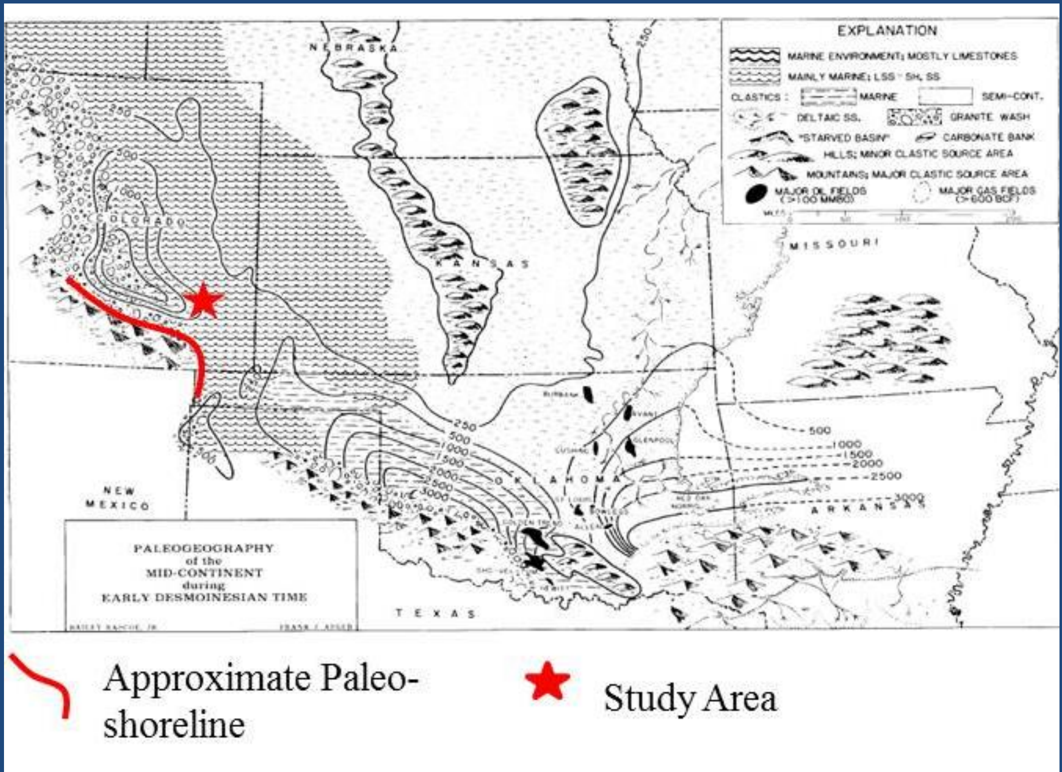
Diagenetic Sequence within Anna

- Meteoric calcite, including crinoid overgrowth
- Stylolitization
- Fracturing
- Mesogenetic calcite cementation in fractures

Myrick Station Limestone

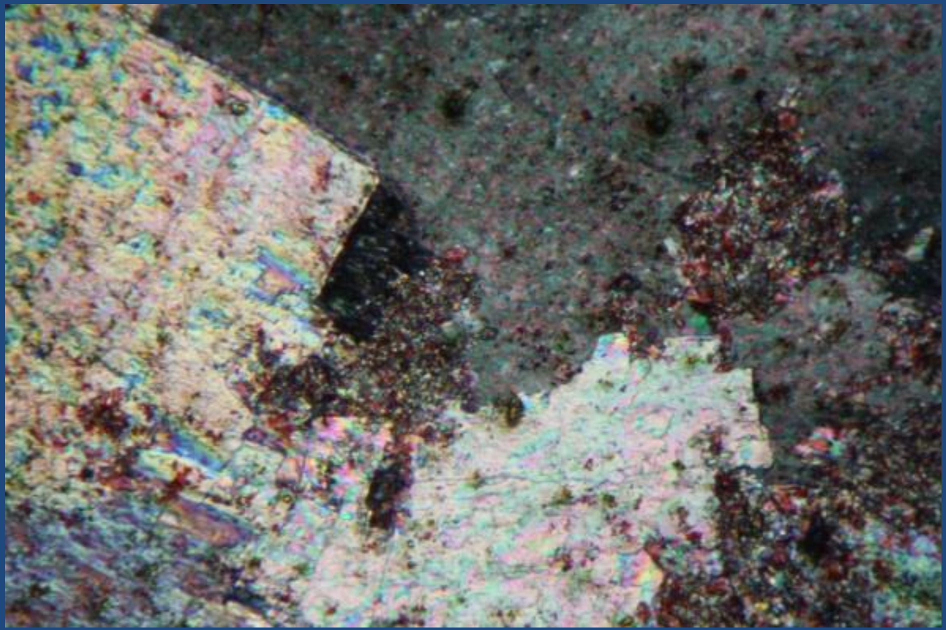


Cross-nicols; 80X



Myrick Station phylloid algal wackestone

Cross-nicols; 80X
Stained with Alizarin red-S

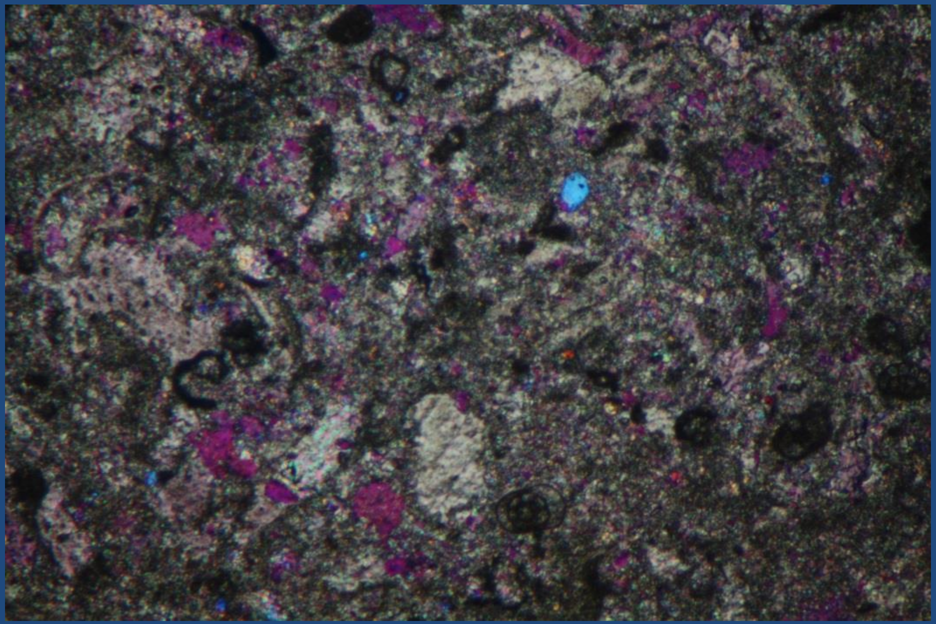


Within algal blade
Aragonite dissolves,
Meteoric calcite fills,
then saddle dolomite partially replaces.

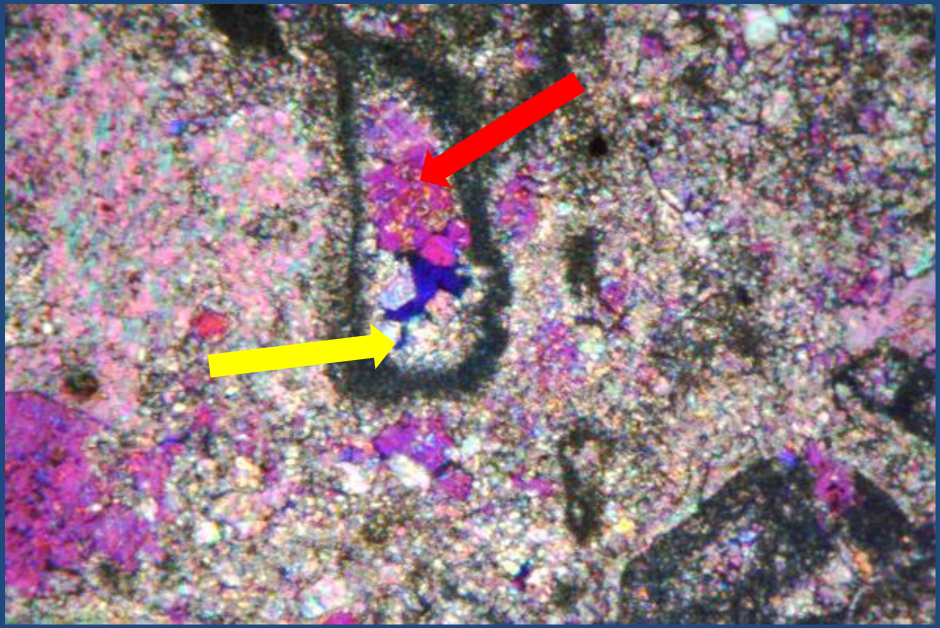
Cross-nicols; 80X

Interior lining of brachiopod
Aragonite cement,
partially replaced by saddle dolomite.

Foraminifera wackestone matrix with *Chaetetes*

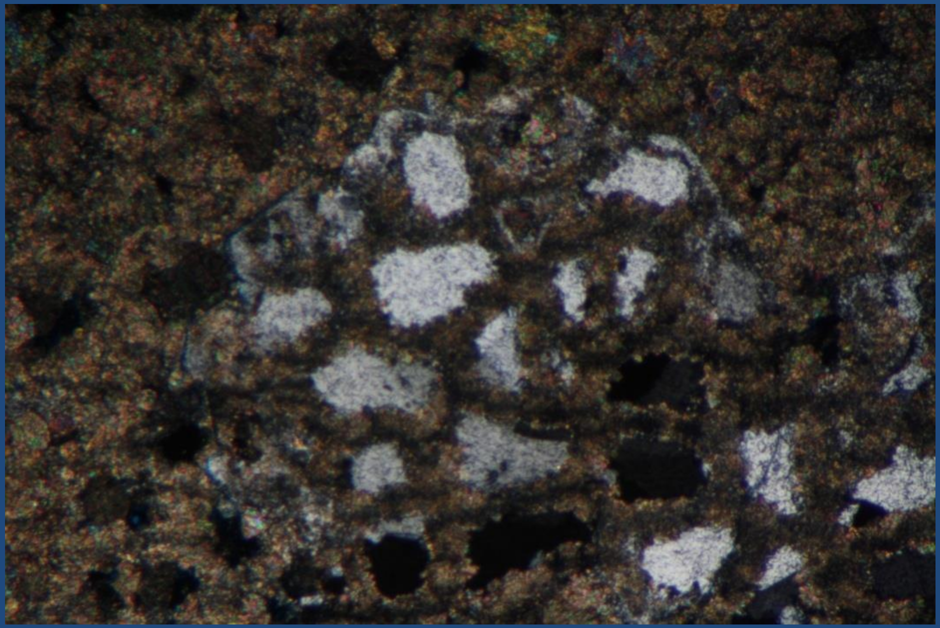


Wackestone matrix
silty,
saddle dolomite porosity occlusion
Cross-nicols; 20X

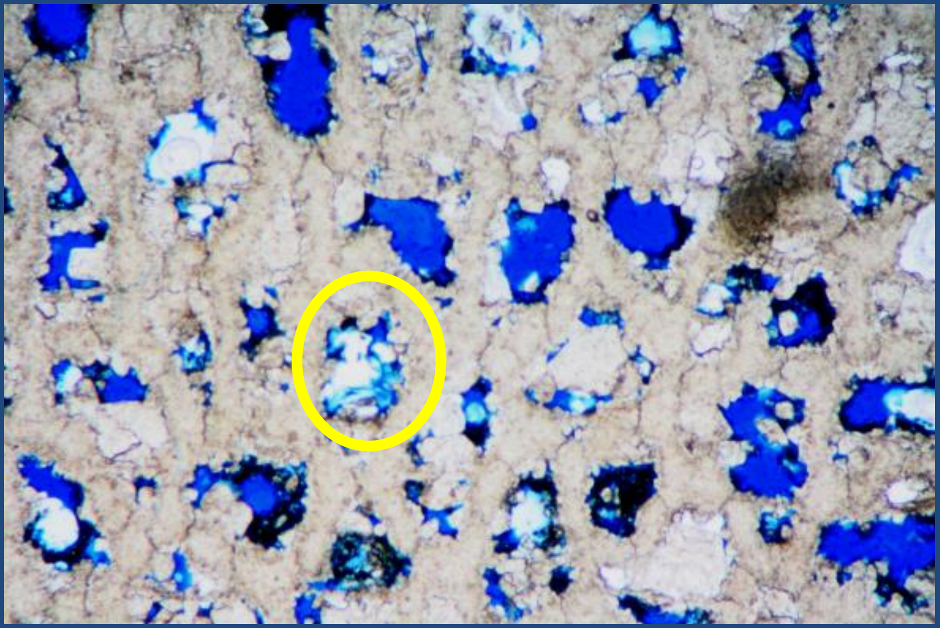


Wackestone matrix
Saddle dolomite and calcite dissolved
(mesogenetic dissolution)
Cross-nicols; 80X

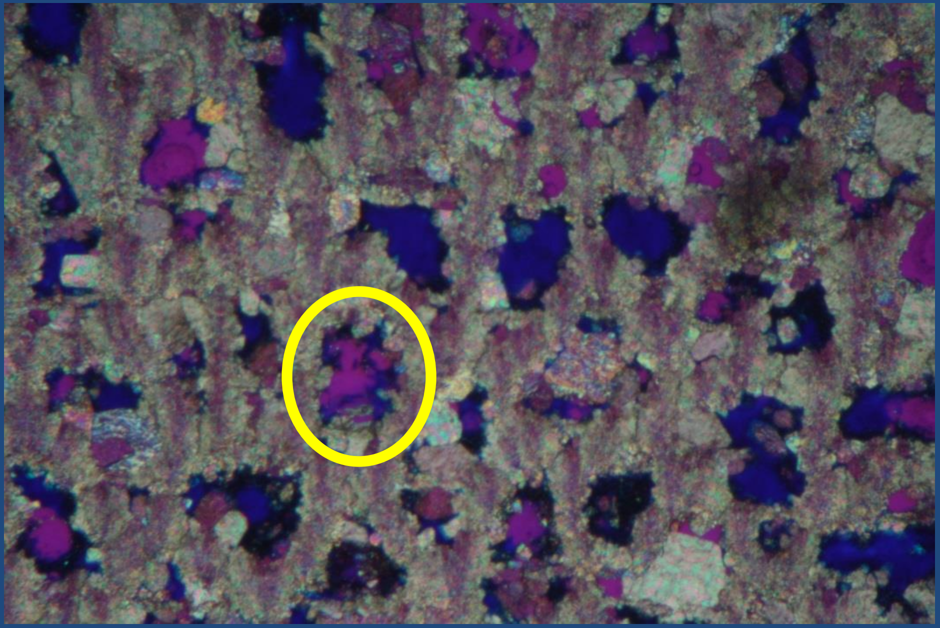
Chaetetes intraparticle porosity



Chaetetes intraparticle porosity occluded by saddle dolomite.
One nicol; 20X



Plain light; 20X



Cross-nicols; 20X

Myrick Station Diagenetic sequence

- Precipitation of high-magnesium marine calcite cement (evidence within brachiopods)
- Originally Aragonite P.A. dissolved upon exposure to meteoric fluids
- Resulting pores were filled with meteoric calcite cement
- Stylolitization
- Meteoric calcite was later partially replaced by saddle dolomite
- Mesogenetic dissolution

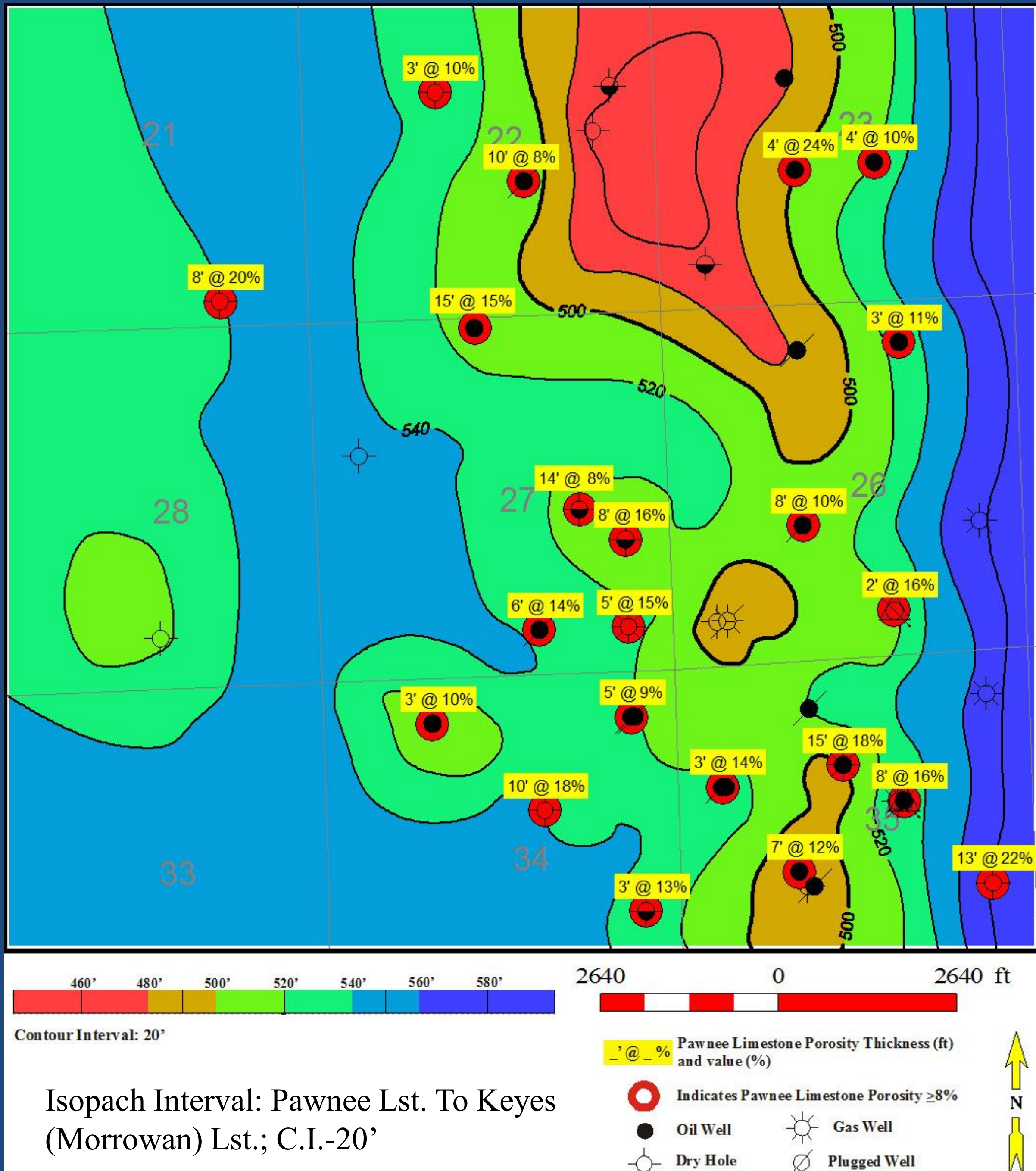
- *Two phases of dissolution?- Very little calcite remains in reef facies

Diagenetic Sequence of the cored interval

- The precipitation of aragonite cement within brachiopods in the Myrick Station Limestone interval and calcite cement throughout the cored interval
- Authogenic silica that originated from detrital quartz silt partially replaced particles within the Higginsville lime mudstones.
- Dissolution of aragonite phylloid algae
- Meteoric calcite cement destroyed porosity throughout the entire cored interval
- Deep burial and stylolitization, causing gash fractures.
- Subsequent fracturing
- Precipitation of saddle dolomite; subsequent replacement of calcite and adjoining micrite by saddle dolomite
- Mesogenetic dissolution

It is possible that multiple phases of dissolution occurred within the core; a first event may have partially dissolved meteoric calcite cements, thus allowing later fluids to invade and precipitate saddle dolomite. A later event may have then caused minor dissolution of saddle dolomite and some remaining meteoric calcite.

Exploration



Isopach Interval: Pawnee Lst. To Keyes (Morrowan) Lst.; C.I.-20'

Higginsville- porosity doesn't correspond to mapping intervals. Valid secondary exploration target

Myrick Station *Chaetetes* reef- can be mapped on paleotopographic flanks

Acknowledgements

- Dr. S.J. Mazzullo
- Ernie Morrison
- Mark Shreve
- Steve Stribling
- Mull Drilling Co., Inc.