Sequence Stratigraphic Control on Reservoir Development: The Middle Silurian Racine Formation in the Sangamon Arch, West-Central Illinois*

Yaghoob Lasemi[1]

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[1]Illinois State Geological Survey, University of Illinois, Champaign, IL (ylasemi@illinois.edu)

Abstract

Several prolific dolomite petroleum reservoirs occur in the upper part of the Middle Silurian Racine Formation in the Sangamon Arch, west-central Illinois. Detailed facies and sequence stratigraphic analyses, and well-to-well correlation of the Racine Formation, along the southeastern flank of the Sangamon Arch, have indicated that the middle part of the Racine Formation is erosionally truncated and subsequently overlapped by the younger Silurian deposits throughout the study area, signifying a pronounced unconformable boundary. This prominent intra-Racine unconformity subdivides the Racine Formation into two depositional sequences comprising several carbonate reservoir units within the highstand systems tracts.

The reservoirs are characterized by porous dolomitized lime mudstone to grainstone and reef/reef rudstone facies. They contain partially dolomitized echinoderm fragments and molds of crinoids, brachiopods and corals, suggesting deposition in a normal shallow marine environment. The reservoir facies were deposited along a southwest trending ramp margin that was roughly parallel to the Sangamon Arch trend and graded basinward into muddy open marine carbonates below wave base. The dolomite reservoirs are generally interlayered with laterally extensive, impermeable limestone beds displaying cyclic reservoir- non-reservoir packages. They constitute the upper parts of small-scale transgressive-regressive cycles within the highstand systems tracts, suggesting sea level fluctuations and percolating seawater as the primary controls for early dolomitization. This interpretation is supported by: (1) gradual loss of porosity laterally, (2) the sharp upper contacts and gradational lower contacts of the reservoir bodies, and (3) resistance of the early-formed dolomite to chemical compaction during burial diagenesis, thus preserving the early original porosity. Depositional, diagenetic and sequence stratigraphic models developed in this study provide important predictive tools for petroleum exploration.

Reference

Kolata, D.R., and W.J. Nelson, 2011, Tectonic history, *in* D.R. Kolata and C.K. Nimz, (eds.), Geology of Illinois: Illinois State Geological Survey, p. 77-89.

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Yaghoob Lasemi
Illinois State Geological Survey
University of Illinois

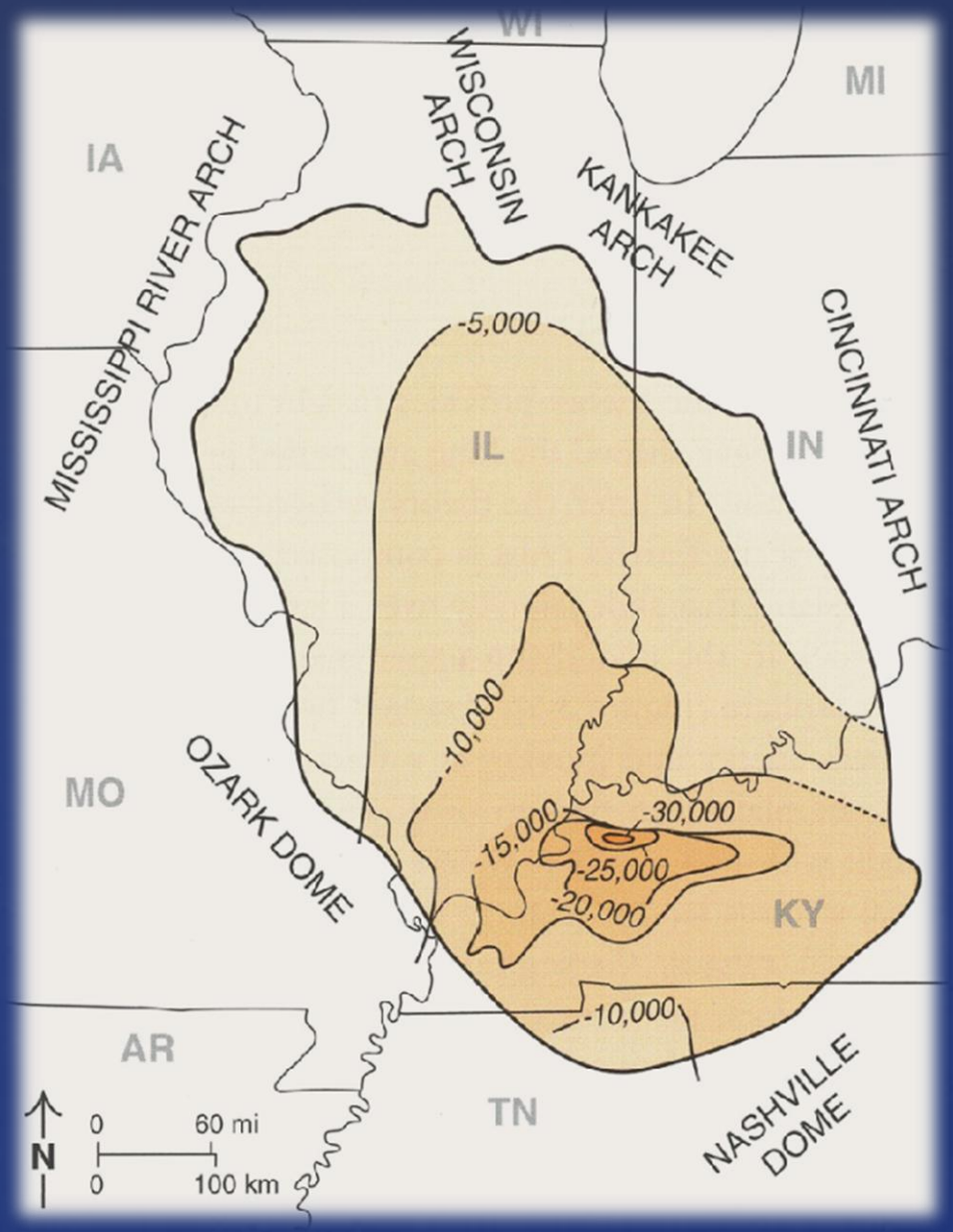
ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline of presentation

- Introduction
- Silurian stratigraphy
- Reservoir occurrence, cyclicity, and facies
- Depositional, diagenetic, and sea level controls on reservoir development

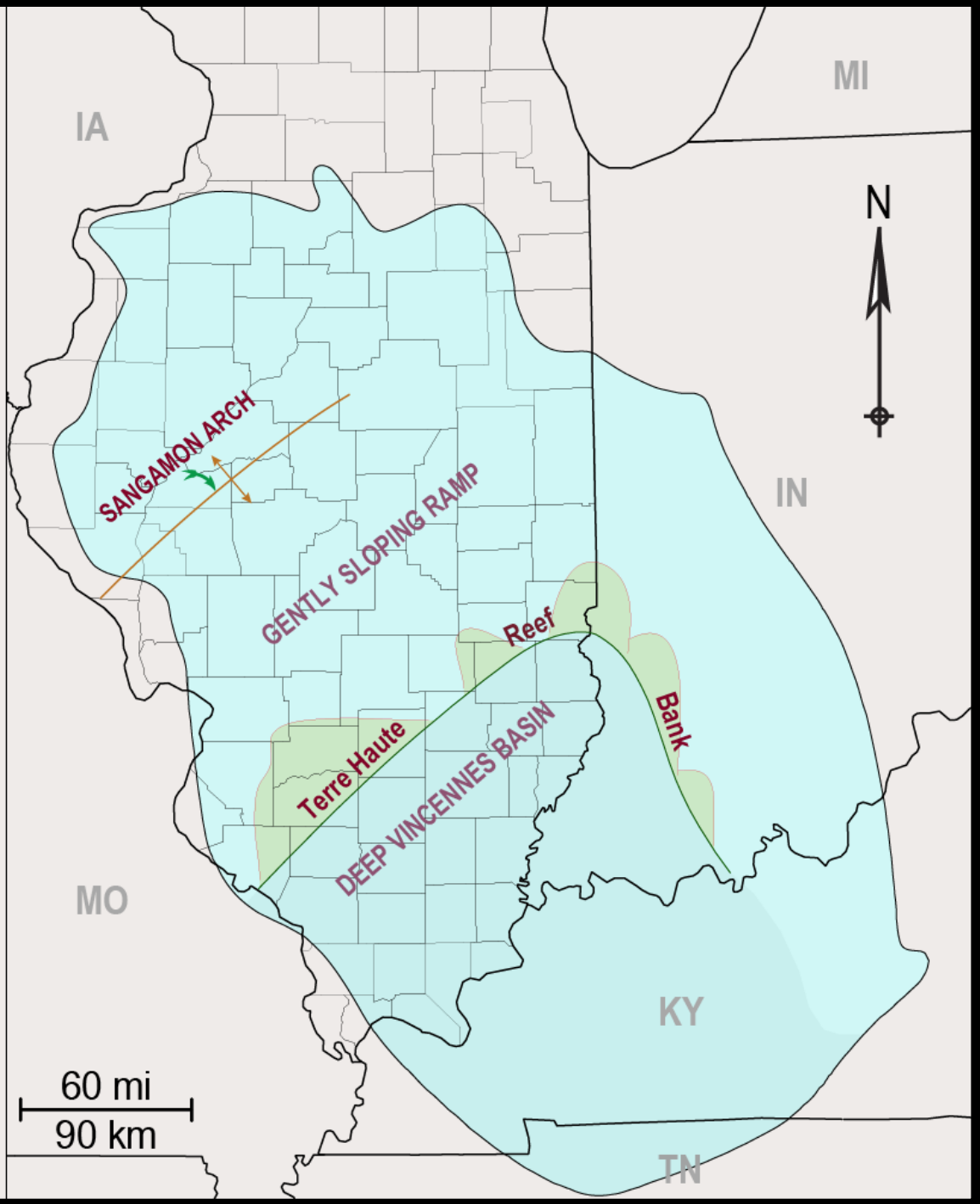
Illinois Basin (shaded) surrounded by prominent arches and domes. Structure contours show the depth to Precambrian basement (from Kolata and Nelson, 2011).



Mid- Late Silurian Time (420-430 MA)

-A broad structural high, the Sangamon Arch, was located in the gently sloping ramp area in the northwest of the basin.

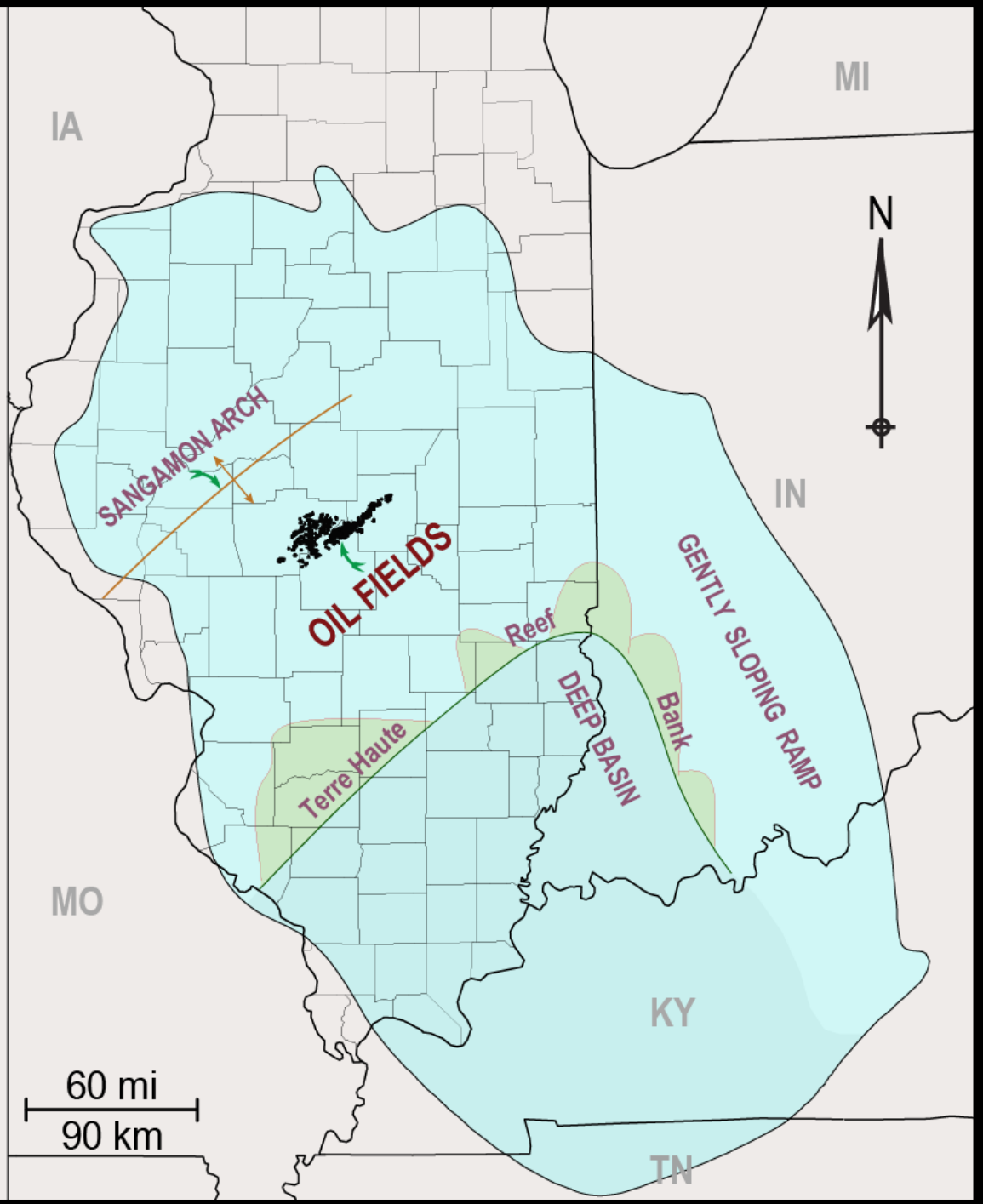
-A platform margin, the Terre Haute Reef Bank, marked a slope break facing the deep Vincennes Basin in the southeast.



Silurian Oil Production

-Commercial oil production began in the Decatur area in 1925; several oil fields are discovered in the southeastern flank of the Sangamon Arch.

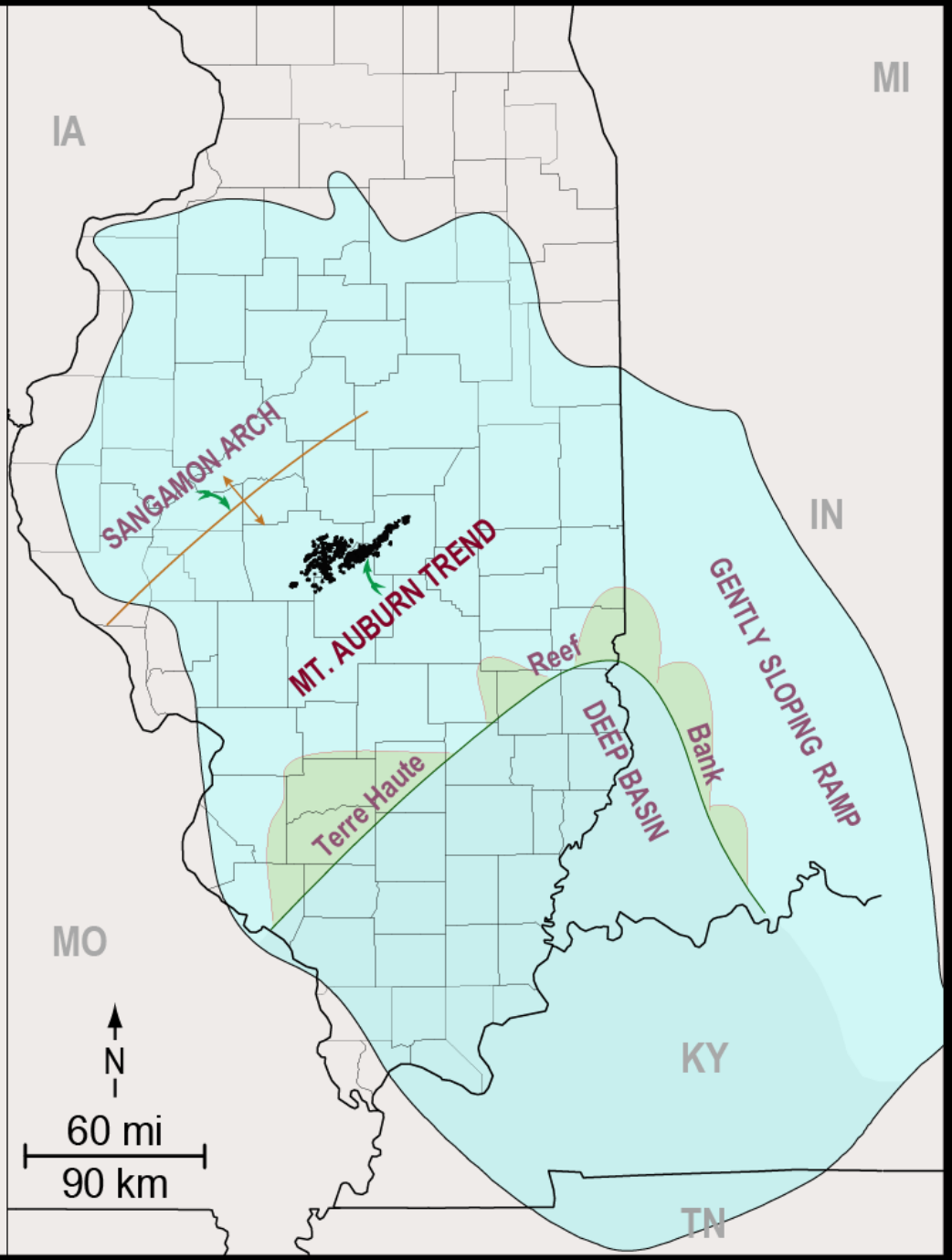
-Over 33 million barrels of oil have been produced from the reservoirs in the upper part of the Silurian deposits.

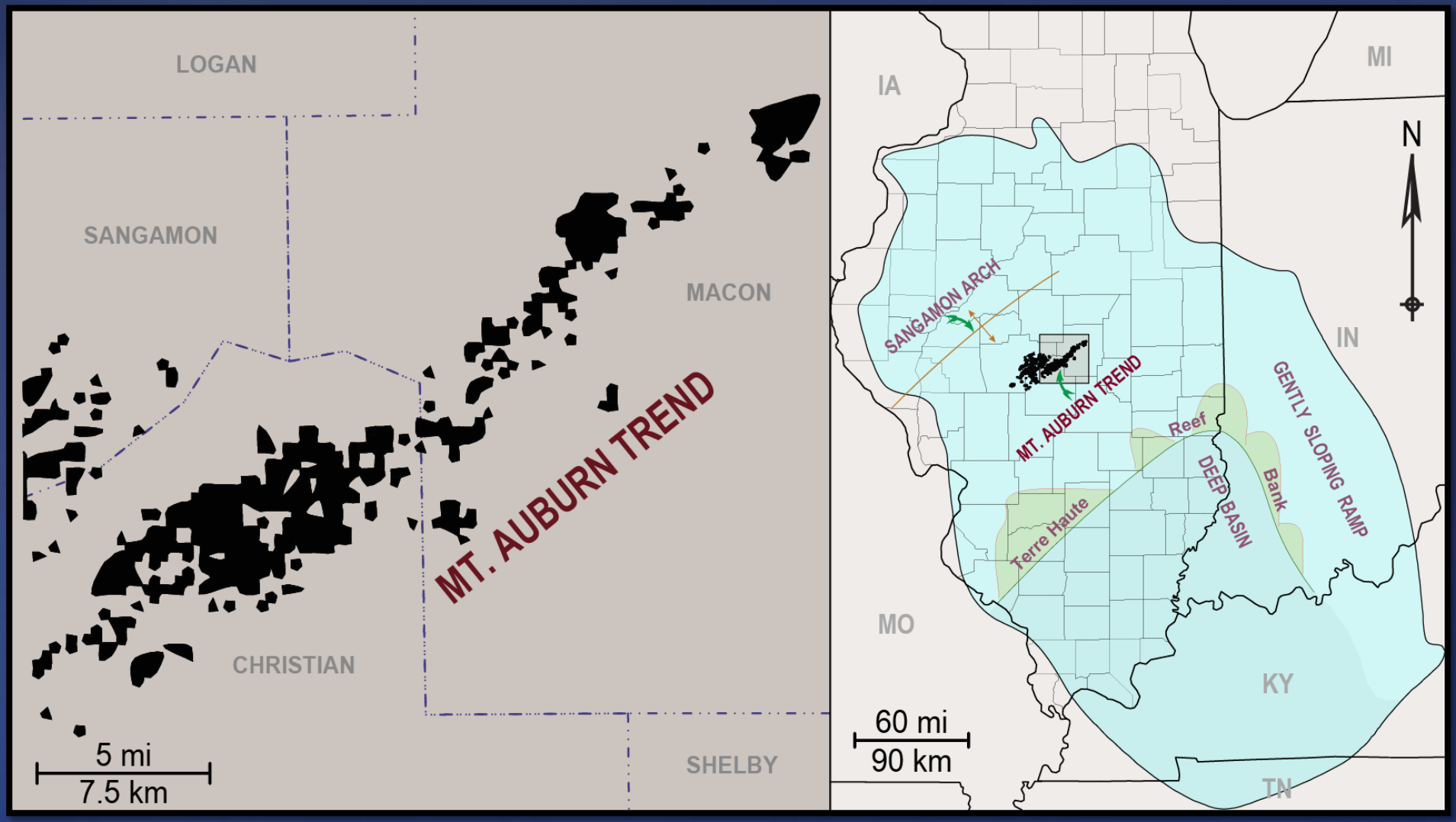


Objectives

-There had been no study on the characterization and precise correlation of the Silurian reservoirs in the Sangamon Arch area.

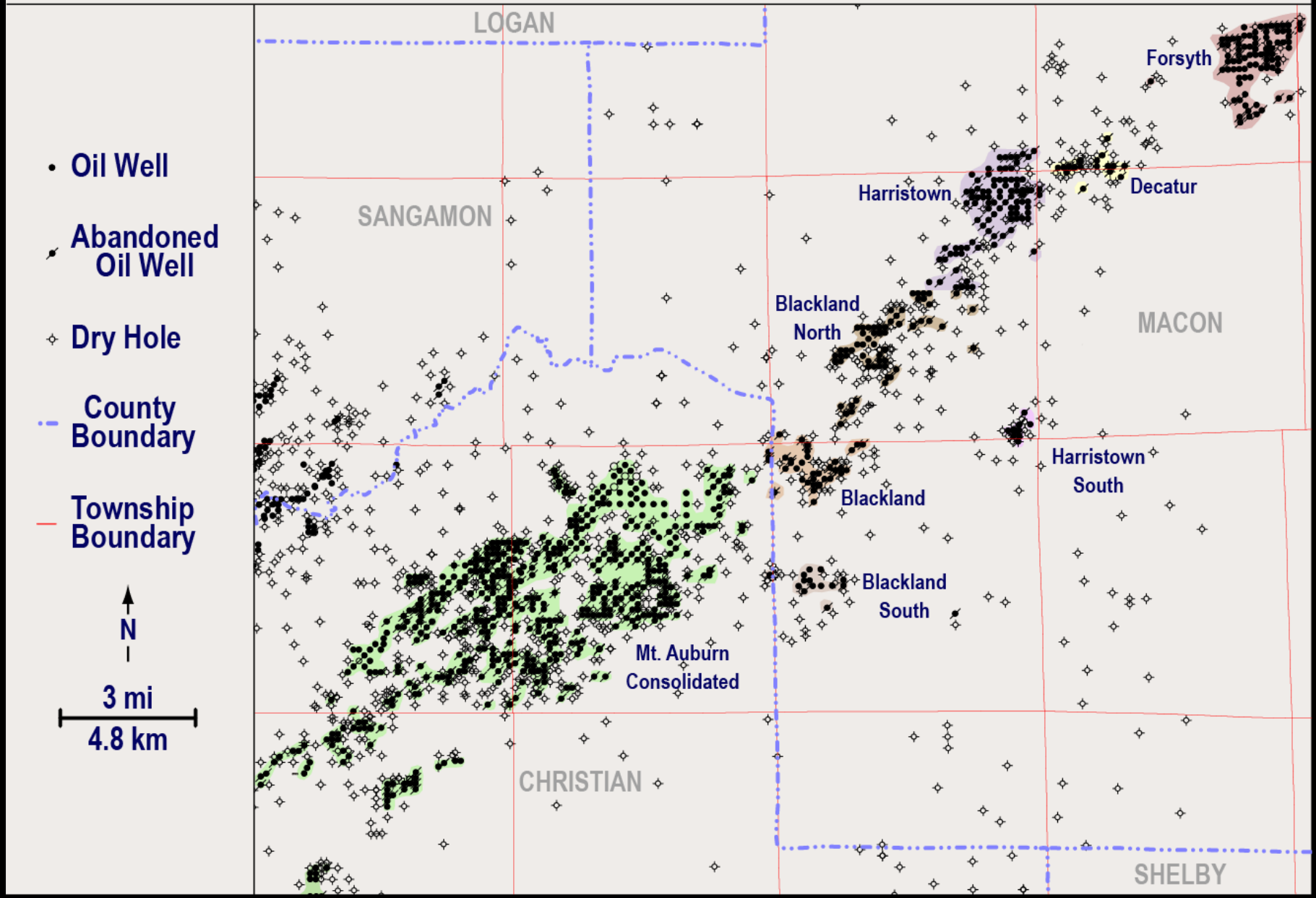
-Research on the Silurian carbonates in the area began by the author in 2009. In this presentation, I will talk about the petroleum reservoirs of the Silurian Racine Formation of the Mt. Auburn Trend.



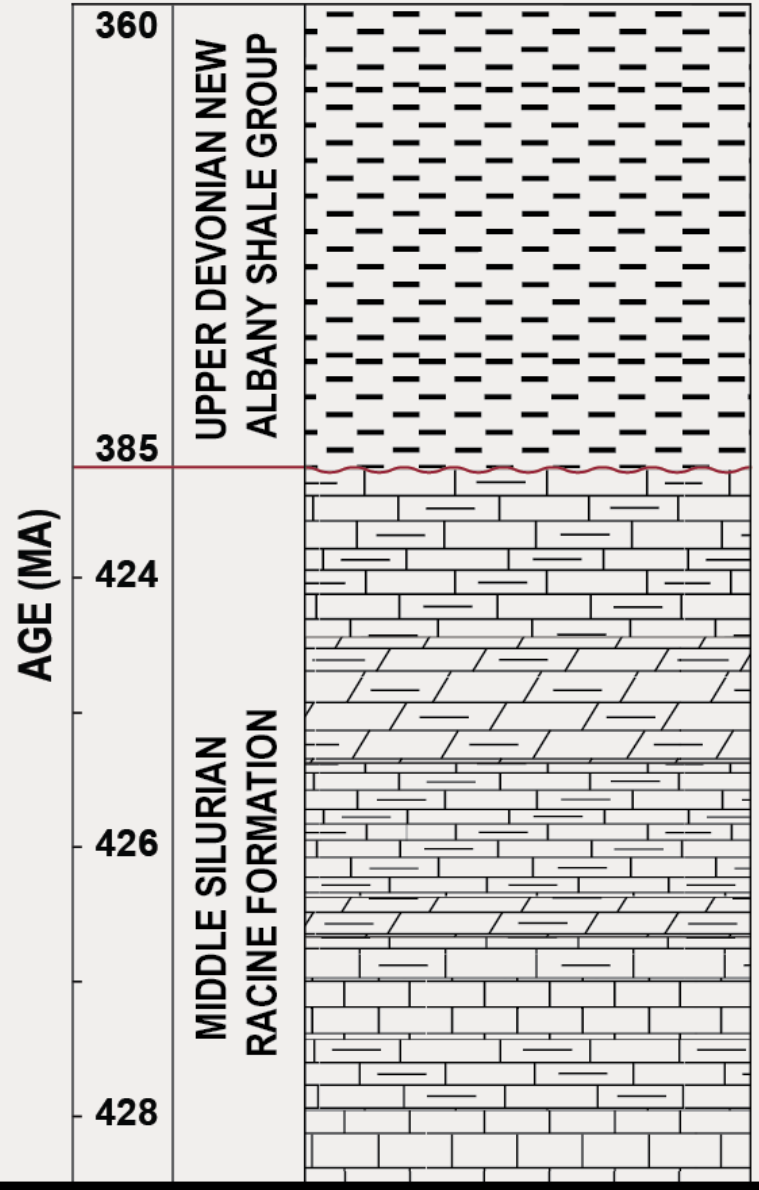


The Mt. Auburn Trend parallels the Sangamon Arch and consists of several oil fields in Macon and Christian Counties.

Oil Fields of the Mt. Auburn Trend



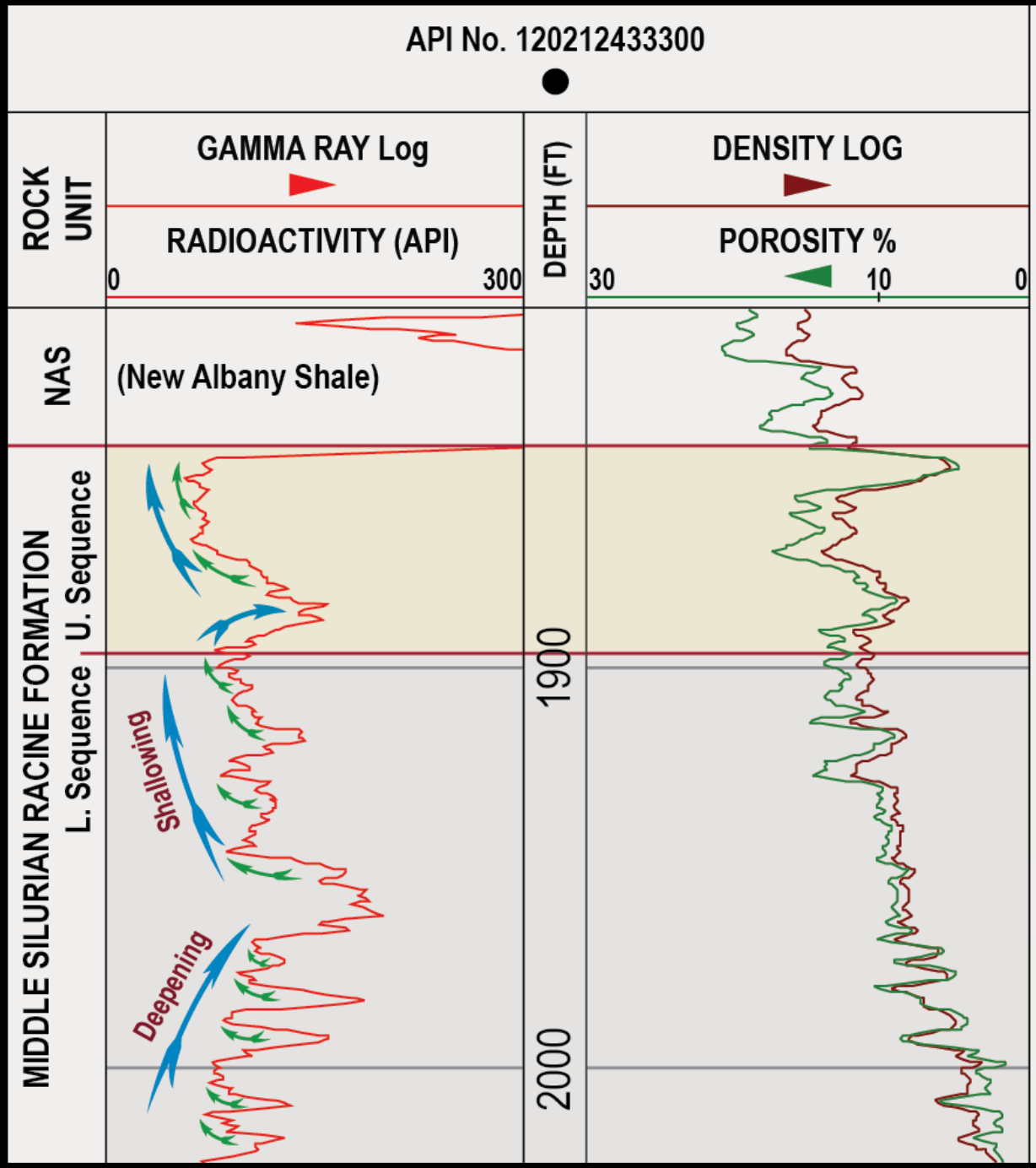
Mt. Auburn Trend Stratigraphy



-The New Albany Shale overlies the Racine Formation with an erosional contact; the time gap at the contact is nearly 40 million years.

-The Racine Formation displays variable thickness and lithology consisting of dolomite, limestone and shale.

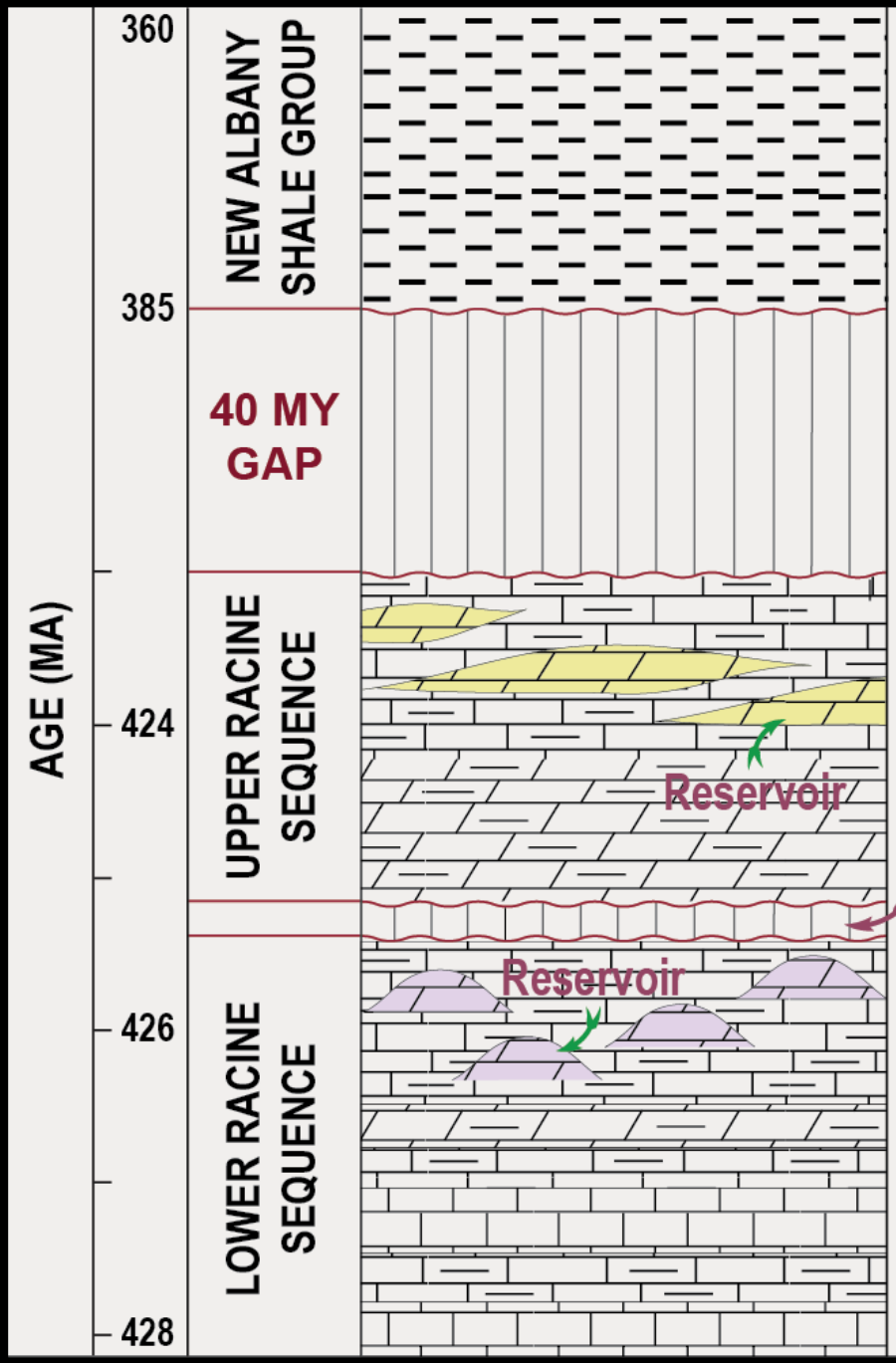
Dolomite Limestone Shale



Vertical Facies Trend and Cyclicity

-The Racine Formation consists of two sequences built by characteristic deepening and shallowing-upward packages.

-These transgressive-regressive packages are Superimposed by small-scale shallowing-upward cycles reflecting short-term relative sea level changes.



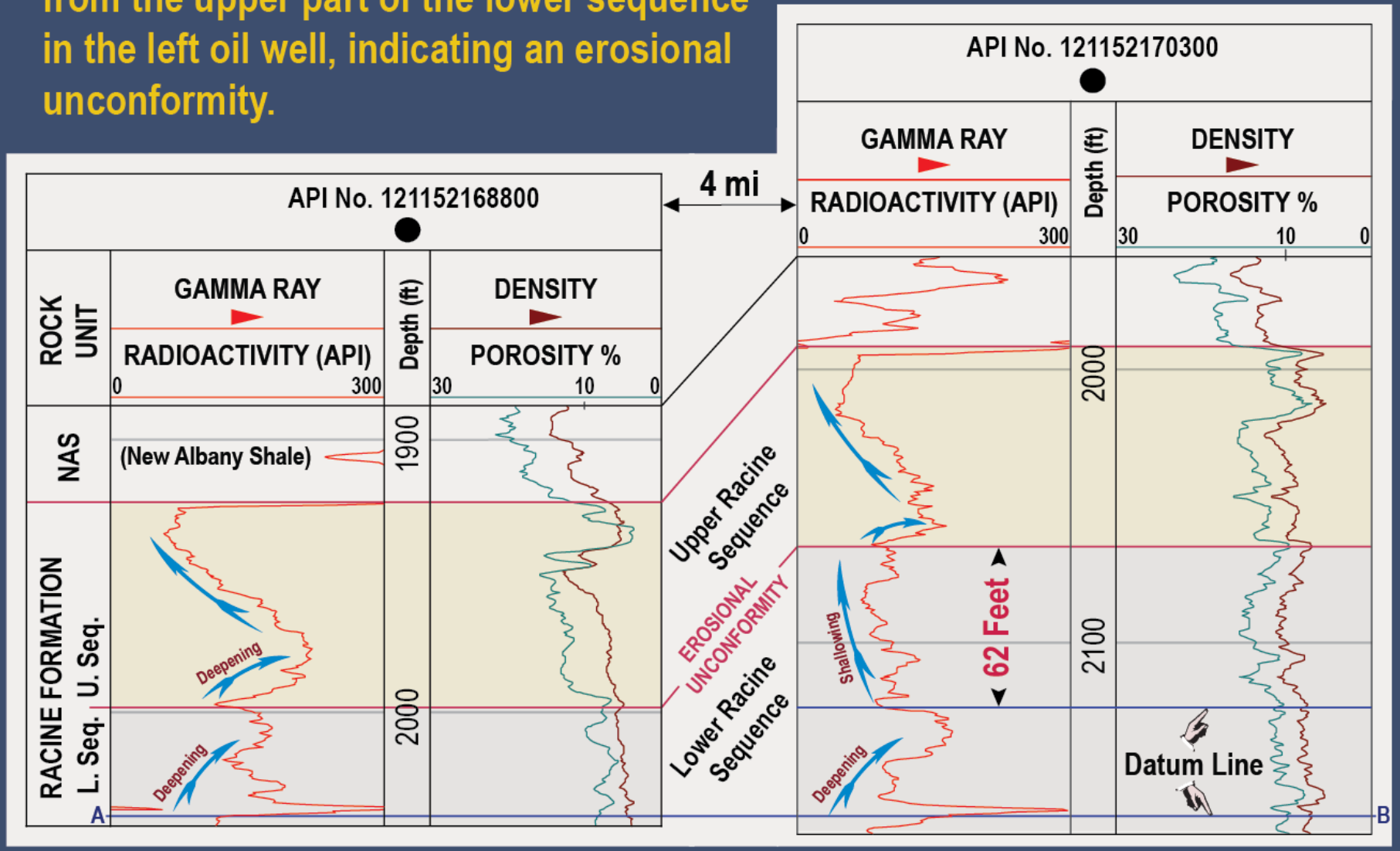
Intra Racine Unconformity and Petroleum Reservoirs

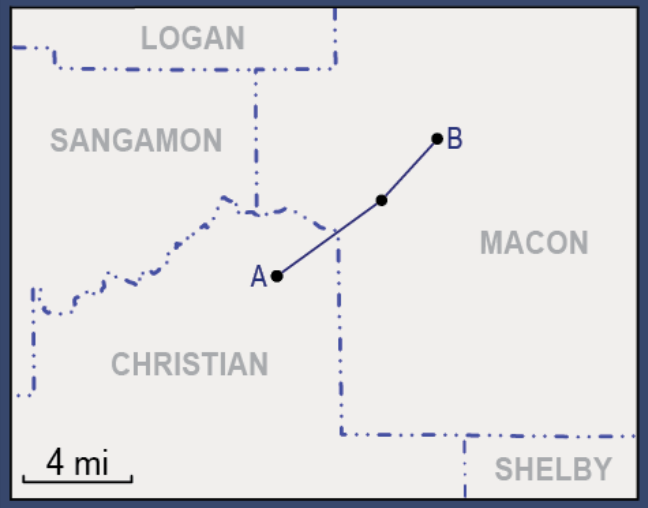
-Detailed well to well correlation has revealed the presence of a prominent erosional unconformity between the Racine sequences.

-Petroleum reservoirs may occur in the upper part of each sequence.

Intra Racine Erosional Unconformity

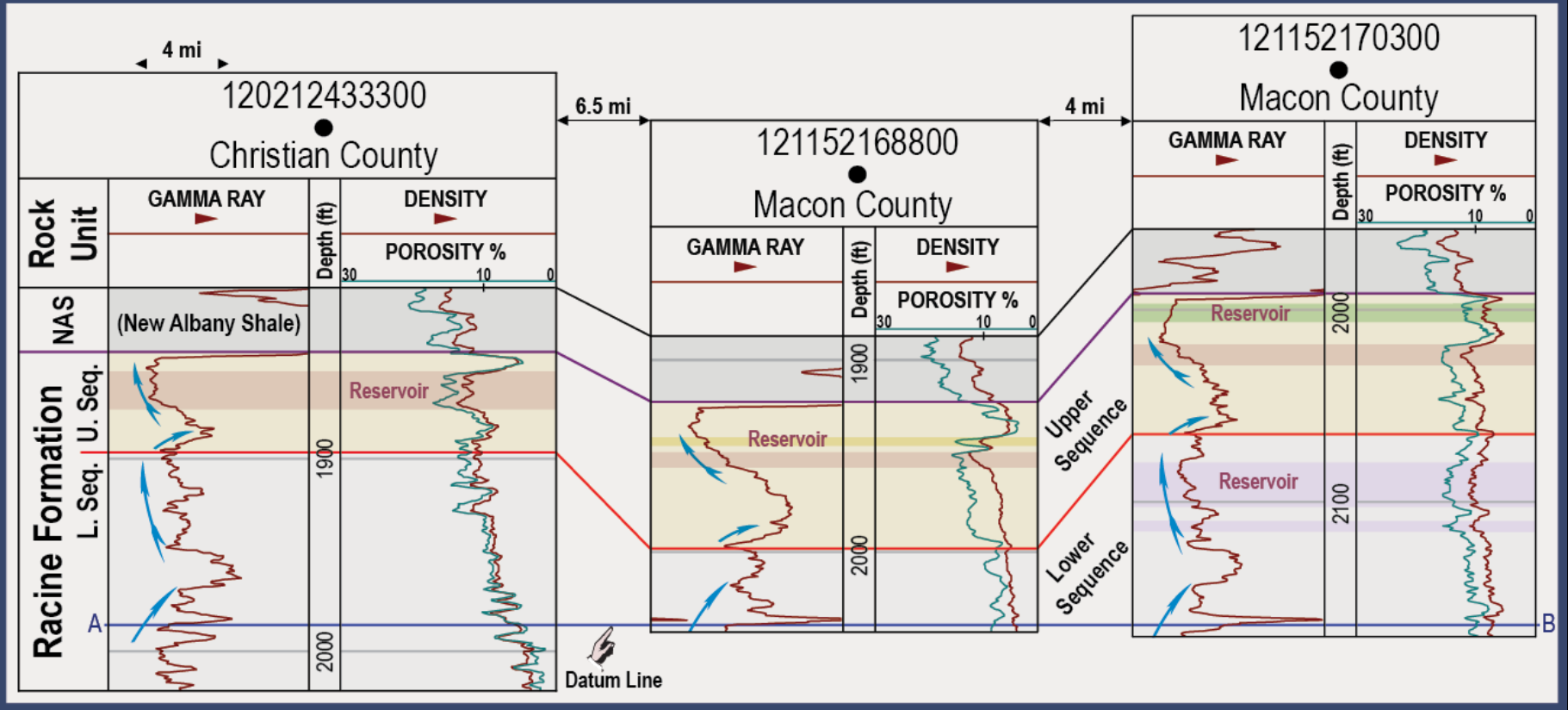
At least 62 feet (the shallowing-upward package) is omitted from the upper part of the lower sequence in the left oil well, indicating an erosional unconformity.

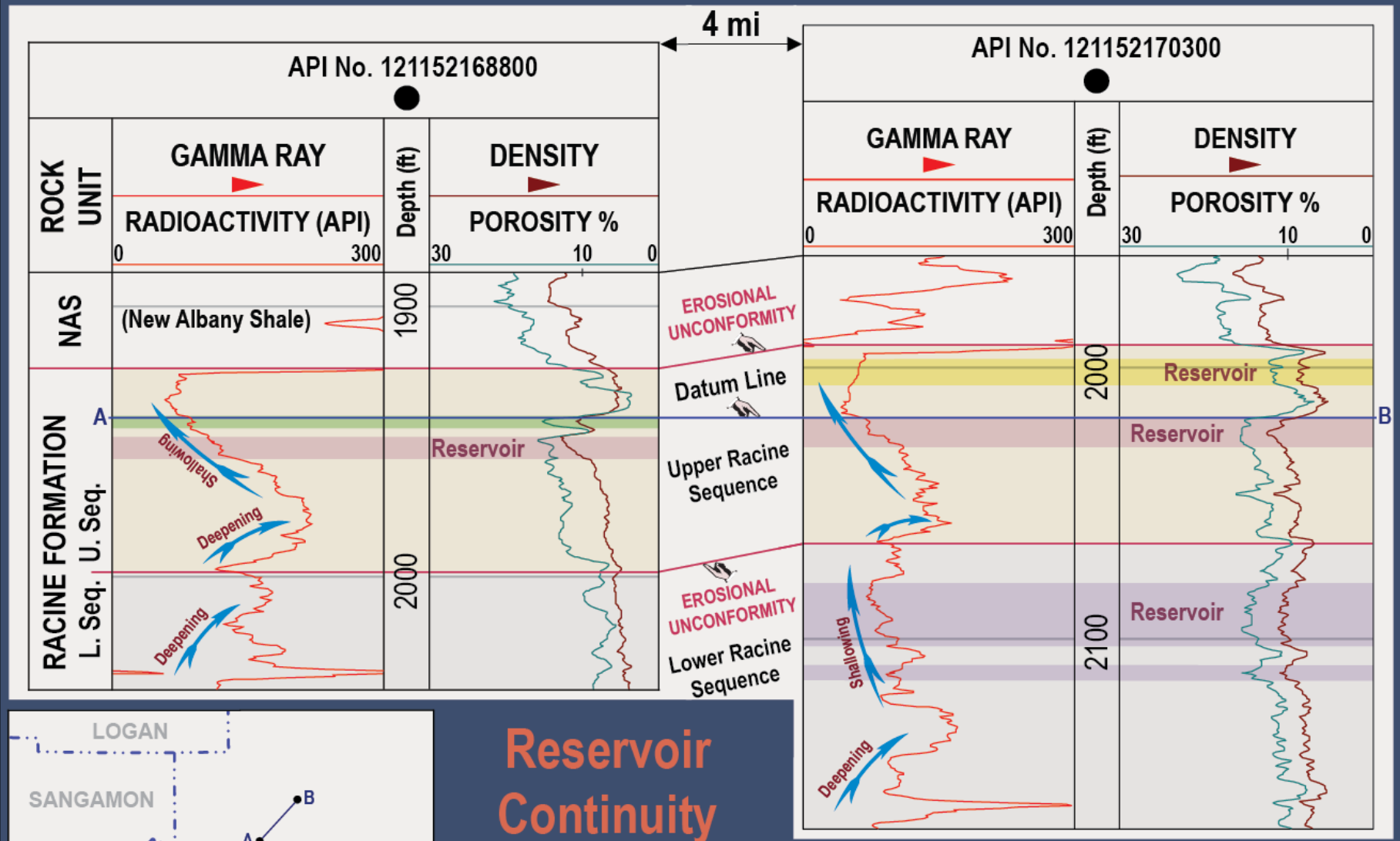




Reservoir Occurrence and Cyclicity

Cyclic reservoirs and laterally extensive impermeable cap rock facies occur in the upper part of the Racine sequences.

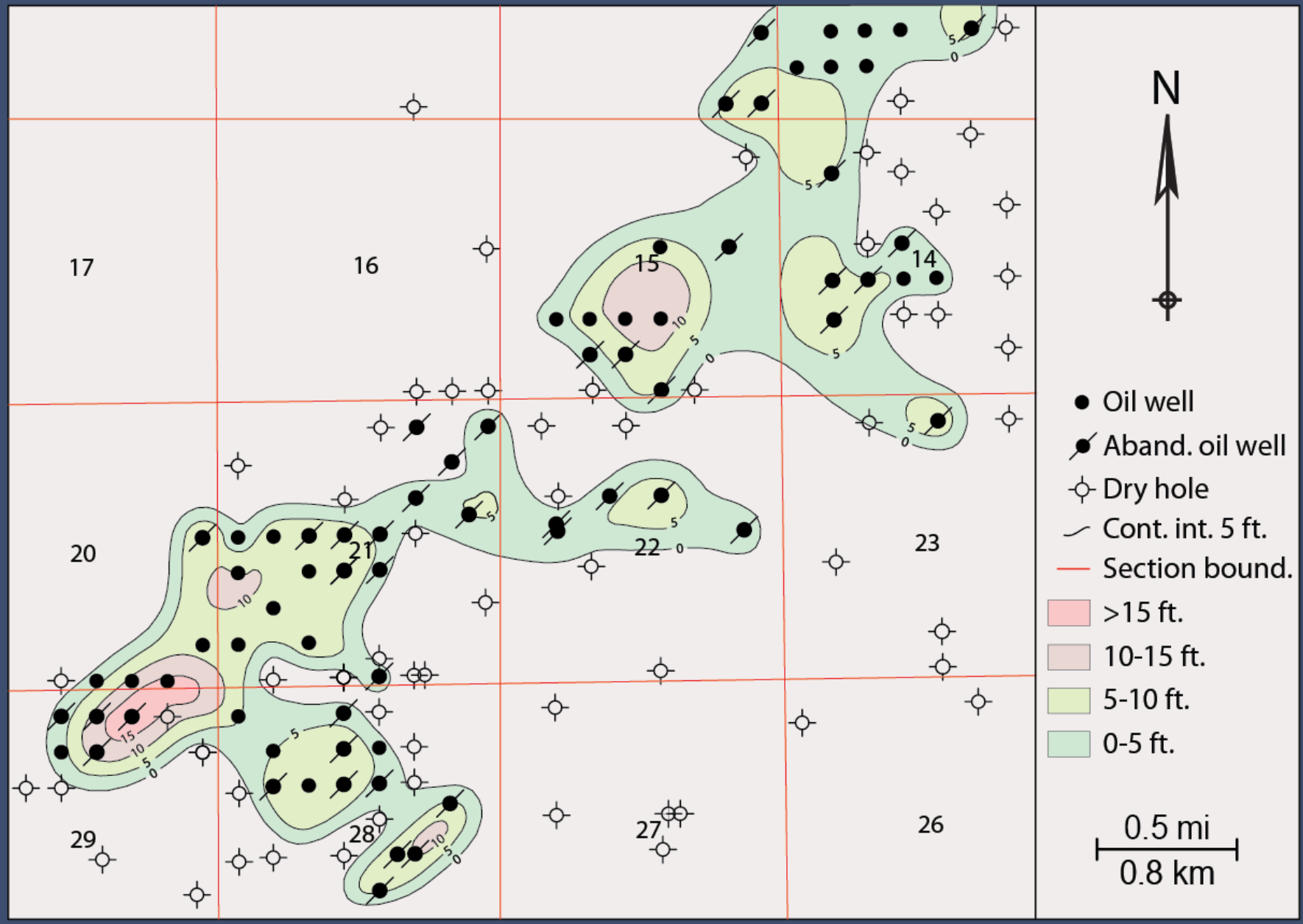




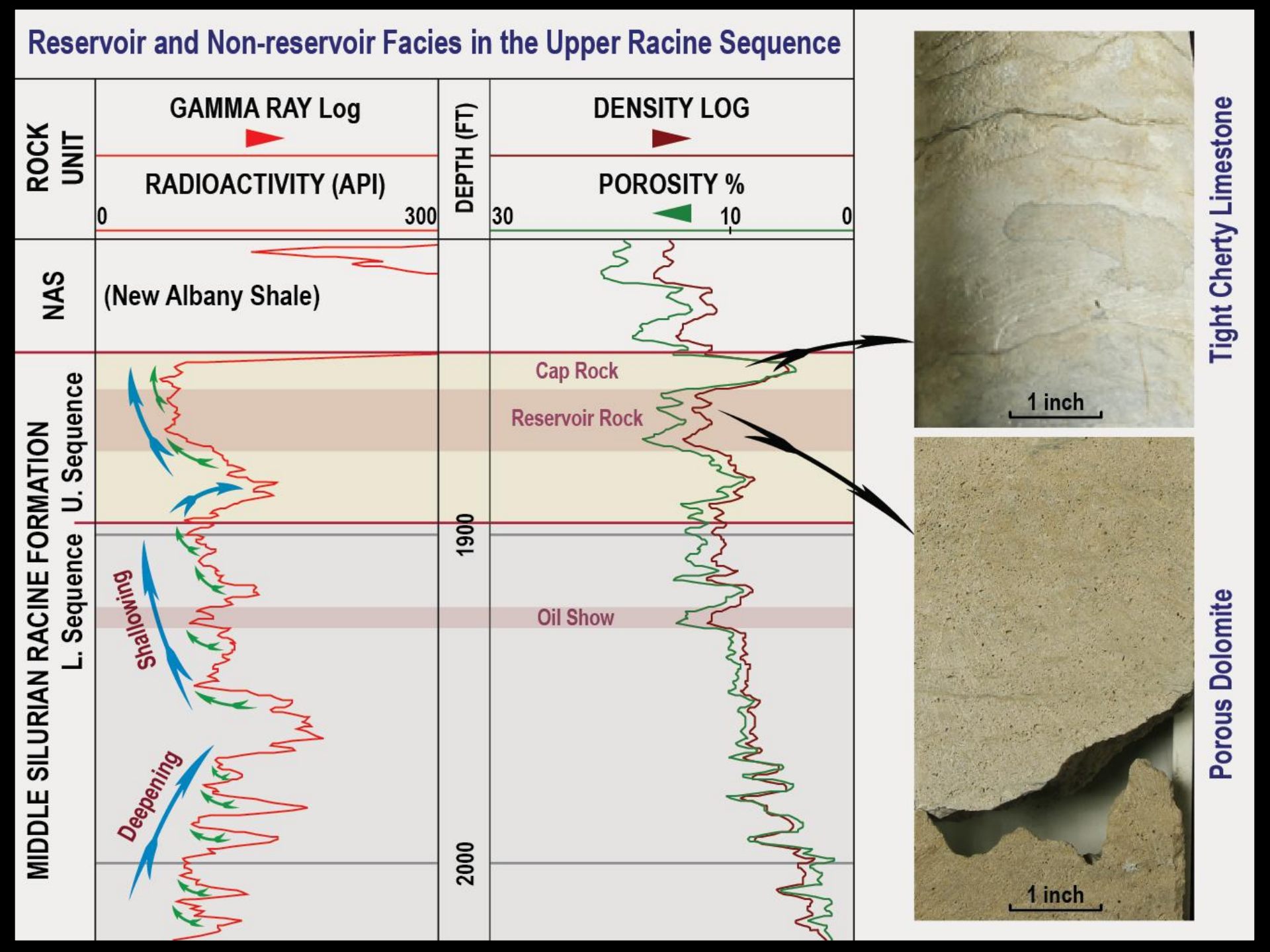
Reservoir Continuity

The reservoirs are laterally discontinuous due to lateral facies changes or erosion at the sequence boundaries.

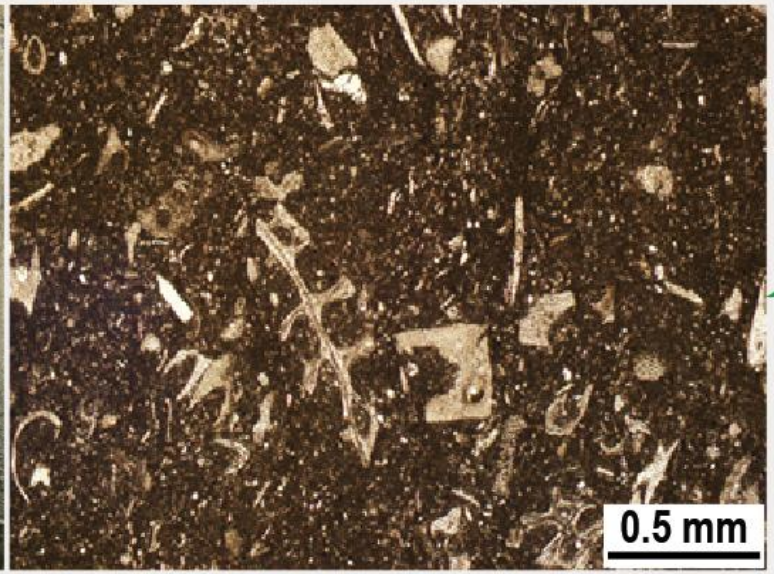
Thickness Map of a Reservoir in the Blackland Field



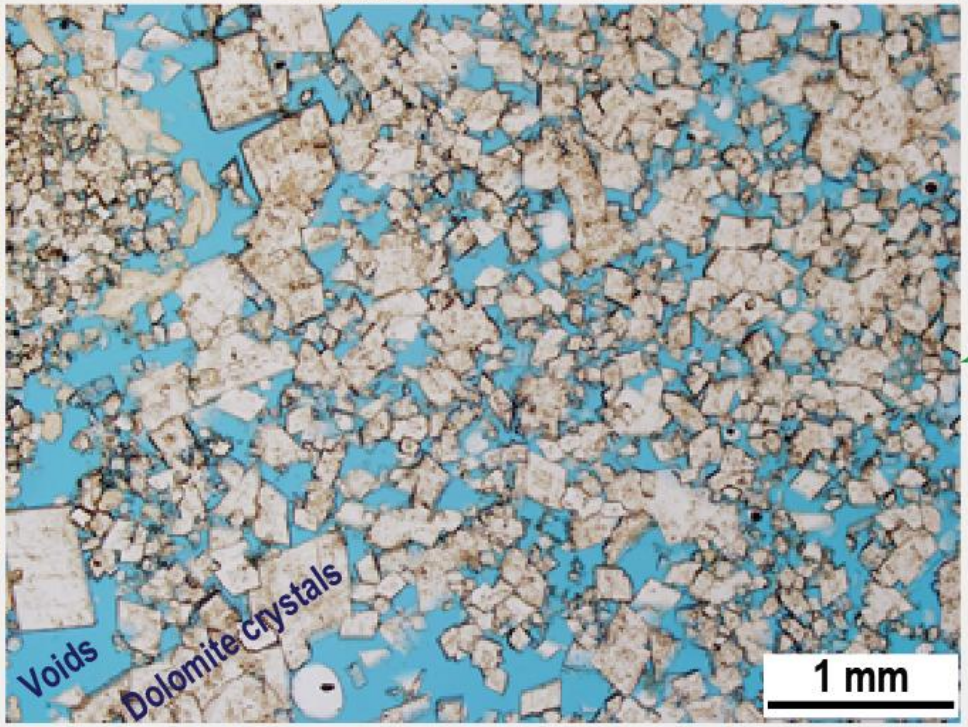
Reservoir and Non-reservoir Facies in the Upper Racine Sequence



Core Samples (Left) and Photomicrographs of Porous Dolomite and Cap Rock Facies in the Upper Sequence

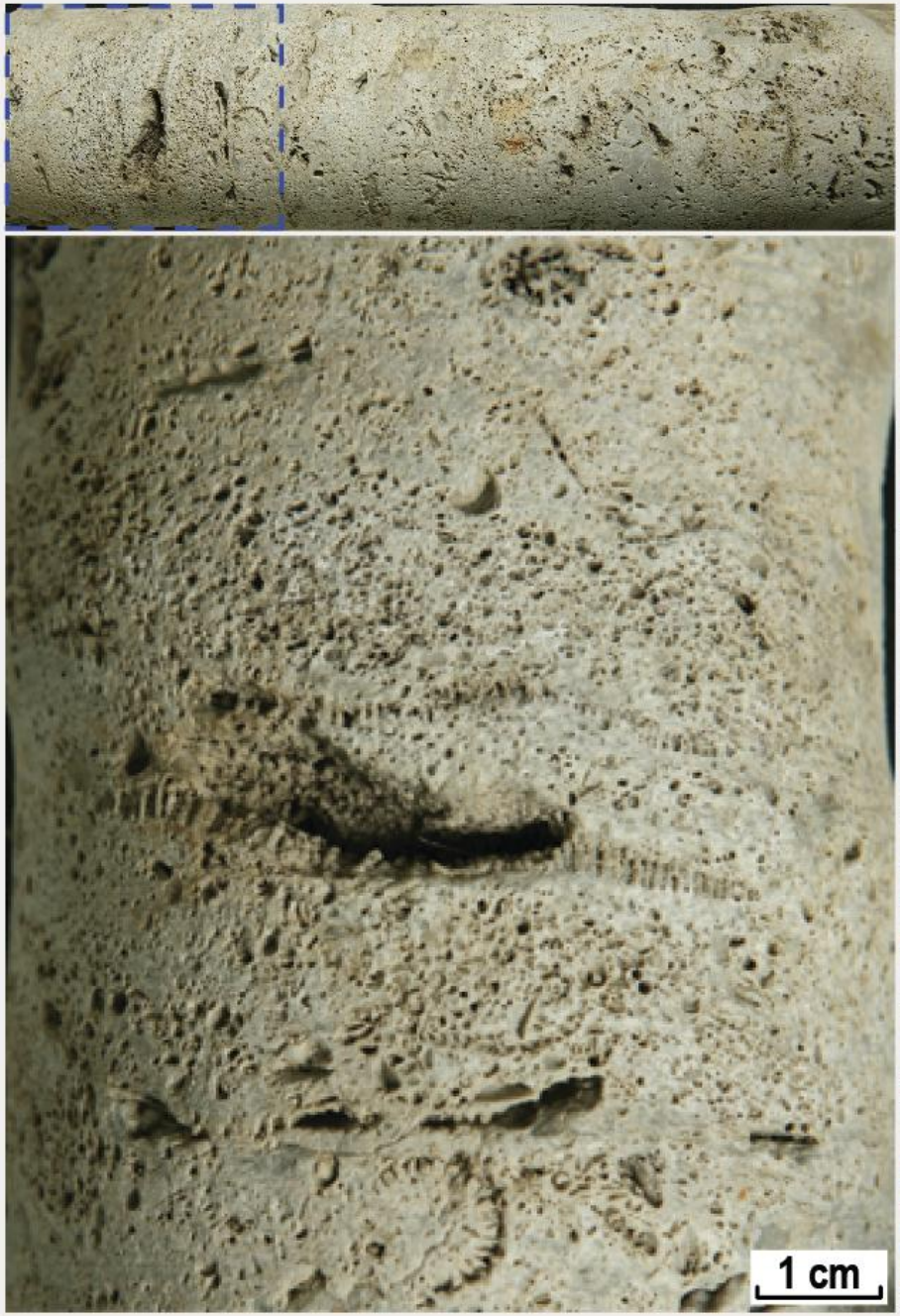


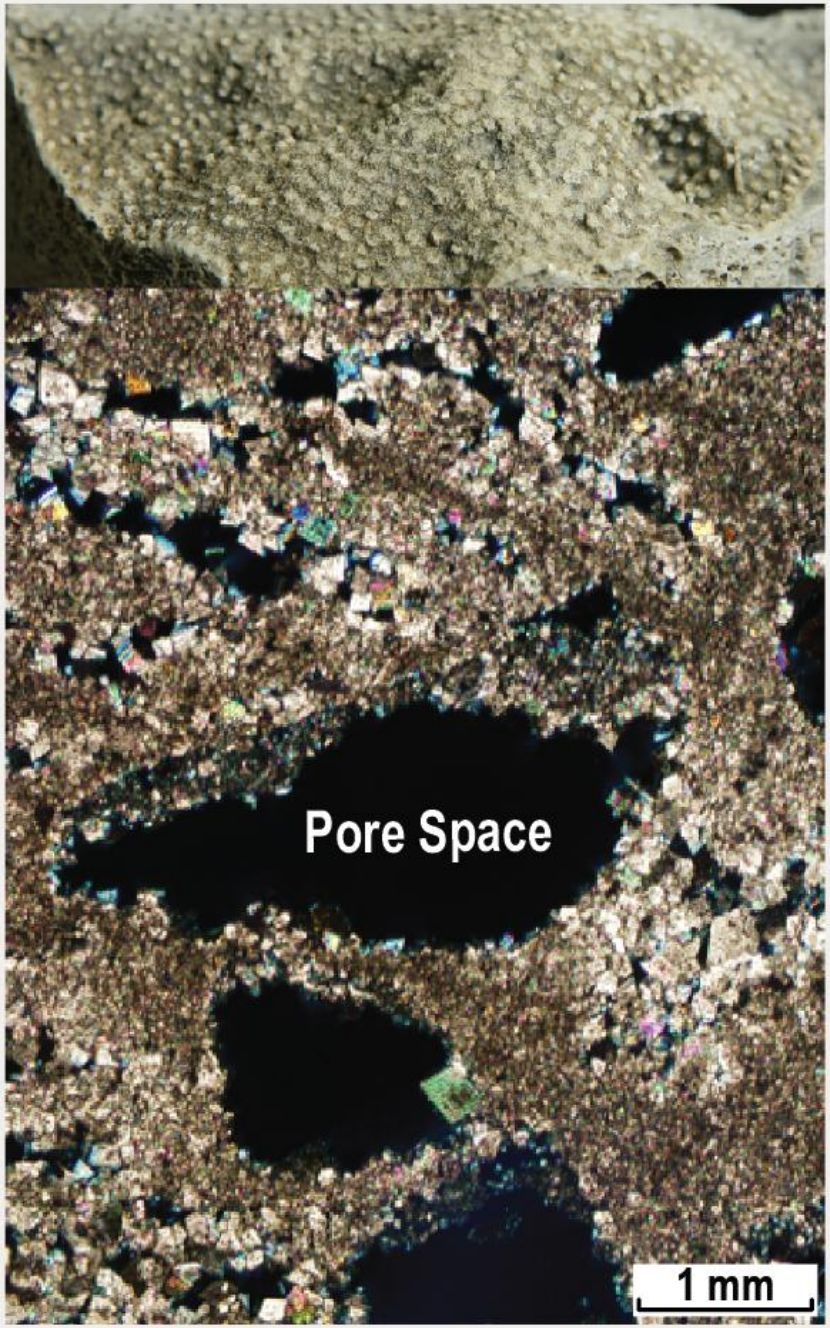
Cap Rock Photomicrograph



Porous Dolomite Photomicrograph

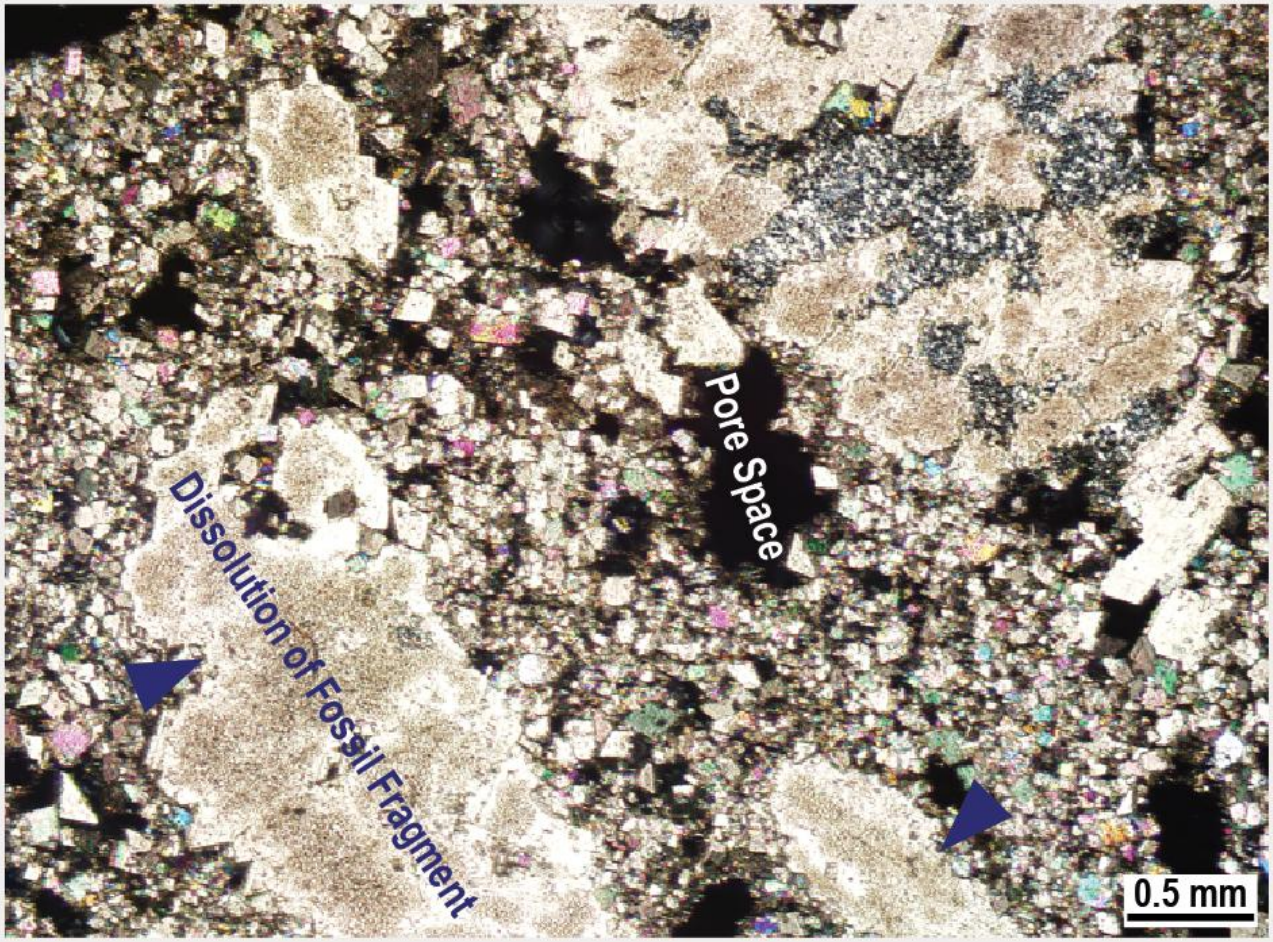
Core Samples and photomicrograph of a Reef Reservoir in the Lower Sequence





How and When Did Dolomite Reservoirs Form?

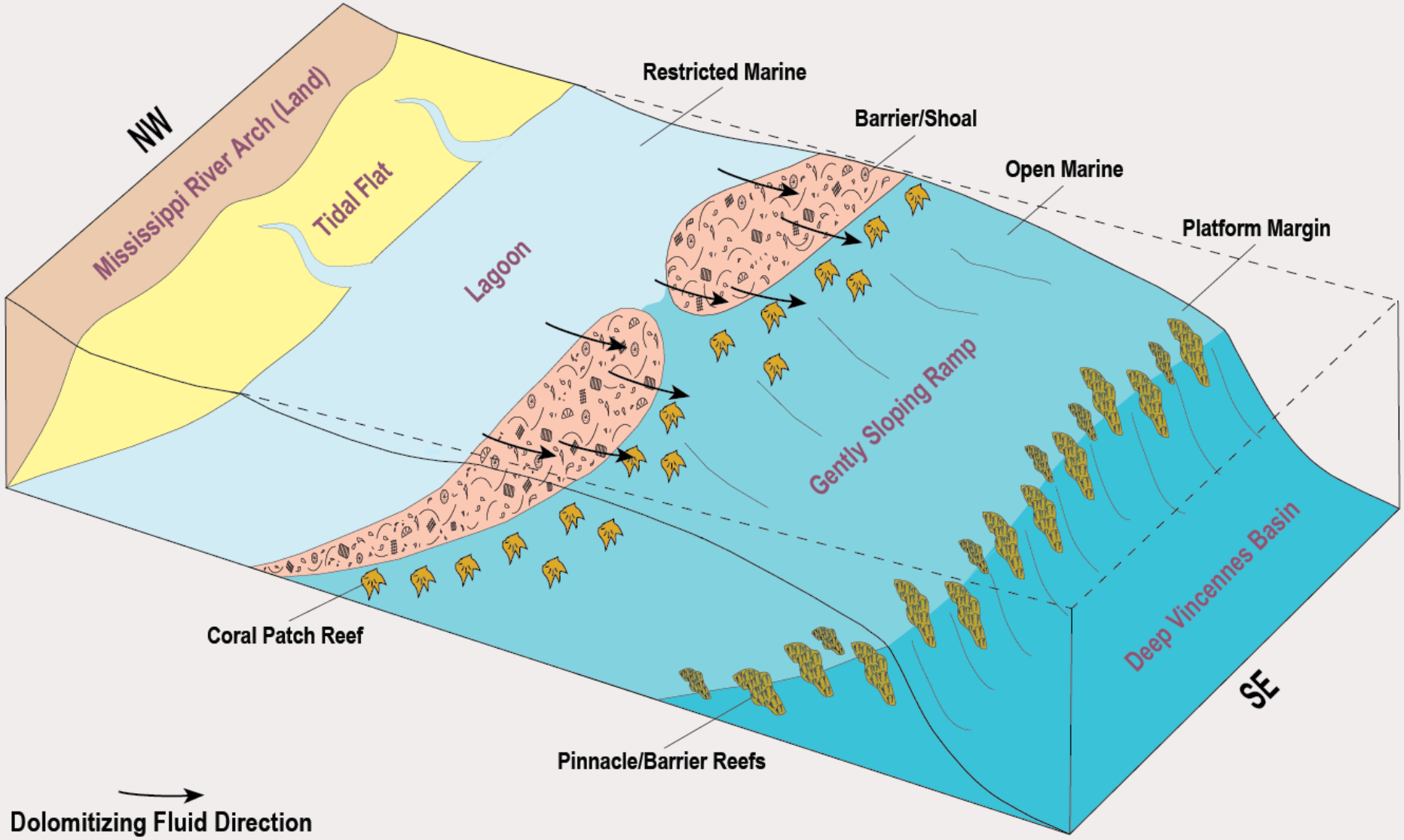
Dolomite and pore spaces formed as a result of dissolution of previously deposited limestone shortly after deposition.



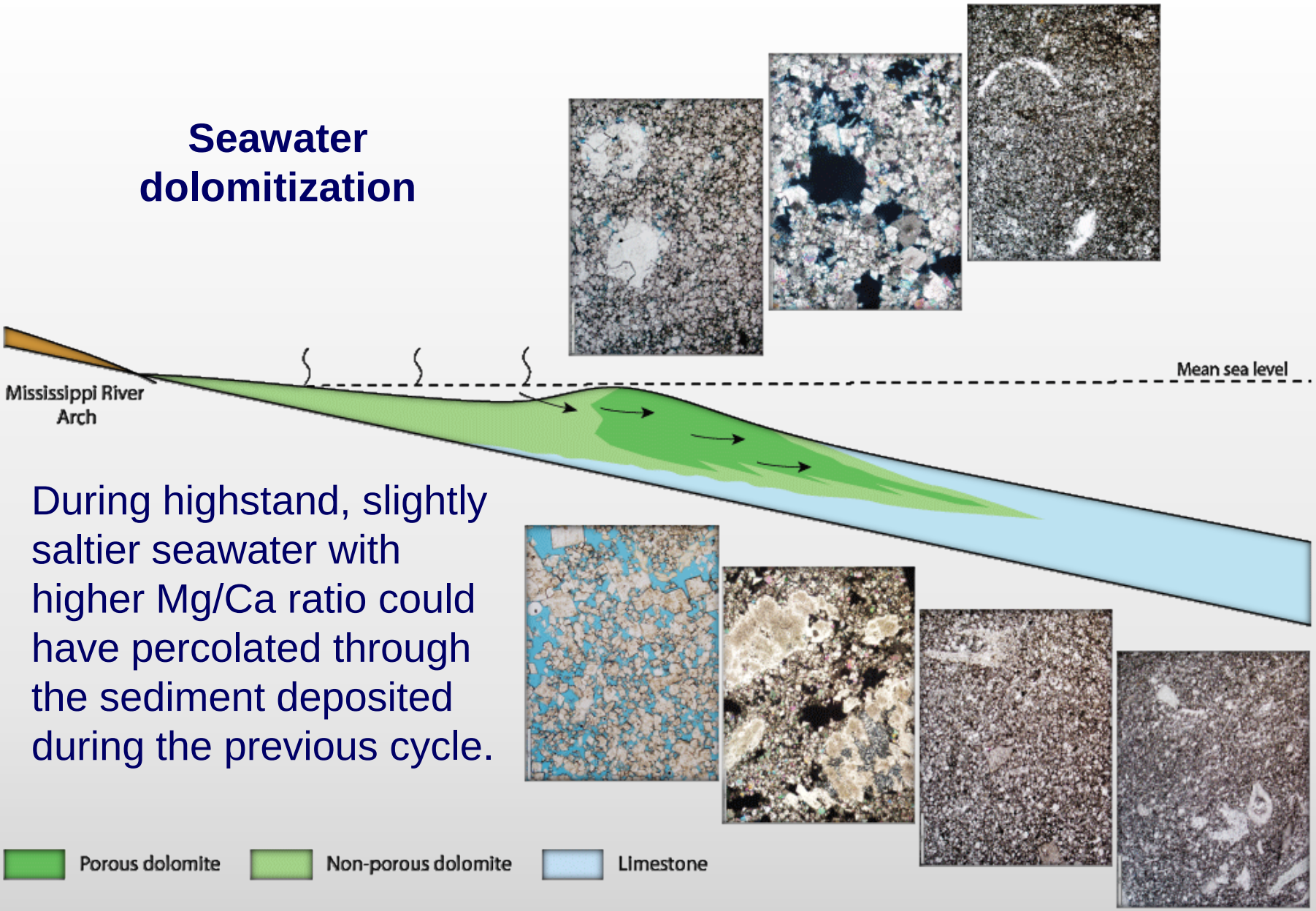
Thin Section Photomicrograph

Core Sample

Depositional Model During the Silurian in the Illinois Basin



Seawater dolomitization

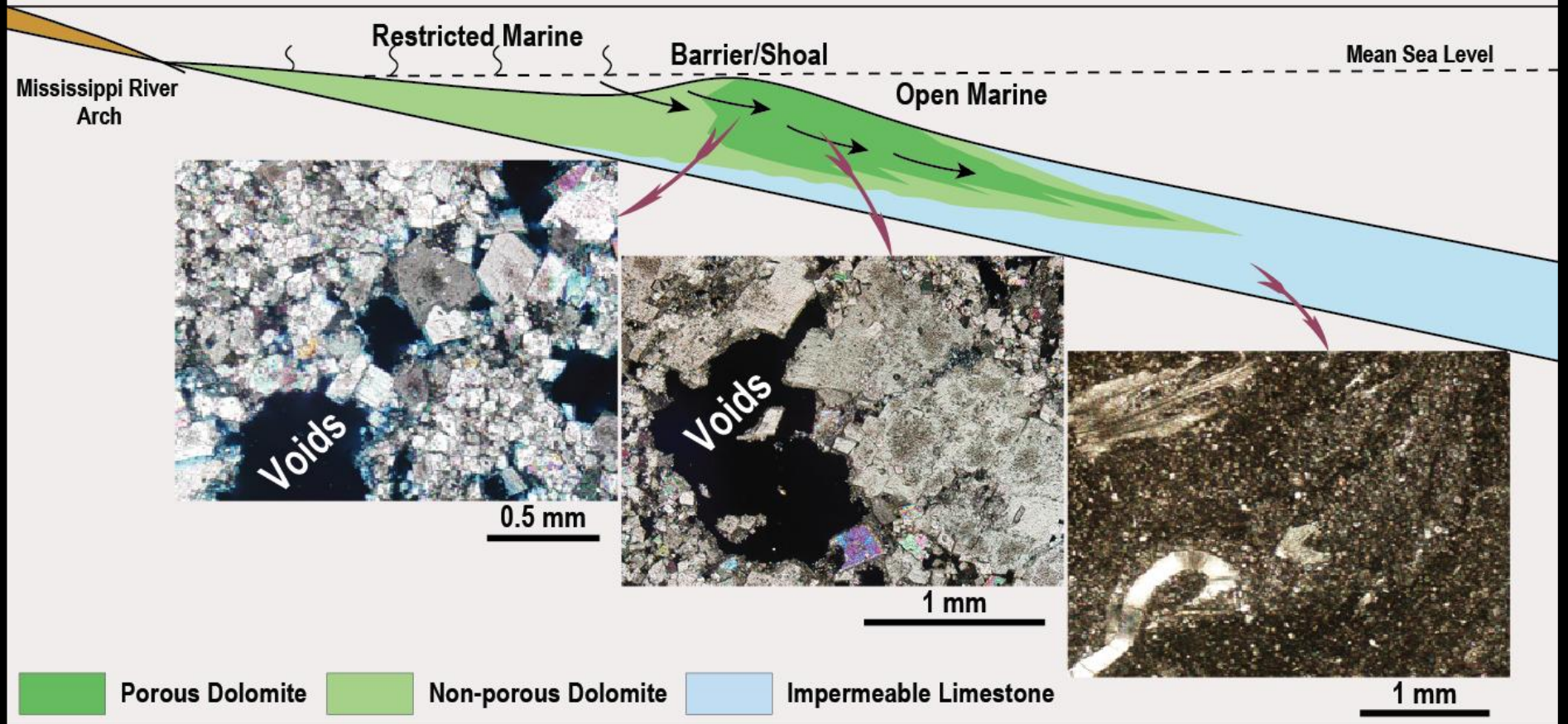


During highstand, slightly saltier seawater with higher Mg/Ca ratio could have percolated through the sediment deposited during the previous cycle.

Dolomitization model

Dolomitization Model for Reservoir Development

-During transgression, laterally extensive deeper marine sediment would form the impermeable capping limestone facies.



Conclusions

- The reservoirs formed during sea level highstand and constitute the upper part of fourth-fifth-order shallowing-upward cycles.

- Dolomitization was caused by reflux of slightly evaporated seawater in an inner ramp setting. Thus, depositional setting, percolating seawater, and sea level fluctuations were the primary controls for their development.

- The proposed dolomitization model, tied to paleoenvironments and sea level fluctuations, provides an important predictive tool for exploration in other areas of the Sangamon Arch.

- This study has already generated renewed interest for exploration in the unexplored areas of the Sangamon Arch and will encourage secondary recovery in the producing fields.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