# Reservoir Architecture and Heterogeneity of Multistorey Fluvial Sandstones of the Mississippian Cypress Formation, Illinois, USA: Implications for $CO_2$ Storage and EOR

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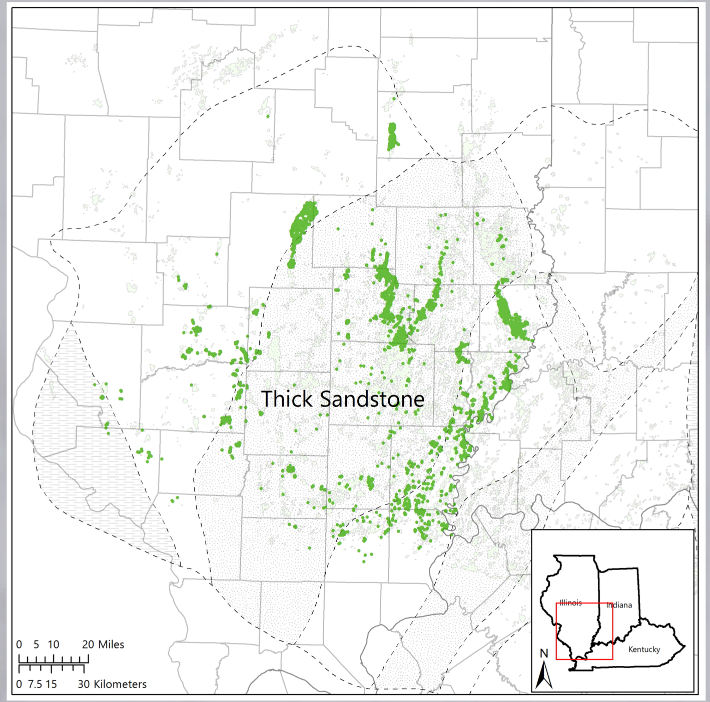
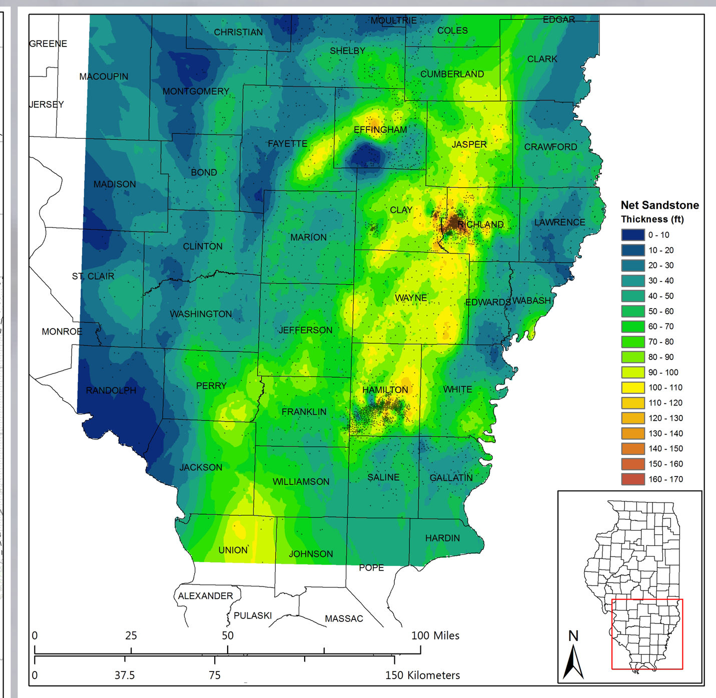
## INTRODUCTION

The Cypress Formation is the most oil-productive unit in the Illinois Basin, USA. In the central part of the basin, the Cypress contains sandstones up to 60 m thick that contain relatively thin main pay zones (MPZs - shown in green in figure on the left) that may be underlain by a residual oil zone (ROZ) and a significant column of brine.




Map showing the extent of the Cypress Sandstone in Illinois with areas of oil production from Cypress reservoirs shown in green. The belt of thick sandstone in Illinois is stippled.

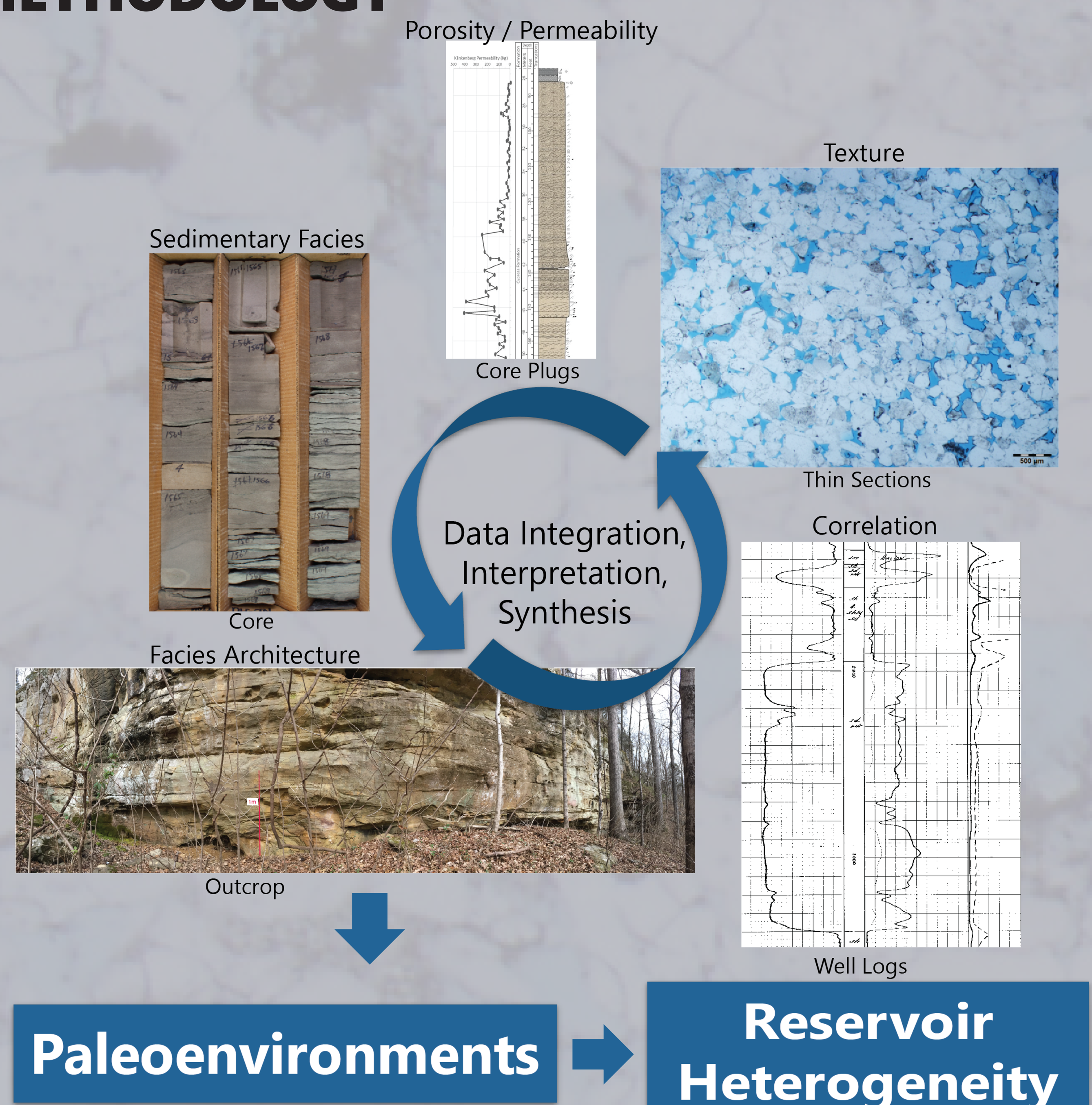



Map showing the net thickness of sandstone within the Cypress. Oil production within the thick sandstone fairway generally occurs in Clay and Richland counties, where the sandstone is thickest.

Thick Cypress sandstones have potential for nonconventional carbon dioxide enhanced oil recovery ($CO_2$-EOR) and storage, whereby $CO_2$ injection aims to store appreciable volumes of anthropogenic $CO_2$ and produce incremental oil from both the MPZ and ROZ. Previous estimates of saline storage potential in the thick Cypress are 0.2 to 2.3 Gt of $CO_2$.

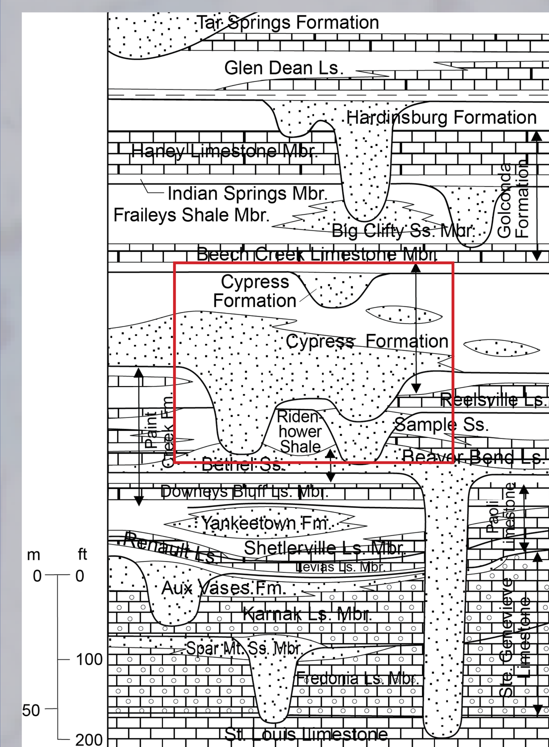
This study focuses on the geologic characterization of the thick Cypress sandstones, which has important implications for $CO_2$ storage and EOR.

## METHODOLOGY



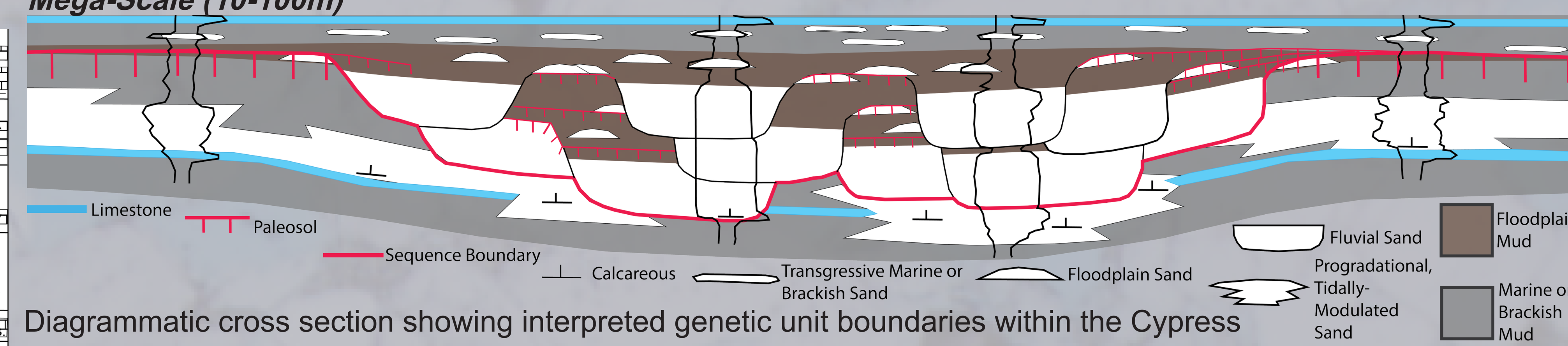

## SCALES AND TYPES OF HETEROGENEITY IN THE CYPRESS SANDSTONE

### *Giga-Scale (>300m)*



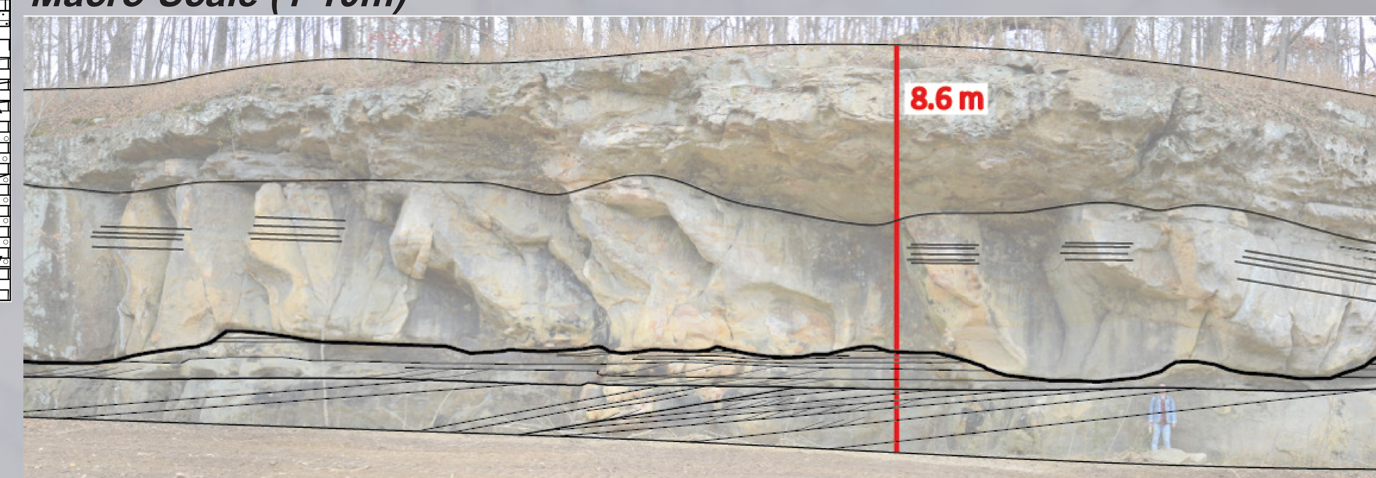

Regional sequence stratigraphic framework of the lower Chesterian succession

### *Mega-Scale (10-100m)*

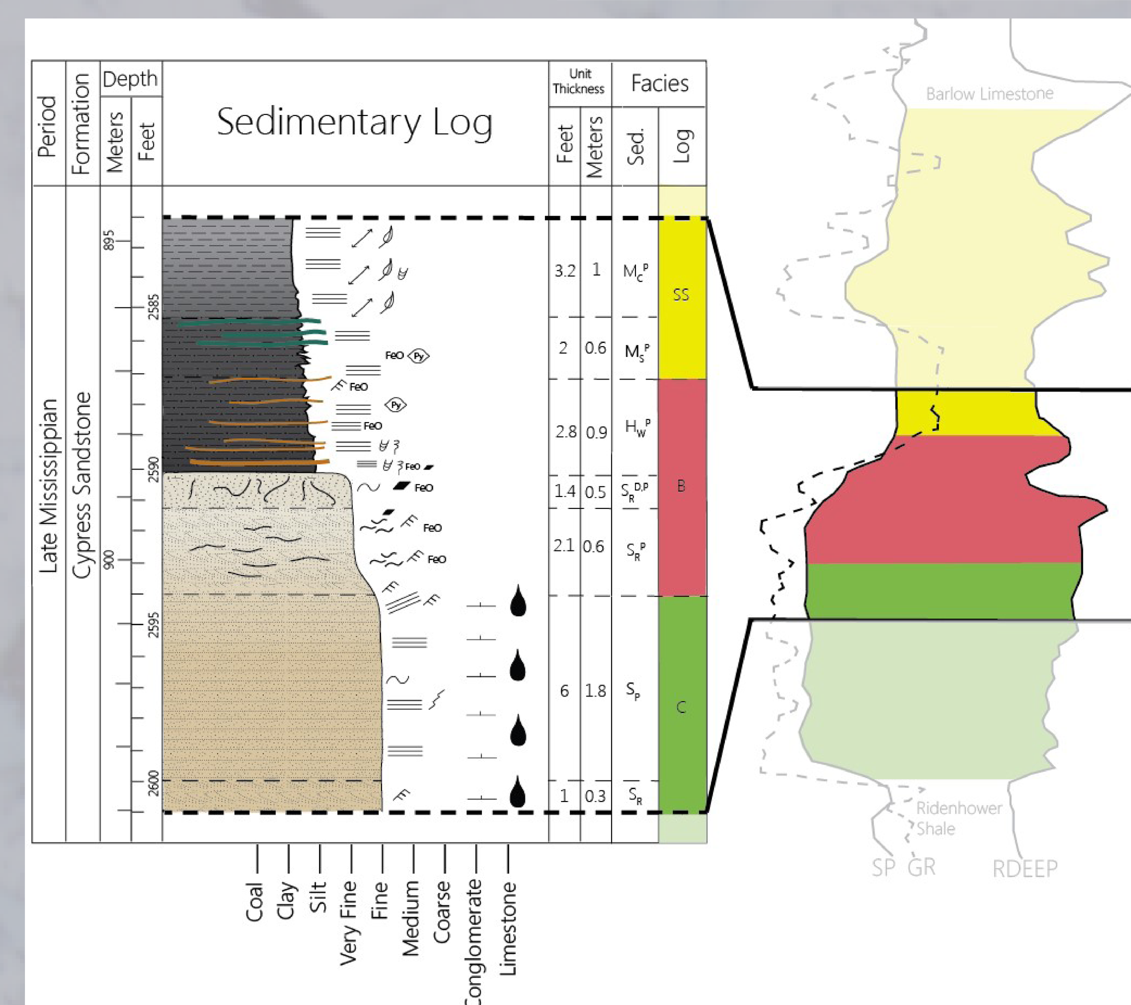


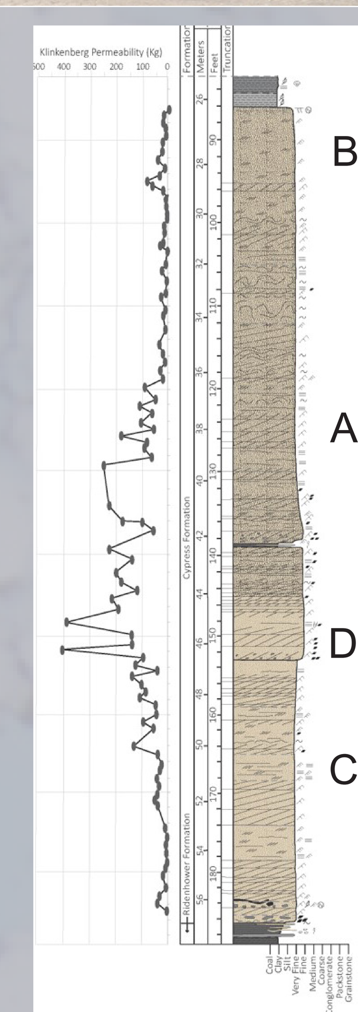

Diagrammatic cross section showing interpreted genetic unit boundaries within the Cypress

### *Macro-Scale (1-10m)*




Outcrop and core show channel element geometry and permeability zonation within genetic units. Mean cross-set thickness is 0.29 m, and cross-sets are superimposed on bar-scale accretion surfaces or low amplitude - high wavelength dunes. Unit bars are ~4 m thick and channel fill storeys are up to ~20 m thick. Such dimensions are used to ensure the geocellular model properly represents genetic flow units.

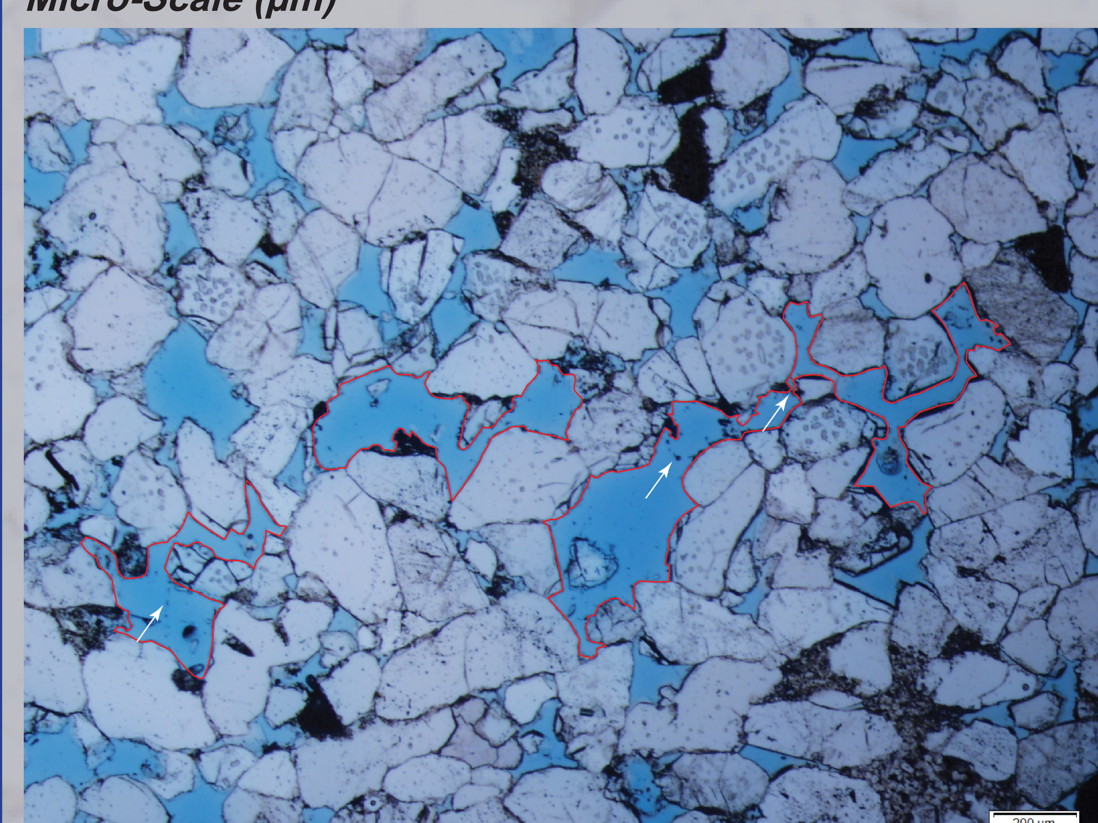



Principal sandstone lithofacies include unidirectional cross-bedding (A), asymmetric ripple cross-bedding (B), and planar bedding (C), all of which contain exceptionally low volumes of detrital clay. Subtle lags with clay clasts and/ or fossil fragments occur at channel bases (D). There are relatively few widespread baffles within genetic units


Geophysical logs are the most common data type for oil field studies. Understanding macro-scale features improves our ability to interpret log signatures.

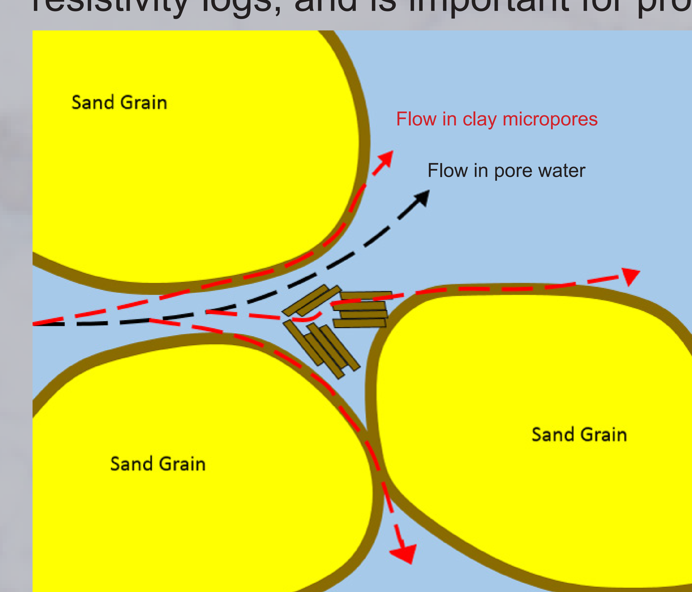
### *Micro-Scale (µm)*

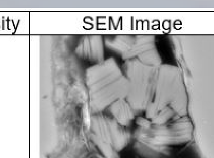
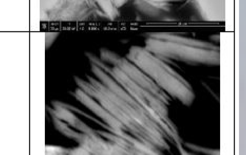
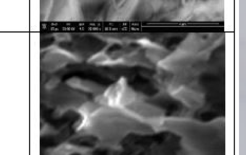



Quartz arenite, $D_{50}$ = 150 µm, subangular to subrounded, and poorly sorted. Diagenetic factors (dissolved grains marked by dust rims [white arrows], elongate secondary pores [red boxes]) are increasingly important at this scale.

Diagenetic clay minerals occlude pore space and contain micropores saturated with fluid that is immobile during hydrocarbon emplacement and production.

Microporosity can have a significant impact on geophysical logs, including resistivity logs, and is important for proper log interpretation.



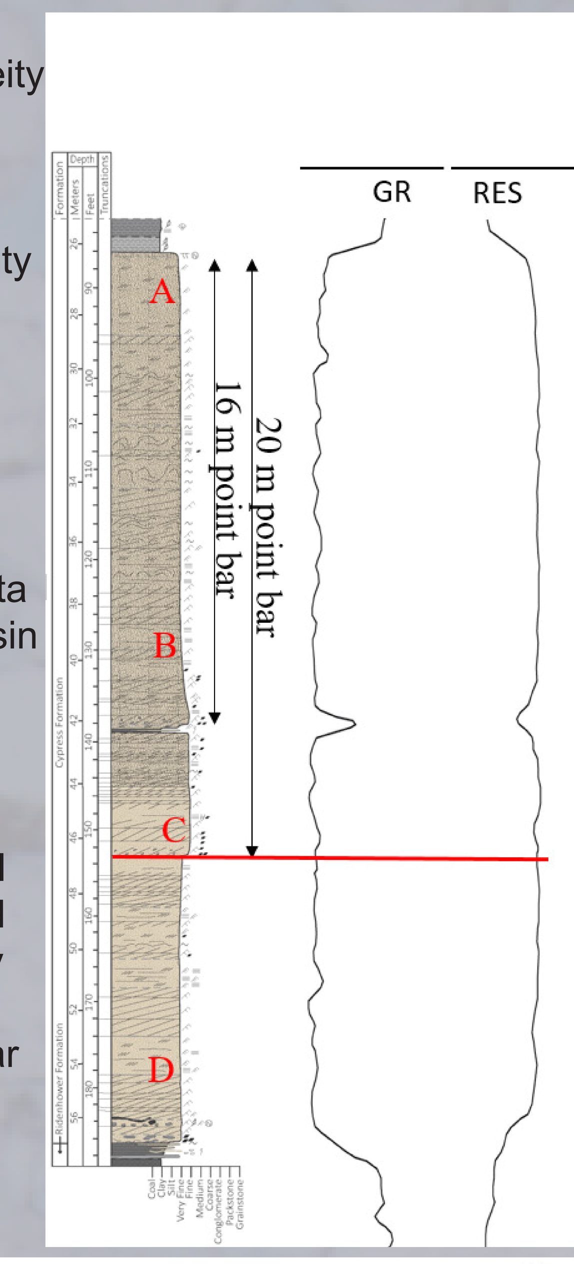

| Mineral | Morphology | Occurrence | Microporosity | SEM Image |
|---|---|---|---|---|
| Kaolinite | Booklets | Pore-filling | 40% |  |
| Kaolinite | Vermicules | Pore-filling | 15% |  |
| Chlorite | Rosettes | Grain-Coating | 50% |  |
| Illite | Fibers | Pore-filling, Bridging | 65% |  |
| Illite-Smectite | Filamentous webs | Pore-filling | 55% |  |

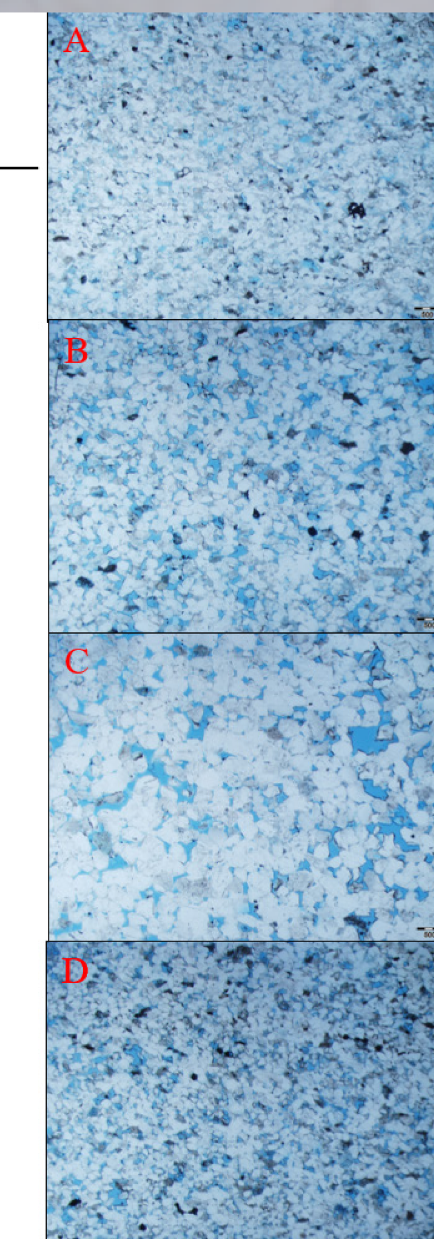
## IMPLICATIONS

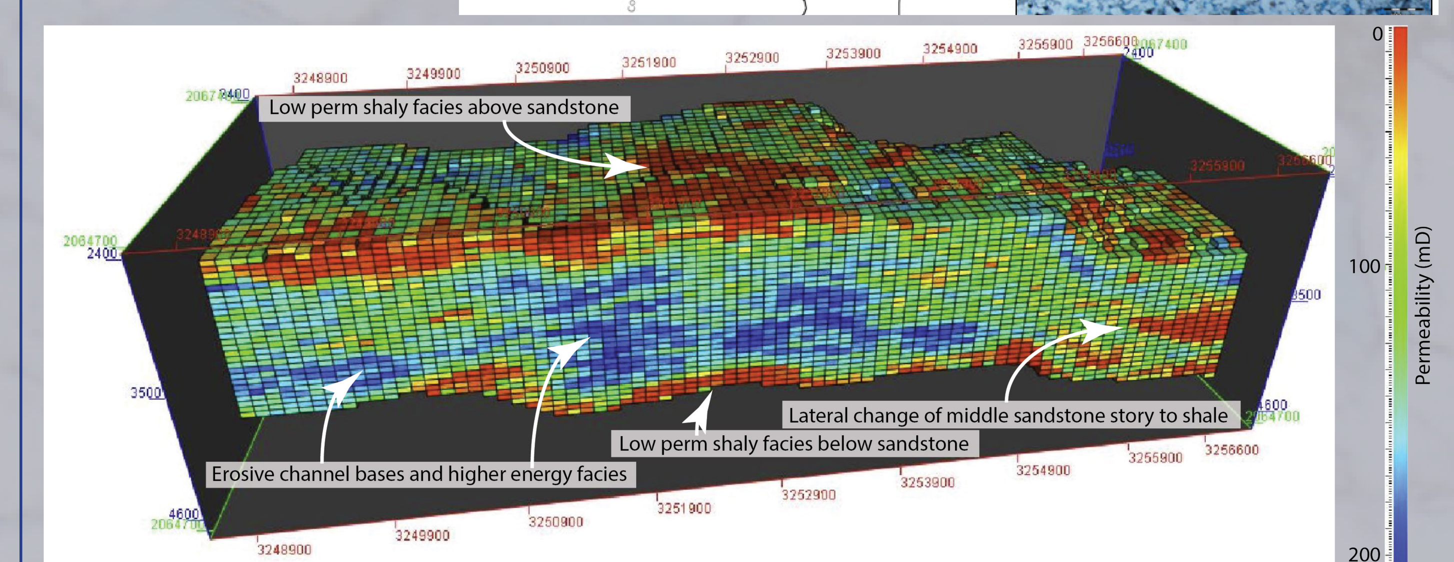
The thick Cypress sandstones predominantly consist of multistorey, falling stage to lowstand deposits of a fine-grained, multithread fluvial system. Areas of increased thickness on the regional isopach map indicate places where multiple sandstone stories are amalgamated.

Reservoir heterogeneity exists along a continuum and understanding the nature of heterogeneity at a certain scale provides the context for interpreting other scales.

Geophysical logs are the most common data type in the Illinois Basin and provide reservoir information across numerous scales of heterogeneity. A solid geological conceptual framework is required to maximixe the utility of the logs when developing geocellular models.




Static, three-dimensional, geocellular models are used to simulate hypothetical $CO_2$ injection scenarios and ultimately predict $CO_2$-EOR performance and $CO_2$ storage efficiency. Development of such models requires a firm understanding of all scales of heterogeneity to infer interwell characteristics and properly represent porosity/permeability relationships. This knowledge is also used to incorporate small-scale features that influence fluid flow, that are poorly represented by logs into the model.

Their spatial extent and thickness, high porosity and permeability, and limited internal baffles make thick Cypress Sandstones excellent targets for $CO_2$-EOR and storage.

## ACKNOWLEDGMENTS

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For project information, including reports and presentations, please visit: http://www.isgs.illinois.edu/research/ERD/NCO2EOR