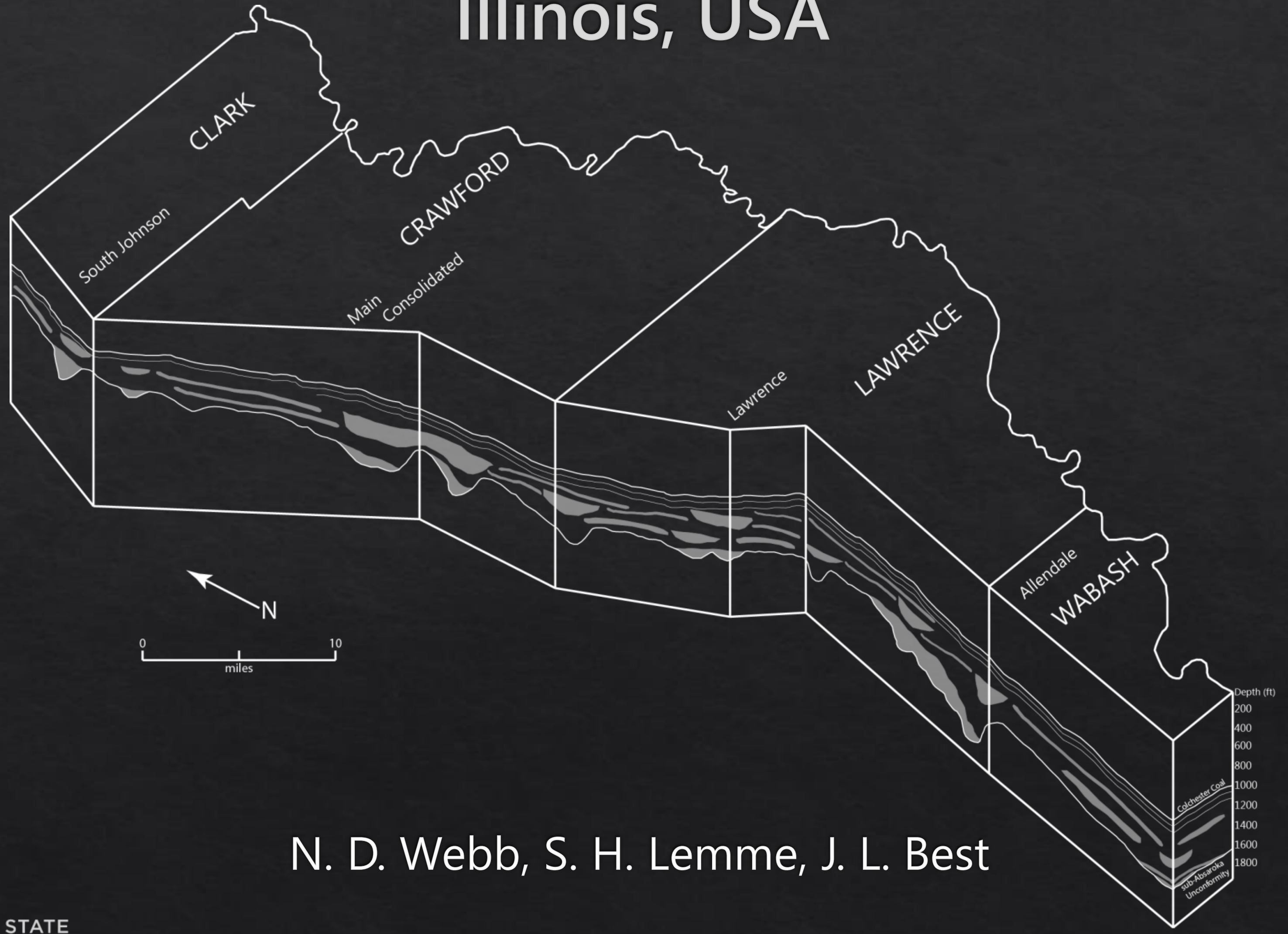
Geometry and Architecture of Fluvial-Estuarine Pennsylvanian Paleovalley Fills, Southeastern Illinois, USA



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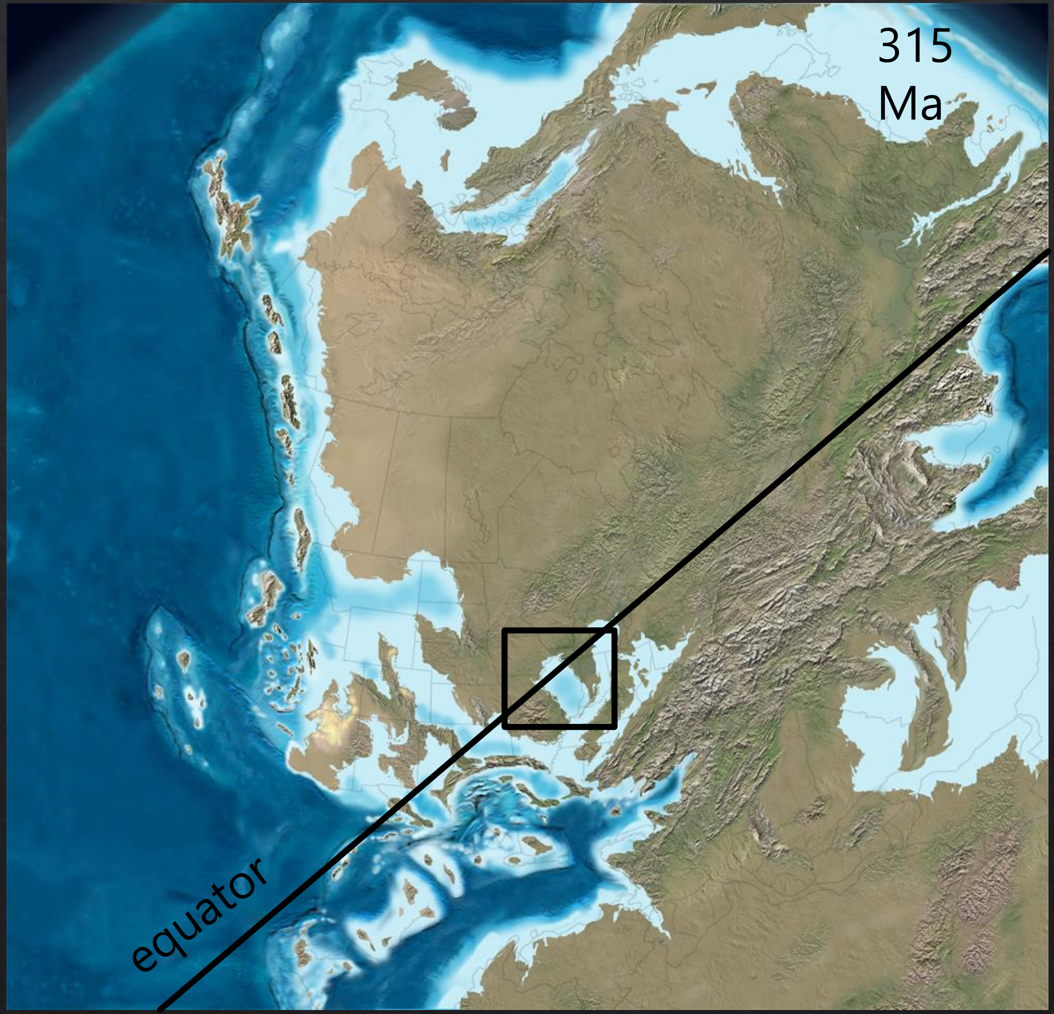
Geologic Setting of the Illinois Basin

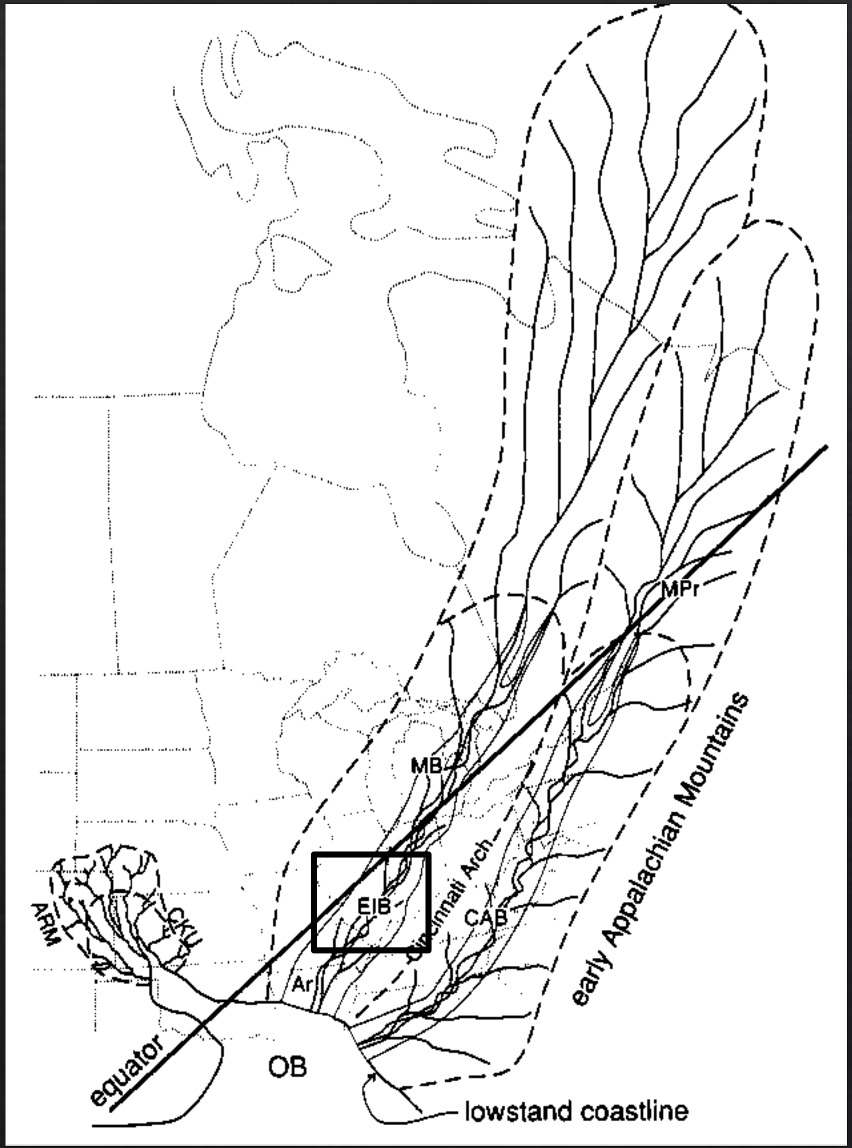
Factors coincident with Pennsylvanian sedimentation:

- Tectonics
  - Basin thermal subsidence
  - Active uplift along several structures
- Climate
  - Southern hemisphere glaciation
  - Tropical humid monsoonal to seasonal precipitation
- Eustacy
  - Sea level fluctuation in response to glaciation
  - Mid-Carboniferous Eustatic Event - significant lowstand



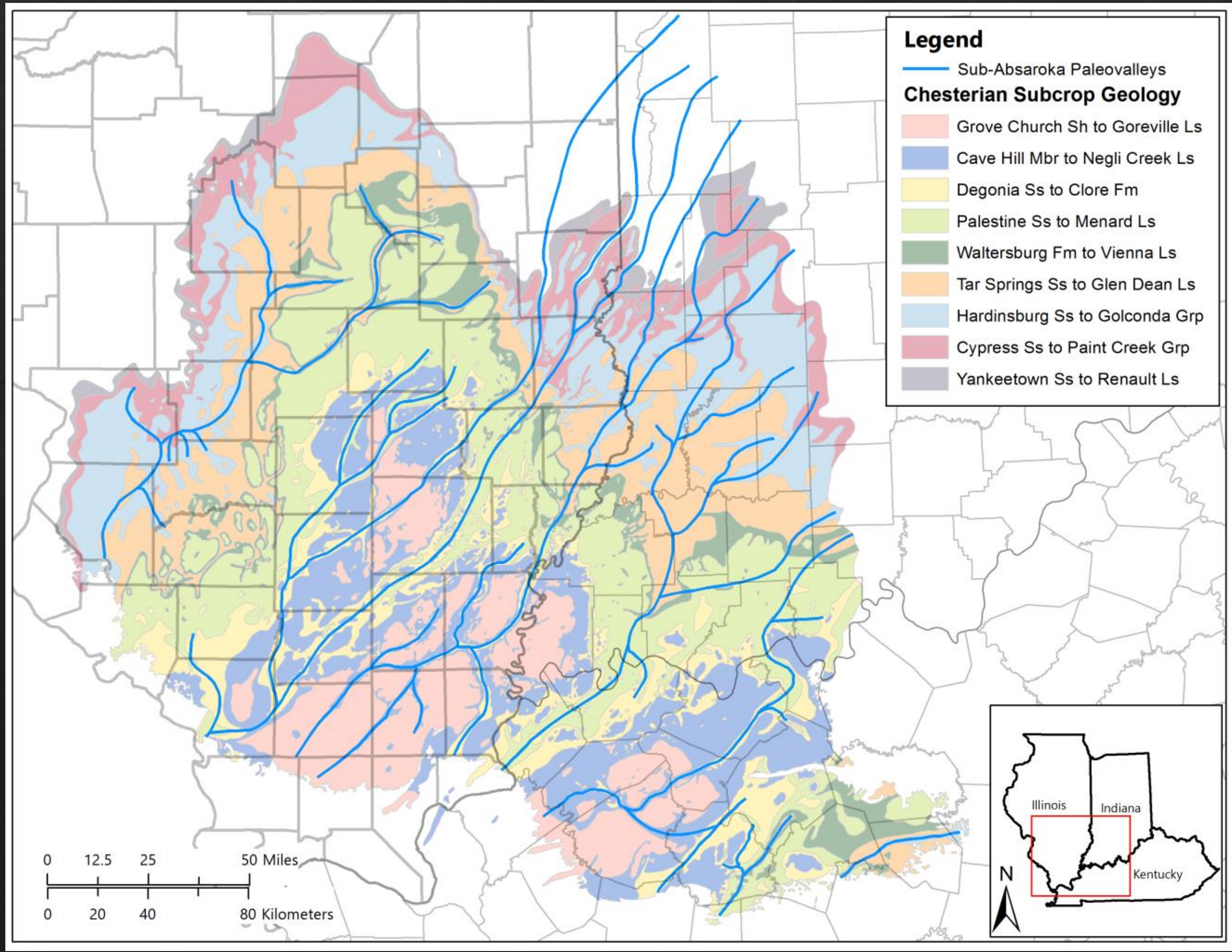
From Blakey 2013

Geologic Setting of the Illinois Basin



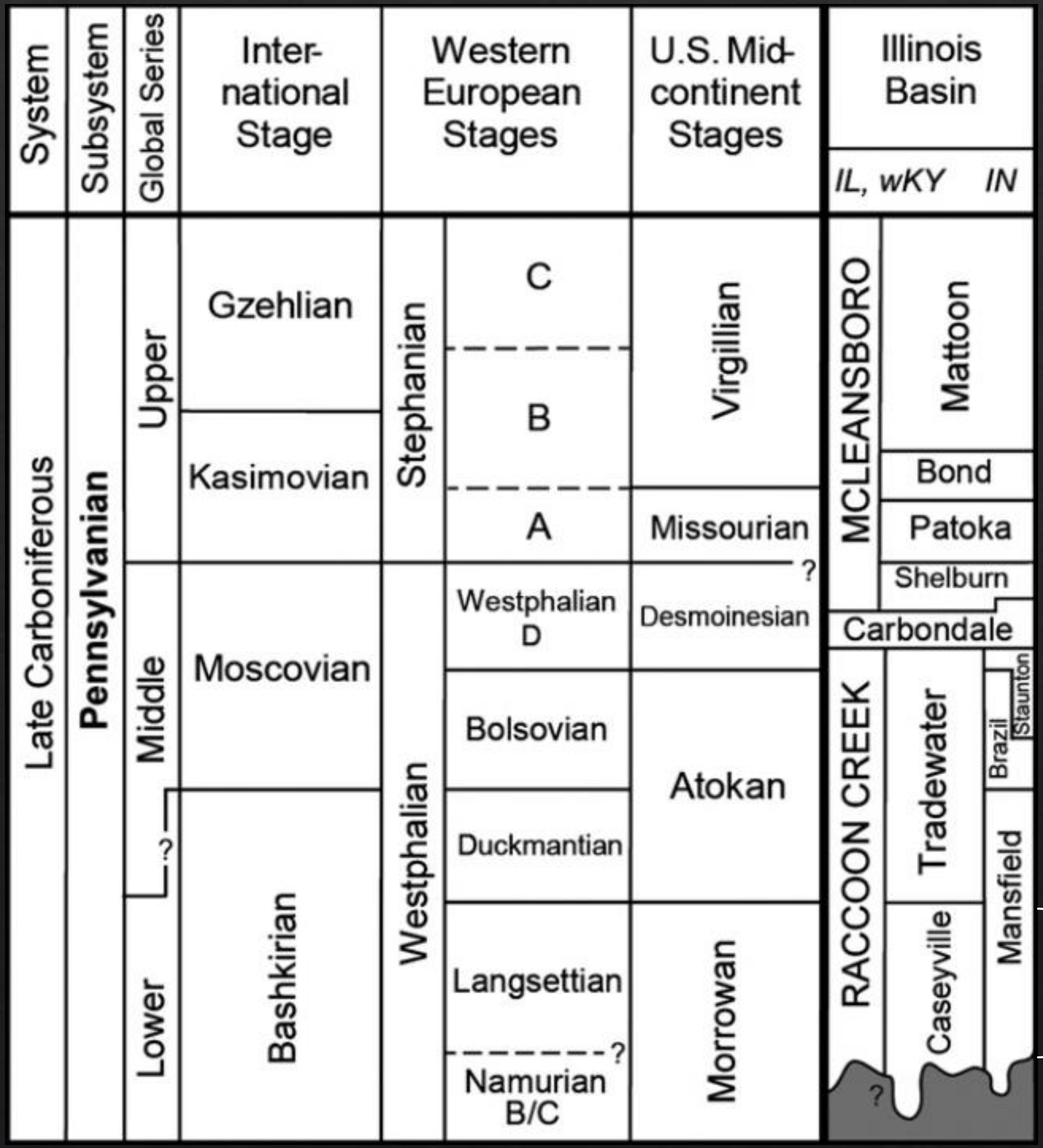
From Archer and Greb 1995

- Amazon scale drainage system
- 20 paleovalleys cross the Illinois Basin

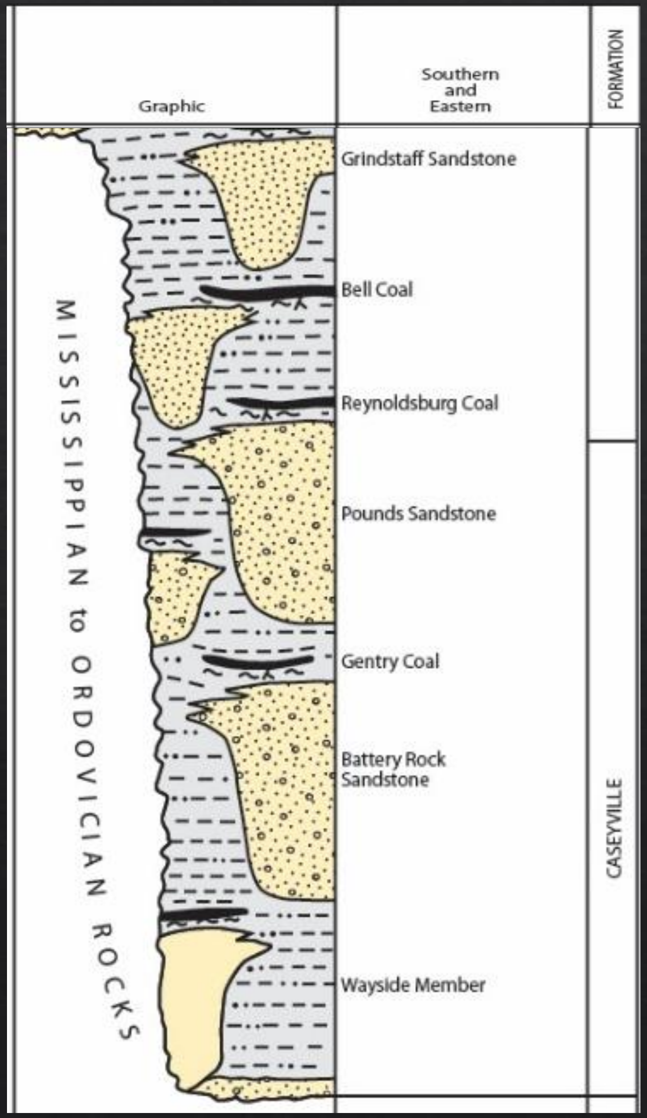


From Bristol and Howard 1971

Lower Pennsylvanian Stratigraphy



From Greb 2013



From Nelson et al. 2011

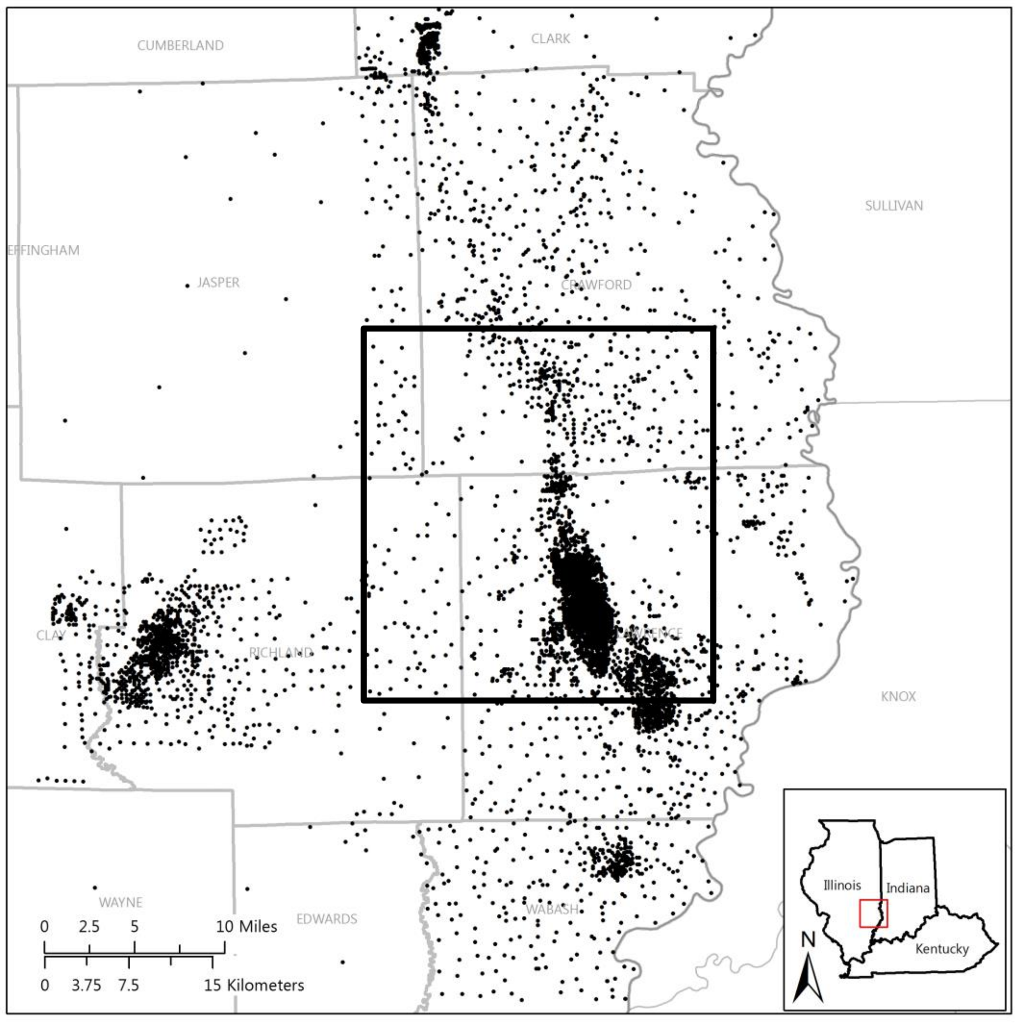
- Caseyville Formation
- Shales and sandstones dominate
  - Coals are localized and relatively minor
- Sub-Absaroka unconformity
  - Inland valleys incised into Upper Mississippian bedrock
  - 150 – 250 m of missing section

Aims

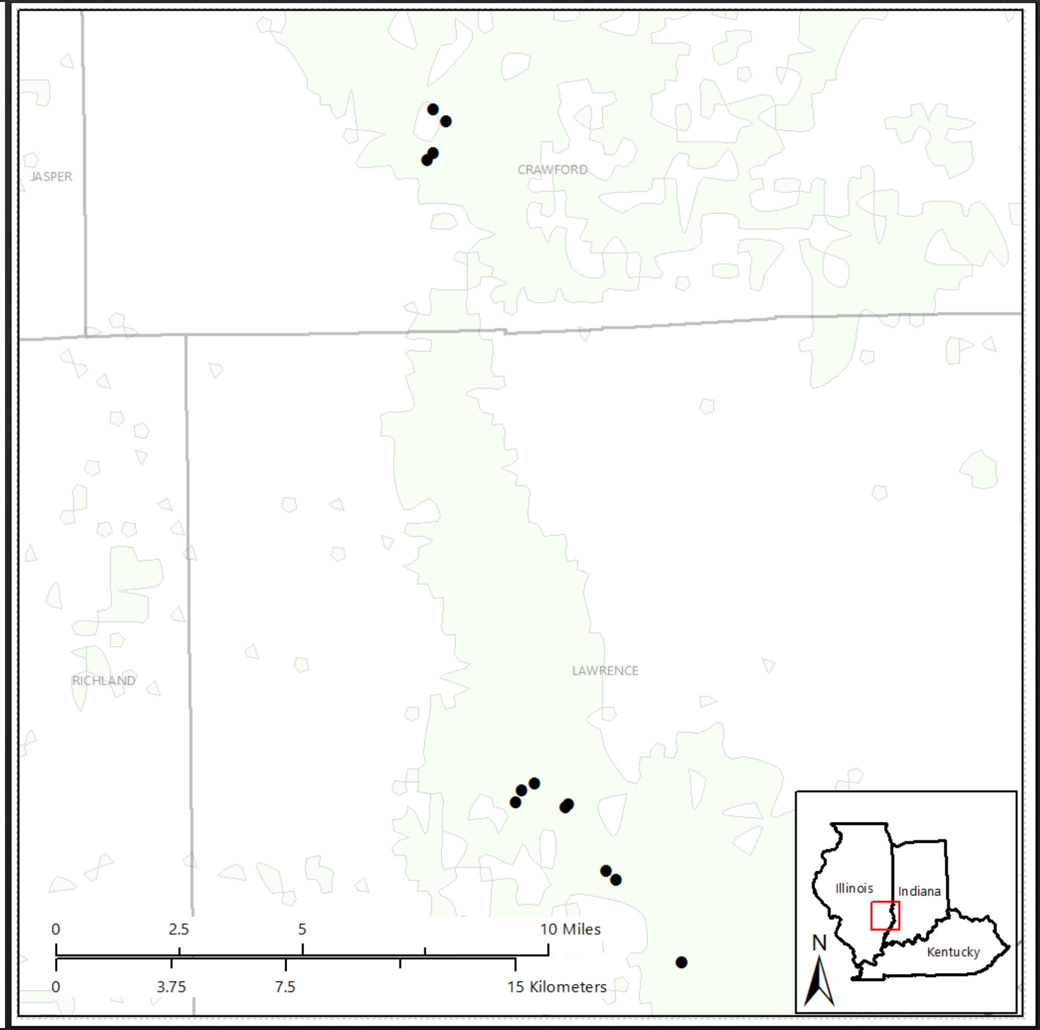
- Detail the characteristics of Pennsylvanian paleovalley fills
- Describe how an understanding of their geometry and architecture can highlight areas that may have the potential for enhanced oil recovery
- Provide revised paleogeographic reconstructions and basin fill evolution of the intracratonic Illinois Basin

Study Area and Data Availability

- Crawford and Lawrence Counties in SE Illinois
- High data density in oil fields (shown in green)
    - Thousands of geophysical logs
    - 13 cores from oil wells



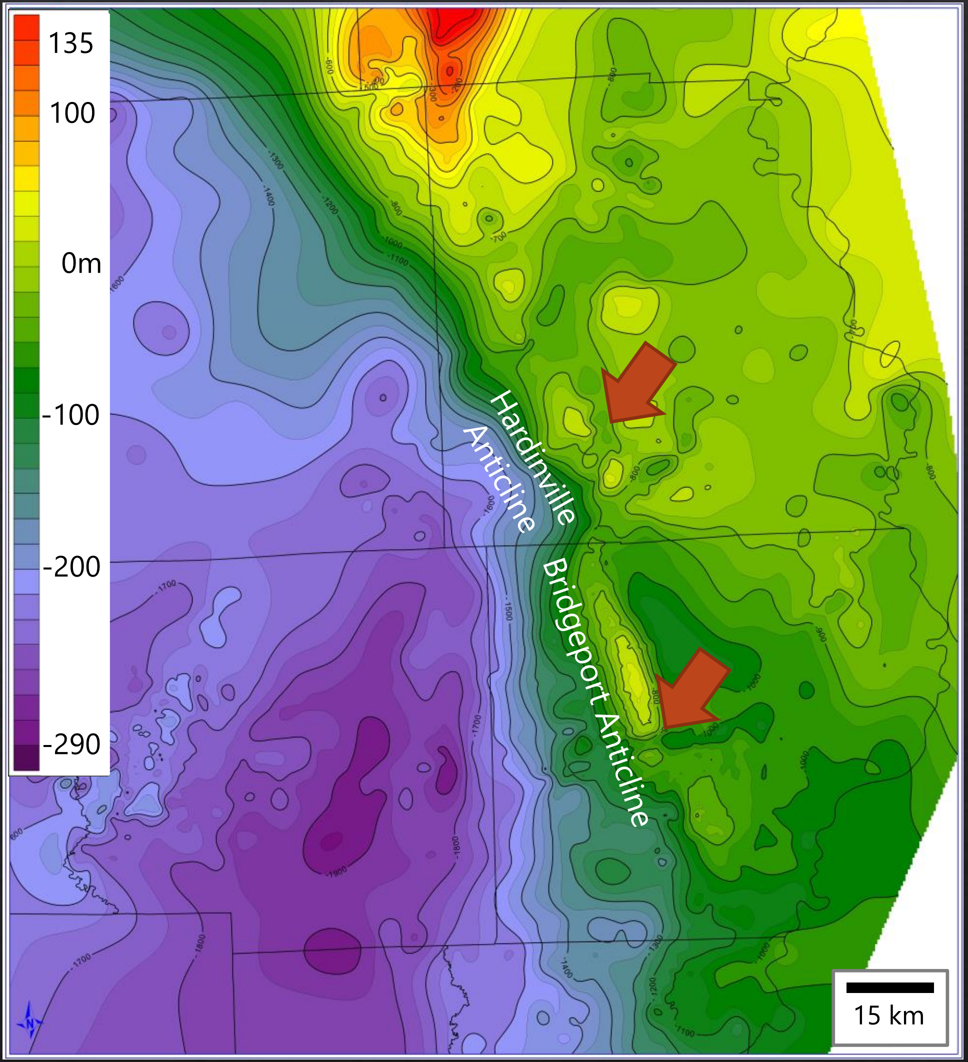
Geophysical log data coverage



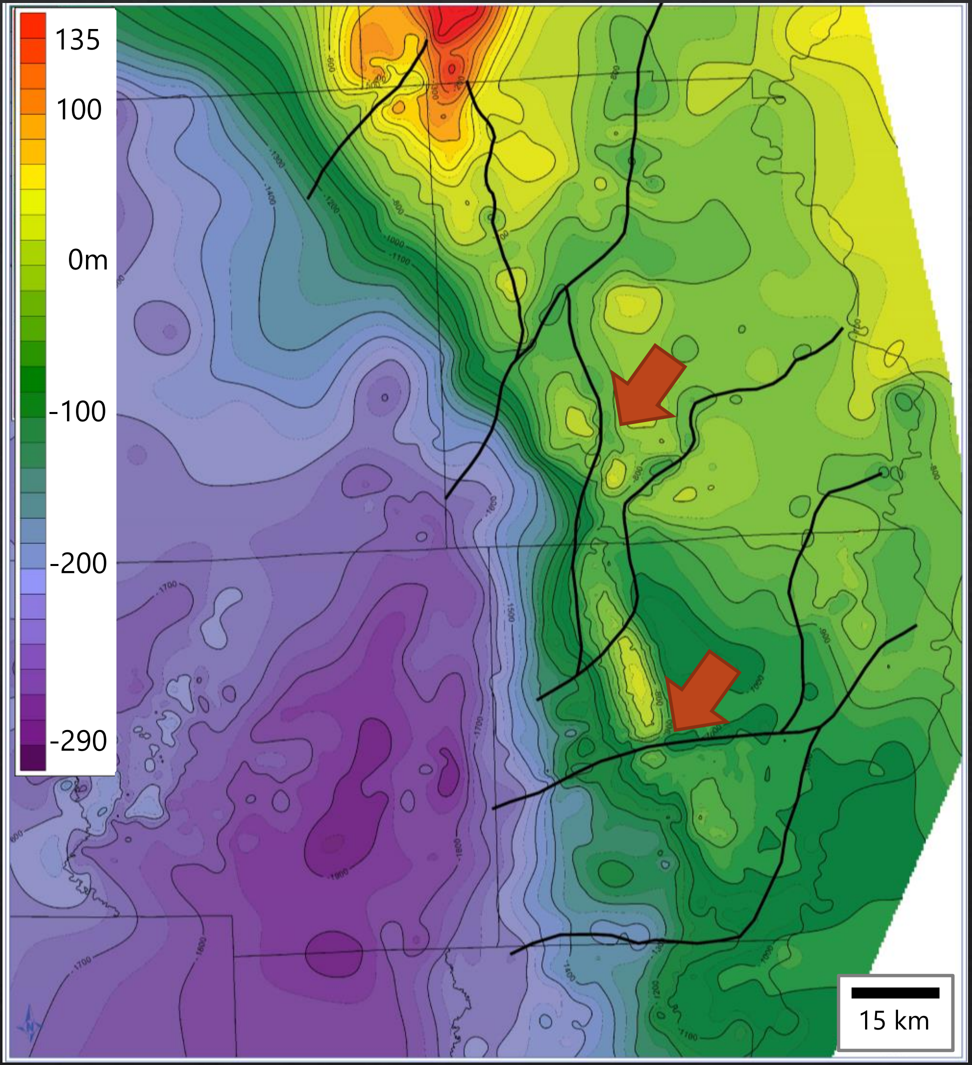
Locations of cores

Unconformity Topography

- Structure map of unconformity surface reflects anabranching paleovalley network
- Where crossing anticlines, valleys narrow from 4-5 km to <1 km wide and become more entrenched
  - 30 to 42 m of incision



Sub-Absaroka Unconformity Structure Map

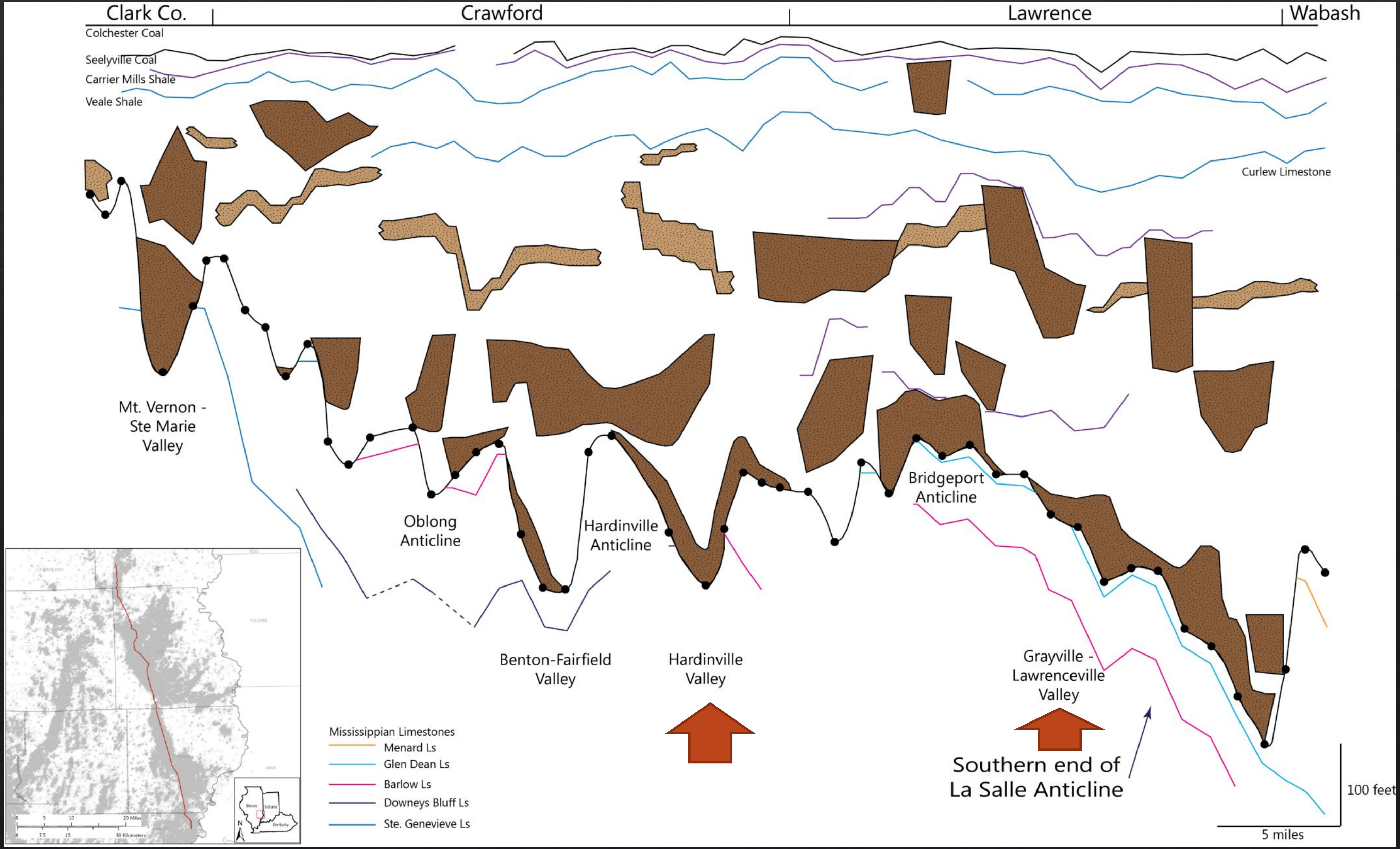


Same map with inferred paleovalleys

Nature of Unconformity

- Sharp contact
- No weathering profile in underlying Mississippian strata
  - Rock intact with little rubble
- Broad terraces with smaller, more deeply incised, steeper walled valleys

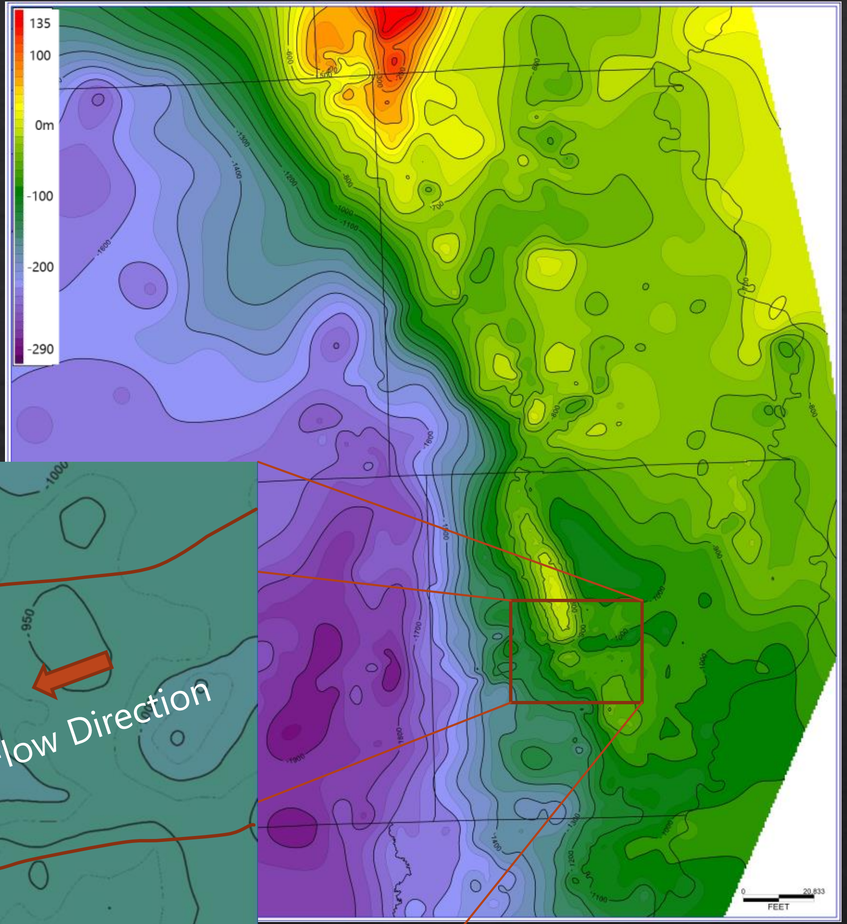
Regional N-S Cross Section



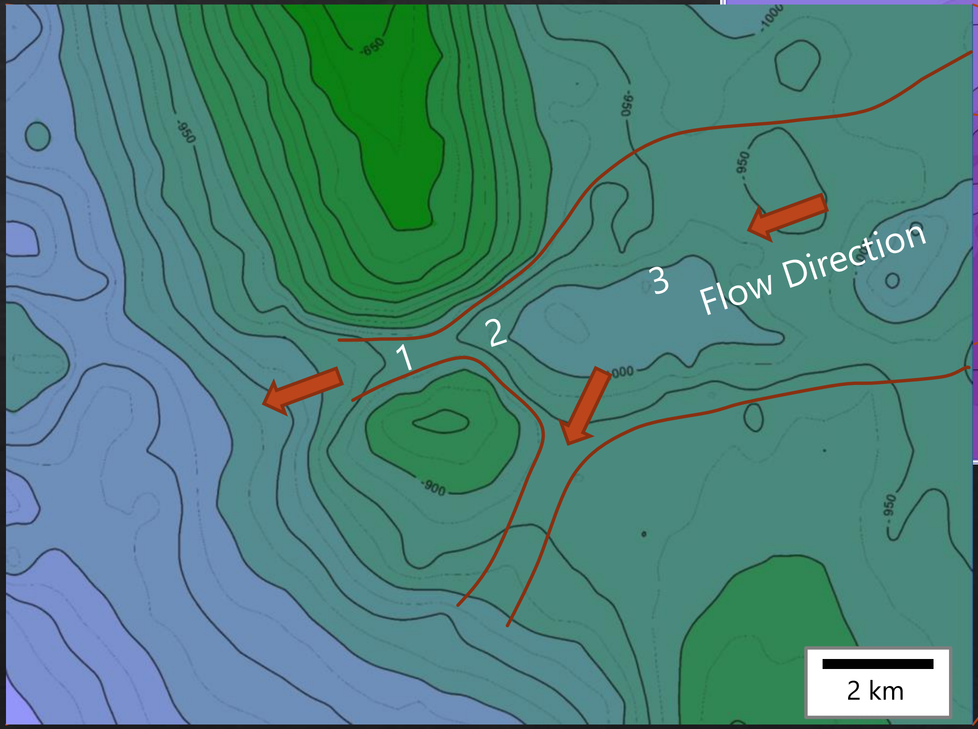
Paleovalley Dimensions

- Unconfined valleys away from structures generally have high W:D ratio
  - Constrict and deepen when crossing structures

Location	W	D	W/D
1	1.3 km	46 m	28
2	2.7 km	32 m	85
3	4.0 km	24 m	167



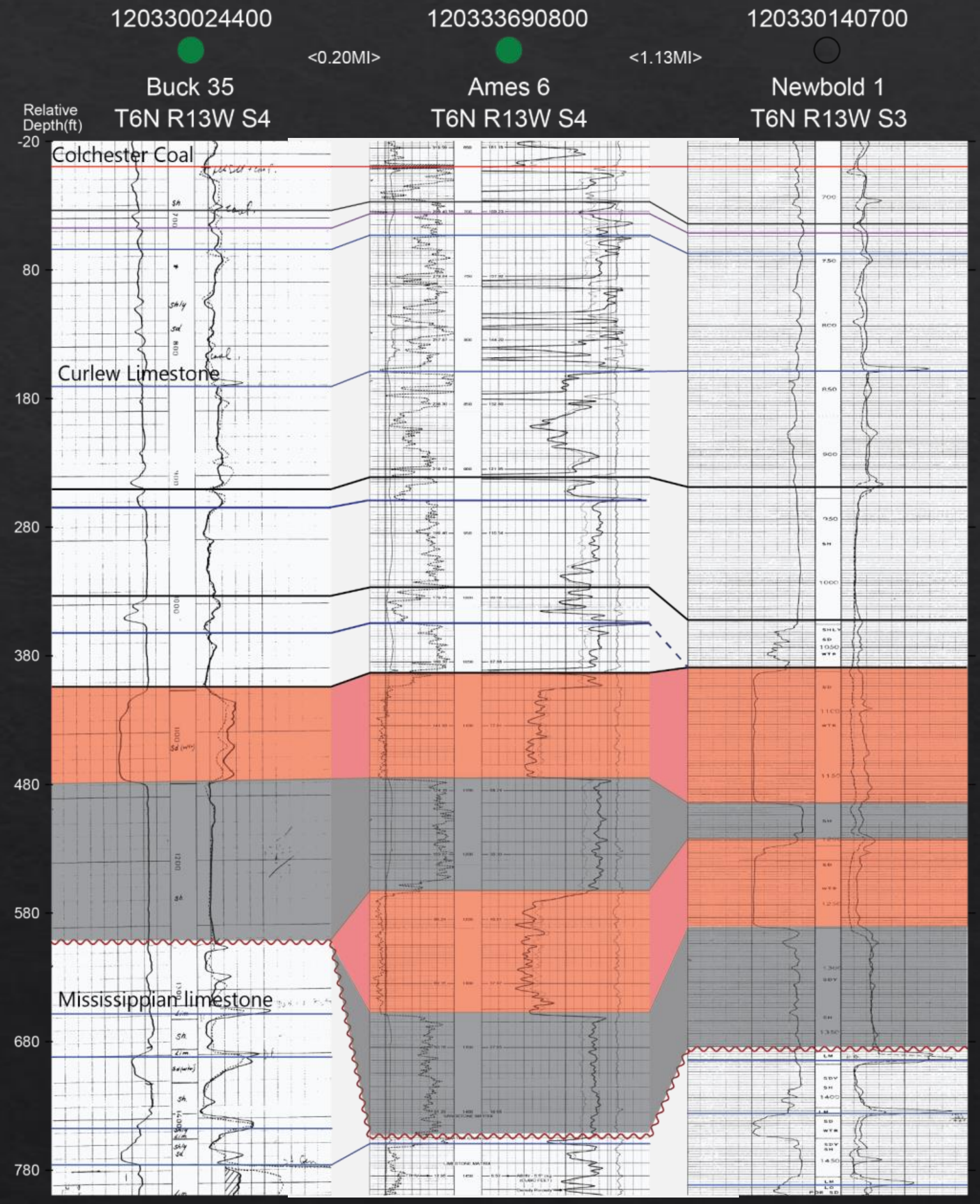
Sub-Absaroka Unconformity Structure Map



Detail view of Grayville-Lawrenceville Channel

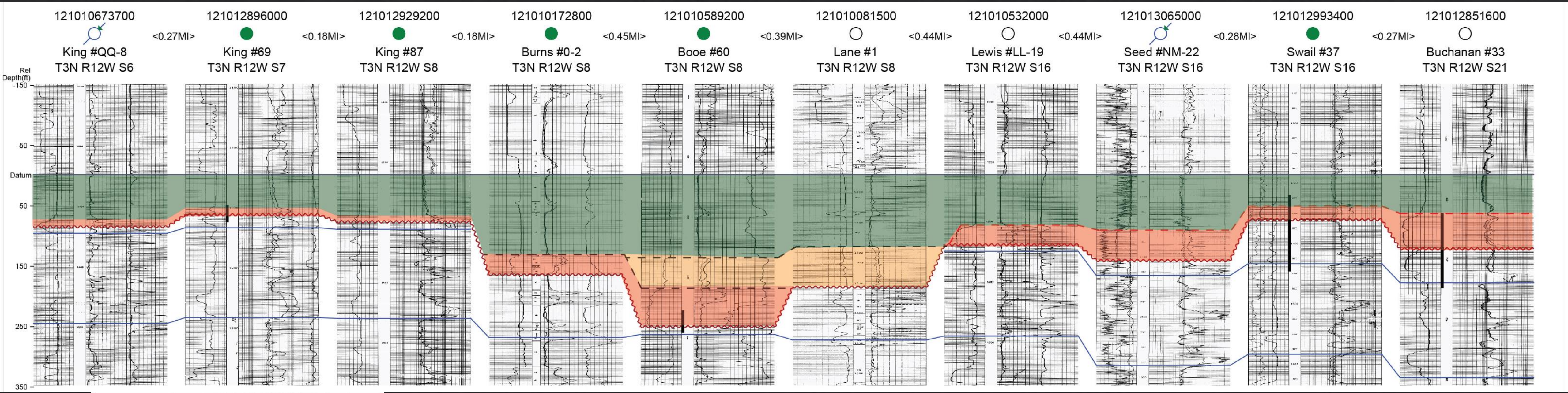
Paleovalley Fills

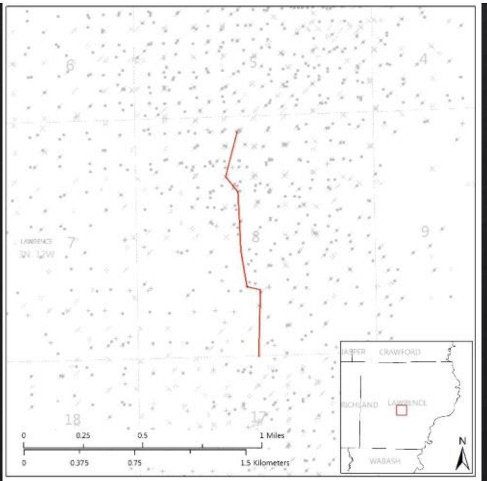
- Valley fill deposits are generally binary in texture
  - Clean sands, clayey shales, sharp contacts, minor proportion of heterolithic facies
  - Many places lack basal sandstones
- Where W:D ratio decreases, shales become volumetrically greater



2.1 km cross section

Paleovalley Fills: Grayville-Lawrenceville Channel





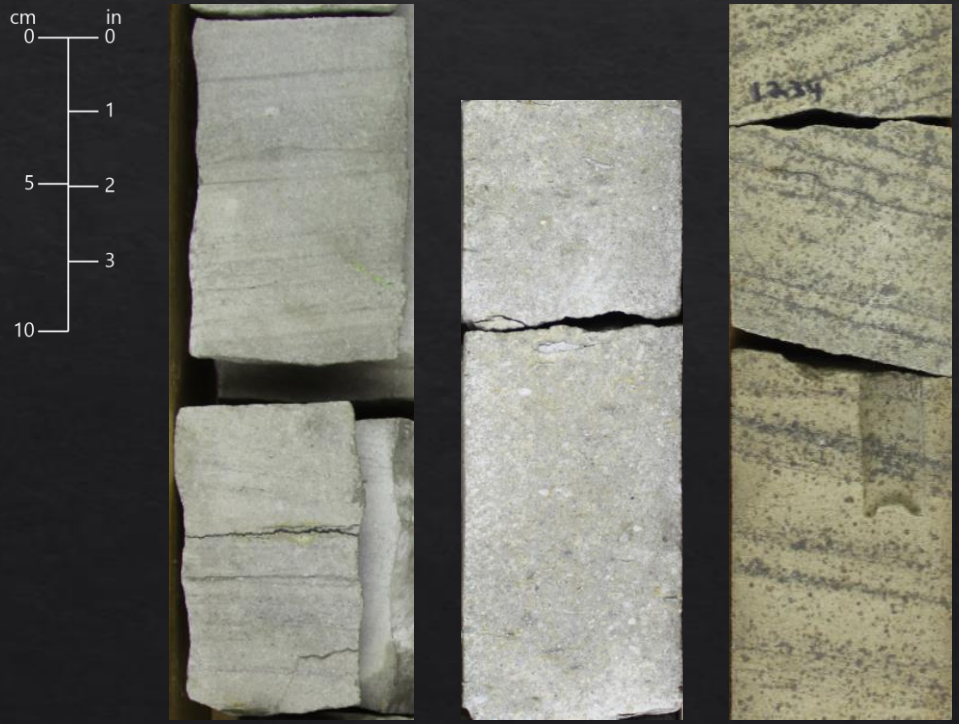
1 mi cross section

- Two basal Pennsylvanian sandstones:
  - Older, early Pennsylvanian regressive fluvial deposits blanket the interfluve areas
  - Paleovalley sandstone bodies confined to entrenched channels
- Valley fill sandstone bodies hydraulically disconnected from blanket sandstones

Fluvial Sandstone

- Cross bedding, massive (structureless) bedding, planar bedding, dominate; few shale interbeds
- Fine to coarse grained
- Clean quartz sandstone

- Medium to coarse grained
- Conglomeratic; contains gravel, shale clasts, wood fragments

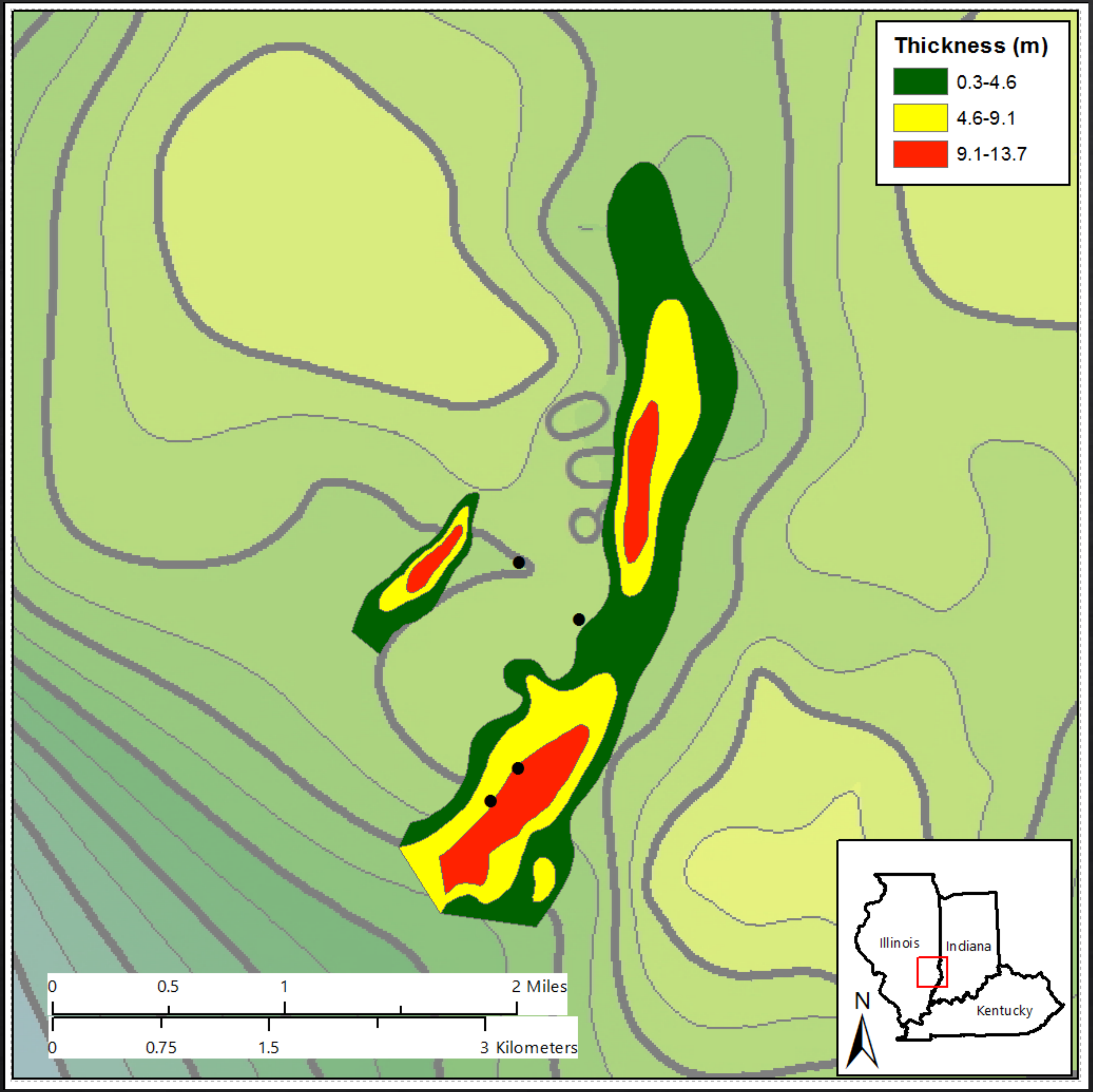


Entrenched paleovalley sandstones

Interfluve area blanket sandstones

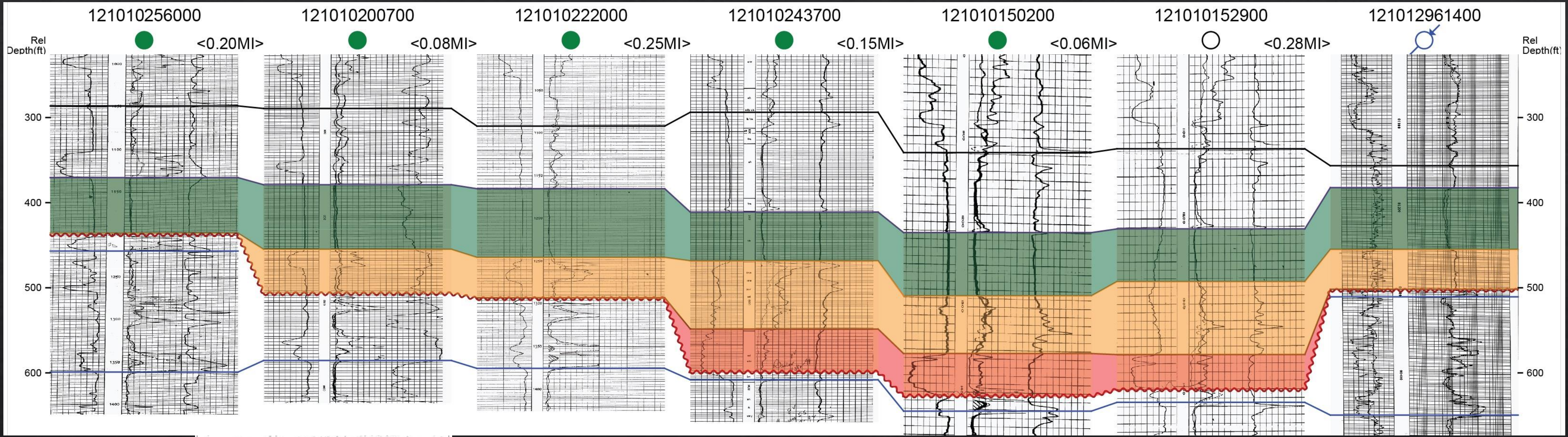
Paleovalley Fills: Hardinville Channel

- Paleovalley sandstone bodies occur along the axis, or sides, at the base of the paleovalleys
- Sandstone body dimensions:
  - Up to 10 m thick
  - 1 km wide
  - 3-5km long
  - Smaller than the paleovalley in which they sit
- Sandstone bodies are generally completely isolated
  - High degree of reservoir compartmentalization and an opportunity for hydrocarbon trapping

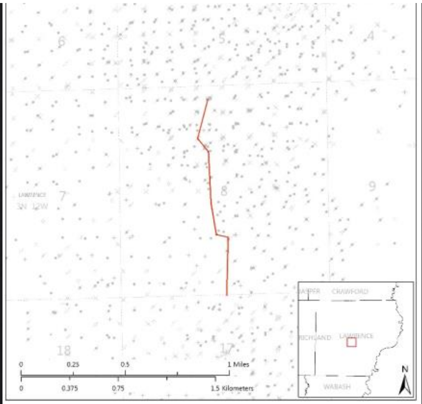


Stratigraphy Example – Lawrence Field

- Example cross section across Grayville-Lawrenceville paleovalley



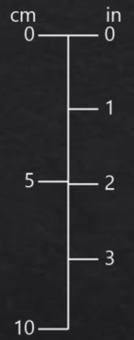
1 mi cross section



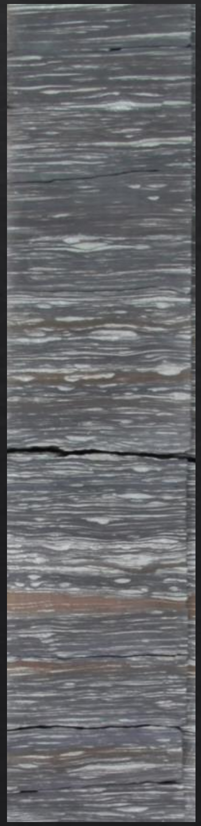
- Valley terraced on Mississippian limestone beds
- Heterolithic facies comprise interbedded silty sandstones and shales and lie laterally adjacent to, and above, the fluvial sandstones

Tide-Influenced Sandstone & Heterolithics

- Fine- to very fine-grained sandstone and shale
- Bidirectional ripples and rhythmic clay drapes
- Bioturbation of varying degrees (*Planolites & Teichichnus)*





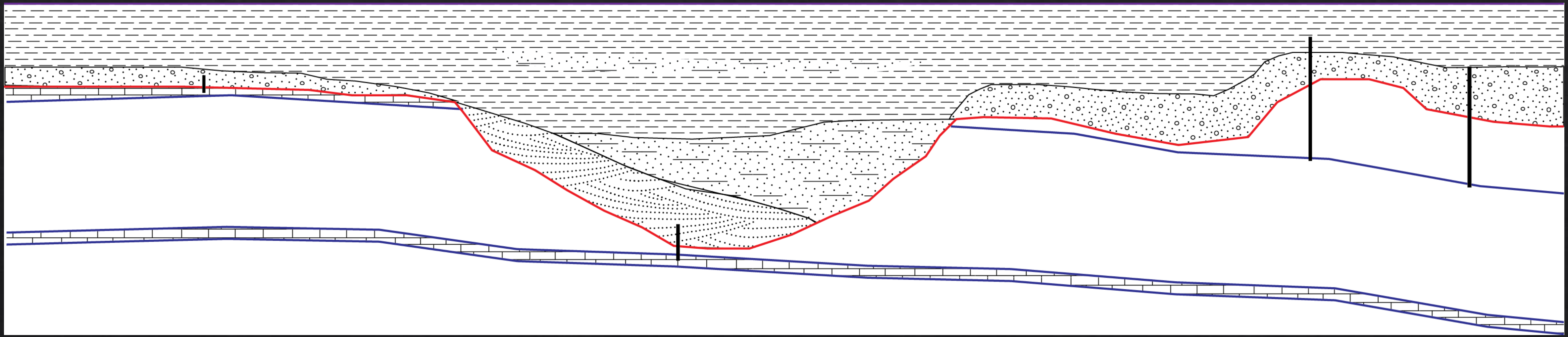



Estuarine Basin Muds

- Dominantly laminated dark grey shale
- Lenticular beds of silt or very fine-grained sandstone (mm to dm scale)
  - Bioturbation common in these interbeds (*Planolites & Teichichnus* observed, but can be homogenized)
- Siderite bands and nodules common in some intervals
- Estuarine basin facies dominates the valley fill succession
  - Extends beyond the paleovalley boundaries over a larger spatial extent

Valley Fill Model

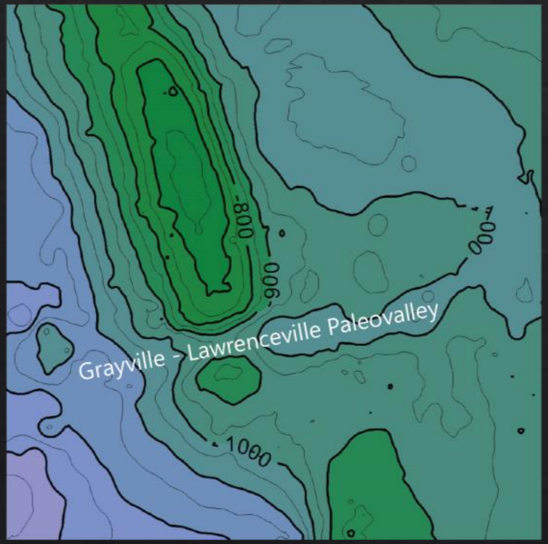
- Interfluve areas blanketed with early Pennsylvanian regressive fluvial sandstones
  - Sandstone thins near deeply incised paleochannels – likely eroded by ultimate incision event
- Paleovalley channels erode early Pennsylvanian fluvial deposits and cut into older Mississippian units
  - Paleovalleys contains isolated sandstone bodies that transition upward into heterolithic deposits
- Entire succession blanketed by extensive estuarine basin facies

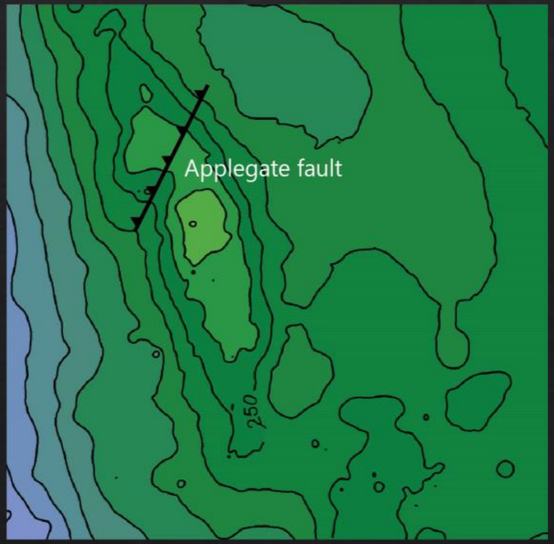


Implications

Controls on deposition

- Structural control of channel pattern and channel dimensions channel pattern
  - Channels become restricted when crossing structures and unconfined on either side of structures
  - Fault control of local fluvial valleys





Reservoir architecture and heterogeneity

- Improved understanding of lithologic heterogeneity of hydrocarbon bearing reservoirs in inland incised valley systems
  - Overall architecture
    - Geometry of reservoir bodies (dimensions, extent)
    - Connectivity of reservoir bodies
    - Internal facies
  - Nature of seal rocks – thick estuarine basin shales
- Best opportunity for oil traps are where paleovalleys cross anticlines, but this is often the most shale rich part of the valley

Acknowledgments

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- Through a university grant program, IHS Petra, Geovariences Isatis, and Landmark Software was used for the geologic, geocellular, and reservoir modeling, respectively.