Microbial Mats as Indicators of Condensation in Black Shales - Examples from the Pennsylvanian Cyclothems of the Mid-Continent USA*

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Abstract

Black shales in Pennsylvanian cyclothems occur in many of the eustatically-controlled cyclic successions throughout the North American mid-continent. This study presents the sedimentology of three representative black shales from three stratigraphic levels in five locations, the lower Desoinesian Excello Shale from south-central Iowa and northeast Kansas, the lower Missourian Hushpuckney Shale from southeastern Kansas, and the lower Virgilian Heebner Shale from east-central Kansas and north-central Oklahoma. The studied black shales contain microbial mats, mudstone clasts, *Planolites* burrows, and phosphate concretions; however, not every core shows all of these components. In the Excello, the amount of microbial mats decreases from south-central Iowa to northeast Kansas, and for the Heebner, a significant decrease is observed from east-central Kansas to north-central Oklahoma. The cores that are devoid of microbial mats generally contain high amounts of either phosphate concretions and/or clay clasts; both of these facies show more clay-rich matrix than in sediments with microbial mats. In addition, each core with abundant microbial mats grades vertically into facies with minor or no microbial mat occurrence towards the upper and lower boundaries of the black shales. Both the microbial mats as well as the phosphate concretions reflect deposition in a condensed environment. However, the lack of siliciclastic fine-grained input suggests that the microbial mats indicate even stronger condensation than the phosphate concretions. The gradation of clay-bearing

sediments with phosphate concretions to clay-poor sediments with microbial mats in two cyclothems therefore seems to reflect increasing condensation within this basinal system. The basin itself, however, cannot have been very deep. Not only does the close relationship of in part shallow-marine carbonates with the black shales indicate an overall shallow basin, but also the presence of microbial mats that need light to flourish reflects clear water and moderate water depth. Further, abundant Planolites burrows with the microbial mats corroborates oxic to dysoxic conditions. Therefore, condensation was strongest away from basin margins; however, the high organic content of these shales was likely a consequence of microbial mat growth in situ.

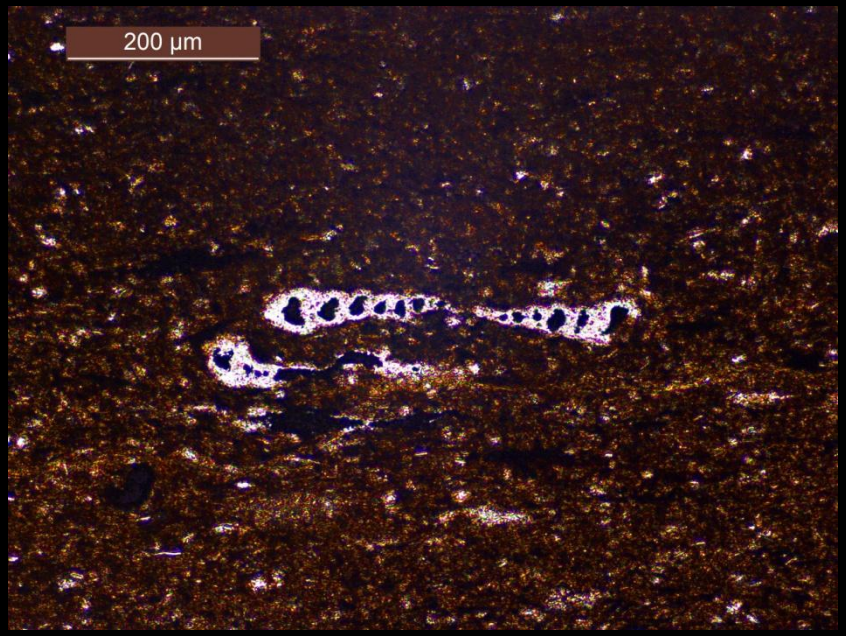
References Cited

Algeo, T.J., and P.H. Heckel, 2008, The Late Pennsylvanian Midcontinent Sea of North America: A review: Palaeogeography Palaeoclimatology Palaeoecology, v. 268, p. 205-221, doi:10.1016/j.palaeo.2008.03.049.

Heckel, P.H., 1986, Sea-level curve for Pennsylvanian eustatic marine transgressive-regressive depositional cycles along midcontinent outcrop belt, North America: Geology, v. 14, p. 330–334, doi: 10.1130/0091-7613(1986)14<330:SCFPEM>2.0.CO;2.

Klein, G. De V., and D.A. Willard, 1989, Origin of the Pennsylvanian coal-bearing cyclothems of North America: Geology, v. 17, p. 152-155.

Microbial mats as indicators of condensation in Black Shales - examples from the Pennsylvanian cyclothems of the Mid-Continent USA



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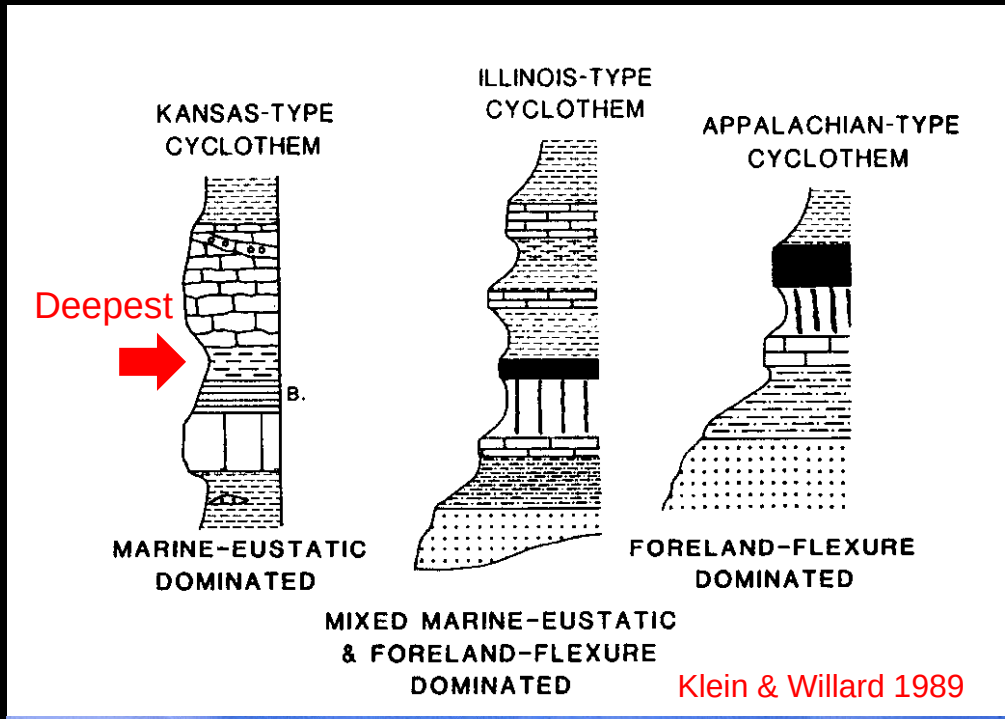
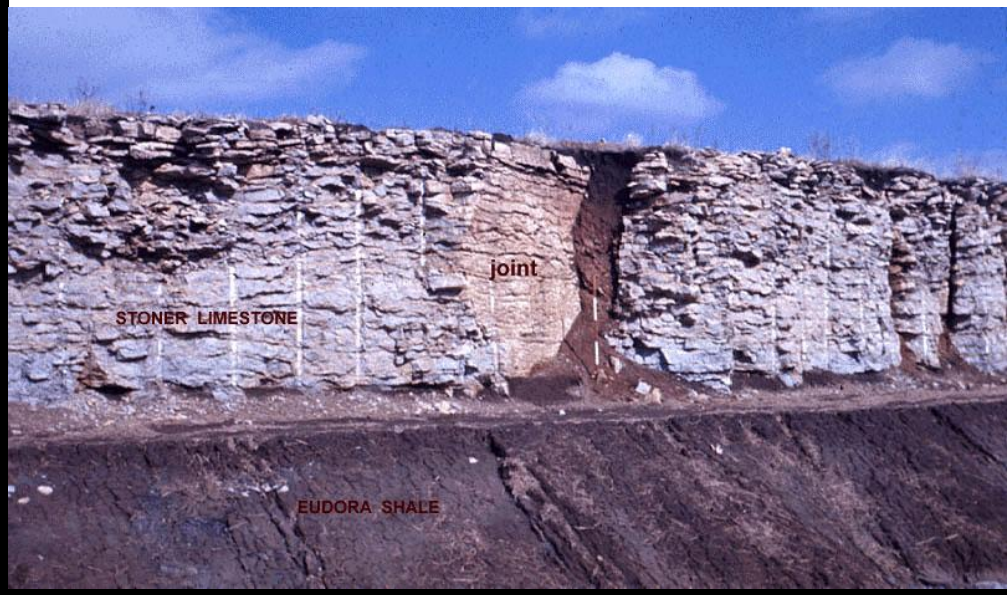
Motivation

- Cyclothems in Kansas, Illinois and Oklahoma world-famous

→ Reflect ice-driven short-term sea-level fluctuations

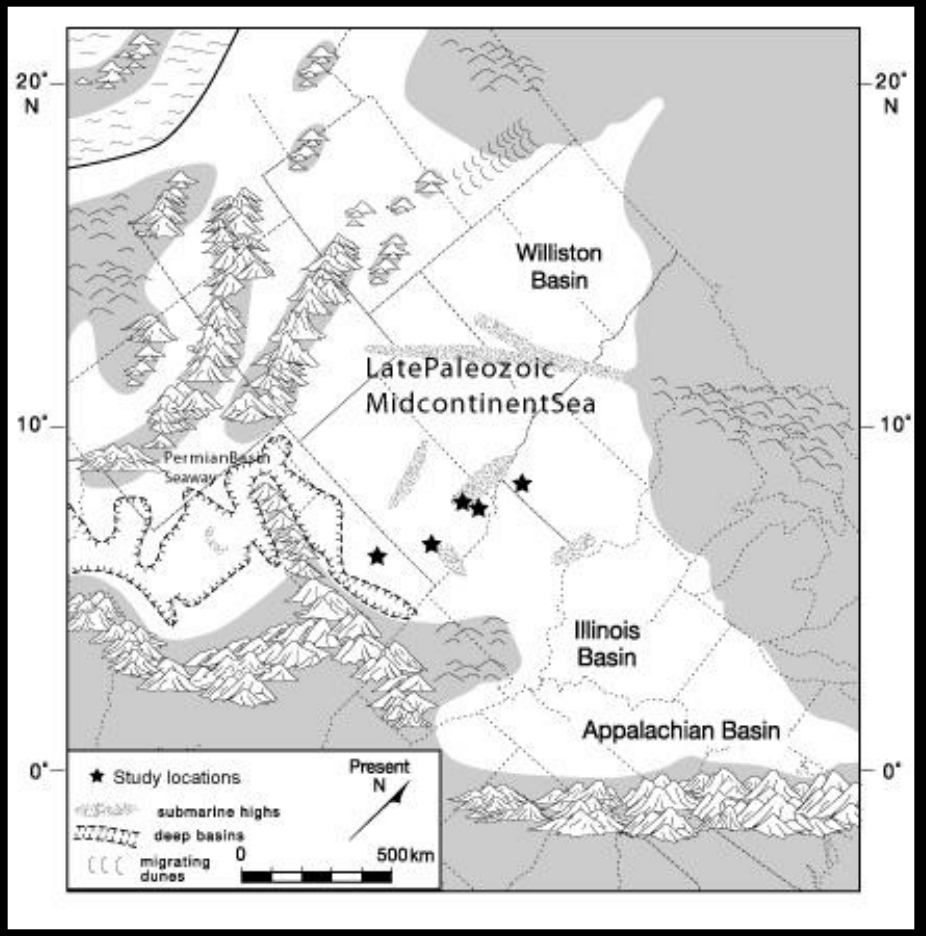
- During highstands of sea-level: deposition of black shale units
- Black shales: thought to be deposited in tranquil anoxic environment





Geological Setting

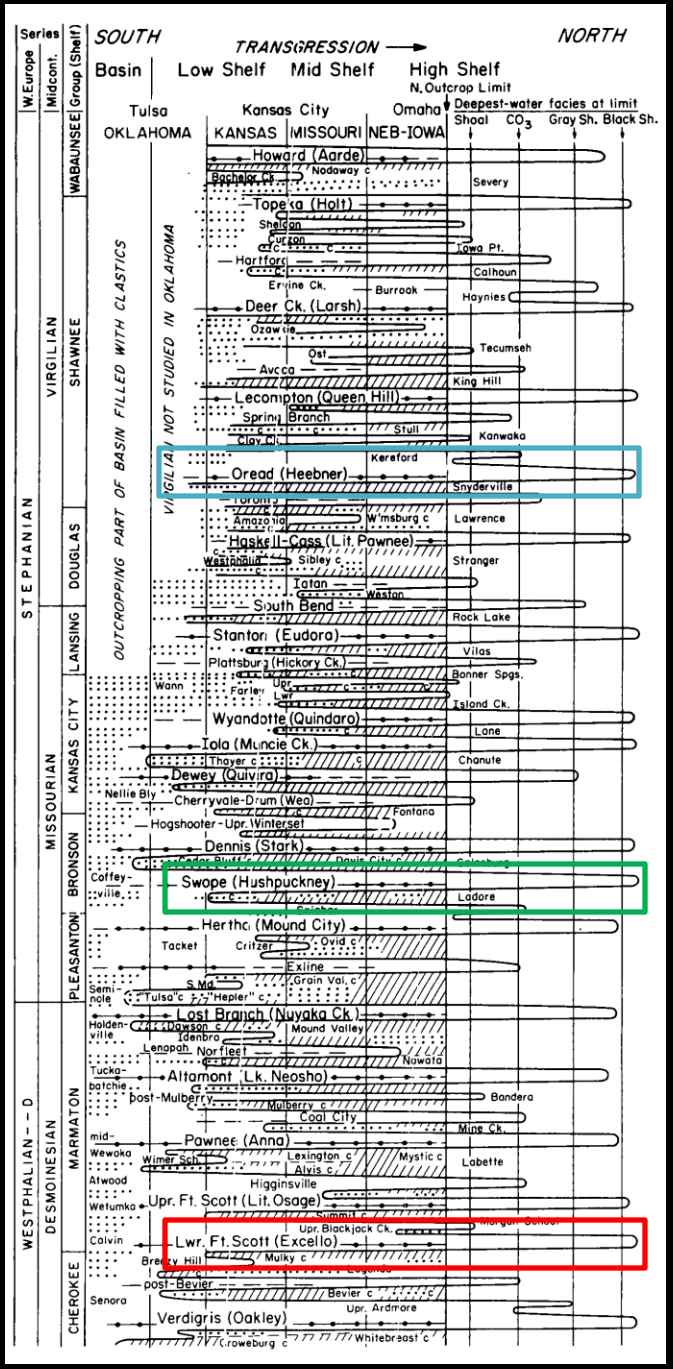
- During Pennsylvanian – US in equatorial position
- This study – based on 5 cores
- From N → S: Logan core (IO), Edmunds core, Heinen core, Clarkson core (all KS), OK-BC core (OK)
- Total of 63 ultra-thin sections



Modified by A. Herrmann, after Algeo and Heckel 2008

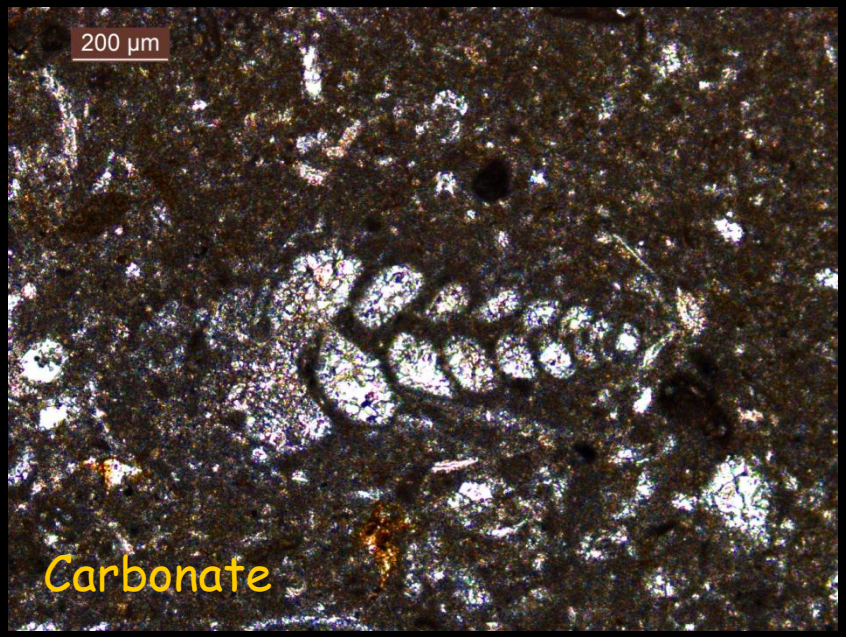
Geological Setting

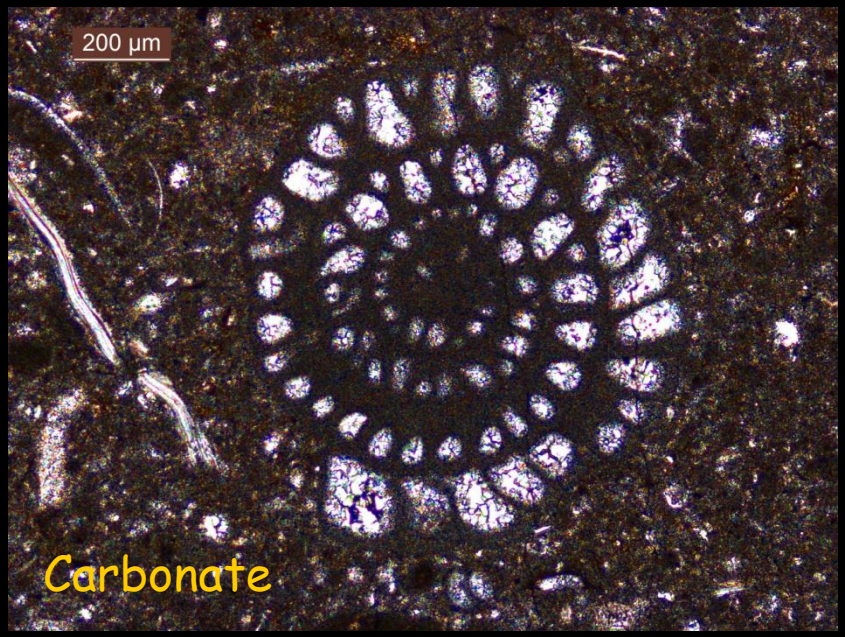
- Stratigraphically, cores = 3 black shale units from lower, central and upper part of Pennsylvanian succession
- Excello Shale (red) – Logan core (Iowa), Edmunds core (Kansas)
- Hushpuckney shale (green): Clarkson core (Kansas)
- Heebner Shale: Heinen core (Kansas), OK-BC core (Oklahoma)



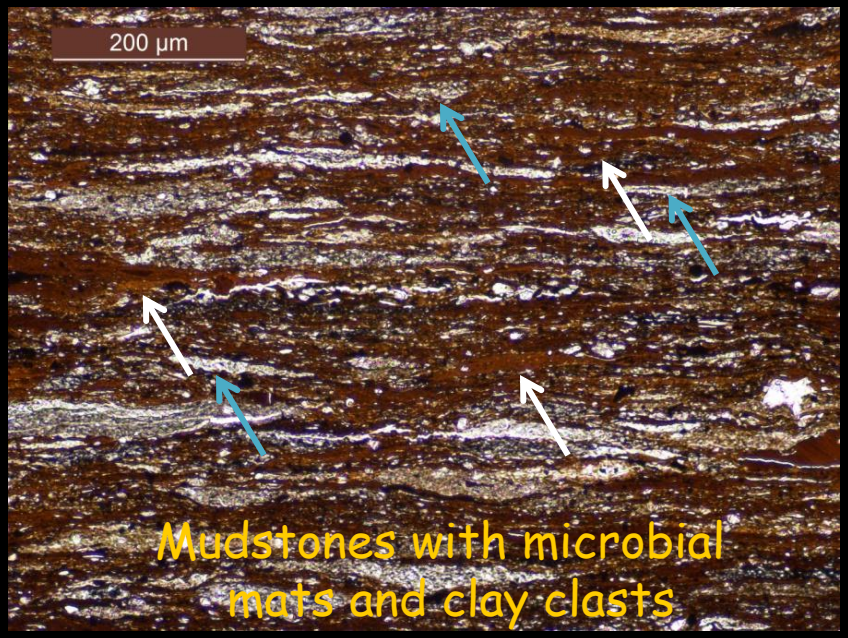
Heckel 1986

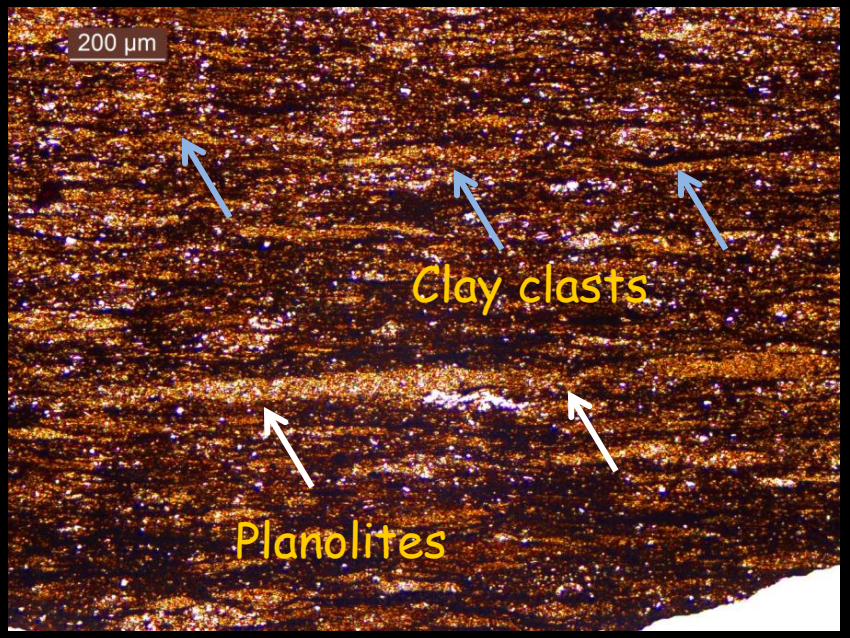
Sedimentology



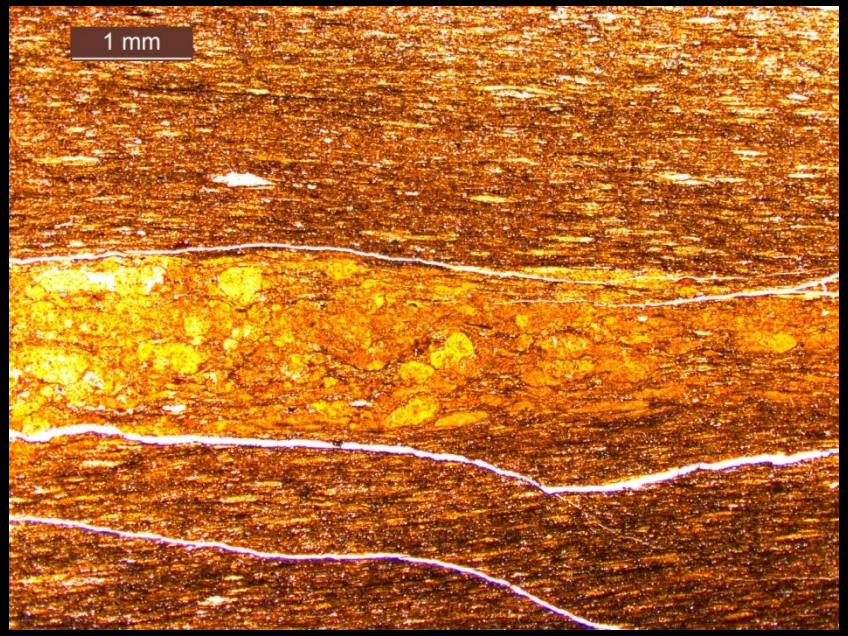


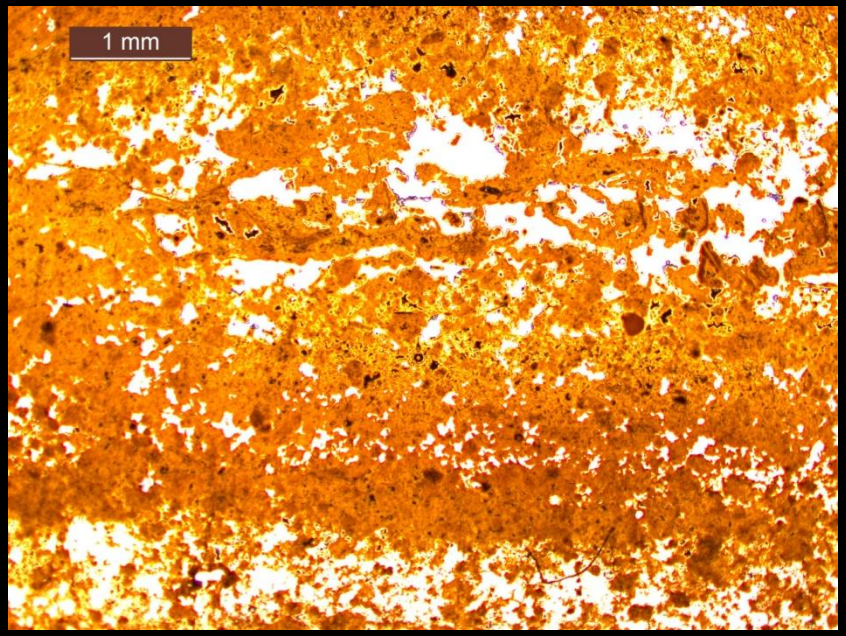
Sedimentology





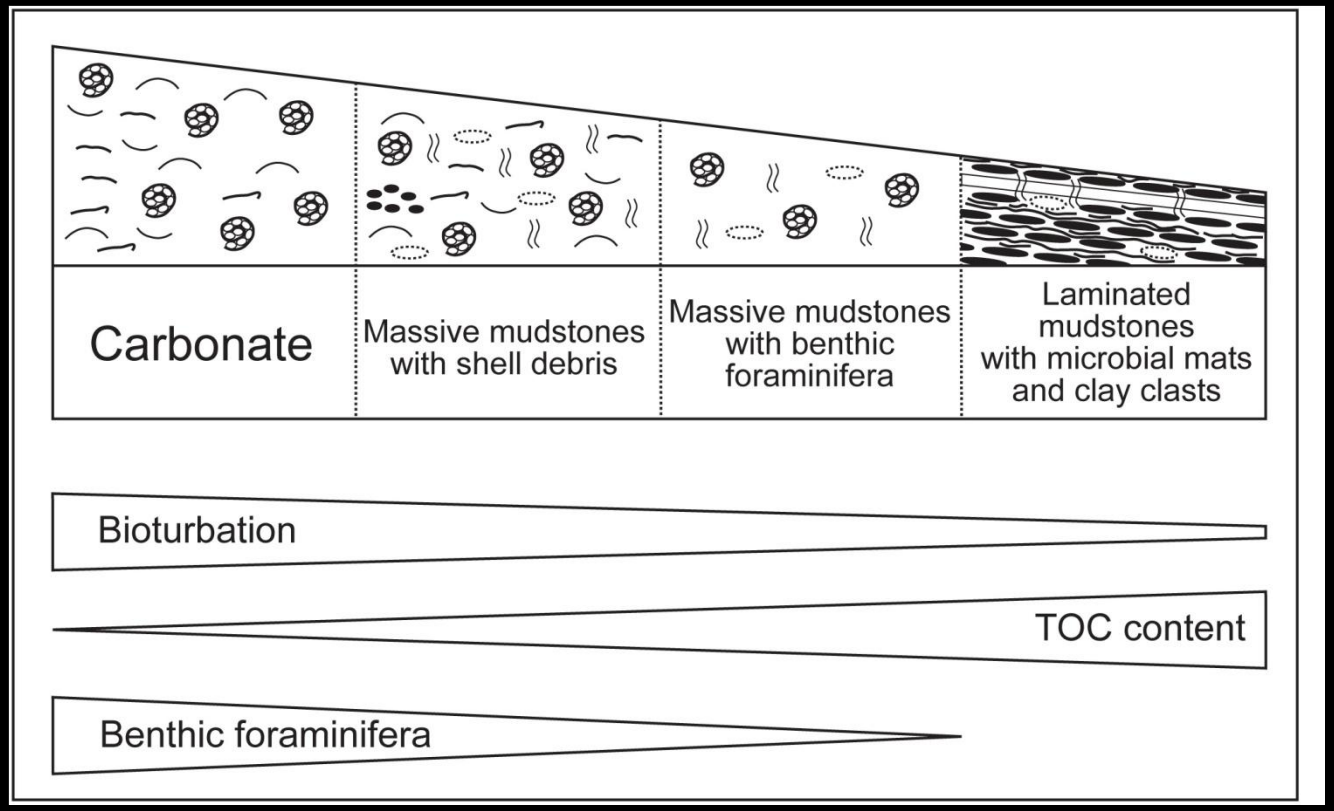
Sedimentology





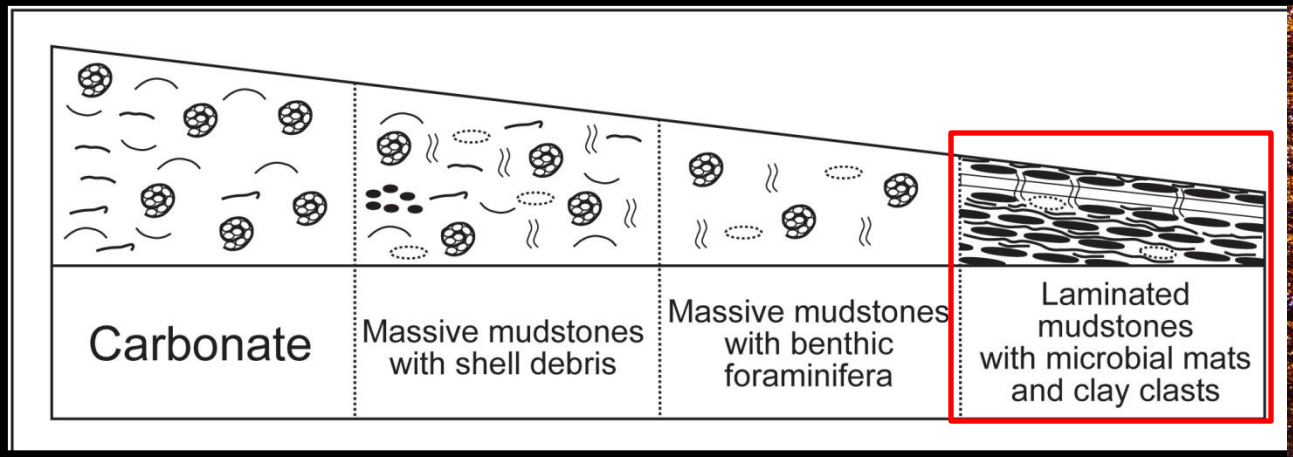
- Associated especially with microbial mats + clay clast facies → phosphate concretions
- Occur in laminae (in places reworked) or elongated to bedding, can be several centimeter in size

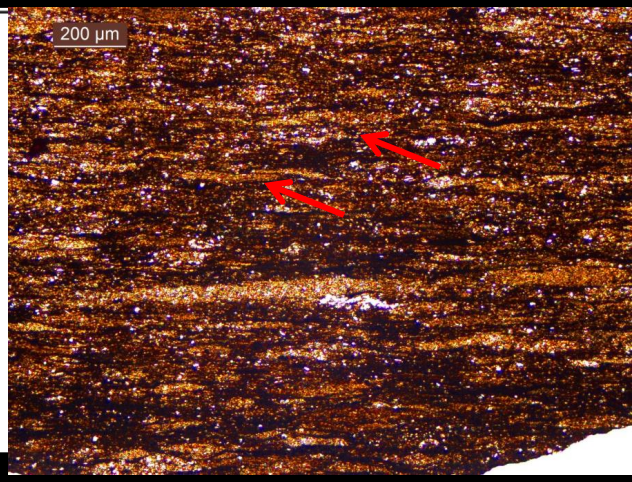
Depositional model

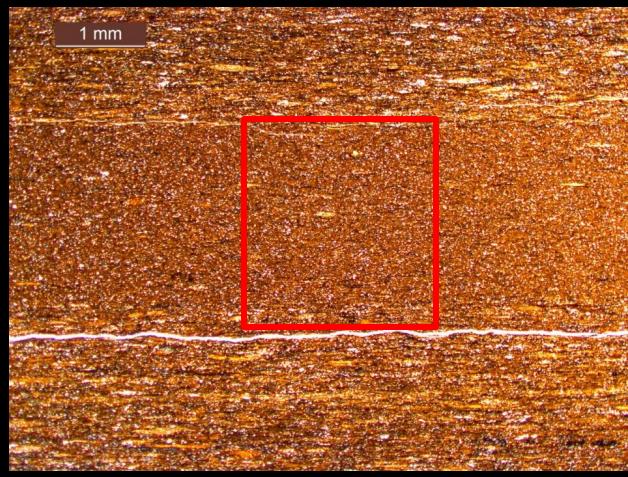


- Total of 4 facies belts, 3 mudstones
- Decrease in grain size (silt) from proximal to distal
- Bioturbation and presence of benthic foraminifera decrease towards offshore, TOC content increases

Distal microbial and clay clast facies

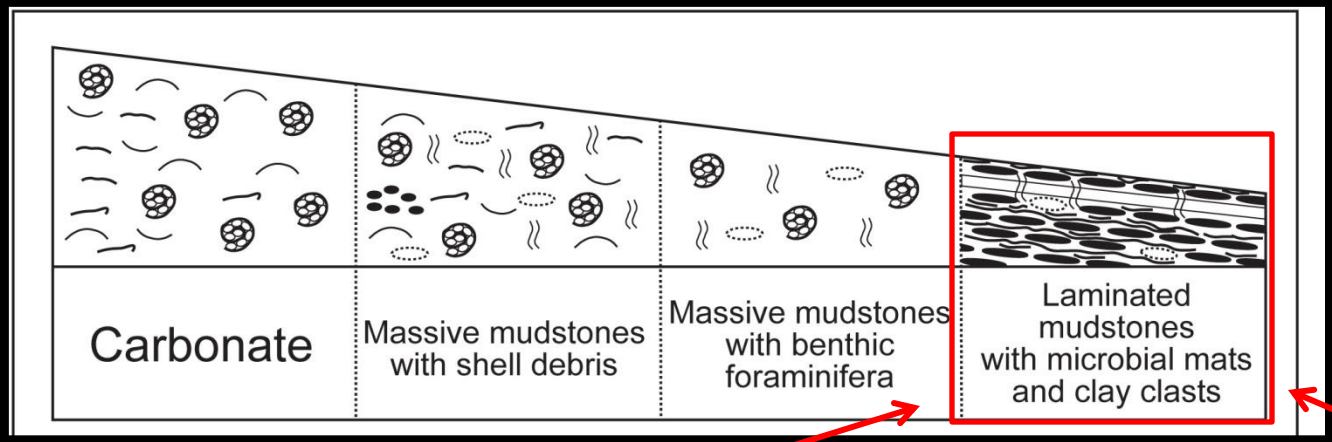


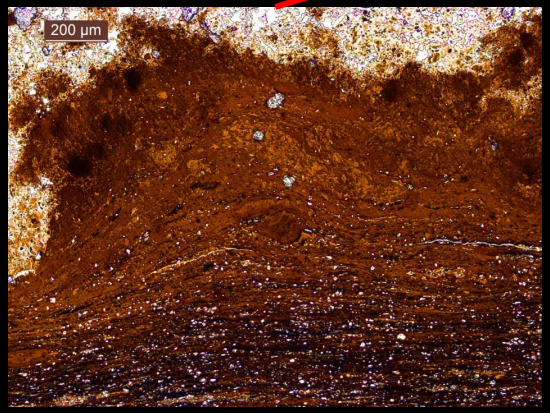




- Deposition of low-energy microbial mats and high-energy clay clasts together in one facies
- Clay clasts represent storm deposition
- Microbial mats show tranquil fair-weather "sedimentation"
- Intercalated massive mudstone laminae = fluid mud?

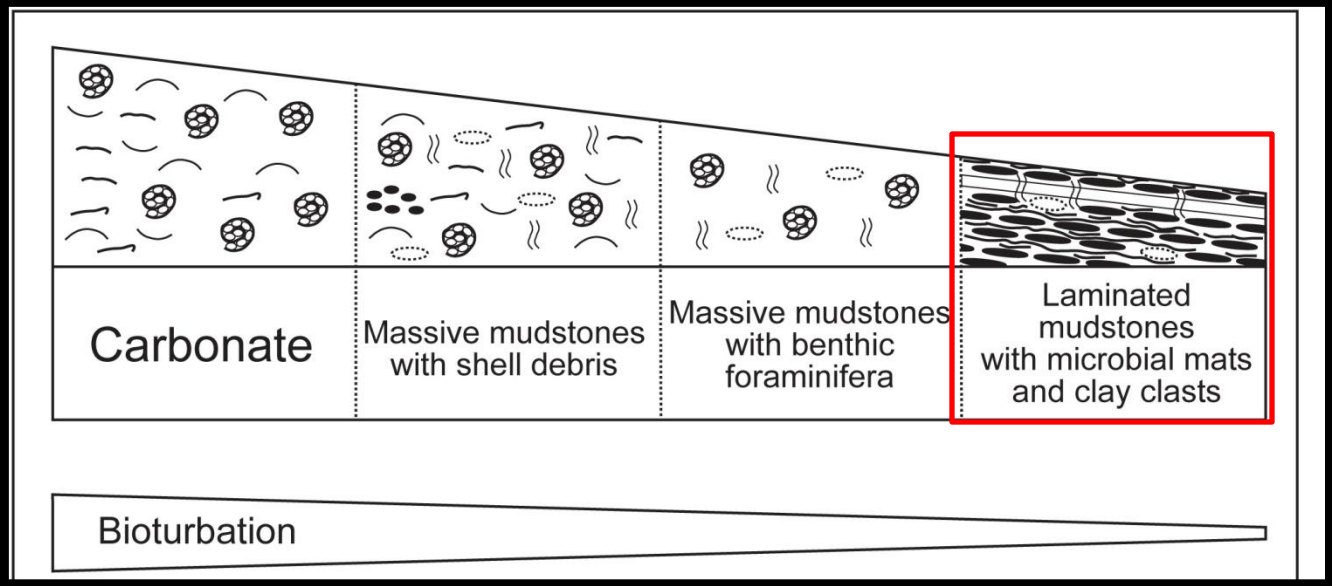
Condensation





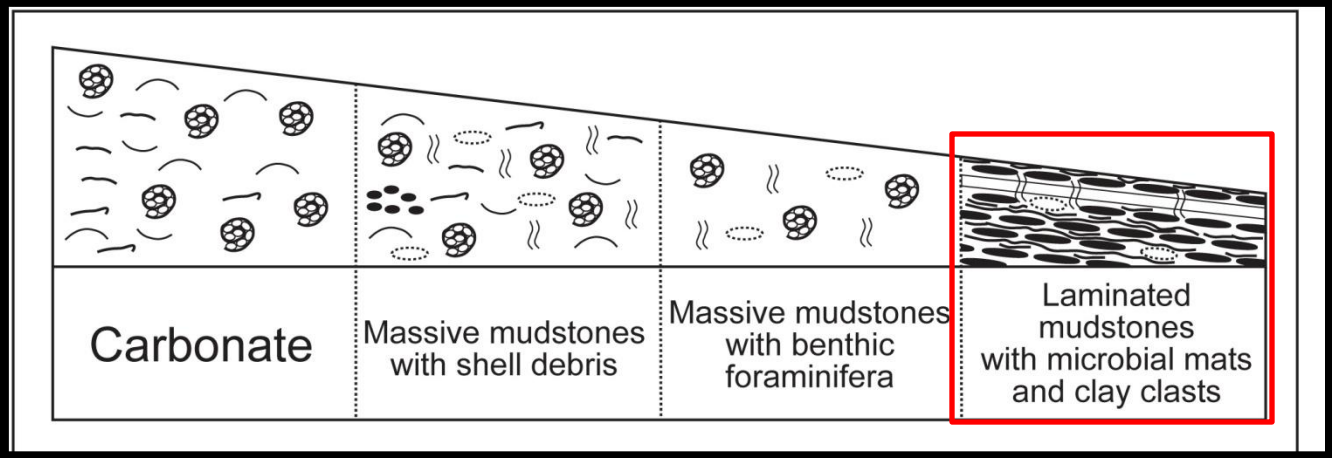
- Most distal facies – only sediment input during storms
- "Condensed" facies (see stromatolite)
- Also mirrored in occurrence of phosphate concretions

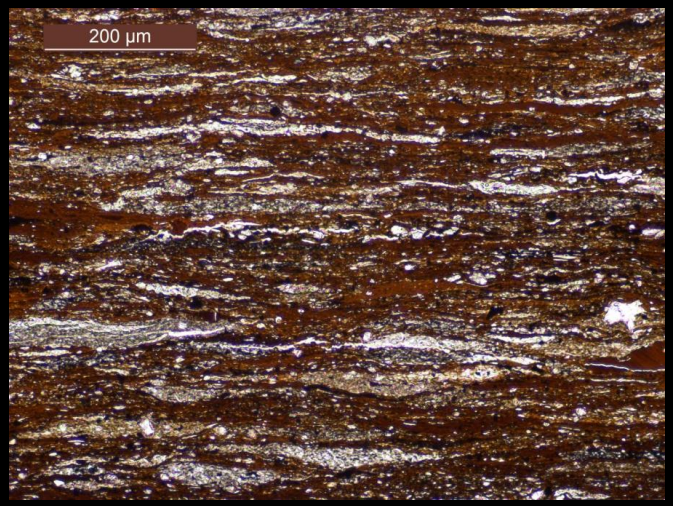
Anoxia

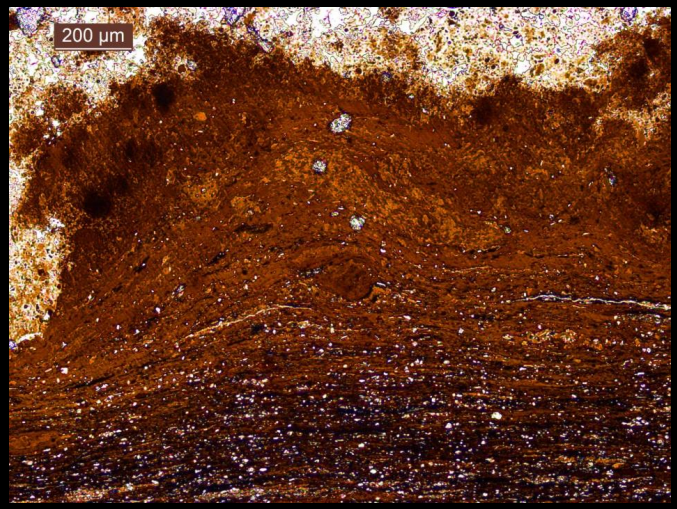


- Bioturbation decreases in abundance proximal → distal
  → likely reflects decrease in oxygen content at sea floor
- But: burrows and fecal strings occur in all facies
- Benthic foraminifera occur in 2 of 3 mudstone facies
  → most likely no persistent anoxia during deposition of Pennsylvanian cyclothems

Depth of basin

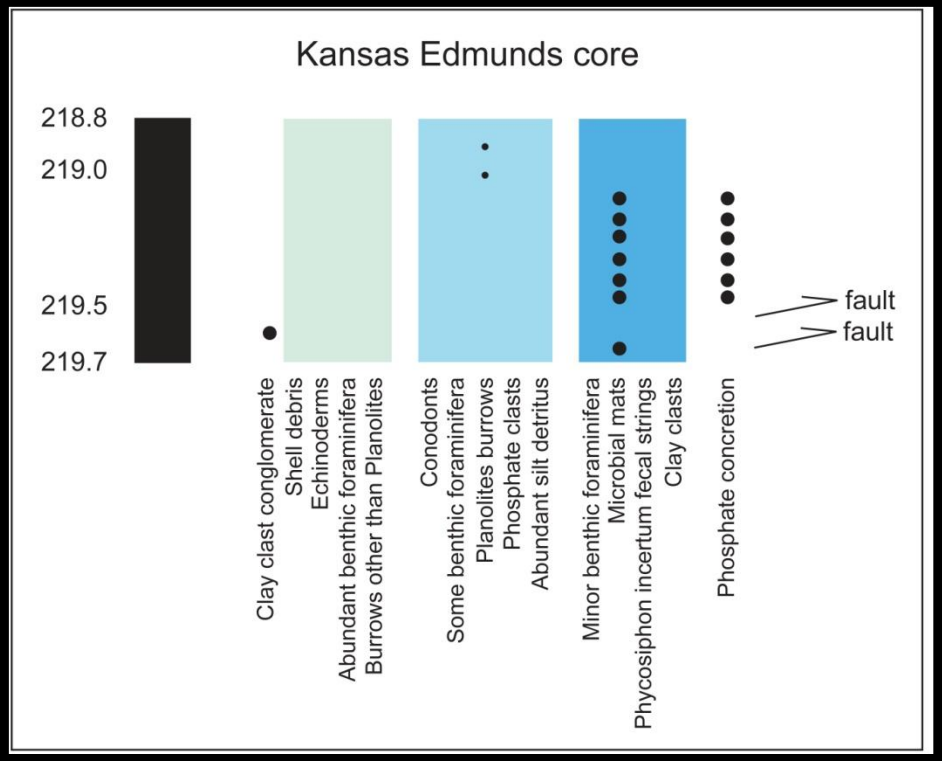


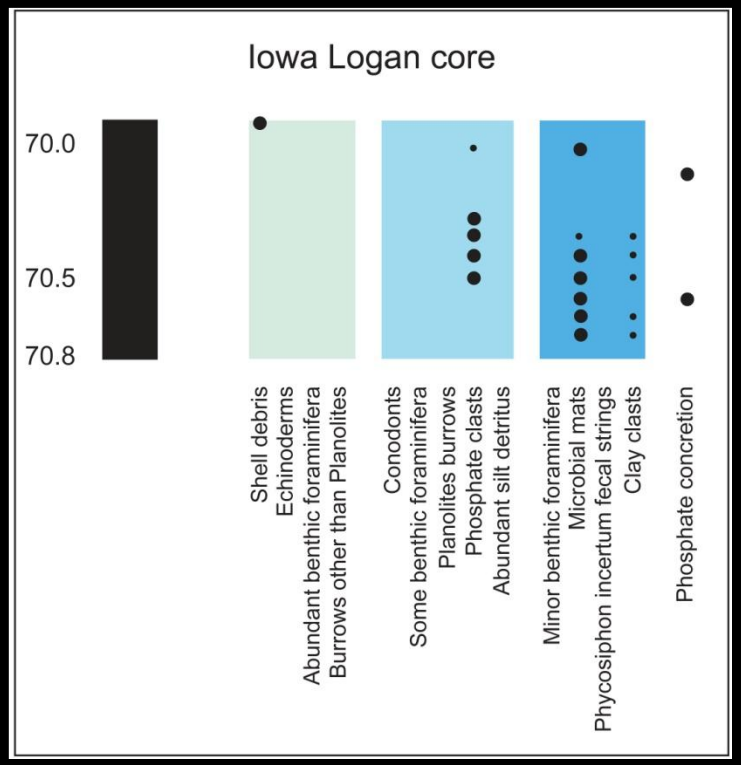




- Deepest part of basin → abundant microbial mats → most likely within photic zone
- Distal, but basin cannot have been very deep

Stratigraphic distribution





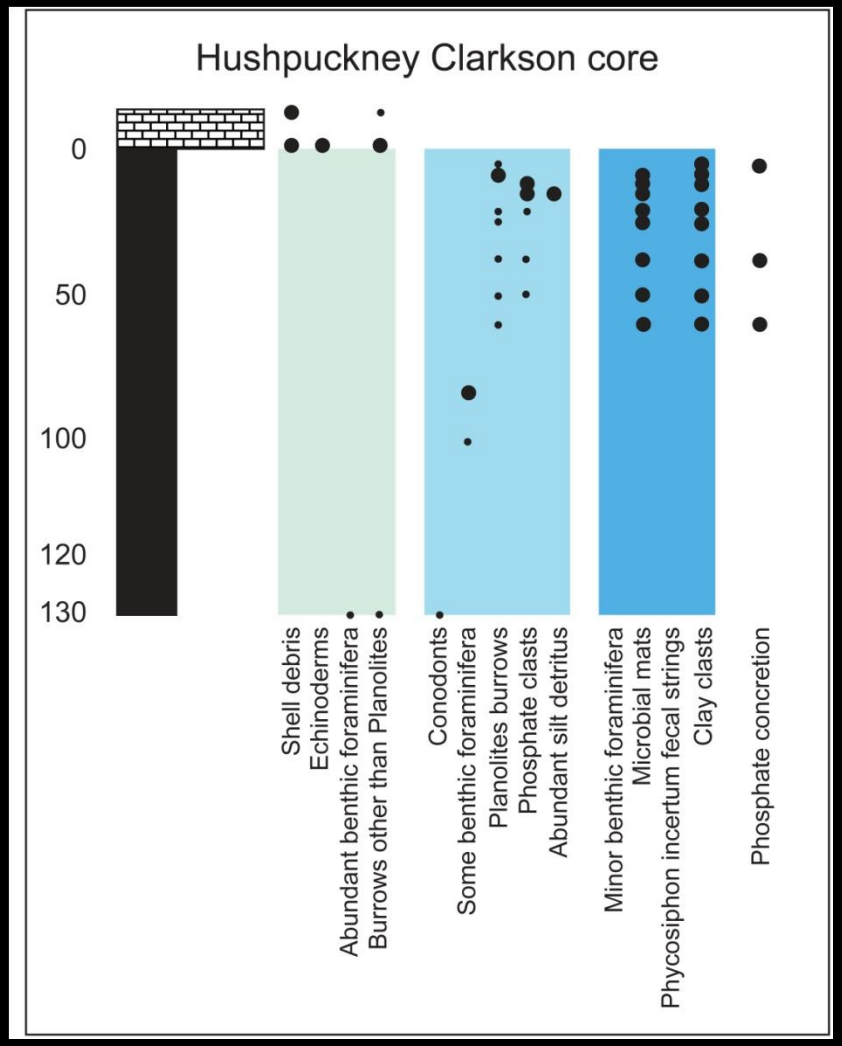
Excello Shale:

- Microbial mats (deepest facies) at base, top records shallowing in both cores

Stratigraphic distribution

Hushpuckney Shale:

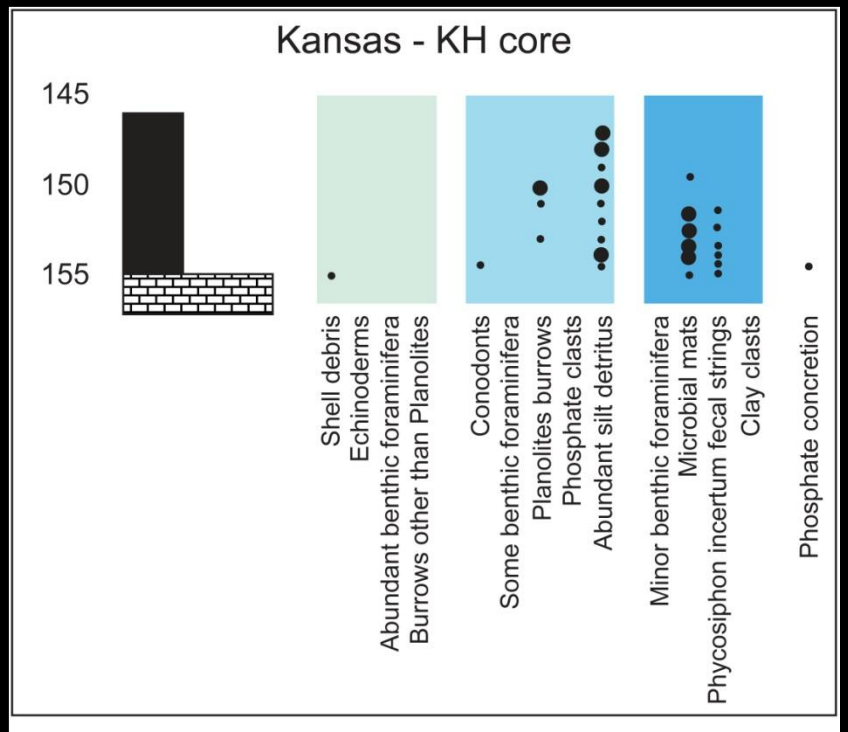
- Shale facies record deepening
- Shallowing only seen in carbonates at top



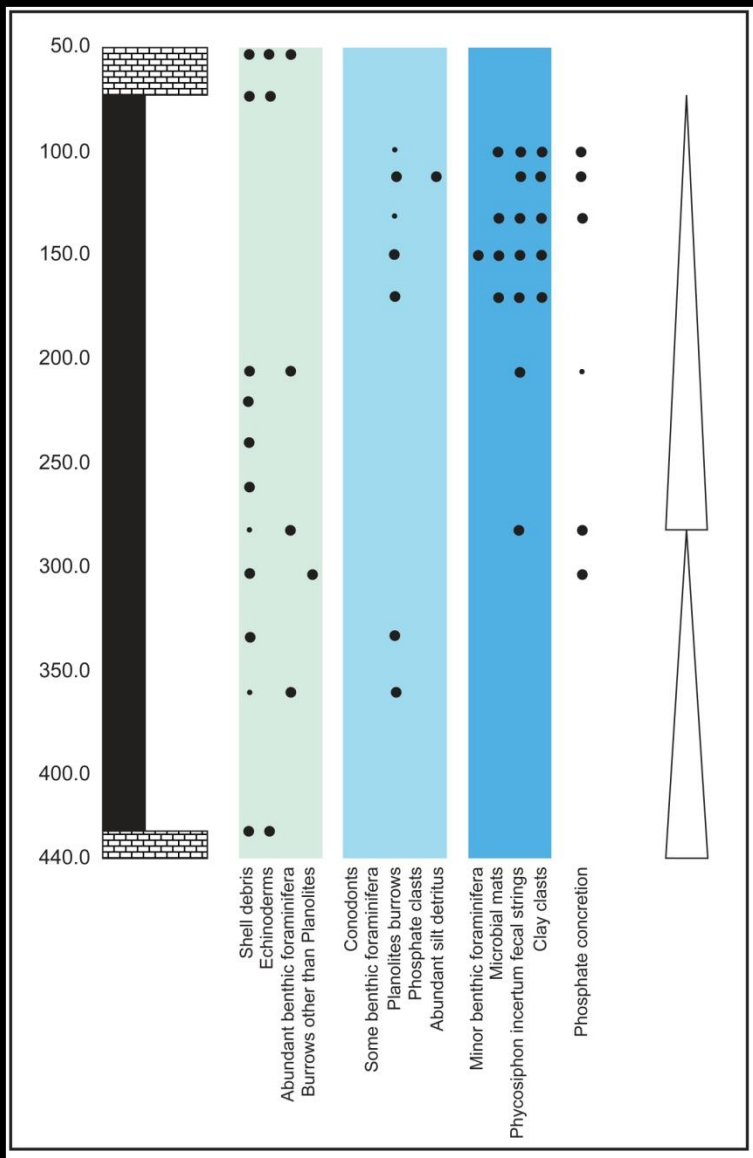
Stratigraphic distribution

Heebner Shale:

- Subdivision in two deepening units in Oklahoma, one slight deepening unit in Kansas
- Summary…



Oklahoma BC core



Conclusions

- Black shales in the Pennsylvanian of the continental US → 3 dysoxic mudstone facies, most distal with microbial mats & stromatolites
- Distal facies: fair weather = microbial mats, storms = clay clasts
- Basin depth – in photic zone + in reach of storm-induced currents (or storm waves)
- Not anoxic – benthic foraminifera and burrows/fecal strings

Thank you!