Chemostratigraphy and Sedimentology of Lower-Middle Pennsylvanian Strata in the Forest City Basin, Southern Iowa

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Project Goals

(1) Characterize the depositional environment of the Lower-Middle Pennsylvanian sedimentary units in southern Iowa.

Tool 1: Apply modern analog and ancient fluvial to marine transition zone facies models from the literature to these strata (Dalrymple and Choi, 2007; Gugliotta et al., 2016; 2017).

(2) Determine whether or not handheld XRF can be a quantitative tool for differentiating between nonmarine and marine sedimentary units.

Tool 2: Utilize chemostratigraphic and geochemical methods for recognition of marine bands (Pearce et al., 2010a) to better understand the origin of these strata.

Goal 1: Lithofacies Modeling

Fluvial to marine transition zone

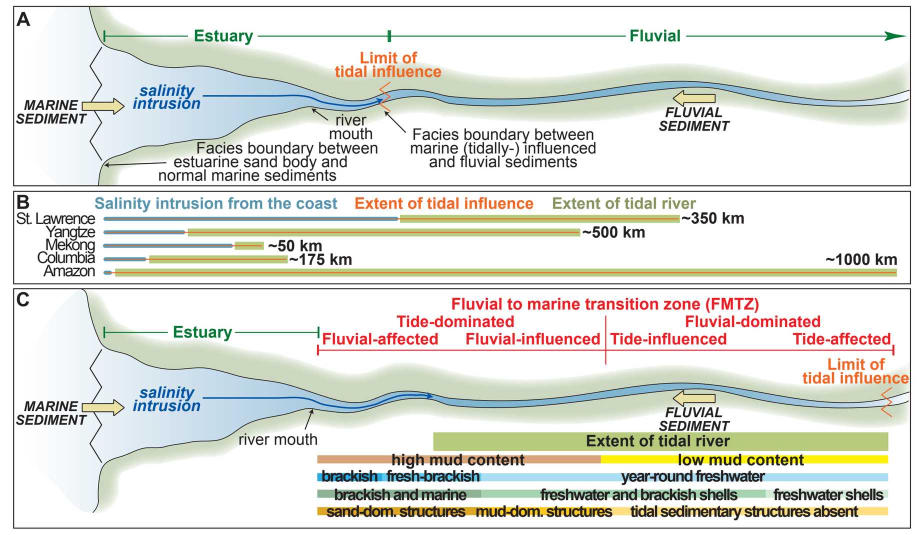


Figure 1. (a) Map view of current facies model (after Boyd et al., 2006). (b) Salinity intrusion and tidal influence lengths in some modern rivers (from Hoitink and Jay, 2016; Gugliotta et al., 2017). (c) New model for fluvial to marine transition zones based on modern analogs (after Gugliotta et al., 2017).

Goal 2: Geochemical Facies from Handheld XRF

Table 1. Criteria used to produce a weighted score from whole-rock geochemical data (modified from Pearce et al., 2010a).

Parameter	Criteria	Score	Nonmarine Interpretation	Marine Interpretation
U	> 6 ppm < 6 ppm	4 1	**Low values.** Oxidizing environments, forms highly soluble U^{6+}.	**High values.** Low oxygen levels and less clastic input, forms insoluble U^{4+}; organic matter is preserved.
Th/U	> 3.0 < 3.0	1 4	**High values.**	**Low values.** Thorium is effectively insoluble in water, no correlation with oxidation.
P_2O_5/Al_2O_3	> 0.02 < 0.02	4 1	**Low values.**	**High values.** Phosphate associated with marine organisms such as *Lingula*.
Mo/Al_2O_3	> 0.0003 < 0.0003	4 1	**Low values.**	**High values.** Molybdenum is present in amorphous organic matter.
Zr/U	> 65	*2	***Uninterpreted.*** *High values are used to compensate for false positive due to heavy mineral abundances.*	***Uninterpreted.***

Table 2. Average ppm in study area and limits of detection for Olympus DELTA Handheld XRF DPO-2000 scanner.

Element	CP80 avg (ppm)	CP56 avg (ppm)	CP10 avg (ppm)	CP24 avg (ppm)	Study area avg (ppm)	LOD (ppm)
U	2.5	3.3	2.4	4.2	**3.1**	3-7
Th	35	34	32	35	**34**	4-8
P	358	304	336	331	**332**	50-175
Al	65115	64841	63910	65789	**64913**	650-2200
Mo	8	8	10	8	**8.5**	2-4
Zr	262	251	239	208	**240**	2-4

Key Points

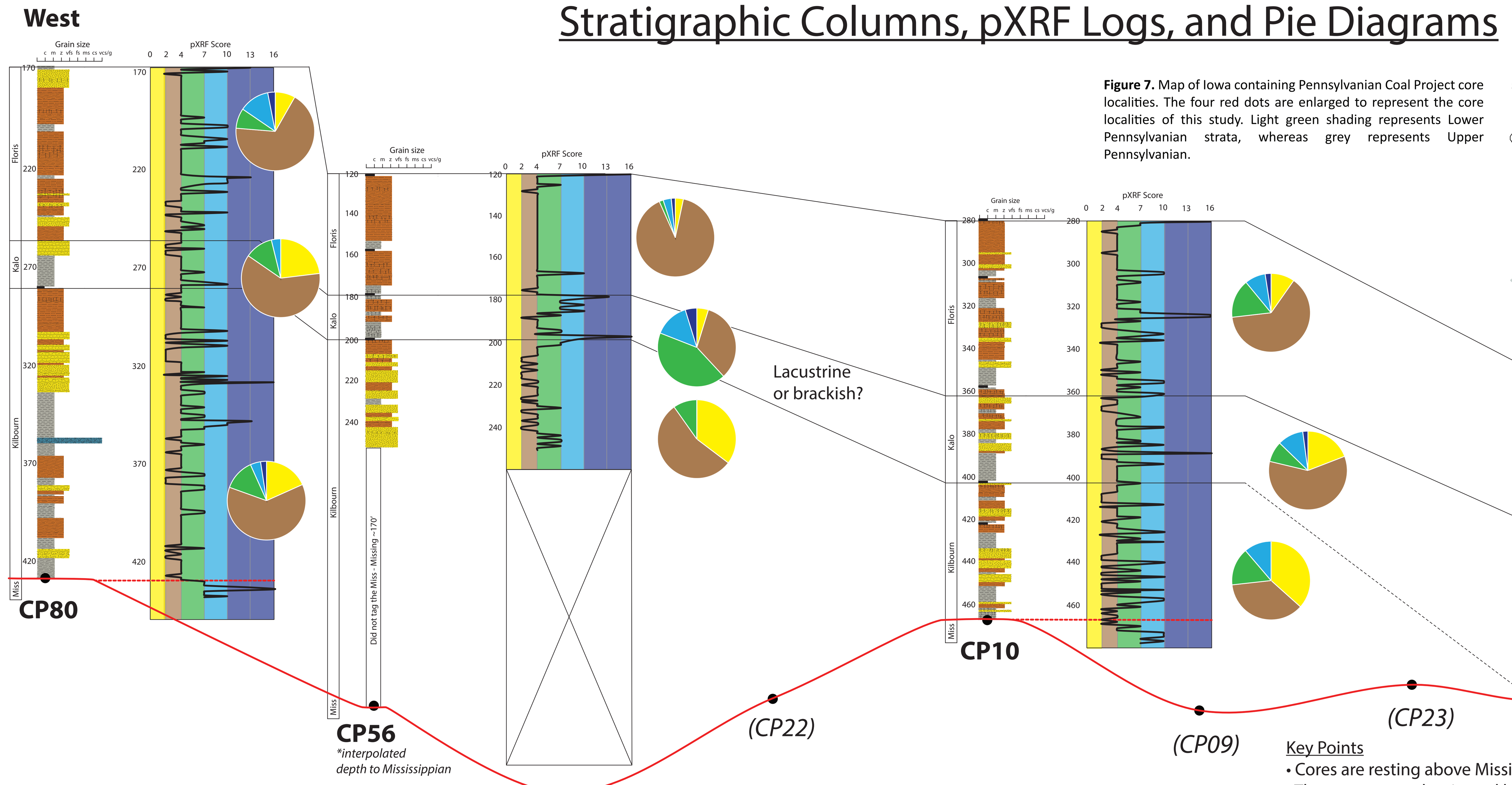
- Cores are logged and lithofacies were assigned to unique lithologies.
- Utilize the Pearce et al. (2010a) method for interpreting marine bands by handheld XRF logging at 1' intervals.
- Average elemental ppm values in study area are relatively consistent.
- Scores are calculated from a combination of proxies listed in Table 1.
- Plan to create an integrated litho-and-chemostratigraphic framework.

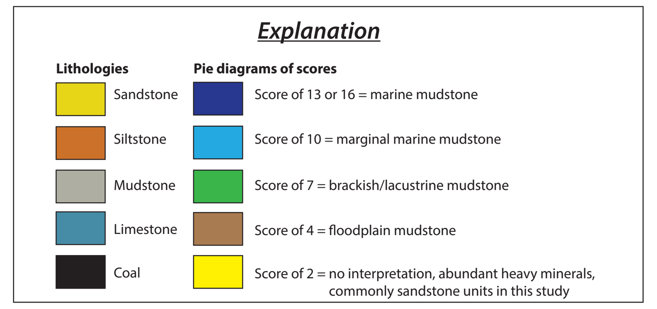
Table 3. Score interpretations (after Pearce et al., 2010a).

Score	Environmental Interpretation	Figure color
13 or 16	Marine	
10	Marginal Marine	
7	Brackish or Lacustrine	
4	Floodplain	
2	Uninterpreted	

Figure 2. Photograph of Handheld Olympus X-Ray Fluorescence detector model DPO-2000 scanner used to collect elemental data for this study.

Stratigraphic Columns, pXRF Logs, and Pie Diagrams





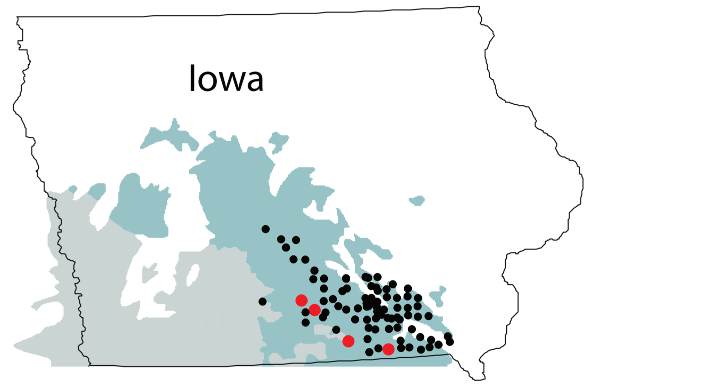


Figure 7. Map of Iowa containing Pennsylvanian Coal Project core localities. The four red dots are enlarged to represent the core localities of this study. Light green shading represents Lower Pennsylvanian strata, whereas grey represents Upper Pennsylvanian.

Figure 8. Stratigraphic cross section from west to east across the southern edge of the study area. Color coded handheld XRF score logs are plotted next to each of the stratigraphic columns. Pie diagrams follow the same color scheme as the score logs and are used to show the general trends within the Kilbourn, Kalo, and Floris Formations of the lower Cherokee Group. The stratigraphic columns rest atop the Mississippian surface (wavy red line) because we plan to interpret the depostional system within the context of the pre-Pennsylvanian landscape.

Key Points

- Cores are resting above Mississippian surface relative to sea level.
- These strata are dominated by fining-upward sequences
- Sparse marine fossils are present throught the succession.
- In general, lithologies are dominantly fine-grained.
- Sandstone units are laterally discontinous.
- Bioturbation is more prevalent towards the east of the study area.
- Scores are calculated from a combination of proxies listed in Table 1.
- These cores are placed within a palynostratigraphic framework (Ravn et al., 1984).
- Coal beds are thin, discontinuous units that are challenging to correlate across the study area.

Handheld XRF Comparison to NIST Standard

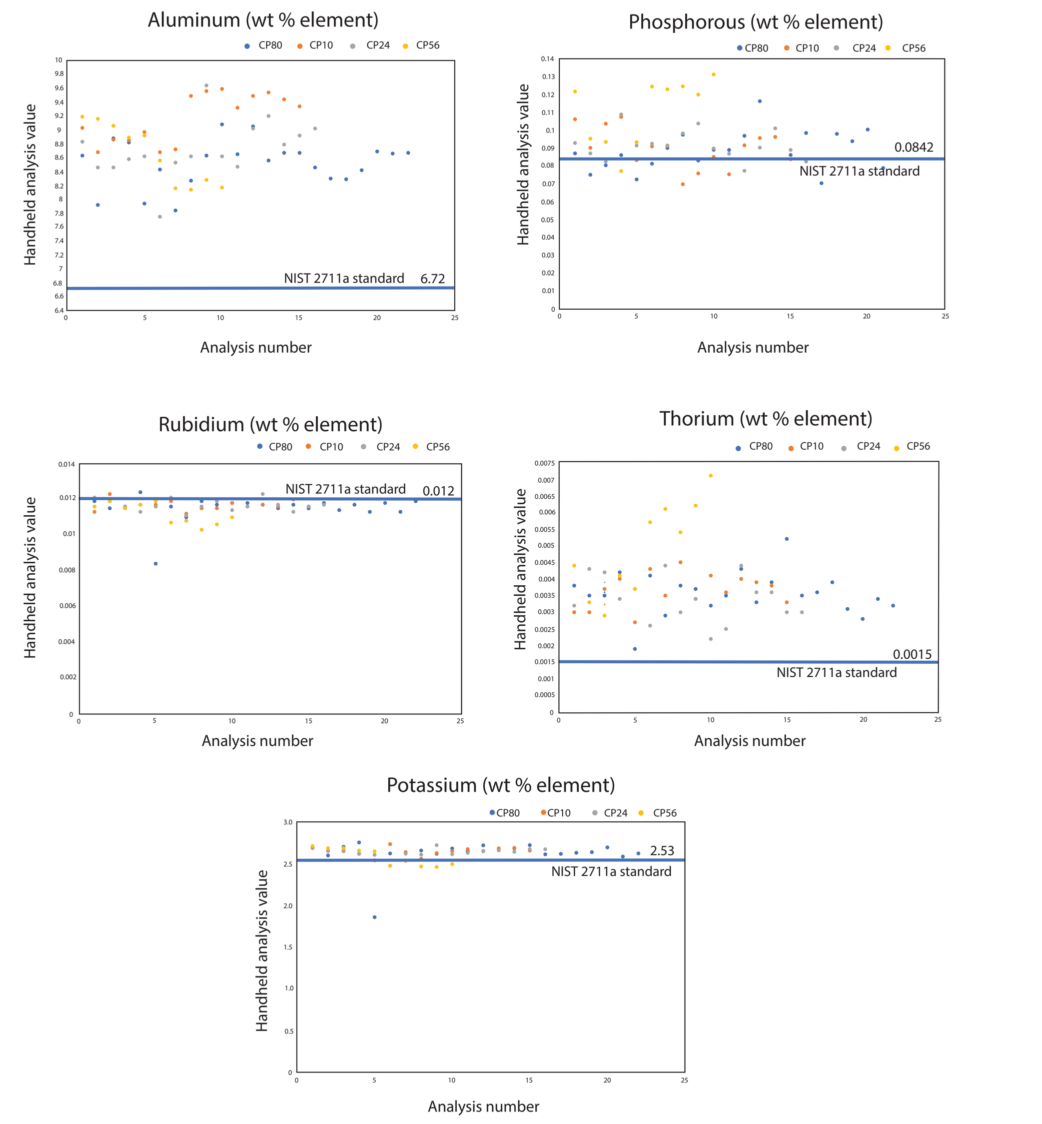


Figure 9. XRF data from the Loess NIST 2711a standard was used for calibration of our pilot study because it contains some of the elements that we are interested in using. Plots contain values for individual analyses from each core examined during this study as well as the expected NIST values (blue solid lines). Elements above display relatively linear trends, and as expected, some will require adjustment (Piercy and Devine, 2014; Rowe et al., 2012). These trends demonstrate that the handheld XRF remained calibrated with minor instrumental drift throughout the data collection process.

Paleogeography and Sea Level

Early Pennsylvanian (~315 Ma) Middle Pennsylvanian (~308 Ma)

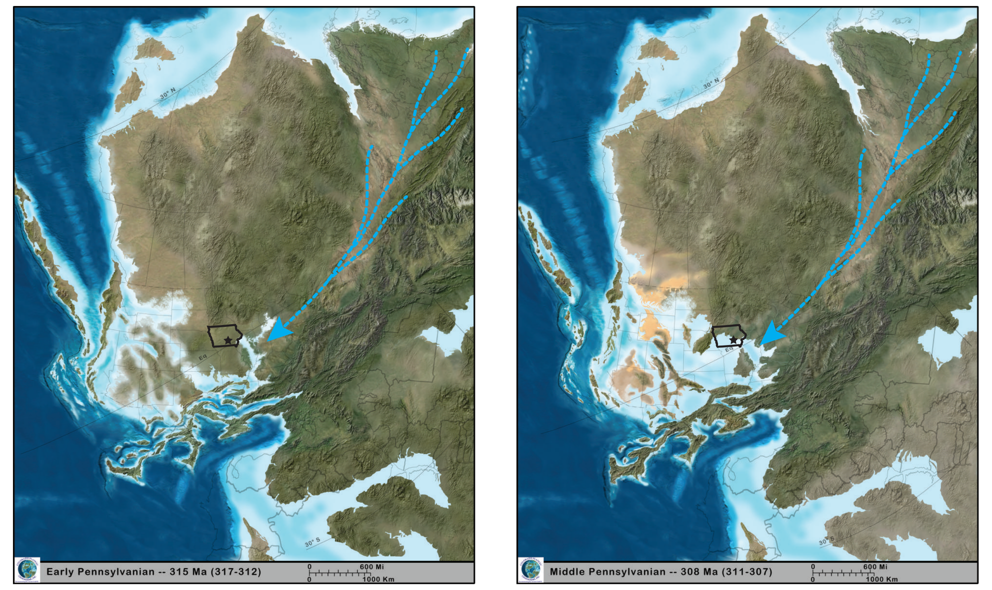


Figure 3. Paleogeographic maps of Pangea during the Early and Middle Pennsylvanian (after Blakey, 2017). Transcontinental river based on the interpretations of Archer and Greb (1995).

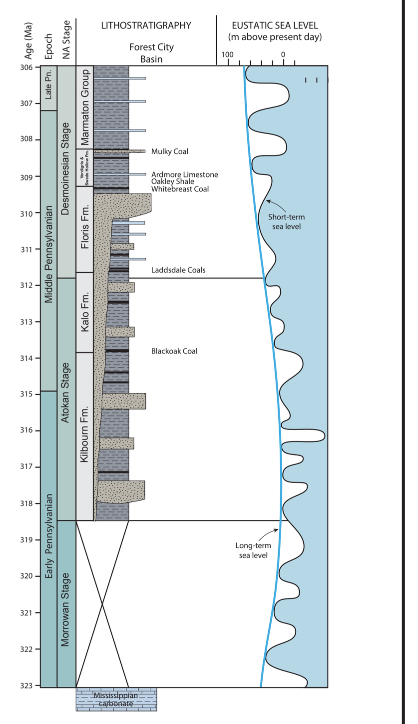


Figure 4. Generalized stratigraphic column and eustatic sea level curve (after Kissock et al., 2017).

Core Localities: Southern Iowa

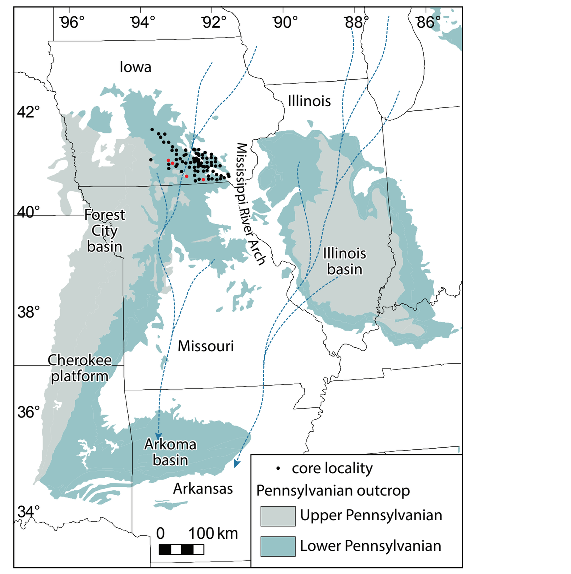


Figure 5. Regional location map of the midwest displaying transcontinental fluvial systems (blue dashed lines) and Pennsylvanian Coal Project cores (black dots) (map modified from Kissock et al., 2017).

Representative Lithofacies

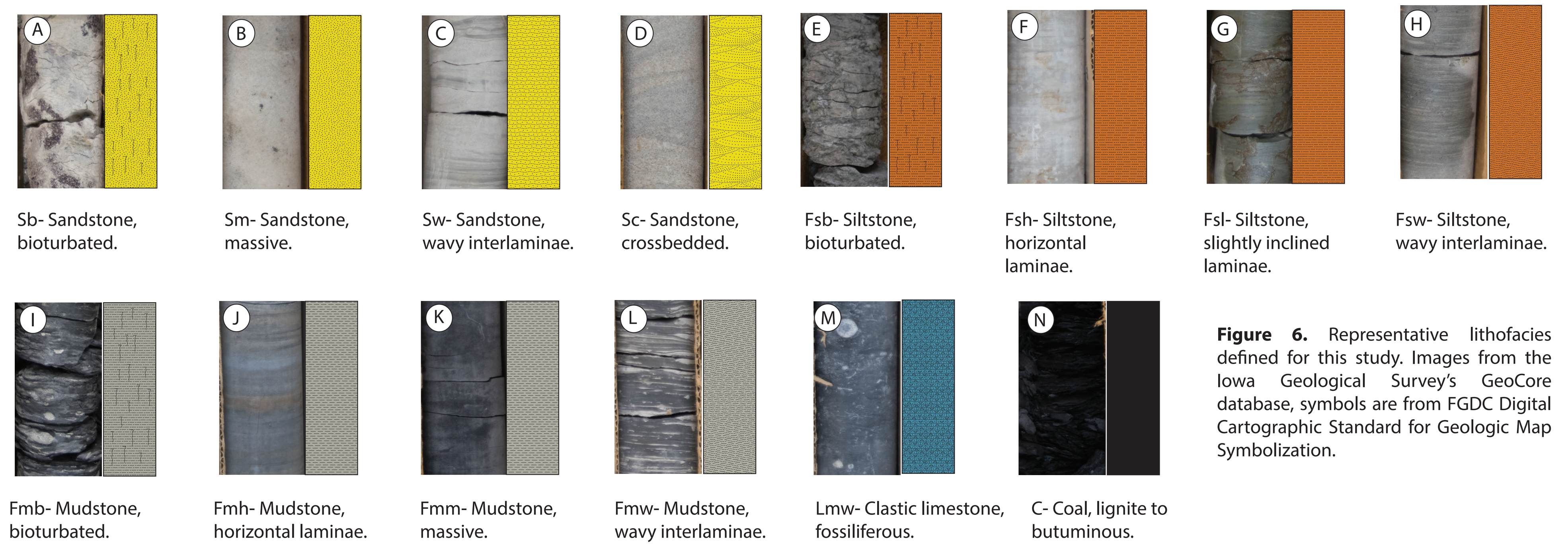
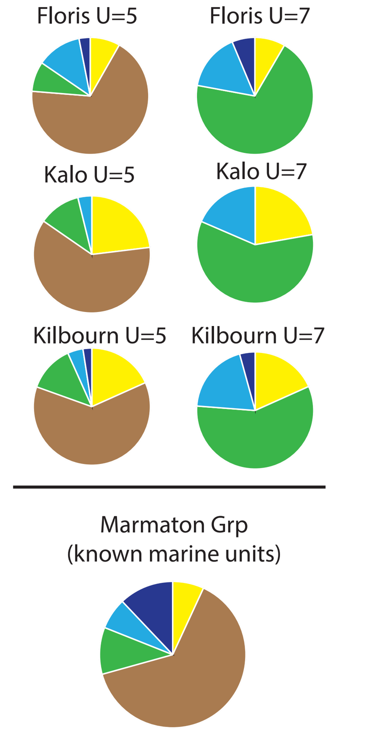


Figure 6. Representative lithofacies defined for this study. Images from the Iowa Geological Survey's GeoCore database, symbols are from FGDC Digital Cartographic Standard for Geologic Map Symbolization.

Discussion and Future Work

The DPO-2000's limit of detection for Uranium is 3-7 ppm, but the score threshold is 6 ppm. If Uranium quanitities are low, this tool may not detect them. So, to calculate a score, we assigned a value U < 6 to all of the NDs.

To test the sensitivity of our results, we assigned a value of U > 6 for all of CP80. This simply elevated the background score by 3 points from floodplain scores to brackish or lacustrine scores. This demonstrates that even though U is important, a sum of all the proxies are required to calculate a score.



When compared to Marmaton Group strata that contain known laterally extensive marine bands, Early-Middle Pennsylvanian strata show a different score distribution.

Since we have potentially demonstrated that this technique is useful, we plan to use multiple standards, create internal standards, take three measurements on each bedding plane at the same sampling interval, and use the ICP-MS to validate pXRF results from the CP80 core.

References and Acknowledgements

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IGS GeoSam IGS GeoCore