Lithostratigraphic Correlations of the Upper Desmoinesian and Missourian Stages (Pennsylvanian) in Eastern Kansas

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Abstract

Upper Desmoinesian through Missourian Stage strata (Pennsylvanian; approximately equivalent to Upper Carboniferous Moscovian through Kasimovian Stages) were re-correlated by means of a series of petrophysical well log transects. These transects incorporate 243 well logs in eastern Kansas, westernmost Missouri, and northeastern Oklahoma at an approximate resolution of one log per six miles. Transects were arranged in a grid and in such a way as to be orthogonal or parallel to known structural elements in the region. This approach permitted circular unit correlation and provided a coherent framework for interpreting both stratigraphic and structural elements in this part of the midcontinent.

Introduction

The Pennsylvanian succession is the most complex and enigmatic sedimentary package in Kansas and neighboring states (Iowa, Missouri, Nebraska, and Oklahoma) and Indian lands (e.g., Osage Nation). This complexity derives from global high-frequency relative sea-level changes and regional contemporaneous tectonic disturbances (e.g., Berendsen and Blair, 1986; Heckel, 2013) that played out across the many basins and arches in the region. The present data are located within the Cherokee-Forest City basin. At the time of deposition for this interval, this basin was likely representative of a backbulge setting of a foreland basin system (DeCelles and Giles, 1996) that experienced intermittent migration of a forebulge associated with the Ouachita Orogeny. These changes in tectono-eustasy, coupled with glacio-eustatic effects from the waxing and waning of Gondwanan ice sheets and the shallow nature of the basin, resulted in a mixed carbonate-clastic stratigraphic succession typically characterized by thin beds of almost all sedimentary lithologies (e.g., sandstone, shale, limestone, coal, and paleosols) except evaporites (Soreghan, 1994). In addition, phylloid-algal mound development within the basin’s studied interval, also, at times, resulted in complex “build-and-fill” stratal geometries that further compound the enigmatic nature of these units (Oborny et al., 2017).

Historically, correlation of these strata has relied on integrating outcrop descriptions, conodont biostratigraphy, and petrophysical well logs, often of widely spaced localities. Additionally, a wide variety of researchers from academia, industry, and government (e.g., geological surveys) have approached the task of correlation with differing goals, tools, and interpretive models. The current authors decided that a new regional framework was needed to resolve long-standing correlation (and thus nomenclatural) issues. In addition, recent interest in the exploration for critical minerals has given new impetus and urgency to the generation of a basin-wide stratigraphic and structural model that can be used for resource assessments.

The first product of this work has been a series of five transects (appendices A–E; i.e., transects A–E) running roughly northwest-southeast with an additional set of four transects running orthogonally (appendices F–I; i.e., transects F–I). These transects are composed mostly of data from eastern Kansas, but some data from Missouri and Oklahoma were included where appropriate (fig. 1).

Data and Methods

Raster petrophysical logs (mostly gamma ray and neutron porosity logs) from 243 wells (table 1, appendices A–I) and driller’s logs were downloaded from the websites of the Kansas Geological Survey, Missouri Department of Natural Resources, and Oklahoma Corporation Commission as TIF and PDF files, (KGS, 2021; MDNR, 2021; OCC, 2021). Logs were imported and correlated manually in Adobe Illustrator using the top of the Hushpuckney Shale Member (i.e., Swope Limestone, Bronson Subgroup, Kansas City Group) as datum. Because these logs were available only in raster format, no advanced petrophysical analysis was attempted (e.g., gamma ray normalization). Due to the dual importance of 1) evaluating structural and depositional models and 2) evaluating stratigraphic nomenclature within the interval, the transects are colored in such a way as to reflect the lithological designations at the formational and/or member level based on the combined nomenclatural schemes of Zeller (1968) and Heckel and Watney (2002). More than 157 type, neostratotypes, and principal reference sections for lithostratigraphic units exist within the Cherokee-Forest City basin (more than 118 located in Kansas, about 75% of total sections). In assigning nomenclature to the interval, we conducted a broad assessment of published works and correlated directly to (illustrated in our correlations, see table 2) or within one township of 87 of these sections (Appendix J, and references within). Twenty-four driller’s logs were also included as needed within transects to further evaluate facies changes in the subsurface. Predominantly carbonate intervals — some including black fissile shales (i.e., highstand shale) — were shaded blue. Predominantly argillaceous and/or arenaceous shale lithologies were shaded light gray and may include discontinuous carbonate lenses (e.g., Cherryvale and Chanute Shale formations) and sandstones (e.g., Pleasanton Group). Coal beds, when identified, were shaded dark gray. The Hepler Sandstone (as originally defined by Jewett, 1940) is colored yellow. Group or subgroup boundaries were denoted using red lines. All transects — apart from transect C — cross at least two other transects.

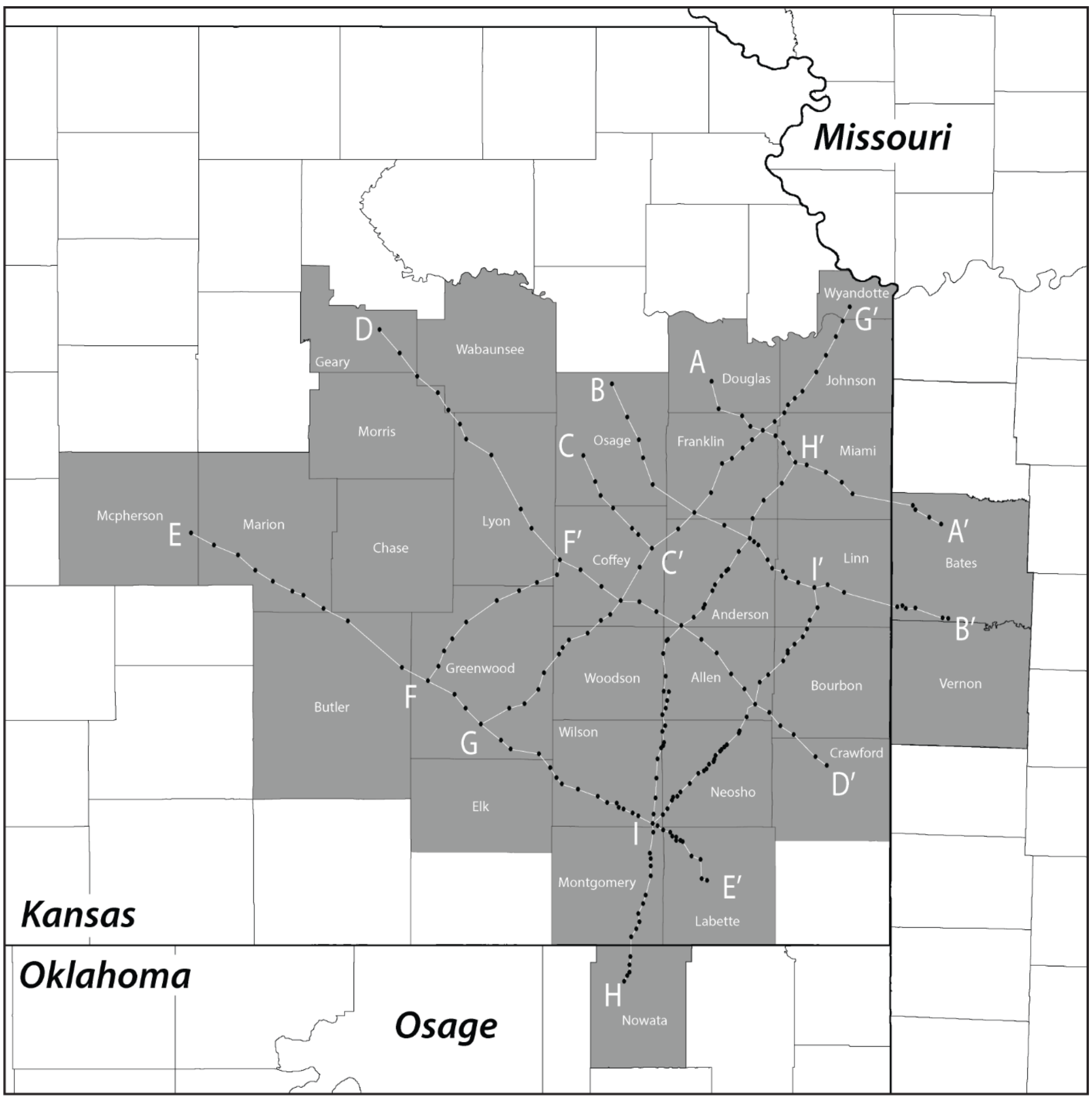

Figure 1. Location map for transects generated as part of this study.

Table 1. Statistical information for transects (appendices A–I).

Transect	# of Logs	Start County	End County	Stratigraphic Interval
A	16	Douglas	Bates (MO)	Upper Cherokee through basal Lansing Groups
B	24	Osage	Bates (MO)	Upper Cherokee through basal Shawnee Groups
C	7	Osage	Coffey	Upper Cherokee through middle Shawnee Groups
D	27	Geary	Crawford	Upper Cherokee through Shawnee Groups
E	42	McPherson	Labette	Upper Cherokee through Shawnee Groups
F	10	Greenwood	Coffey	Upper Cherokee through Shawnee Groups
G	32	Greenwood	Wyandotte	Upper Cherokee through middle Shawnee Groups
H	48	Nowata (OK)	Miami	Upper Cherokee through basal Lansing Groups
I	37	Wilson	Linn	Upper Cherokee through Shawnee Groups
	243			

Borehole gamma ray logging tools respond to the natural radioactivity of potassium (K), uranium (U), and thorium (Th) in rocks (Doveton, 2017). Typically, shales and paleosols tend to have a higher gamma ray response than other lithologies due to the presence of clay minerals rich in potassium or, in the case of organic-rich shales, the adhesion of uranium to organic matter. Sandstones, limestones, and coals tend to exhibit low gamma ray response because of their lack of these elements. However, potassium can be present in these lithologies if there is an admixture of clay material or potassium-rich feldspars (potassium-feldspar-rich sandstones are known colloquially as “hot sands” due to their high gamma ray responses). Occasionally, high uranium and thorium in limestones and sandstones can arise from diagenetic cements (often calcite). No spectral gamma ray logs were available, so the relative effects of potassium, uranium, and thorium on certain gamma-ray log signatures were not assessed.

Neutron porosity logging tools measure the response of natural geological materials to an active radioactive source of neutrons (Doveton, 2017). The log response is roughly a measure of the hydrogen density of the natural material, which is commonly interpreted to be either the result of water-filled pore space or hydrogen bound to clay minerals.

Table 2. Reference lithological sections included in petrophysical transects (appendices A–I).

Transect	Reference	Section Type
ALL	Heckel and Watney (2002)	Generalized Section
A	Newell (1935)	Type Block Limestone Member
B	Heckel and Watney (2002)	Type Mantey Shale Member
B	Heckel and Watney (2002)	Principal Reference Shale Hill Formation
D	French and Watney (1993)	Generalized Section
D	Heckel and Watney (2002)	Neostratotype and Principal Reference of Hepler Formation
E	Jewett (1941, 1945)	Type Idenbro Limestone Member
E	Heckel (1988)	Type Dennis Limestone
E	Heckel and Watney (2002)	Neostratotype Tacket Formation
E	Jewett (1941)	Type Altamont Limestone
G	Heckel and Watney (2002)	Principal Reference Zarah Subgroup
H	Heckel and Watney (2002)	Type Cherryvale Formation
I	Jewett (1932)	Type Critzer Limestone Formation

The strata in this study fall within the Desmoinesian and Missourian North America stages. These stages are roughly correlative to the Moscovian and Kasimovian international stages. A correlation chart is included to assist the reader in comparing the studied strata with counterparts located further afield. (fig. 2).

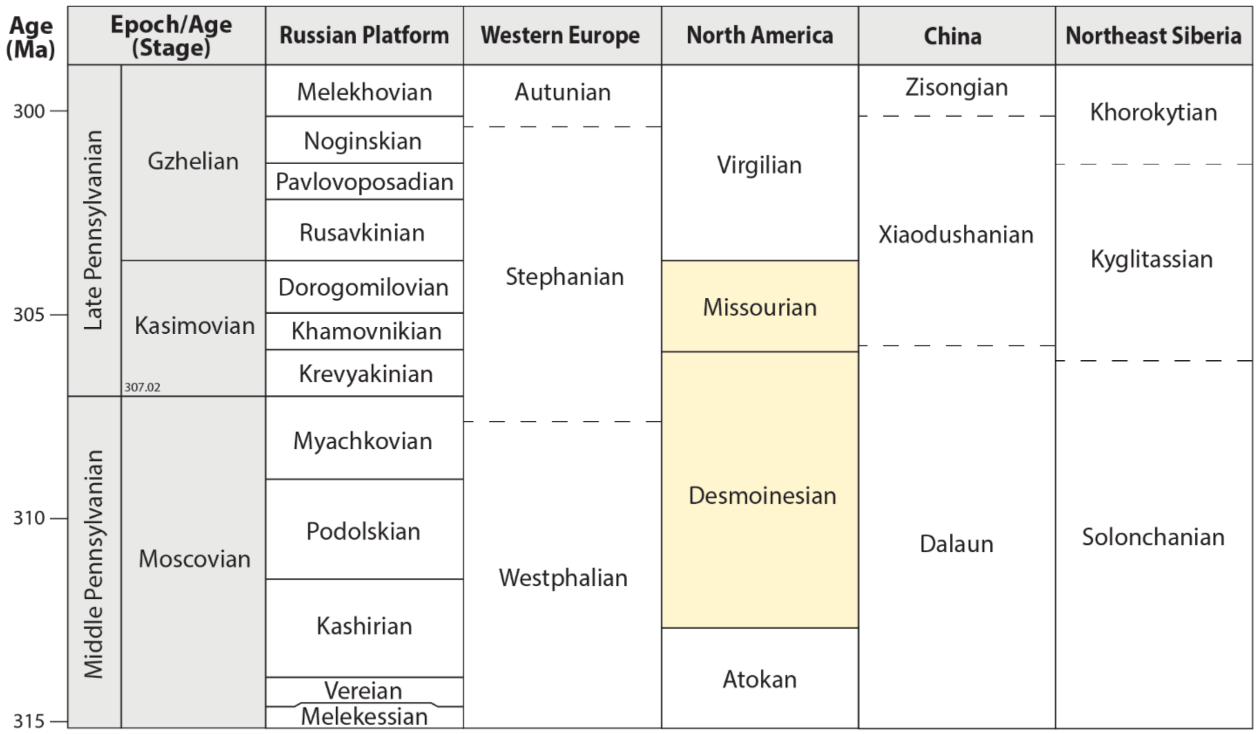

Figure 2. Correlation chart showing relationship between North American stages of strata in this study to international stages (after "Carboniferous Regional Subdivisions" chart, fig. 23.5, in Aretz et al., 2020).

Results and Discussion

The subcrop-to-outcrop correlations presented here provide new interpretations for basin geometry, facies belts, and structural history for this part of the U.S. midcontinent. The purpose of releasing these data is to allow other working groups and ongoing investigations to use them as soon as possible. For this reason, a detailed discussion of each individual correlation is beyond the scope of this report, and we are instead preparing three additional manuscripts: one on the Desmoinesian Stage (Marmaton/Pleasanton), one on the Missourian and lower Virgilian Stages, and one focused on new interpretations of facies belts and structural history within the Cherokee-Forest City basin. These manuscripts will describe the detailed historical context for the correlated units as well as the stratigraphic and structural problems that the current transects aim to fix. To satisfy the reader's curiosity, we provide a brief, yet we recognize not complete, list of key observations that will be discussed in detail in the three forthcoming papers:

1) The Hepler Sandstone (as originally defined by Jewett, 1940), which is used in defining the Marmaton-Pleasanton Group boundary, cannot be correlated beyond a township from the unit's type location and is therefore problematic in defining the group boundary.
2) The basal contact of the Nuyaka Creek Shale is a significant regional disconformity, and we tentatively used this boundary in our correlations as the Marmaton-Pleasanton Group boundary.
3) Facies belts trend southwest-northeast, perpendicular to historical interpretations.
4) The entire Pennsylvanian succession thickens to the southeast toward a depocenter where the Ozark Plateau currently resides. This observation indicates that the Ozark Plateau became a prominent physiographic feature after the Pennsylvanian.
5) The Pleasanton Group (as defined herein to include the Nuyaka Creek Shale) and Lane Shale appear similar in distribution and overall lithology. Based on the regional geometry of these units, we propose that they were deposited within a backbulge setting of a foreland basin system.
6) Due to the stratigraphic architecture observed in our northwest-southeast trending transects, there appears to exist a southwest-northeast anticlinal structure that underwent differential migration throughout Pennsylvanian time. This structure appears to terminate in northeastern Linn County, Kansas. This observation, combined with prior observations of the Lane and Pleasanton shales, suggests that a backbulge-forebulge setting existed in eastern Kansas during deposition of this interval associated with development of the Arkoma basin during the Ouachita Orogeny to the southeast in Arkansas. This hypothesis may be supported by the existence of the many coal deposits in the Cherokee-Forest City basin along a general southwest-northeast trend, a facies that commonly develops in backbulge settings of foreland basin systems.
7) The Mound Valley Limestone and underlying Ladore Shale appear to be closely associated with the Hertha Limestone, and we therefore tentatively include these units within the Hertha in our correlations, revising prior interpretations of Heckel and Watney (2002).
8) The Lenapah Limestone consists of a single limestone unit, and we discontinue the use of its member designations.

Conclusions

Nine new transects showing the correlation of Upper Desmoinesian through Missourian strata were produced in a grid across eastern Kansas to address long-standing correlation and nomenclature issues in the region. These transects are consistent with an interpretation of the environment being a southwest-northeast backbulge-forebulge setting that documents the intermittent northwest-southeast movement of the Ouachita Orogeny's forebulge. These observations have significant implications for facies belts in the region, which play a large factor in when, where, and how critical minerals are deposited.

Future work will focus on increased data density, integration of fully digital logs (i.e., LAS files), drill cores, and outcrops so that maps of key stratigraphic intervals can be generated. Additionally, the integration of biostratigraphic (in this case, predominantly from conodonts) and chemostratigraphic data (e.g., $\delta^{13}C$ analyses of marine carbonate material) to these transects will allow the chronostratigraphic significance of correlated surfaces to be fully evaluated.

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Acknowledgments

We would like to acknowledge the Archives/Data Resource Library (Nikki Potter, Deb Stewart, Sally Hendershot) and the Computing Services Group (Kurt Look, Mike Killion, Glen Gagnon) of the Kansas Geological Survey for stewarding the digital geoscience data of Kansas, without which this project would have been impossible. We also acknowledge the professional editing of the KGS's Julie Tollefson, who makes our manuscripts better than they have any right to be. We acknowledge all the previous workers in eastern Kansas and Cherokee-Forest City basin stratigraphy. Dave Newell, also at the KGS, and Phil

Heckel, at the University of Iowa, reviewed early drafts of subsurface correlations generated by this investigation, and we thank them immensely for t time and effort in verifying our petrophysical data.