Examination of the Mississippian-Pennsylvanian Boundary within the Williston Basin of Western North Dakota

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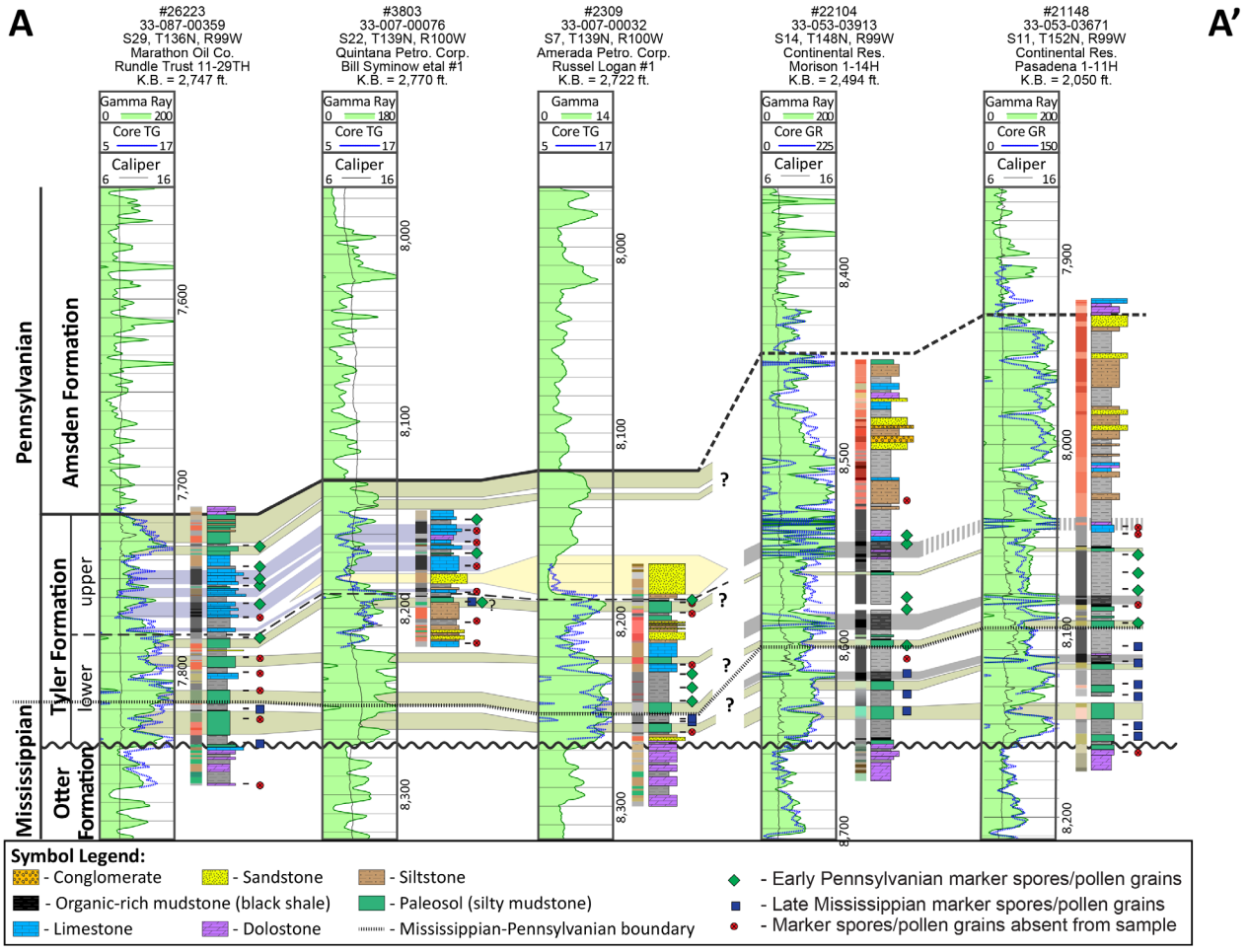

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Edward C. Murphy, State Geologist
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Core Laboratories, Inc. - palynological reports and data

ABSTRACT

The Tyler Formation is a sedimentary rock unit present in western North Dakota's subsurface that is stratigraphically positioned at the Mississippian-Pennsylvanian boundary (Lower-Middle Carboniferous). Early reports from the 1940s referred to the Tyler equivalent sedimentary rock section as the Heath Formation and assumed the unit was Late Mississippian in age. The name and geologic age of the Tyler/Heath section transitioned over the ensuing decades. Presently, the North Dakota stratigraphic column exclusively uses the term Tyler Formation for the sedimentary rock section positioned between the Otter and Amsden Formations and places the entire Tyler Formation within the Pennsylvanian Period. Recently completed biostratigraphy palynology supports that most of the Tyler Formation is Pennsylvanian, but indicates that the basal portion of the formation may be Late Mississippian. This report provides an introduction, context, and summary of recently completed palynological efforts to characterize the age of the Tyler Formation.

INTRODUCTION

The Tyler Formation is an oil and gas-producing rock unit in western North Dakota that is stratigraphically positioned at the Mississippian-Pennsylvanian boundary in western North Dakota (Figs. 1 and 2). The name and geologic age assignments of the Tyler Formation have

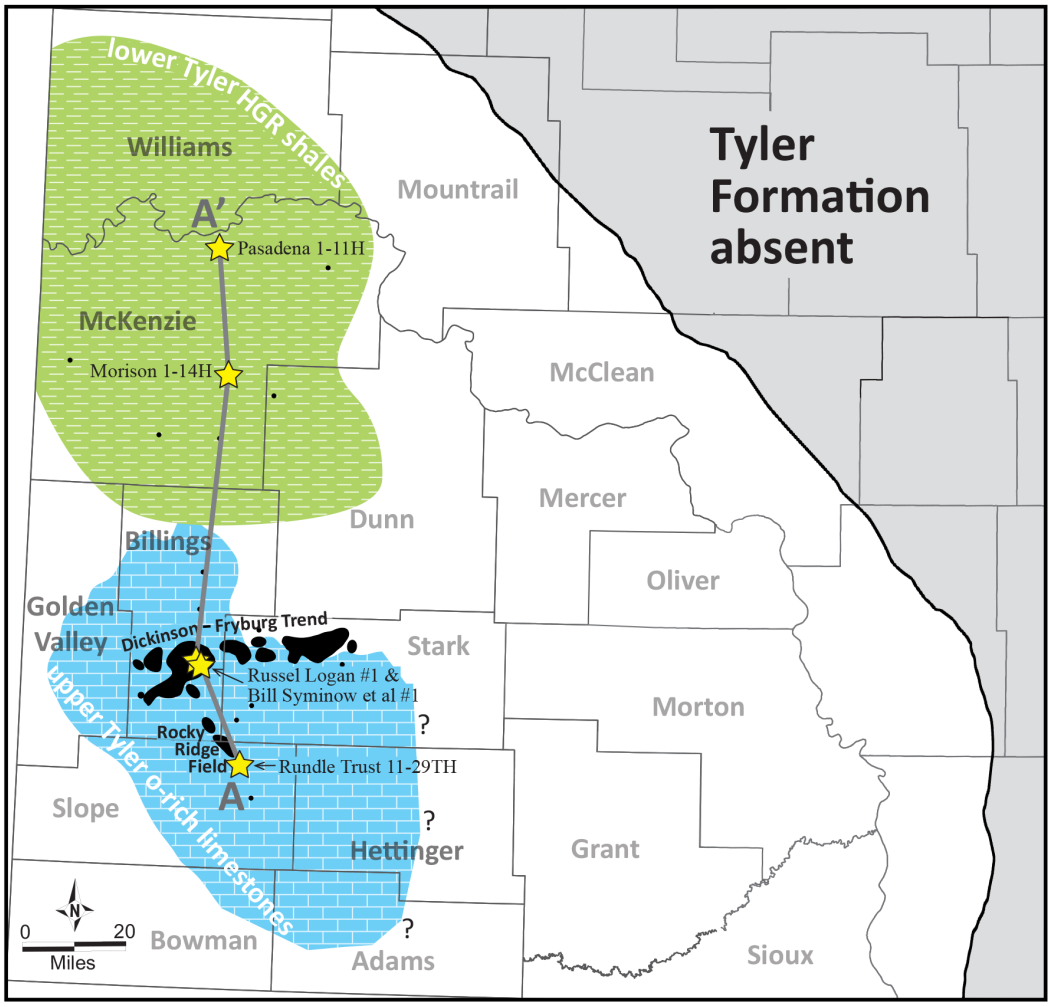

FIGURE 1.
Map of study area displaying the study cores (yellow stars), historical Tyler oil and gas fields (black areas), and thermally mature petroleum source beds (blue and green areas).

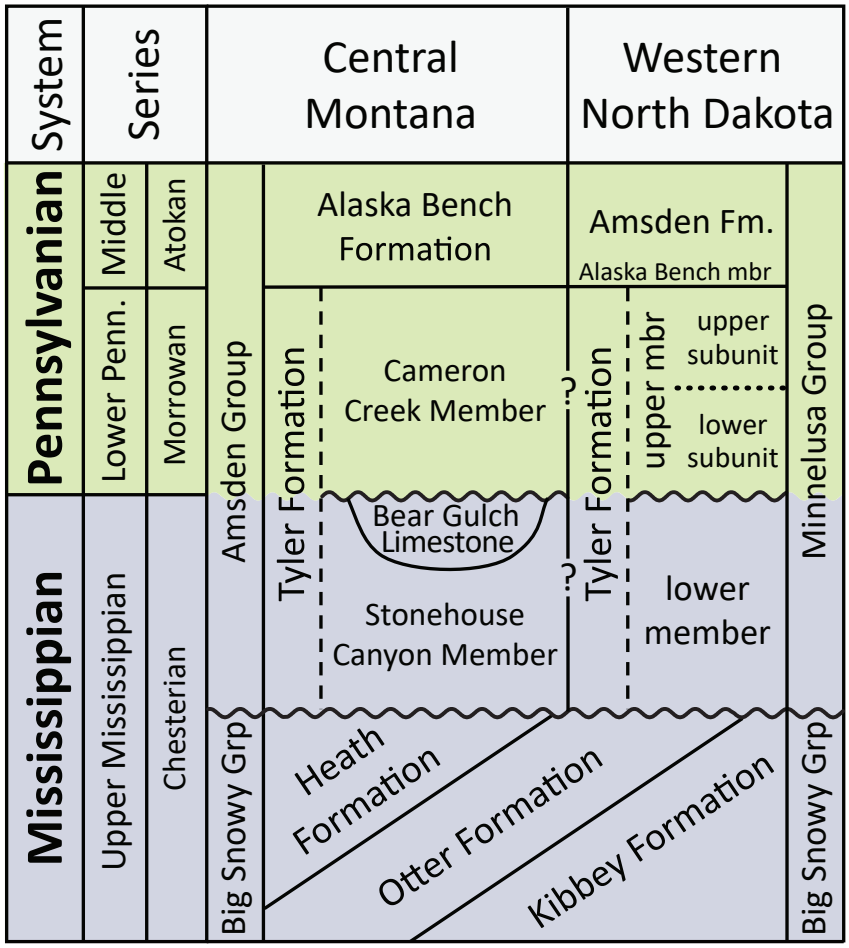

FIGURE 2.
Stratigraphic nomenclature for the lower Pennsylvanian and upper Mississippian for central Montana (modified from Smith and Gilmour, 1979; Williams, 1983; Maughan, 1984) and western North Dakota (modified from Sturm, 1983; Murphy et al., 2009). Wavy lines signify unconformities.

evolved over the past 70+ years. Early subsurface stratigraphy reports from the 1940s, which were based upon very limited well control and drill cutting samples, referred to the approximate Tyler Formation equivalent sedimentary rock section as the Heath Formation and placed a Mississippian age assignment to the unit (Laird, 1944; 1946).

Following the discovery of commercial oil resources in western North Dakota in 1951, including the Tyler Formation during the 1950s, thousands of well penetrations and hundreds of cores of the Tyler Formation have added substantial geologic information on the unit. Multiple stratigraphic studies have been completed on the Tyler Formation which led to a renaming of the unit from the Heath to Tyler Formation and a change from a Mississippian to Early Pennsylvanian age assignment. The most extensive, publicly available biostratigraphy study of the Tyler Formation was completed by Grenda (1977), which examined 34 Tyler cores and concluded that the formation is Pennsylvanian in age. Following Grenda's study, the state of North Dakota shifted to recognizing the Tyler Formation as being exclusively Early Pennsylvanian (Middle Carboniferous) (Bluemle et al., 1981; 1986), a name and age distinction that has continued to the current day (Murphy et al. 2009).

Most of the Tyler Formation cores that Grenda (1977) examined primarily spanned the upper portions of the formation in southwestern North Dakota, where most Tyler productive oil wells have been drilled. A more recent phase of exploration drilling and coring of the Tyler Formation during the early 2010s has added multiple complete cores of the formation across a more geographically extensive area (e.g., Nesheim, 2017). One of those recent cores, Marathon Oil Company's Rundell Trust 11-29H (NDIC: 26223, API: 33-087-00359, S29-T136N-R99W), had an unpublished palynology study completed on 10 core samples of the Tyler Formation. Three samples from the basal portions of the Tyler Formation within the Rundle Trust core identified palynomorphs indicative of a Late Mississippian (Chesterian, Early Carboniferous) age, while overlying samples contained Pennsylvanian palynomorphs.

Bottjer et al. (2020) recently conducted regional stratigraphic correlations of the Tyler Formation between the Central Montana Trough, which contains abundant biostratigraphic data, and western North Dakota, which contains limited biostratigraphy. Their study correlated most of the Tyler Formation in southwestern North Dakota (Dickinson-Fryburg trend) with the Stonehouse Canyon Member of the Central Montana Tyler Formation, which is Late Mississippian (Chesterian) in age. Additionally, they correlated the lower Tyler Formation within the central basin area (McKenzie County) with the Heath Formation of Central Montana, which underlies the Stonehouse Canyon Member and is also Late Mississippian (Chesterian) in age. Therefore, Bottjer et al. (2020) concluded that most of the Tyler Formation in western North Dakota is Late Mississippian based upon their regional correlations.

The assigned age of the Tyler Formation in the subsurface of western North Dakota has continued to vary over the past 80 years from Late Mississippian to Early Pennsylvanian. Published biostratigraphic data for the Tyler Formation in western North Dakota was previously limited to Grenda (1977). The purpose of this study is to examine the biostratigraphy of the Tyler Formation using the palynological analysis of recovered spores and pollen grains across multiple complete to near-complete cores in the Williston Basin. Refining the depositional age of the Tyler Formation will enable future studies to better understand its regional and global geological context.

METHODS

Five cores of the Tyler Formation were selected to form a north-south transect, extending from the conventional sandstone production areas of the Dickinson-Fryburg trend to the central basin region (~McKenzie County) (Figs. 1, 3, and 4; Table 1). Three of these cores span the entire Tyler Formation (Rundle Trust 11-29TH, Pasadena 1-11H, and Morison 1-14H), while the remaining two (Russel Logan #1 and Bill Syminow etal #1) combine to form a near-complete section of the formation. Each core was described/logged and lithological logs were created in Adobe Illustrator. Core gamma ray logs were compiled from NDIC (North Dakota Industrial Commission) well files or generated at the Wilson M.

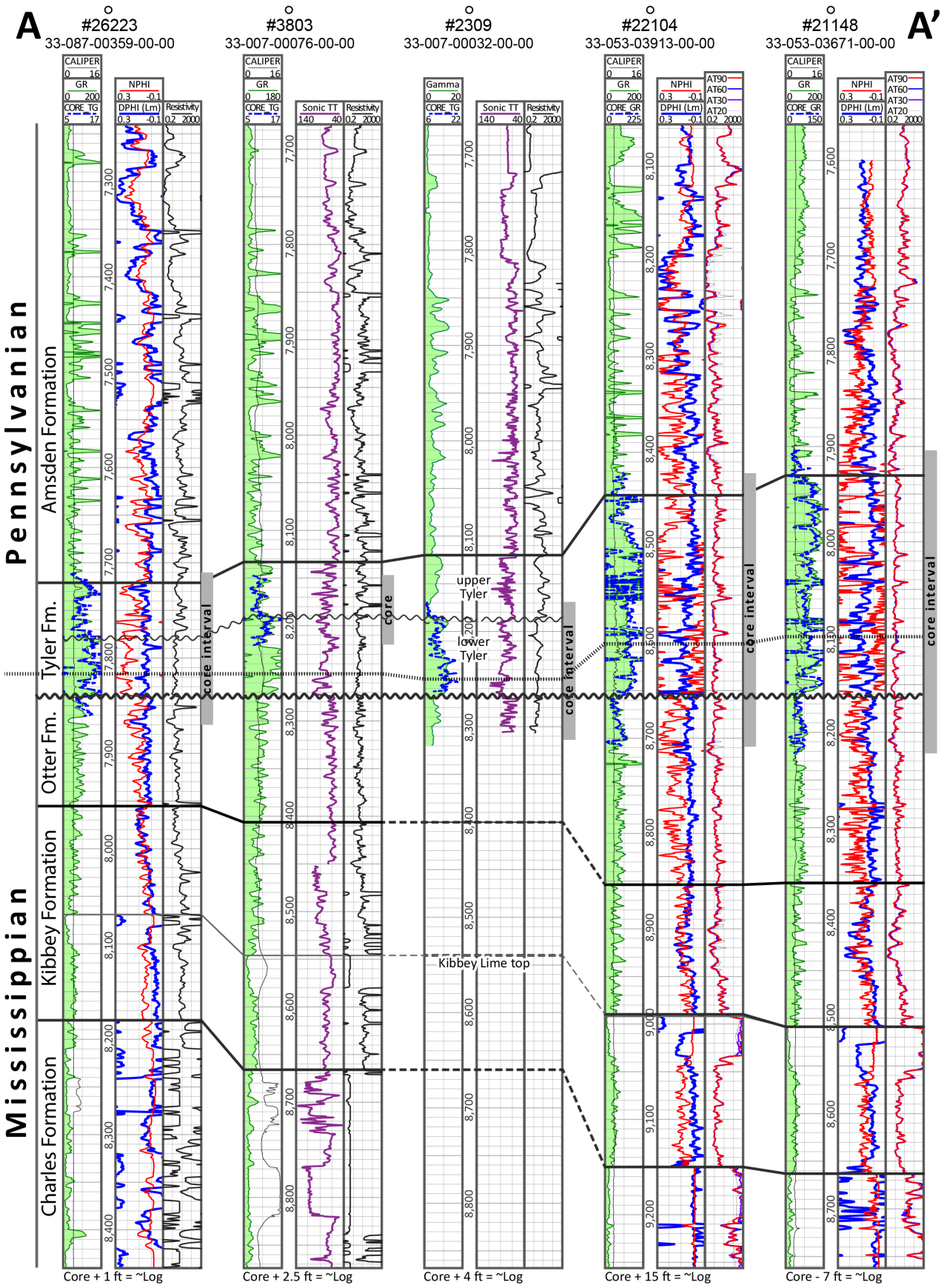

FIGURE 3. Stratigraphic cross-section of the Amsden, Tyler, Otter, Kibbey, and upper Charles Formations displaying the study core intervals.

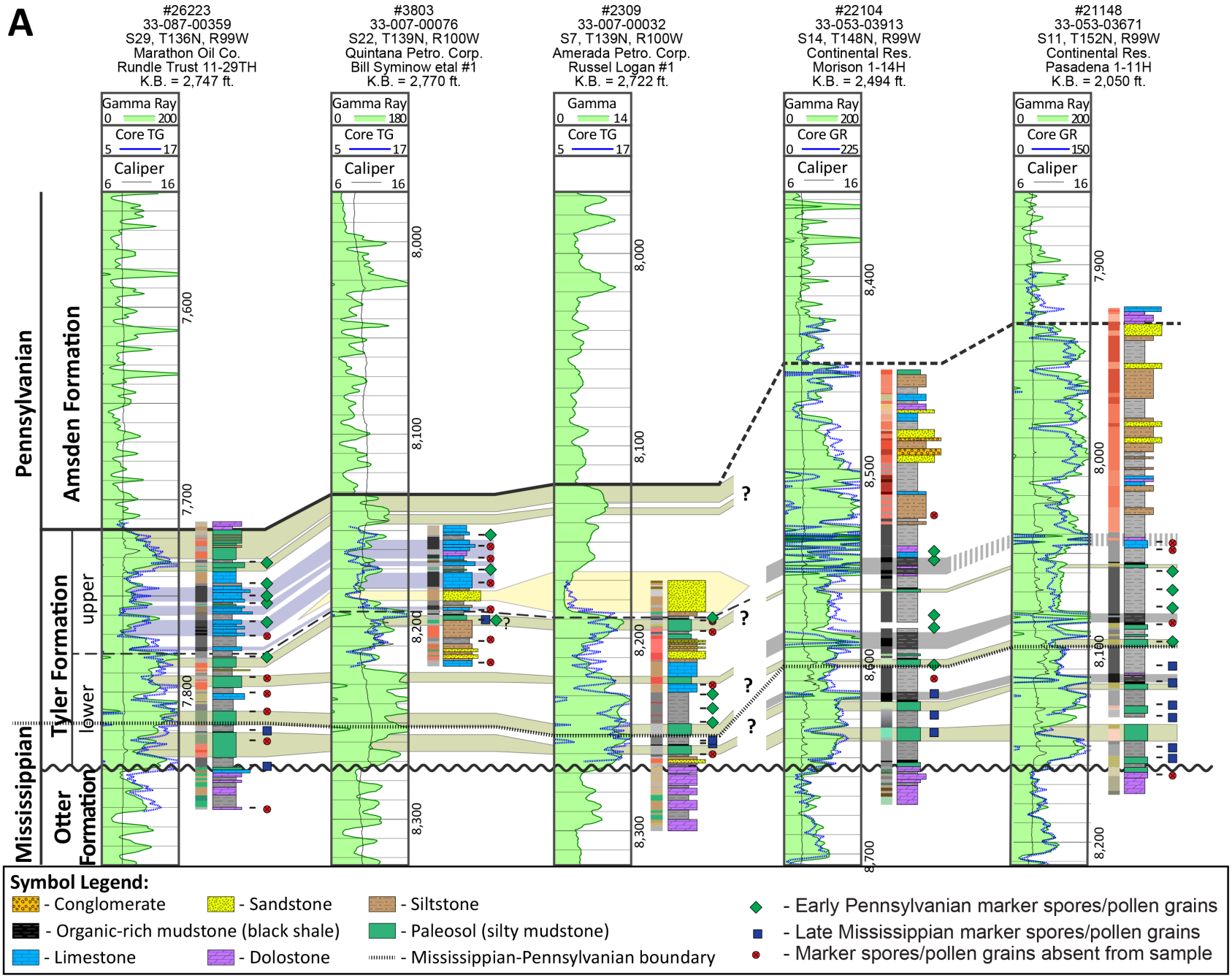

FIGURE 4. Stratigraphic cross-section of the Tyler Formation with core-log illustrations of the study cores and palynological sample locations. Rock color is displayed on the left-hand side of each core-log illustration.

TABLE 1. Well Information for logged (described) and sampled core intervals.

NDIC #	API Number	Original Well Name	Original Operator	Section-Township-Range	Latitude	Longitude	Core Top (ft)	Core Base (ft)
2309	33-007-00032-00-00	RUSSEL LOGAN #1	AMERADA PETROLEUM CORP.	NWSE 7-139-100	46.866791	-103.344979	8165	8310
3803	33-007-00076-00-00	BILL SYMINOW ETAL #1	QUINTANA PETROLEUM CORP.	NENW 22-139-100	46.845249	-103.285984	8145	8218
21148	33-053-03671-00-00	PASADENA 1-11H	CONTINENTAL RESOURCES, INC.	SESW 11-152-99	47.99341	-103.318385	7910	8228
22104	33-053-03913-00-00	MORISON 1-14H	CONTINENTAL RESOURCES, INC.	NWNE 14-148-99	47.644848	-103.258534	8406	8691
26223	33-087-00359-00-00	RUNDLE TRUST 11-29TH	MARATHON OIL COMPANY	NWNW 29-136-99	46.568586	-103.15237	7710	7860

Laird Core and Sample Library, with each core depth adjusted to align with wireline logs. Regional correlations were made using these wireline logs. A total of 59 samples were collected from the five described and logged Tyler Formation cores with approximately one sample per 10 feet. These samples were sent to Core Labs and subcontracted to a palynologist consultant (Dr. Ahmed Mansour) for sample preparation and evaluation in support of palynological biostratigraphy.

LITHOSTRATIGRAPHY

Tyler Formation

The Tyler Formation is comprised primarily of interbedded paleosols and marine to non-marine siliciclastic mudstones with variable amounts of carbonate beds depending on location (e.g., Fig. 5). The paleosol horizons are generally medium grey to green and occasionally red silty mudstone. Lower contacts are gradational with the underlying parent material while upper contacts are sharp, commonly with a thin coal bed up to a few inches thick. Siliceous and/or calcareous nodule horizons are sometimes present as well as carbonized plant fragments. Minor amounts of poorly sorted silt to sand-sized grains, angular to rounded in shape, are commonly observed in thin-section.

The marine to non-marine siliciclastic mudstones are medium to very dark grey and faintly laminated. Fossil assemblages range from normal marine (brachiopods, crinoids, and corals) to brackish (ostracods and *Lingula* brachiopods) to freshwater (bivalves), similar to faunal assemblages described in more detail by Grenda (1977). Fossiliferous storm beds are intermittently present. Siliceous nodules tend to occur where marine fossils are absent.

Additional lithologies of note in the Tyler Formation include limestone, sandstone, and black shale. In southwestern North Dakota, medium grey-brown to very dark grey/black lime mudstone and fossil lime wackestone to packstone beds occur in the Tyler Formation in increasing frequency moving upwards in section. Also in southwestern North Dakota, medium grey to dark brown (oil-stained) quartz sandstone is locally present in proximity to the upper-lower Tyler contact along the Dickinson-Fryburg trend. In west-central North Dakota, up to three distinct beds of black shale (organic-rich mudstone) with high gamma-ray signatures are present (Nesheim and Nordeng, 2016).

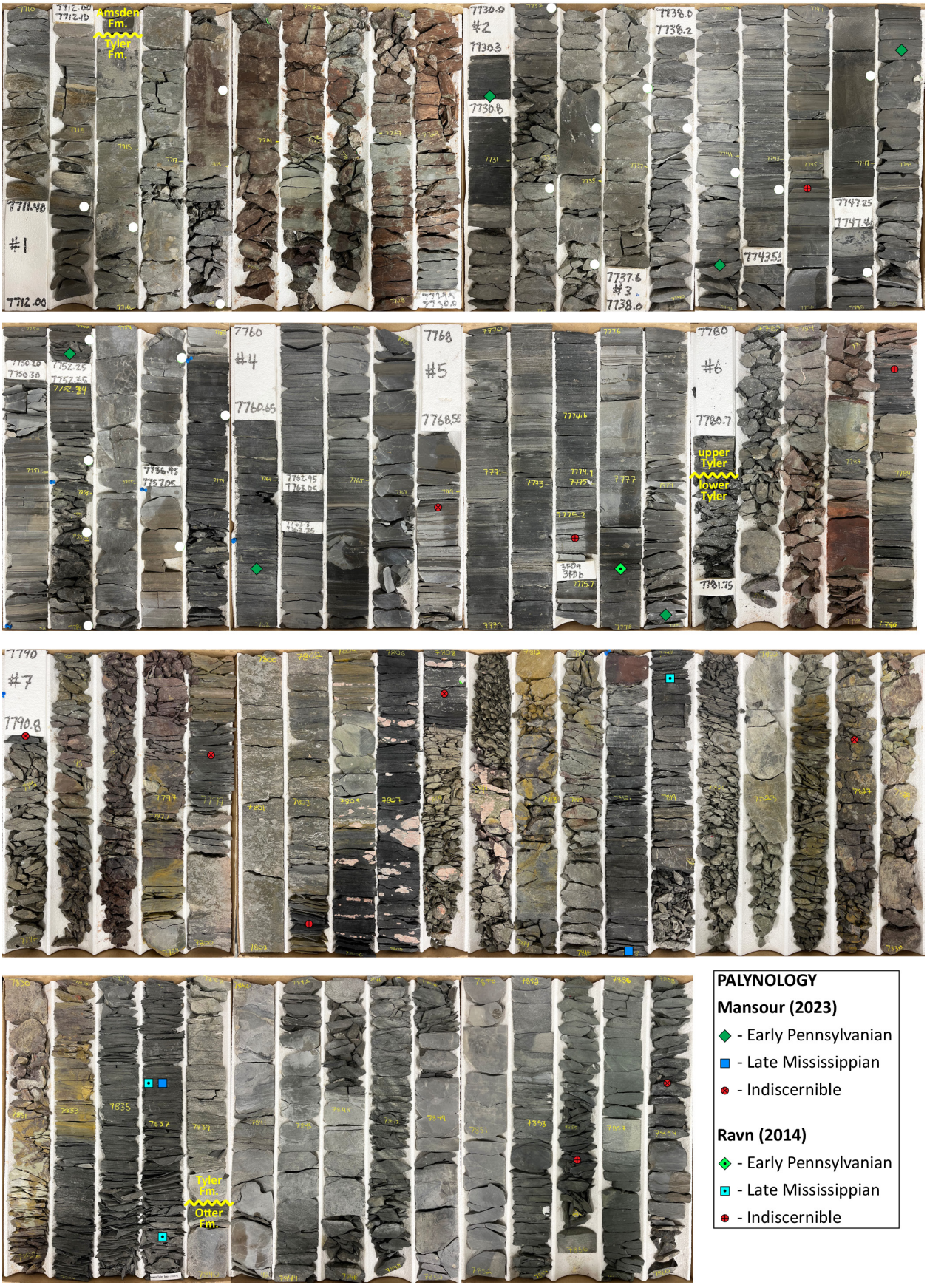

FIGURE 5. Core photographs of a complete Tyler Formation section from Marathon's Rundle Trust 11-29TH (NDIC: 26223, API: 33-087-00359-00-00) with palynology sample locations and age distinctions. White circles within depth interval 7,713-7,759 ft. are covering core labels/stickers.

Otter Formation

The upper portions of the Otter Formation logged in the study cores is primarily comprised of two lithofacies: 1) medium to dark grey to green, siliceous-argillaceous mudstone to claystone, slightly calcareous and/or dolomitic in part, and 2) medium tan/brown to grey, poorly to well laminated, slightly argillaceous, silty dolostone that is calcareous and/or lithoclast-bearing in part (e.g., Fig. 5). Contacts between the two facies are occasionally sharp, but tend to be gradational. Wave ripples are occasionally present in the laminated dolostone. Fossil content is minimal but includes occasional small shells and ostracods. When preserved in core, the Tyler-Otter contact tends to be sharp with brecciation/rip-up clasts along the formational contact.

Palynostratigraphic Synopsis

Core samples were processed and examined for biostratigraphic purposes from the middle and upper portions of the Tyler Formation. The recovered palynomorph assemblages included several age-diagnostic spores, which suggest an Early Pennsylvanian (Morrowan) age (Figs. 4 and 6). Notably, Early Pennsylvanian (Morrowan) marker palynomorphs include *Cirratriradites saturnii, Crassispora kosankei, Sinuspores sinuatus,* and *Triquitrites Sinani* (Fig. 6). Meanwhile, palynomorph assemblages of core samples collected from the basal portions of the Tyler Formation were found to consistently indicate a Late Mississippian (Chesterian) age (Figs. 4 and 7). The Late Mississippian (Chesterian) palynomorphs include *Tripartites vetustus, Densosporites diatretus,* and *Knoxisporites triradiatus* (Fig. 7). Of the 59 core samples evaluated, 21 contained palynomorph assemblages indicative of Early Pennsylvanian affinity, 13 samples contained palynomorph assemblages indicative

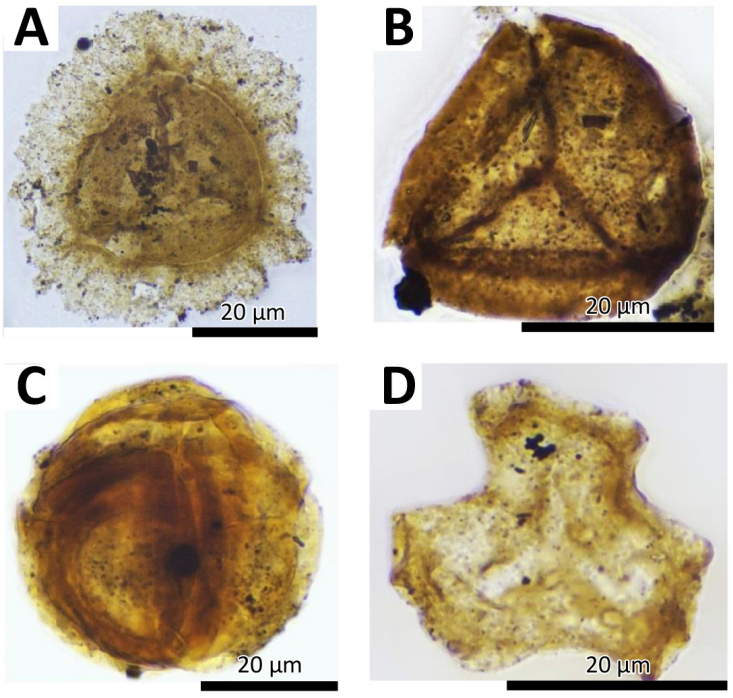

FIGURE 6.
Photomicrographs under transmitted white light microscopy of recovered palynomorphs with Early Pennsylvanian affinity from Tyler Formation cores of western North Dakota. **A)** *Cirratriradites saturnii* from Pasadena 1-11H (#21148) at core depth 8,075.5 ft, **B)** *Crassispora kosankei* from Bill Syminow etal #1 (#3803) at core depth 8,149 ft, **C)** *Sinuspores sinuatus* from Rundle Trust 11-29TH (#26223) at core depth 7,730.7 ft, and **D)** *Triquitrites Sinani* from Pasadena 1-11H (#21148) at core depth 8,075.5 ft. Scale bars are located in the bottom right corner of each image.

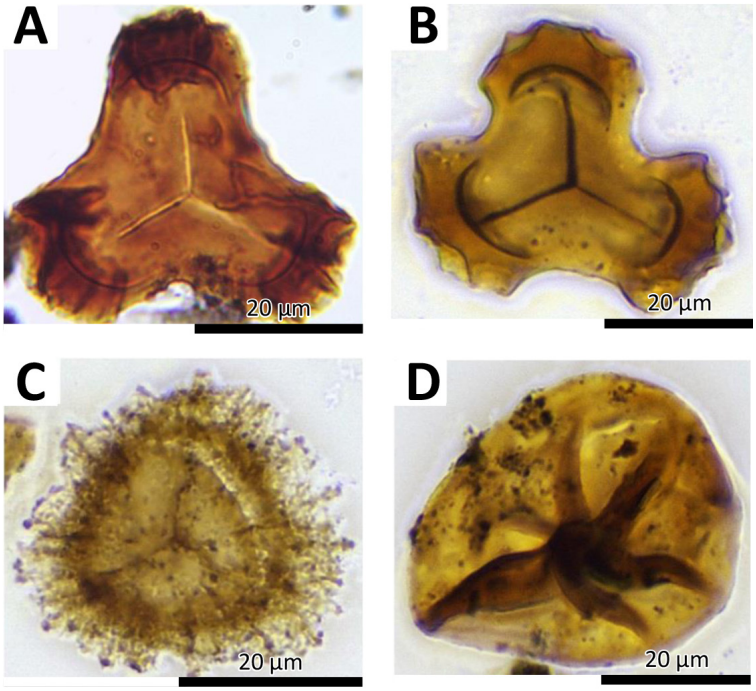

FIGURE 7.
Photomicrographs under transmitted white light microscopy of recovered palynomorphs with Late Mississippian affinity from Tyler Formation cores of western North Dakota. **A)** *Tripartites vetustus* from Pasadena 1-11H (#21148) at core depth 8,160 ft, **B)** *Tripartites vetustus* from Rundle Trust 11-29TH (#26223) at core depth 7,818 ft, **C)** *Densosporites diatretus* from Pasadena 1-11H (#21148) at core depth 8,154.6 ft, and **D)** *Knoxisporites triradiatus* Russel Logan #1 (#2309) at core depth 8,250 ft. Scale bars are located in the bottom right corner of each image.

of Late Mississippian affinity, 24 samples were indiscernible, and one sample was questionable (Bill Syminow et al #1, NDIC: #3803, depth: 8,193 ft).

Based upon the palynostratigraphic and lithostratigraphic correlations of the five study cores, the Mississippian-Pennsylvanian boundary appears to occur within the lower Tyler Formation. All four study cores that extend across the lower Tyler-Otter Formation contact yielded two or more lower Tyler core samples with Late Mississippian palynomorphs, which are overlain by multiple samples with Early Pennsylvanian palynomorphs (Fig. 4). Based upon the available data and preliminary stratigraphic correlations, the Mississippian-Pennsylvanian boundary appears to trend with lower Tyler paleosol horizons (Fig. 4), indicating the boundary represents a prolonged phase of subaerial exposure that developed and preserved a paleosol.

Multiple formations within the Williston Basin of western North Dakota contain geologic time boundaries. The Devonian-Mississippian boundary is located within the Middle Member of the Bakken Formation (Holland et al., 1987; Thrasher, 1987). Additionally, the Ordovician-Silurian boundary occurs within the upper portions of the Stonewall Formation (Nowlan and Haidl, 1999). Given that the rock types directly above and below the Mississippian-Pennsylvanian boundary in the lower Tyler Formation are comparable with one another, the lithostratigraphic assignment of the Tyler Formation does not need to be adjusted.

The supplementary material of this report includes the original palynological reports prepared by Dr. Ahmed Mansour, from which the palynological data from Figures 5 and 6 as well as the palynomorph images on Figures 6 and 7, were extracted. Additionally, Dr. Mansour has published an initial paper on the Tyler Formation palynology (Mansour et al., 2024) and is currently preparing a second manuscript.

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