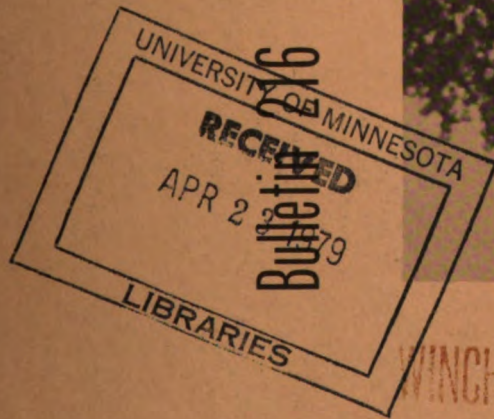


Stratigraphy of the Lower Permian Wreford Megacyclothem in Southernmost Kansas and Northern Oklahoma



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Stratigraphy of the Lower Permian Wreford Megacyclothem in Southernmost Kansas and Northern Oklahoma

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EXECUTIVE SUMMARY

Previous studies of the Nebraska and Kansas portions of the Wreford Megacyclothem have yielded extensive knowledge of the lithology, stratigraphic relationships, paleogeography, and paleoenvironmental implications of these rocks. However, comparably detailed understanding of the Oklahoma Wreford has not been achieved until now, as presented in this paper. This thorough knowledge of Wreford stratigraphy will provide background for making detailed studies of the various well-preserved Wreford fossil groups. An improved understanding of the environment at the time of deposition of the Wreford will result.

Field tracing of the stratigraphic units of the Wreford Megacyclothem into northern Oklahoma reveals that major facies changes take place within a short distance south of the Kansas-Oklahoma border; there, all of the typically marine Wreford horizons of Kansas grade laterally into interbedded red shales and red sandstones. Several units (the entire Speiser, middle and upper Havensville, upper Schroyer, and the Wy-more) become red beds only a few miles south of the border. The remaining horizons comprise two marine tongues extending farther south and thus indicate shoreline fluctuations of the Wreford sea. The upper tongue, newly discovered and poorly exposed, includes

algal-molluscan limestone (lower Schroyer) overlain by grayish-yellow mudstone (middle Schroyer), and extends to about 40 miles (64 km) south of the state line. The lower tongue consists of two algal-molluscan limestones (lower Threemile and lower Havensville equivalent) bracketing a thin brachiopod-molluscan limestone (middle and upper Threemile), and extends to about 50 miles (80 km) south of the border. Both tongues pass through tan quartzose sandstone or red clayey molluscan limestone as they grade southward into red shale and red sandstone.

The Wreford in Oklahoma is dominated by fewer rock types than in Kansas. Red shales interbedded with red sandstones comprise the greatest volume of any rock type. Also important are pelecypod-burrowed algal-molluscan limestones. These rocks show southward increases in molluscs, algally (*Osagia*) or inorganically coated grains, and fine quartz sand content, along with a simultaneous decrease in brachiopods and bryozoans. These limestones may represent calcarenite shoals as well as shallow, level bottoms in the Wreford sea, immediately offshore from the coastal plain to the south. Other distinctive Oklahoma Wreford rock types include tan quartzose sandstone and red clayey molluscan limestone.

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ANNE B. LUTZ-GARIHAN¹
AND
ROGER J. CUFFEY²

Stratigraphy of the Lower Permian Wreford Megacyclothem in Southernmost Kansas and Northern Oklahoma

INTRODUCTION

Purpose of Study

The stratigraphy and environments of deposition of the Lower Permian Wreford Megacyclothem in Kansas were studied intensively by Hattin (1957). Thus, it became possible to accomplish detailed investigations of the various fossil groups present in the Wreford Megacyclothem against the stratigraphic, lithologic, paleoecologic, and geographic background provided by Hattin's Kansas study.

Such detailed paleontologic investigations began with study (Cuffey, 1967) of the bryozoan *Tabulipora carbonaria*. Treatments of the Wreford rhomboporoids (Newton, 1971) and fistuliporoids (Warner and Cuffey, 1973) soon followed. Currently, in addition to several other bryozoan groups, the various brachiopod groups present in the Wreford Megacyclothem are being studied; investigation of the Wreford population of the brachiopod *Composita* has been completed (Garihan, 1973; Lutz-Garihan, 1976).

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Because Hattin (1957) had worked out the detailed stratigraphy of the Wreford only within the boundaries of Kansas, comparably extensive interpretation of the southernmost portions of the megacyclothem did not exist until now. Therefore, in order to provide comprehensive knowledge of the Oklahoma Wreford and to complete the detailed background for bryozoan and brachiopod investigations in progress, measured stratigraphic sections (Appendix) of the Wreford Megacyclothem in Oklahoma were studied in detail. Results of this study are reported in this paper; the information concerning the detailed stratigraphy of the Oklahoma Wreford is presented so that it can be meshed with knowledge of the Kansas Wreford. Therefore, for the first time a comprehensive view of the entire Wreford throughout its geographic extent can be obtained.

Methods of Investigation

As the basis for the present study, stratigraphic sections were examined and measured, and rock samples (as well as brachiopods) were collected from Wreford outcrops in southernmost Kansas and northern Oklahoma. These measured sections are described in the Appendix.

Localities upon which the extension of Wreford stratigraphy into Oklahoma is based are briefly listed (Table 1) and mapped (Figure 1). More detailed descriptions of each may be found in previous papers (Cuffey, 1967; Newton, 1971; Lutz-Garihan, 1976). The numbering system for those works is continued here in order to facilitate integrated use of all these contributions.

Rock samples included bulk samples of shales for laboratory kerosining, chips of indurated rocks (mostly limestones and sandstones) for oriented thin-sections, and chunks of limestones, sandstones, and shales for insoluble residue studies. Thin-sections of key beds were examined to determine both rock type and fossil content.

Insoluble residues, determined as weight percentages of constituents for key beds, also provided information relevant to the present stratigraphic study. These percentages are indicated in the Appendix. The rock samples were crushed and weighed and then dissolved in acetic acid for two to four days; the resulting residue was dried and weighed. The residue was next washed through a 100 mesh screen (to remove the clays), dried again, and finally observed with a binocular dissecting microscope.

TABLE 1. Wreford localities in southernmost Kansas and northern Oklahoma.

Locality Number	Locality Type	Locality Location	
CY30	road cut	NW ¼ sec. 30, T.33S., R.7E.	Cowley Co., Kansas
CY32	road cut	SW ¼ sec. 31, T.33S., R.7E.	
CY33	road cut	NE ¼ sec. 12, T.34S., R.6E.	
CY34	road cut	NW ¼ sec. 11, T.34S., R.6E.	
CY35	road cut	NW ¼ sec. 11, T.34S., R.6E.	
CY36	road cut	NE ¼ sec. 10, T.34S., R.6E.	
CY37	spillway	SW ¼ sec. 8, T.34S., R.6E.	
CY38	road cut	SW ¼ sec. 18, T.34S., R.7E.	
CY39	road cut	SW ¼ sec. 18, T.34S., R.7E.	
CY40	road cut	center sec. 23, T.34S., R.5E.	
CY41	stream bed	NW ¼ sec. 33, T.34S., R.5E.	
CY43	stream cut	SE ¼ sec. 8, T.35S., R.6E.	
CY44	gully	SE ¼ sec. 7, T.34S., R.6E.	
CY45	gully	NW ¼ sec. 29, T.34S., R.7E.	
CY46	road cut	SE ¼ sec. 30, T.34S., R.7E.	
CY47	road cut	NW ¼ sec. 31, T.34S., R.7E.	
CY48	road ditch	SW ¼ sec. 31, T.34S., R.7E.	
CY49	stream cut	NW ¼ sec. 13, T.35S., R.6E.	
KA01	road ditch	NE ¼ sec. 30, T.29N., R.5E.	
KA02	road cut	NE ¼ sec. 30, T.29N., R.5E.	
KA03	gully	SW ¼ sec. 31, T.28N., R.5E.	
KA04	road cut	SW ¼ sec. 31, T.28N., R.5E.	
KA05	butte top	SW ¼ sec. 31, T.27N., R.5E.	
KA06	road cut	SW ¼ sec. 29, T.29N., R.5E.	
KA07	stream cut	NW ¼ sec. 19, T.29N., R.5E.	
KA08	hillside	NW ¼ sec. 12, T.27N., R.4E.	
OS01	road cut	SE ¼ sec. 30, T.26N., R.5E.	
OS02	gully	NE ¼ sec. 31, T.26N., R.5E.	
OS03	butte top	NW ¼ sec. 21, T.24N., R.4E.	
OS04	road cut	SW ¼ sec. 35, T.29N., R.5E.	
OS05	road ditch	NE ¼ sec. 2, T.24N., R.4E.	
PW01	road cut	SW ¼ sec. 3, T.22N., R.4E.	
PW02	road cut	SW ¼ sec. 18, T.22N., R.4E.	
PW03	road cut	SW ¼ sec. 21, T.23N., R.4E.	
NO01	road ditch	NE ¼ sec. 1, T.21N., R.3E.	
NO02	road ditch	NE ¼ sec. 1, T.21N., R.3E.	

Cowley
Co.,
Kansas

Kay
Co.,
Okla.

Osage
Co.,
Okla.

Pawnee
Co.,
Okla.

Noble
Co., Okla.

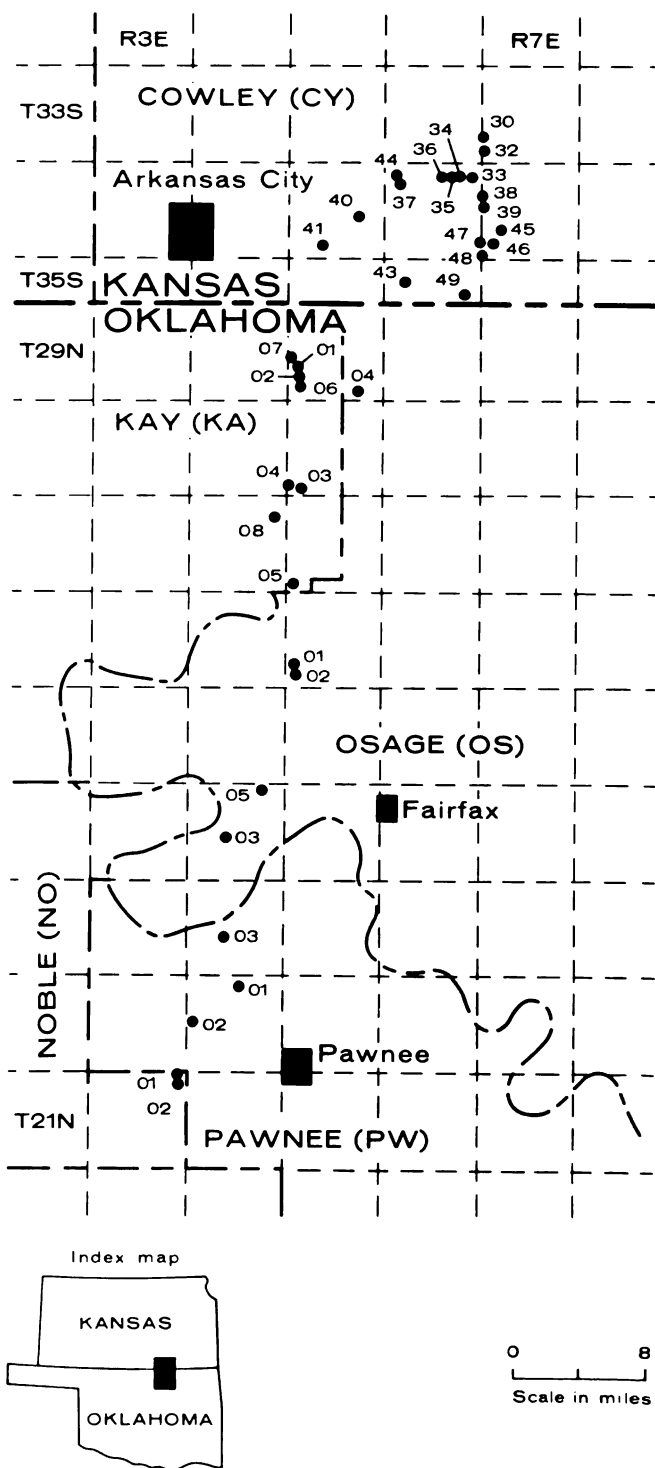


FIGURE 1. Wreford localities in southernmost Kansas and northern Oklahoma (separately numbered in each county).

HISTORICAL REVIEW OF WREFORD INVESTIGATIONS

Studies in Kansas

Historical summaries elsewhere (Hattin, 1957, p. 7-9; Cuffey, 1967, p. 8) adequately review the discovery and naming of the rock units contained in the Wreford Megacyclothem in Kansas, and thus will not be repeated here.

The location of the Wreford outcrop belt in Nebraska, Kansas, and Oklahoma is shown in Figure 2. In Nebraska, the Wreford is largely obscured by glacial deposits; moreover, only about 30 miles (48 km) north of the Nebraska-Kansas border, it disappears beneath Cretaceous rocks (Newton, 1971, p. 13). In Kansas, the Wreford rocks are widely exposed, yield abundant fossils, and display their cyclic character extremely well. However, once into Oklahoma, these rocks exhibit drastic changes. The entire Wreford section becomes a series of interbedded red shales and red sandstones, making the megacyclothem unrecognizable beyond a point about 50 miles (80 km) south of the Kansas-Oklahoma border (Garihan, 1973; Garihan and Cuffey, 1973). Newton (1971, p. 13-14) briefly reported results of a reconnaissance survey of these changes; the present paper contains results from a detailed investigation of Oklahoma Wreford stratigraphy. It modifies some and confirms other of his conclusions.

The rock units that contain the Wreford Megacyclothem are of Early Permian age, and belong to the top of the Council Grove Group and the basal Chase Group (Figure 3; Zeller, 1968, p. 43-48). The two cyclothem included in the Wreford (and indicated on Plate 1) are the Threemile cyclothem below and the Schroyer cyclothem above.

The detailed stratigraphy of the Wreford Megacyclothem throughout its region of outcrop can be summarized succinctly by the large cross-section (Plate 1). This cross-section represents updating of preliminary versions (Cuffey, 1967, p. 14-15; Newton, 1971, p. 8-9) along with new information generated by the present stratigraphic investigation and by companion Wreford brachiopod (Lutz-Garihan, in preparation) and bryozoan (Cuffey, in preparation) studies.

The many thin strata included within the Wreford Megacyclothem represent comparatively few rock types which recur in a cyclic pattern. The characteristics and paleoenvironmental interpretations of these rock types in Kansas have been treated in detail by Hattin (1957, p. 51-104), Cuffey (1967, p. 10-13), and

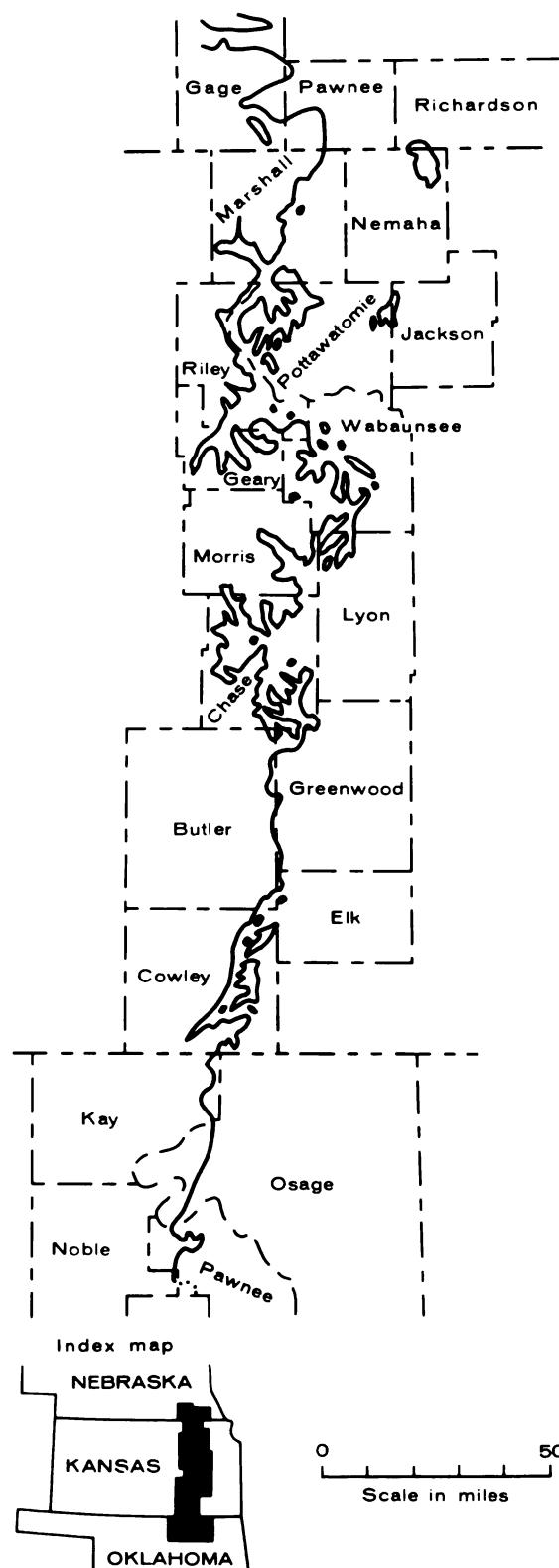


FIGURE 2. Outcrop of Wreford Limestone in Nebraska, Kansas, and Oklahoma (adapted from Geologic Bedrock Map of South-eastern Nebraska, 1966; Geologic Map of Kansas, 1964; and Geologic Map of Oklahoma, 1954).

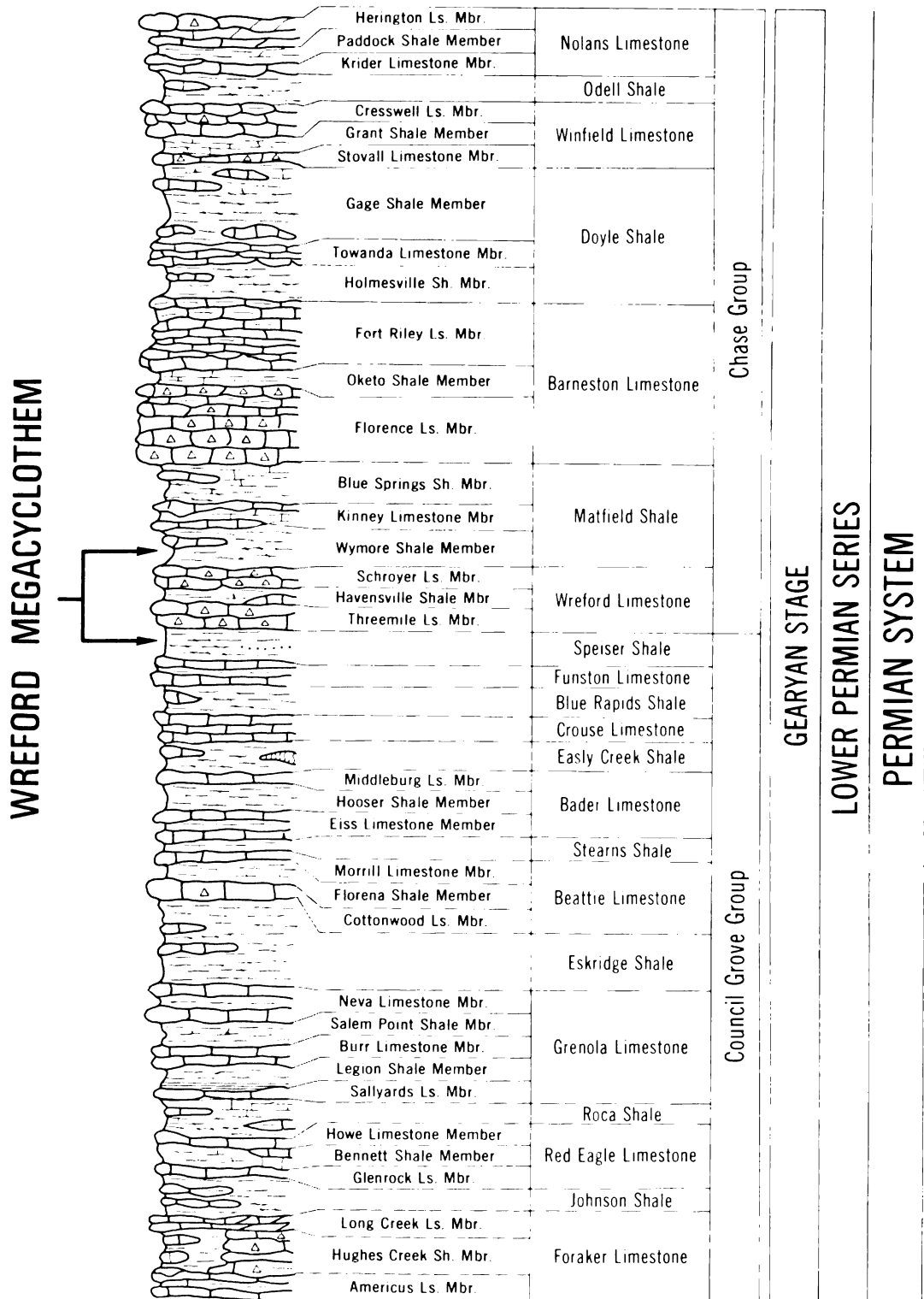


FIGURE 3. Stratigraphic column of part of the Kansas Lower Permian, including units contained in the Wreford Megacyclothem (adapted from Zeller, 1968).

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Newton (1971, p. 7-10). This information is briefly summarized here (Tables 2 and 3; see also Garihan, 1973, p. 191-198) to provide necessary background for the present stratigraphic study. In addition, a few papers which shed light on other aspects of Wreford rock types have appeared since these detailed descriptions.

TABLE 2. Abbreviations for Wreford rock types, used in Table 3 and Figure 4 to summarize aspects of Wreford stratigraphy.

Abbreviation	Rock Type
alg ls	algal limestone
alg-moll ls	algal-molluscan limestone
argill ls	argillaceous limestone
black sh	black shale
brach-moll ls	brachiopod-molluscan limestone
calc sh	calcareous shale
chlky ls	chalky limestone
chnl cgl	channel conglomerate
chty ls	cherty limestone
coal	coal
grn sh	green shale
gr-yl mud	gray-yellow mudstone
int brecc	intraformational breccia
moll ls	molluscan limestone
red sh	red shale
red ss	red channel sandstone
resid cl	red residual clay
tan ss	tan quartzose sandstone

Rasmussen and others (1971) report that a vertebrate assemblage from an intraformational conglomerate of Late Pennsylvanian age in Kansas includes sharks, fishes, reptiles, and amphibians. Thus, both fresh-water and marine vertebrates contributed to the debris found in these channel conglomerates.

Lee (1972) found little change vertically in clay mineralogy of the Havensville Shale Member, but significant variation laterally between near-shore and offshore marine shales. Kaolinite is found only in near-shore facies in southern Kansas. Montmorillonite decreases northward as illite increases, although some illite was probably derived diagenetically from the montmorillonite. Mixed-layer chlorite exists at all the localities studied but decreases in abundance northward. He concluded that both detrital and diagenetic effects are evident in this Havensville clay-mineral assemblage.

Isotopic data were also considered for the clay minerals of the Havensville Shale (Chaudhuri and Lee, 1972). These data imply that the clay minerals (especially illite) had inherited radiogenic strontium

TABLE 3. Paleoenvironmental interpretations of Wreford rock types, considered in approximate cyclic order (compiled from Hattin, 1957; Cuffey, 1967; and Newton, 1971).

Rock Type	Water Depth	Distance from Shore	Salinity	Water Movement	Substrate	Physiography
tan ss	very shallow	near	brackish	moderate	terrigenous sand	level sea bottom or intertidal flat
alg-moll ls	very shallow to 10' (?) to 60' (?)	near	brackish	moderate	carbonate mud or sand	level sea bottom or intertidal flat
alg ls	very shallow to 10' (?) to 60' (?)	near	brackish? (possibly hypersaline?)	sometimes moderate	carbonate sand or mud	level sea bottom or calcarenite shoal
chlky ls	very shallow to 10' (?) to 60' (?)	near to far	normal marine	weak?	carbonate mud	carbonate mud banks
chty ls	10' to 60'	near to far	normal marine	none	carbonate mud	level sea bottom
calc sh	10' to 30' (possibly to 60')	near to far	normal marine	none	mixed terrigenous and carbonate mud	level sea bottom
brach-moll ls	10' to 60'	near to far	normal marine or brackish	none to weak	carbonate mud	level sea bottom
moll ls	10' to 60'	near to far	normal marine or brackish	weak	carbonate mud	level sea bottom
int brecc	very shallow	near to far	normal marine or brackish	strong	mixed mud	level sea bottom
gry-yl mud	very shallow	near	brackish	weak?	terrigenous mud	level sea bottom
coal; black sh	very shallow	near	brackish	none?	plant debris	depressions in sea bottom
grn sh	very shallow or low intertidal	very near or onshore	brackish	weak?	terrigenous mud	intertidal flat or level sea bottom
red sh	very shallow or high intertidal	very near or onshore	fresh or brackish	weak?	terrigenous mud	flood plain or intertidal flat
red ss	very shallow	very near or onshore	fresh or brackish	strong	terrigenous sand	stream channel
chnl cgl	very shallow	very near or onshore	fresh or brackish	strong	terrigenous gravel	stream channel

at the time of deposition, that the illites are detrital, and that the clays from northern versus southern Kansas were derived from different sources.

Chaudhuri and Methot (1972) discussed reasons for high Sr⁸⁷/Sr⁸⁶ values in Permian limestones in general, because a high value may imply that this ratio was also high for the isotopic composition of the environment of deposition. They conclude merely that the strontium-isotopic composition of limestones might help in reconstructing the environment in which these rocks were formed.

Turning attention again to more general matters, the distribution of the various rock types throughout the formally recognized rock-stratigraphic units containing the Wreford Megacyclothem also has been considered extensively by previous writers (Hattin, 1957, p. 24-50; Cuffey, 1967, p. 13-14). Again, this information is presented succinctly by the detailed

cross-section (Plate 1), and is also summarized by Garihan (1973, p. 199-202).

Inspection of the Wreford cross-section (Plate 1) indicates that many strata can be traced laterally for considerable distances. Further study has permitted the subdivision of the Wreford strata into 22 successive stratigraphic horizons (Cuffey, 1967, p. 71-72), each dominated by one or only a few rock types as it is traced laterally throughout the Wreford outcrop belt. Because these horizons have proven so useful in previous studies (as, for example, Cuffey, 1967, p. 73-78), they have been tabulated here (Table 4). The dominant rock types at each horizon in each geographic region are also briefly indicated (Figure 4), although this information could also have been presented in more detail in the form of 22 lithofacies maps, one for each of the 22 horizons.

Each of the 22 Wreford horizons mapped is a rock

TABLE 4. Abbreviations for stratigraphic horizons recognized within the Megacyclothem and utilized in clarifying Wreford stratigraphy in southernmost Kansas and Oklahoma.

ABBREVIATION	STRATIGRAPHIC HORIZON		
mMw	middle part] —of Wymore Shale Member]	—of Matfield Shale
lMw	lower part		
uWs	upper part] —of Schroyer Limestone Member]	
umWs	upper beds		
lmWs	lower beds		
lWs	lower part] —of Havensville Shale Member]	—of Wreford Limestone
uuWh	upper beds		
luWh	lower beds		
mWh	middle part		
ulWh	upper beds		
ullWh	upper portion		
lllWh	lower portion] —of Threemile Limestone Member]	
uuWt	upper beds		
muWt	middle beds] —of upper part]	
luWt	lower beds		
mWt	middle part		
lWt	lower part] —of upper part]	—of Speiser Shale
uuSp	upper beds		
muSp	middle beds		
uluSp	upper portion		
lluSp	lower portion		
mSp	middle part		

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	Northern Kansas and Southernmost Nebraska	Central Kansas	Southern Kansas	Southernmost Kansas and Northernmost Oklahoma	Northern Oklahoma
mMw	red sh	red sh	red sh	red sh	
lMw	grn sh	grn sh	grn sh	red sh	
uWs	alg ls	alg ls	alg ls	alg-moll ls	
umWs	chty ls; calc sh	brach-moll ls	chty ls; calc sh	calc sh	
lmWs	calc sh	calc sh	calc sh	calc sh	
lWs	chty ls	chty ls	chty ls	chty ls	
uuWh	calc sh	calc sh	calc sh	calc sh	
luWh	moll ls	brach-moll ls	alg ls	alg-moll ls	
mWh	gr-yl mud	gr-yl mud; calc sh	gr-yl mud	brach-moll ls	
ulWh	moll ls	brach-moll ls	alg ls	alg-moll ls	
ullWh	calc sh	calc sh	alg ls	alg-moll ls	
lllWh	calc sh	calc sh	alg ls	alg-moll ls	
uuWt	chty ls	chty ls	chty ls	chty ls	
muWt	chlky ls	chlky ls	chty ls	chty ls	
luWt	chty ls	chty ls	chty ls	chty ls	
mWt	calc sh	calc sh	calc sh	calc sh	
lWt	chty ls	chty ls	chty ls	brach-moll ls	
uuSp	calc sh	calc sh	calc sh; brach-moll ls	calc sh; brach-moll ls	
muSp	moll ls	moll ls	calc sh; brach-moll ls	gr-yl mud	
uluSp	gr-yl mud	gr-yl mud	gr-yl mud		
lluSp	grn sh	grn sh	gr-yl mud		(ruled pattern indicates interbedded red shale and red sandstone)
mSp	red sh	red sh	red sh		

FIGURE 4. Dominant rock types at each Wreford stratigraphic horizon in different geographic areas; rock type abbreviations from Table 2, stratigraphic horizon abbreviations from Table 4.

unit, rather than a time unit. There is no firm evidence for precisely locating time lines within the sections; for example, there are no marker beds such as bentonite layers that could indicate a time plane over the whole region. Consequently, the exact time significance of the 22 horizons is uncertain. Within Kansas, most workers have assumed that a cyclothem bed of a particular lithology is essentially time-parallel, and this has seemed a reasonable presumption in view of the remarkably widespread geographic extent and lithologic and thickness similarities of the rock units. McCrone (1963, p. 50) believed that a knife-sharp contact between a limestone and a black shale in the Red Eagle Cyclothem reflected a sudden widespread change in conditions of deposition and thus could be considered a time line. He then assumed that the rest of the rock units in the Red Eagle Cyclothem were also contemporaneous.

When the Wreford is traced into Oklahoma, where

most of the beds thin drastically and change lithology, the 22 stratigraphic horizons recognized in the Kansas Wreford can still be followed. Thus, although precise time relationships southward into Oklahoma are not certain, it still would seem reasonable to regard these horizons as essentially synchronous planes there, in the absence of evidence to the contrary.

Studies in Southernmost Kansas and Oklahoma

The rock units cropping out in east-central Oklahoma, a series of interbedded red sandstones and red shales, presented several problems to stratigraphers in the late 1800s. These problems included the geographic distribution of their red color, their geologic age, and their relationships to rocks in the adjoining states of Kansas and Texas (Beede, 1907).

In Texas, the red beds were initially assigned ages ranging from Permian to Tertiary, but only on the basis of lithostratigraphic evidence. Paleontologic

dating was first employed when Cope (1878) recognized the red beds as Permian, based on their contained vertebrate fossils. White (1889) described the first invertebrate fossils from the same units and concurred that the rocks were Permian. In 1901, Cummins divided the Texas Permian into three divisions, and for the first time indicated upper and lower boundaries for the Permian of this region. Cummins (1897) also noted that by walking north along an outcrop belt in Texas, the gradual lithologic change of a particular unit from fossiliferous limestone to unfossiliferous calcareous sandy clay could be observed.

In Kansas, many rock units are light-colored marine limestones with abundant invertebrate fossils which allowed early determination of their Permian age by various workers. Expanding upon this evidence, Cragin (1897) assigned a Permian age to the red beds in Kansas.

In Oklahoma, early workers had assumed that the so-called "color line," the northeastern boundary of the geographic area underlain by red beds, paralleled the strike of the late Paleozoic rocks. However, Adams (1898, 1901) traced two Carboniferous limestones along strike from Kansas, where both were gray limestones, into Oklahoma, where both changed to red beds. By noting the localities where these units changed from gray to red in color, Adams mapped a "line of color change," which surprisingly was "diagonal to the strike of the Carboniferous and Permian formations" (Adams, 1901, p. 386). Moreover, Adams' tracing demonstrated that the Oklahoma red beds were of the same age as the marine beds in Kansas. Although the examples studied were Carboniferous, Adams suggested that the same situation applied to the Permian beds and that therefore the Oklahoma red beds were also partly of Permian age. Gould (1901, 1902) also discussed the tracing of light-colored rocks in Kansas into red beds in Oklahoma; in 1905, he presented a geologic map of Oklahoma, in part based upon this practice.

Knowing that the Permian rocks of Kansas have their equivalents in Oklahoma red beds, the next problem was the correlation of specific units. In particular, Kirk (1905) tried to trace the Wreford Limestone across Oklahoma, and concluded that the Wreford is replaced by two coalescing layers of sandstone, the Payne, which in turn could be traced as far south as Norman, Oklahoma. Beede, in his thorough review of Midcontinent red-bed stratigraphic problems (1907, p. 135), mentioned Kirk's work, and expressed the hope that the Wreford-Payne could be traced on into Texas to provide "an unimpeachable connecting link between the Kansas and Texas Permian."

However, this correlation of the Wreford Limestone is not confirmed by the present detailed stratigraphic investigations. They show that the red sandstones in the Oklahoma Wreford are lenticular and do not extend laterally for more than short distances. Moreover, these sandstones are identical to those in southernmost Kansas, which can be interpreted paleoenvironmentally as stream-channel deposits on a wide alluvial coastal plain. Therefore, it is highly unlikely that any sandstone unit would be extensive enough to trace across much or all of Oklahoma. Moreover, in 1905 Kirk had access to only a few rock exposures, and no detailed studies of the sequence of Wreford rock units had yet been made; both factors would greatly magnify the difficulty of accurately correlating a particular unit. For these reasons, Kirk's correlation of the Wreford Limestone is rejected here, and the improbability of Beede's hopes ever being realized is suggested.

Several papers (Heald, 1916; White and others, 1922; Aurin, Officer, and Gould, 1926; Beckwith, 1928; Patterson, 1933; Grieg, 1959) are concerned with Permian rocks in Oklahoma. Information from their measured sections and regional geologic maps was valuable to the present study by indicating localities where the Wreford Megacyclothem units might be examined in outcrop.

WREFORD STRATIGRAPHY IN SOUTHERNMOST KANSAS AND OKLAHOMA

Lithologic Changes in Wreford Stratigraphic Horizons in Oklahoma

The 22 stratigraphic horizons recognized informally within the five formations or members comprising the Wreford Megacyclothem change lithologically from gray shales and limestones to red beds in Oklahoma a few miles south from Kansas. These changes are summarized in the detailed Wreford cross-section (Plate 1) and the chart of dominant lithofacies at each Wreford horizon (Figure 4). The evidence supporting these conclusions may be examined on the correlation chart of measured sections of the Wreford Megacyclothem in southernmost Kansas and Oklahoma (Plate 2); these measured sections are also described in detail in the Appendix.

The changes that occur in the lithology of the various Wreford horizons can be considered in three groups (Garihan and Cuffey, 1973): 1) units that become interbedded red shales and red sandstones about 10 miles (16 km) south of the state line; 2) a newly discovered but poorly exposed marine tongue that extends to about 40 miles (64 km) south of the state line; and 3) a previously recognized and well-exposed marine tongue extending to about 50 miles (80 km) south of the state line.

Many Wreford horizons become interbedded red shales and red sandstones a few miles south of the Kansas-Oklahoma border. These include the middle and upper parts of the Speiser Shale, the middle and upper parts of the Havensville Shale Member, the upper part of the Schroyer Limestone Member, and the lower and middle parts of the Wymore Shale Member. The middle Speiser red shales grade into interbedded red shale and red sandstone just north of the state line, while the various non-cherty limestones and shales of the upper Speiser become red beds about 10 miles (16 km) south of the state line. This red-bed sequence thickens rapidly to the south. The middle and upper Havensville and the upper Schroyer likewise change from shales and non-cherty limestones to red beds a few miles south of the border. Finally, the lower and middle Wymore, red shale in southernmost Kansas, also grades into a thick sequence of interbedded red sandstones and shales at about the same latitude.

The second group of changes to be considered

involves those in a newly discovered but poorly exposed upper marine tongue that extends to about 40 miles (64 km) south of the state line. This marine tongue includes the horizons of the lower and middle parts of the Schroyer Limestone Member. The lower Schroyer is cherty limestone in Kansas, but changes to algal-molluscan limestone approximately at the state line. Farther south, this limestone grades into tan quartzose sandstone, and that in turn into red beds. The middle Schroyer is a thin calcareous shale up to 10 miles (16 km) south of the state boundary, and then passes through grayish-yellow mudstone before being replaced by interbedded red shales and red sandstones.

The third group of changes is found within a lower marine tongue that extends somewhat beyond the upper tongue for a total of 50 miles (80 km) down into Oklahoma. This tongue was recognized previously (Grieg, 1959; Newton, 1971) because it is much better exposed than the one just discussed. This lower tongue includes all of the horizons of the Threemile Limestone Member and of the lower part of the Havensville Shale Member. Through most of the extent of this tongue, the lower Threemile and lower Havensville are represented by algal-molluscan limestones that bracket a thin brachiopod-molluscan limestone equivalent to the middle and upper Threemile farther north. At the northern end of this tongue, approximately at the Kansas-Oklahoma border, the lower Threemile grades from the cherty limestone facies found throughout Kansas into brachiopod-molluscan limestone; a few miles farther south that grades in turn into algal-molluscan limestone. The lower Havensville equivalent has already passed from algal limestone into algal-molluscan limestone a few miles north of the border, where these beds have previously been labeled uppermost Threemile (Hattin, 1957, p. 105; Cuffey, 1967, p. 13-14). At the southern end of this lower tongue, the middle brachiopod-molluscan limestone (the middle and upper Threemile equivalent) changes to red beds about 10 miles (16 km) farther north than the algal-molluscan limestones above and below it. These two algal-molluscan limestones thus become separate sub-tongues. Each grades into tan quartzose sandstone and then a short distance farther south into red clayey molluscan limestone before finally disappearing into the red beds.

ROCK TYPES PROMINENT IN OKLAHOMA WREFORD

Generalities

The petrologic features and inferred paleoenvironments of those rock types important in the Oklahoma Wreford are described here. Information concerning their characteristics as developed in southernmost Kansas and Oklahoma is stressed. The Wreford Megacyclothem in Oklahoma is dominated by fewer rock types than in Kansas, where a variety of rock types is abundantly represented (see Plate 1).

Virtually all of the rock types for which insoluble residues were examined contain quartz and either hematite or limonite. In most samples, quartz is the dominant constituent, either as subhedral or rounded grains, or as fine-grained masses. Limonite and hematite are present in lesser quantities as distinct grains and encrusted on other grains. A few samples yield small rhombs, many of which are clear, which might be carbonate rhombs secondarily replaced by silica. Also, many samples contain silicified fragments of organisms that originally secreted calcareous shells.

During Wreford deposition, Kansas was covered by a shallow sea, while much of Oklahoma was low-lying coastal plain. Changes in shoreline position are suggested by observing the northernmost occurrences of red beds (Plate 1). In particular, the shoreline, as inferred from the northern limit of red beds, seems to have been in approximately the same position throughout deposition of the Speiser, middle and upper Havensville, and upper Schroyer and Wymore. This lack of shoreline fluctuation confirms that other factors in addition to changing water depth determined the depositional environments (Cuffey, 1967, p. 10-13, 87; Newton, 1971, p. 14). Twice during Wreford time, the shoreline apparently migrated southward significant distances, resulting in deposition of the two marine tongues discussed above.

Red Sandstone and Red Shale

Interbedded red sandstones and red shales comprise the greatest volume of rock in the Wreford section in Oklahoma. They tend to be relatively poorly exposed because they commonly form vegetated slopes; only at a few localities do massive sandstones form ledges that crop out. Moreover, the lenticular character and limited lateral extent of the red sandstones is evident as these beds are traced within and between outcrops.

The sandstones are red or reddish purple; they

range from shaly-bedded to massive and are fine-grained, quartzose, and friable. The shales are red, moderately calcareous, and lack primary features such as graded beds or ripple marks. Fossils are completely absent.

The sand grains of the red sandstones are mostly quartz and are well sorted and angular, probably due to secondary crystal growth; thus, they can be classified petrographically as orthoquartzites. Thin sections of the red shales show a predominance of quartz sand and silt and the presence of hematite or limonite.

Insoluble residues of the red sandstones and red shales are composed mainly of subhedral pink and clear quartz grains, with a substantial amount of hematite coating the quartz and existing as distinct grains. Mica flakes also occur in many of these samples. Amounts of insoluble residues of these rocks, as indicated in the Appendix, range from 87 to 100 percent.

The environmental interpretation of the red sandstones and red shales has been discussed by Hattin (1957, p. 82-85), Cuffey (1967, p. 11), and Newton (1971, p. 7). The sandstones probably represent stream channel deposits, and it seems likely that the red shales represent subaerial coastal plain deposits.

Algal-Molluscan Limestone

Algal-molluscan limestones are the most conspicuously and extensively exposed rock type in the Oklahoma Wreford.

In outcrop in southernmost Kansas and northern Oklahoma, these limestones are light gray, light yellowish gray, or grayish brown, and weather medium gray to orangish gray and rounded. They are thin-, medium-, or thick-bedded, hard, burrowed, and contain some rust or dark brown spots about 1 mm in diameter. Many "osagites" (rocks containing abundant algally coated grains) (McCrone, 1963, p. 66-67) are included in this rock type. As in Kansas, typical for algal-molluscan limestones are large burrows (up to 5 cm in diameter), formed by large burrowing clams (*Allorisma* or *Aviculopinna*) which are found in place at the bottoms of the burrows at some localities (such as OS02). The algal-molluscan limestones change southward; in that direction they have more coated grains ("*Osagia*"), more molluscs, and fewer brachiopods and bryozoans (these latter are usually absent from the southernmost exposures of these limestones).

Also obvious in hand specimens, and in thin sections and insoluble residues, is the increasing abundance of fine quartz sand to the south.

Algal-molluscan limestones, in thin sections, are sparse to packed biomicrites (using the terminology of Folk, 1959, 1962); where there are many coated grains, they may even be classified as biosparites. These rocks often contain intraclasts and oolites. Brachiopod and pelecypod fragments are common in the algal-molluscan limestones. The algal structures are *Osagia*, made up of intergrowths of algae and various encrusting forams. This gives the name to osagite texture (Lane, 1958, p. 146, 147; McCrone, 1963, p. 64-67) and *Osagia* facies (Imbrie, Laporte, and Merriam, 1959, p. 72, 77). However, in many specimens, only laminated micrite is visible surrounding the nucleus; it is possible that such grains may be coated with inorganic micritic crusts, as Boyer (1972) has observed in the modern Florida reef tract.

Algal-molluscan limestone insoluble residues are quite varied. Again, abundant quartz and chert and common hematite and limonite are found in these samples. Many samples also contain silicified fossils, rare vertebrate fragments, and rare to common arenaceous forams; a few samples have mica flakes, sponge spicules, conodonts, and rhombs (probably silica replacing carbonate). The amount of insoluble residue is usually well below 25 percent.

The micritic algal-molluscan limestones were deposited in a near-shore marine environment, in water that was probably shallow or very shallow, brackish, and at least sometimes agitated (Hattin, 1957, p. 96-97; Cuffey, 1967, p. 12). The presence of burrowing clams has been taken to indicate that the water was brackish, probably due to freshening of sea water from runoff from the nearby shore (which also contributed some sand and silt grains) (Hattin, 1957, p. 98). Algae are thought to have thrived in both hypersaline and brackish water; thus their presence can also be explained with this model. The osagite-type rocks (especially where intergrain spaces are spar-filled rather than micrite-filled) may represent more turbulent water over calcarenite shoals rising slightly above the surrounding carbonate-mud level bottoms.

Tan Quartzose Sandstone

Prominent because it replaces algal-molluscan limestones in the southernmost Wreford exposures, tan quartzose sandstone is also an interesting rock type because it does not occur farther north in the Kansas Wreford (Newton, 1971, p. 10).

Tan quartzose sandstones are white, light tan, or dark brown, weathering dark gray or brown, thin-bedded to massive, somewhat calcareous rocks. At

some localities, there are burrows similar to those made by clams in the algal-molluscan limestones. The surfaces of this rock type frequently have dark brown blotches, thought by Grieg (1959, p. 106, 109) to be limonitized *Osagia*. Nodules or lenses of molluscan or algal-molluscan limestones occur in several places within this sandstone. Fossil pelecypods are present at many exposures of tan quartzose sandstone.

These rocks in thin section are orthoquartzites. They are composed of well-sorted, subangular, fine- to medium-sized quartz grains. They contain a small amount (less than five percent) of calcareous cement.

The insoluble residues show that the tan quartzose sandstones contain subhedral, clear quartz grains, which may be coated with limonite. Individual limonite grains are also present and furnish the tan color of these rocks. Mica flakes are common in most samples; one sample also contained a few arenaceous forams. The insoluble residue amounts are usually near 100 percent.

The tan quartzose sandstones might represent shallow, loose, shifting quartz sand bottoms just offshore. Or, because they occur only as the southern lateral equivalents of increasingly sandy algal-molluscan limestones, they may actually represent very sandy algal-molluscan limestones whose calcareous material has largely been removed by leaching during Late Cenozoic weathering (Newton, 1971, p. 10).

Molluscan Limestone

Molluscan limestone, of character quite different from typical Kansas molluscan limestones, is also noticeable because it is found only at the most southern Oklahoma Wreford exposures.

These northern Oklahoma molluscan limestones are red to red mottled with yellow. They are very hard, dense limestones, occurring in thin to medium beds; they contain some pelecypods and crinoid columnals.

In thin sections, the Oklahoma molluscan limestones are sparse biomicrites or even calcareous sandstones. Intraclasts are occasionally present. These rocks contain numerous fossils, especially pelecypods, gastropods, crinoid debris, and some ostracods. Other groups are noticeably absent, especially bryozoans and brachiopods.

The insoluble residues of molluscan limestones have quartz and hematite in about equal amounts. Hematite casts of gastropods, pelecypods, crinoid columnals, ostracods, and a few small bryozoan fragments occur in the insoluble residues. They also have clear rhombs (possibly silica replacing carbonate) and rare arenaceous forams. The amount of insoluble residue for these samples is about 40 percent.

Typical Kansas molluscan limestones represent

deposition in shallow, brackish to normal marine waters (Hattin, 1957, p. 86-89; Cuffey, 1967, p. 11; Newton, 1971, p. 8, 10). The Oklahoma molluscan limestones were probably deposited in similar environments. The mix of fossils implies brackish water; and the red color, as well as their extreme southern position, implies a position very close to shore. It may be that there were brackish lagoons between the red bed coastal plain and regions of purer quartz sand bottoms (possibly including bars) just offshore.

Brachiopod-Molluscan Limestone

The Wreford section in Oklahoma exposes some brachiopod-molluscan limestone, much like similar rocks found in the Kansas Wreford.

In outcrop and hand specimen, the southern Kansas and Oklahoma brachiopod-molluscan limestones are light gray rocks, weathering light yellowish gray or light brownish gray; they are thin-bedded to massive, hard, burrowed, and have some small (about 1 mm) yellowish-brown stains which, as mentioned above, are probably limonitized *Osagia*. As their name suggests, they contain both molluscs (especially pelecypods) and brachiopods as common or abundant constituents. Some beds contain noticeably abundant *Derbyia* and *Composita*.

Thin sections of these limestones show that they are sparse to packed biomicrites. They sometimes contain intraclasts, and numerous fossils are present, especially brachiopods and pelecypods, as well as some bryozoans, forams, gastropods, algae, and crinoid and echinoid debris.

Most insoluble residues of brachiopod-molluscan limestones have quartz and detrital angular chert as the most abundant elements, and also rare to common vertebrate fragments. In addition, some samples contain silicified fossils and limonite and hematite, and a few have rare arenaceous forams or conodonts. One bed (the brachiopod-molluscan limestone of the lower Threemile at locality KA02) contains abundant clear rhombs, apparently silica replacing carbonate. The amount of insoluble residue is usually under 25 percent.

Because the lithology and faunal content of brachiopod-molluscan limestones are intermediate to those of molluscan limestones and calcareous shales, it was presumed by Cuffey (1967, p. 12) that their environment of deposition was also intermediate. This environment was probably shallow and of normal marine salinity. The localities where abundant *Derbyia* and *Composita* shells are found may have been large shell beds in the Wreford sea.

Cherty Limestone

Some cherty limestone occurs in the Wreford rocks of extreme northern Oklahoma; this rock type is essentially like the Wreford cherty limestones in southernmost Kansas, and trends such as the continuing decrease in chert quantity (Hattin, 1957, p. 29, 31, 45) are maintained southward across the border.

In outcrop and hand specimen, cherty limestone is light gray, thin- to thick-bedded, hard, and sometimes has dark brown spots (limonitized *Osagia*). The chert is noncalcareous light to dark gray or calcareous bluish to brownish gray and concentrically layered.

Cherty limestone thin sections indicate that these rocks in northern Oklahoma are micrites or sparse biomicrites. The dominant fossils are bryozoans, brachiopods, and crinoid and echinoid fragments.

Quartz and chert are the primary components in insoluble residues of most cherty limestone samples. Other components include abundant silicified fossils, rare to common vertebrate fragments, and minor limonite and hematite. A few samples also include rare sponge spicules, many silicified productid(?) or echinoid(?) spines, and small rhombohedral grains (some attached to the spines) which may be silica replacing carbonates. One sample contains mainly vertebrate fragments, along with minor quartz and hematite. Amounts of insoluble residues are usually less than 20 percent.

The environment of cherty limestone deposition (Hattin, 1957, p. 91-92; Cuffey, 1967, p. 12) was probably quiet, normal marine water, deeper than the zone of intense wave action.

Calcareous Shale

Minor calcareous shale, much like that seen throughout Kansas in the Wreford Megacyclothem, accompanies cherty limestone in the Wreford of northern Oklahoma.

The calcareous shales are light grayish yellow, medium hard, and silty (Hattin, 1957, p. 61-63; Cuffey, 1967, p. 12; Newton, 1971, p. 10). They do not seem to be as fossiliferous as those found in Kansas. Thin sections of these rocks from Oklahoma are fossiliferous micrites or sparse biomicrites containing bryozoans, brachiopod and pelecypod shell fragments, and echinoid and crinoid debris.

The most abundant constituents of the calcareous shale insoluble residues are quartz and chert as discrete grains and as fine-grained masses. Most samples also contain common or abundant silicified fossils, such as crinoid columnals, brachiopod and pelecypod shell fragments, and productid and echinoid spines. Most samples also have hematite and limonite. Verte-

brate fragments occur in many calcareous shales; some may also have rare conodonts, sponge spicules, arenaceous forams, mica flakes, and pyrite grains. The amounts of insoluble residues normally vary between 30 and 60 percent.

The environment of deposition of calcareous shales was described by Hattin (1957, p. 90), Cuffey (1967, p. 12), and Newton (1971, p. 10) as being fairly quiet, normal marine water. The less fossiliferous nature of the beds in Oklahoma perhaps reflects less favorable conditions than in Kansas, possibly a brackish near-shore environment.

Grayish-Yellow Mudstone

Some grayish-yellow mudstone, generally not exposed, is present in the Oklahoma Wreford section.

In characteristics, the Oklahoma rocks of this type are essentially the same as those in Kansas. These rocks are grayish yellow, silty, calcareous and are sparsely fossiliferous, containing productid spines, ostracods, and forams.

Quartz grains are abundant, whereas limonite and hematite are rare in insoluble residues of grayish-yellow mudstones analyzed. Some arenaceous forams, a few silicified shell fragments, and a few vertebrate fragments may also be encountered. Insoluble residue amounts are usually near 80 percent.

The environment of deposition of grayish-yellow mudstones was probably very shallow, near-shore, slightly brackish marine water (Hattin, 1957, p. 85-86; Cuffey, 1967, p. 11).

CONCLUSIONS

1) Major facies changes in the units of the Wreford Megacyclothem occur within short distance south of the Kansas-Oklahoma border. These changes are evident from measured stratigraphic sections, and can also be summarized diagrammatically by a cross-section (Plate 2).

2) One facies change involves the middle and upper Speiser Shale, the middle and upper Havensville Shale Member, the upper Schroyer Limestone Member, and the lower and middle Wymore Shale Member, all of which become interbedded red shales and red sandstones about ten miles (16 km) south of the state line.

3) Other facies changes involve two marine tongues. The upper tongue, newly discovered but poorly exposed, and extending some 40 miles (64 km) south of the state line, includes the horizons of the lower and middle parts of the Schroyer Limestone Member. The lower marine tongue, extending for 50 miles (80 km) down into Oklahoma, includes all of the horizons of the Threemile Limestone Member and the equivalents of the lower part of the Havensville Shale Member.

4) Rock types prominent in the southernmost Kansas and Oklahoma part of the Wreford are interbedded red sandstone and red shale, algal-molluscan limestone, tan quartzose sandstone, and molluscan limestone. Other rock types present there are similar to those found in the Kansas Wreford, such as brachiopod-molluscan limestone, cherty limestone, calcareous shale, and grayish-yellow mudstone.

5) The prominent Oklahoma Wreford rock types indicate paleoenvironments of deposition that differ from those of the typical marine units of the megacyclothem in Kansas. Molluscan limestones, algal-molluscan limestones, and tan quartzose sandstones all seemingly imply deposition in shallow, near-shore, normal marine to brackish waters, while interbedded red shale and red sandstone represent deposits of a subaerial coastal plain traversed by stream channels.

6) The shoreline of the Wreford sea was apparently near the Kansas-Oklahoma border throughout much of the time of deposition of the Wreford Megacyclothem. However, the shoreline migrated noticeably southward during deposition of the two marine tongues discussed here.

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APPENDIX
DESCRIPTIONS OF MEASURED STRATIGRAPHIC SECTIONS OF
WREFORD ROCKS IN NORTHERN OKLAHOMA

Nine key sections of the Wreford Megacyclothem in Oklahoma are described here; additional ones are presented elsewhere (Garihan, 1973, p. 174-190). The sections are presented in descending stratigraphic order, and individual units are numbered from the base upwards. Locations are given in Table 1 and shown

on Figure 1 in the text; their correlation is indicated on Plate 2. This figure is a continuation into Oklahoma of the correlation of the Wreford Megacyclothem in Kansas by Hattin (1957, Plates 1, 2, 3). Insoluble residue percentages are indicated in parentheses at the end of the description of each unit.

Locality KA01

Unit

WREFORD LIMESTONE

Schroyer Limestone Member, 1.5 feet

	thick- ness, feet
10. Limestone, very poorly exposed, light grayish orange, speckled with rusty spots, weathers light to medium gray, thin- to medium-bedded, dense, hard, bored; FOSSILS, <i>Derbyia</i> , crinoid stems, algae, (13%) ^o	1.0
9. Covered	0.5

Havensville Shale Member, 5.1 feet

8. Covered	0.5
7. Limestone, light grayish orange, weathers medium gray, bored, medium-bedded (>6"), rounded weathering, large borings (3"-4") enhanced by weathering; FOSSILS, algae, crinoid stems, echinoid spines, <i>Composita</i> , <i>Derbyia</i> , bryozoans, clams, (4%)	2.0
6. Limestone, shaly, nodular, light gray, weathers grayish orange to light brownish gray, thin-bedded, burrowed, medium hard; FOSSILS, <i>Derbyia</i> , productids, crinoid stems, pelecypods, gastropods, bryozoans, echinoid spines, (9%)	1.1
5. Limestone, algal, light grayish orange with rust-colored stains, weathers light to medium gray, dense, weathers rounded, bored, medium-bedded; FOSSILS, algae, <i>Derbyia</i> , crinoid stems, gastropods, bryozoans, echinoid spines, (1%)	1.5

Threemile Limestone Member, 9.0 feet

4. Limestone, cherty, light gray, weathers grayish orange, thick-bedded, hard; CHERT, light to medium gray; upper third: FOSSILS, crinoid stems, productid spines, <i>Derbyia</i> , (11%); middle third: FOSSILS, bryozoans, crinoid stems, <i>Derbyia</i> , (13%); lower third: FOSSILS, <i>Derbyia</i> , <i>Composita</i> , bryozoans, productid brachiopods, echinoid spines, (42%)	4.0
3. Limestone, shaly, light yellowish gray to medium yellowish gray, weathers dark yellowish gray, medium hard, (43%)	0.5
2. Shale, light grayish yellow, weathers yellowish brown, shaly-bedded, calcareous, medium hard, (45%)	1.0
1. Limestone, medium brown, weathers yellowish brown, thick-bedded; FOSSILS, very common <i>Composita</i> , <i>Derbyia</i> , <i>Enteletes</i> , productid brachiopods, crinoid stems, bryozoans, pelecypods, (29%) ..	3.5

Total 14.1

^o Percentages refer to proportion of insoluble residue.

Locality KA02

Unit

WREFORD LIMESTONE

Schroyer Limestone Member, 3.5 feet

	thick- ness, feet
20. Limestone, very poorly exposed, light yellowish gray, weathers medium gray, thick-bedded, pitted weathering, burrowed, very fossiliferous; FOSSILS, algae, <i>Derbyia</i> , <i>Composita</i> , echinoid spines, crinoid stems, echinoid plates, bryozoans, (13%)	1.5
19. Shale? Covered	1.0
18. Limestone, very poorly exposed, light yellowish gray, weathers medium gray, thick-bedded, pitted weathering, burrowed; FOSSILS, algae, (8%)	1.0

Havensville Shale Member, 7.4 feet

17. Shale? Covered	1.0
16. Limestone, medium yellowish brown, weathers grayish brown, thin-bedded, pitted weathering, nodular, hard, (12%)	1.0
15. Limestone, light yellowish white to light yellowish gray, weathers medium gray, medium- to thick-bedded, hard, burrowed, rounded weathering, pitted where burrowed; FOSSILS, algae (<i>Osagia</i> ?), <i>Derbyia</i> , echinoid spines, <i>Composita</i> , echinoid plates, crinoid stems, (18%)	2.0
14. Interbedded limestone and shale; limestone, light gray, weathers medium gray to grayish orange, nodular beds, medium-bedded, hard; shale, light gray, weathers medium gray, shaly-bedded; FOSSILS, limestone, vertical <i>Aviculopinna</i> ?, crinoid stems, brachiopods, (13%)	1.6
13. Limestone, light gray, weathers grayish orange, hard, medium-bedded, slightly burrowed, abundant fossils; FOSSILS, productids, <i>Composita</i> , <i>Derbyia</i> , echinoid spines, crinoid stems, bryozoans, vertical <i>Aviculopinna</i> ?, algae, (17%)	1.8

Threemile Limestone Member, 11.0 feet

12. Shale, medium gray, weathers olive gray, medium hard, shaly-bedded, calcareous; FOSSILS, <i>Composita</i> , (47%)	0.2
11. Limestone, cherty, contains one chert bed at the bottom, and scattered chert nodules, light yellowish gray, weathers grayish orange, thick-bedded, hard, pitted weathering where exposed to weathering longest; CHERT, light to medium gray; FOSSILS, crinoid stems, bryozoans, <i>Composita</i> , fossil hash, (11%)	1.5
10. Limestone, cherty, with chert as scattered nodules, light gray to light yellowish gray, weathers grayish orange, thick-bedded, hard; CHERT, light to medium gray; FOSSILS, <i>Derbyia</i> , crinoid stems, bryozoans, fossil hash, (10%)	1.8

	thick- ness, feet		thick- ness, feet
9. Limestone, with chert, light gray, weathers grayish orange to yellowish gray, thick-bedded, hard; CHERT , three nodular beds, non-calcareous, medium to light gray, other scattered chert nodules medium to light gray; FOSSILS , <i>Derbyia</i> , crinoid stems, bryozoans (fenestrate, branching), (31%) ..	2.0	9. Shale, light grayish brown, weathers to light gray, shaly-bedded, soft, friable, calcareous, powdery weathering, unfossiliferous, (lower half, 53%; upper half, 58%)	1.3
8. Shale, olive gray, weathers medium yellowish gray to olive gray, shaly-bedded, grades down into shaly limestone below, medium hard; FOSSILS , rare, <i>Derbyia</i> , pelecypods, crinoid stems	0.1	8. Limestone, light grayish green, weathers light yellowish gray, thick-bedded, hard; FOSSILS , very abundant <i>Composita</i> , <i>Derbyia</i> , productids, crinoid stems, bryozoans, rare vertical pinna clams, (22%) ..	2.3
7. Shaly limestone, light yellowish gray to medium yellowish gray mottled yellow to yellow white, weathers dark yellowish gray, medium hard; FOS- SILS , <i>Composita</i> , <i>Derbyia</i> , pelecypods, (56%)	0.3	SPEISER SHALE, 23.3 feet	
6. Shale, light grayish yellow, weathers yellowish brown, shaly-bedding, calcareous, medium hard, silty(?), calcareous nodules present; FOSSILS , <i>Chonetes</i> , <i>Derbyia</i> , <i>Composita</i> , productids (uncommon), bryozoans, crinoid stems, (lower half, 51%; upper half, 36%)	1.3	7. Shale, medium gray, weathers light yellowish gray, shaly-bedded, calcareous; FOSSILS , <i>Derbyia</i> , bryozoans, pelecypods(?), (37%)	0.1
5. Limestone, light gray, weathers yellowish gray or yellowish brown, thick-bedded, upper 6" thin-bedded, about 8" from bottom has a horizon with very abundant <i>Composita</i> , top half of unit more <i>Derbyia</i> -rich, pinna clams only in bottom 1.3'; FOSSILS , very abundant <i>Composita</i> , <i>Derbyia</i> , productids, vertical pinna clams, crinoid stems, gastropods, bryozoans (<i>Rhombopora</i>), (39%)	3.8	6. Shale, light grayish yellow, mottled with light grayish blue, calcareous, unfossiliferous, (74%)	0.1
SPEISER SHALE, 4.8 feet		5. Shale, medium reddish brown, mottled with light grayish green, weathers reddish gray, shaly-bedded, calcareous, not resistant, unfossiliferous, (90%)	3.5
4. Shale, contains lenticular limestone; shale, yellowish brown, weathers dark yellowish orange to rusty manganese stained, calcareous, shaly-bedded, very friable and weathers easily, sparsely fossiliferous; limestone, fossiliferous; FOSSILS , shale, <i>Derbyia</i> ; limestone, <i>Derbyia</i> , (29%)	0.3	4. Covered	3.8
3. Limestone, light gray, weathers yellowish brown, thick-bedded, upper part cross-bedded(?), weathers pitted, stylolites present; FOSSILS , <i>Derbyia</i> , molluscs, (9%)	2.5	3. Sandstone, light reddish purple, mottled with white in places, weathers light reddish brown, cross-bedded, medium- to thick-bedded, fine-grained, quartzose, friable, unfossiliferous, (100%)	7.5
2. Shale, medium gray, calcareous, soft, shaly-bedded, unfossiliferous, (83%)	1.5	2. Covered	2.8
1. Shale, basal part covered, exposed portion is dusky red, mottled medium gray, calcareous, soft, shaly-bedded, unfossiliferous, (87%)	0.5	1. Sandstone, pale reddish brown, weathers reddish brown, thin-bedded, fine-grained, quartzose, friable, covered at bottom, unfossiliferous, (95%)	5.5
Total	26.7	exposed	
Locality KA04		67.6	
Unit		Total exposed	
MATFIELD FORMATION		Locality KA05	
Wymore Shale Member, 30.5 feet		Unit	
13. Sandstone, light red, quartzose, fine-grained, friable, thin-bedded, unfossiliferous, (99%)	5.5	WREFORD LIMESTONE	
12. Covered, largely red shale (and sandstone??)	25.0	Schroyer Limestone Member, lower, 2.0 feet	
WREFORD LIMESTONE		11. Limestone float on butte top, algae, medium grayish brown with dark brown spots closely spaced throughout, weathers medium brownish gray, smooth weathering, bored, thin-bedded; FOSSILS , algae, vertical pinna clams, (10%)	
Havensville Shale Member, lower, 1.8 feet		10. Covered	
11. Limestone, bored, light gray with many 1 mm diameter dark rust spots, weathers medium gray to medium brown, rounded weathering, medium-bedded, hard, forms pavement in field; FOSSILS , echinoid spines, algae, crinoid stems, <i>Derbyia</i> , <i>Composita</i> (some, small), (10%)	1.8	Havensville Shale Member, middle and upper, 5.0 feet	
Threemile Limestone Member, 7.0 feet		10. Covered	
10. Limestone, contains chert, light yellowish brown with many 1 mm diameter dark brown pellets (limonitized <i>Osagia</i>), weathers medium brown to yellowish brown, chert is a 6" bed 1" up from base of unit, thin- to medium-bedded; CHERT , non-calcareous, nodular bedded, light yellowish brown, weathers medium yellowish brown, contains productid spines(?), small red spots (limonite??); FOSSILS , algae, (lower half, 53%; upper half, 10%)	3.4	Havensville Shale Member, lower, 2.2 feet	
		9. Limestone, algal, light olive gray with some 1 mm dark brown stains (not as many as in unit 11 above), weathers medium gray, vertically bored, rounded weathering, hard, dense; FOSSILS , algae, vertical pinna clams, <i>Composita</i> (?), (9%)	
		8. Limestone, light gray with dark yellowish brown limonitic(?) stains as small dots, weathers medium gray, hard, dense; FOSSILS , algae(?), molluscs(?), brachiopods(?), crinoid stems, (6%)	
		7. Limestone, shaly, light yellowish gray, weathers grayish orange, some yellowish brown stains, medium hard, medium-bedded, not very resistant; FOSSILS , algae(?), crinoid stems, <i>Composita</i> (?), molluscs, (17%)	
		6. Limestone, light grayish brown, weathers light to medium grayish brown (tending towards osagite?), hard, dense; FOSSILS , algae(?), <i>Derbyia</i> , <i>Composita</i> , crinoid stems, molluscs, (9%)	
		5. Limestone, medium gray, weathers same with brown lichen, has dark brown 1 mm to 1 cm spots (<i>Osagia</i> ?), medium-bedded, bored, hard, dense; FOSSILS , algae, <i>Composita</i> , crinoid stems, molluscs, (9%)	
		4. Limestone, light brown, weathers light grayish brown, occasional dark brown 1 mm spots, lenticular thin- to medium-bedded, dense, top 1/2" is shaly parting; burrowed; FOSSILS , algae(?), (7%)	

	thick- ness, feet		thick- ness, feet	
SPEISER SHALE, 46.5 feet				
3. Covered, red soil	41.0	Locality OS03		
2. Sandstone, medium red laminated with dark red layers, weathers dark red, very finely laminated, slabby weathering, forms rubble-covered slope, quartzose, poorly exposed, unfossiliferous, (99%) ..	5.5	Unit		
FUNSTON LIMESTONE, 0.8 feet exposed				
1. Limestone, light gray, weathers dark gray, medium-bedded, hard, poorly exposed, lichen-covered	0.8	WREFORD LIMESTONE		
Total	60.5	Schroyer Limestone Member, 2.0 feet		
Locality OS02				
Unit				
WREFORD LIMESTONE				
Schroyer Limestone Member, lower, 2.8 feet				
9. Limestone, very light gray with some yellowish-gray staining, weathers light gray, fine-grained, brittle, dense, lower 0.5" thin-bedded, becomes very finely laminated 1.8' above base, upper foot medium-bedded, unfossiliferous, (lower part, 12%; upper part, 17%)	2.8	10. Covered, sandstone rubble to top of butte; sandstone, light tan, weathers dark gray to grayish orange, orange lichen-covered, fine-grained, quartzose, bored, thin- to medium-bedded; FOSSILS, pelecypods, crinoid stems, (99%)	2.0	
Havensville Shale Member, middle and upper, 4.0 feet				
8. Covered	4.0	Havensville Shale Member, middle and upper, 2.0 feet		
Havensville Shale Member, lower, 2.5 feet				
7. Limestone, medium gray, weathers same, some orange staining, vertical borings, rounded weathering, small pits in weathered surface, thick-bedded but variable thickness (because bottom undulates); FOSSILS, algae, molluscs, vertical pinna clams, other pelecypods, <i>Derbyia</i> , <i>Composita</i> , crinoid stems, echinoid spines, (13%)	2.1-2.3	9. Covered	2.0	
6. Limestone, algal, light gray, with yellowish-brown spots, weathers medium grayish orange, shaly-bedded, variable thickness (undulating top and bottom surfaces); FOSSILS, algae, productids(?), (6%)	0.2-0.3	Havensville Shale Member, lower, 1.5 feet		
Threemile Limestone Member, 3.1 feet				
5. Limestone, moderately algal, medium gray, weathers medium dark gray, rarely geodal (siliceous), sugary texture, hard, fossils not obvious in field; FOSSILS, algae, brachiopods, molluscs, (14%) ..	0.1	8. Limestone, algal, with many fossil fragments, light grayish orange to medium gray with some 1 mm orange spots (limonitized <i>Osagia?</i>), weathers medium to dark gray, bored, medium- to thick-bedded, hard, ledge former, lower 0.3' shaly, upper 0.7' sandy and bored, middle 0.5' highly recrystallized, with some pockets of coquina 2-3" in diameter; FOSSILS, algae, pelecypods, crinoid stems, gastropods, echinoid spines, abundant shell cross-sections and fragments throughout, (lower part, 14%; middle part, 21%; upper part, 28%)	1.5	
4. Limestone, algal, light yellowish gray with some yellowish-brown spots (limonite?), weathers medium gray, rounded weathering, sometimes porous, hard, medium- to thick-bedded, pitted, bored; FOSSILS, algae, <i>Composita</i> , molluscs(?), (21%) ..	1.2	Threemile Limestone Member, 2.2 feet		
3. Limestone, algal, with a 1-2" shaly parting at top, light brownish gray with common medium brown 1 cm spots (limonite?), weathers yellowish gray to medium gray, weathers rounded, thick-bedded, hard, includes abundant gastropods and pelecypods (coquinoid); FOSSILS, algae, gastropods, abundant pelecypods	1.8	7. Limestone, shaly, medium grayish brown, some yellowish-brown limonitized <i>Osagia</i> , weathers medium gray, thin-bedded, somewhat more calcareous locally, somewhat less resistant to erosion than over- and under-lying units and so forms a re-entrant, locally slumped over and covered by more massive units above; FOSSILS, algae, brachiopods, molluscs, (16%)	0.5	
SPEISER SHALE, 45.0 feet				
2. Covered, red soil, slabs of unit 3 above on surface ..	31.0	6. Limestone, slightly algal, medium grayish brown, weathers medium gray, hard, slightly sandy, forms a ledge; FOSSILS, algae, pelecypods, (20%)	0.4	
1. Interbedded shale and sandstone; shale, medium red, weathers same, shaly-bedded, medium hard, unfossiliferous; sandstone, finely laminated, white, fine-grained, quartzose (from float), (100%)	14.0	5. Limestone, rarely algal, medium grayish brown with medium brown 1 mm blotches (limonitized <i>Osagia</i>), weathers dark gray, slightly bored, hard, lower half medium-bedded, upper half thin-bedded; FOSSILS, algae, pelecypods, brachiopods(?), (upper part, 37%)	1.3	
Total	57.4	SPEISER SHALE, 54.1 feet		
4. Covered				
3. Shale, poorly exposed, medium red brown; soil medium red brown, clayey, probably not thick (shale near surface), (90%)				
2. Covered				
1. Sandstone, dark red brown, weathers same, fine-grained, quartzose, medium-bedded, slightly friable, unfossiliferous, (99%)				
exposed				
Total exposed				
61.8				
Locality PW01				
Unit				
WREFORD LIMESTONE				
Havensville Shale Member, lower, 1.5 feet				
3. Limestone, sandy, light gray, with dark brown blotches more unevenly distributed than in lower units (2-3 mm diam.), weathers medium gray with some red staining, sandy textured, recrystallized, hard, sandy partings in places, has some rare red shale chips, borings, lenses of pelecypod coquina, lower half more sandy than upper half and can be regarded as sandstone; FOSSILS, pelecypods, (lower part, 100%; upper part, 61%)				1.5

	thick- ness, feet
Threemile Limestone Member, 4.2 feet	
2. Sandstone, calcareous; lower 1.5' medium red brown with some white mottling, weathers dark red, has many small (1 mm) dark brown blotches, medium-bedded, friable; upper 1.7' light grayish orange to red with some white mottling, large dark brown blotches (2-3 mm), weathers dark red brown, thin-bedded, friable; both sections very weathered, contain burrow fillings and borings; FOSSILS, pelecypods(?), (lower half, 100%; upper half, 100%)	3.2
1. Sandstone, calcareous, light gray with some dark brown blotches, weathers light grayish orange, has some limestone nodules, medium-bedded, red-stained, medium hard, blocky outer surface, weathered surface (1/2") sandy from loss of carbonate; FOSSILS, pelecypods, (58%)	1.0 exposed
Total exposed	5.7

Locality PW02

Unit

12. Sandstone, medium brown red with dark brown 1-2 mm blotches, weathers same to dark red brown, well-developed cross beds, thick-bedded, moderately friable, slightly calcareous, unfossiliferous, (94%)	4.9-5.0
11. Shale, red brown, purple and yellow mottled, weathers red brown, shaly-bedded, not resistant, unfossiliferous, has a small limestone layer 1' from sandstone, which thickens from 1" to 2" in 15' from north to south, (100%)	3.7

WREFORD LIMESTONE

Havensville Shale Member, 0.8 feet

10. Sandstone, very calcareous, light gray mottled yellowish gray, weathers grayish red, forms a resistant ledge, very hard, dense, 2" thick; 10' to the south unit becomes limestone, shaly, 4" thick, contains abundant molluscs, dark reddish purple with limonite and hematite stains common, weathers medium reddish brown; FOSSILS: sandstone, pelecypods(?); limestone, pelecypods, gastropods, crinoids, (48%)	0.2-0.3
9. Shale, reddish purple with some limonite staining, shaly-bedded, unresistant, non-calcareous, unfossiliferous, (96%)	0.3

	thick- ness, feet
8. Sandstone, light grayish blue with limonite staining, weathers yellowish brown, may be stained red from above units, fine-grained, quartzose, thin-bedded, calcareous, not very resistant, burrowed(?); FOSSILS, pelecypod molds(?), (98%) ..	0.3

Threemile Limestone Member, 3.1 feet

7. Shale, variegated reddish purple, grayish blue, moderate yellow, green, weathers reddish brown and blue, shaly-bedded, not resistant, non-calcareous, unfossiliferous, contains some lenticular light grayish-blue sandstone lenses (like unit 8) at base, (94%)	2.6
6. Limestone, similar to unit 10 above, looks conglomeratic, medium yellowish gray, weathers grayish blue to moderate yellow, heavily stained with limonite, outer 1/2" stained grayish blue, medium-bedded, recrystallized; FOSSILS, gastropods, pelecypods, (38%)	0.5

SPEISER SHALE, 5.4 feet

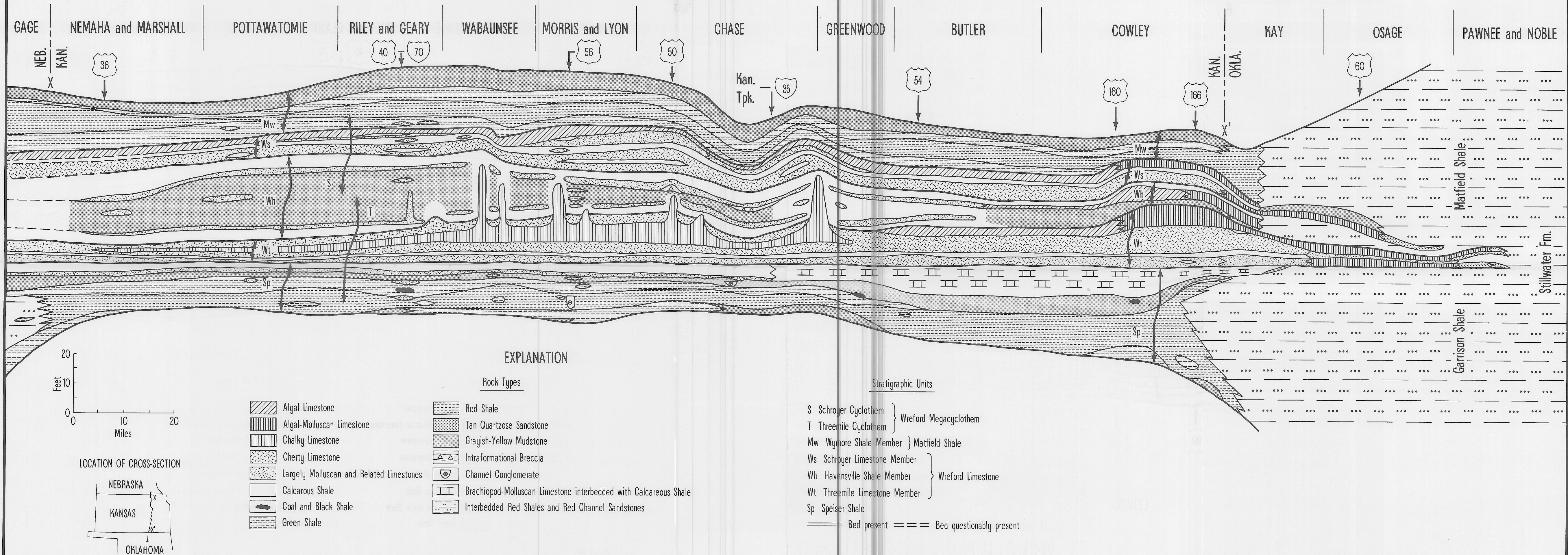
5. Shale, medium reddish brown, weathers same, very slightly calcareous, shaly-bedded, not resistant, unfossiliferous, (97%)	1.7
4. Sandstone, light grayish blue, weathers same, red stained, calcareous, fine-grained, quartzose, thin-bedded, unfossiliferous, (100%)	0.1
3. Shale, calcareous, medium reddish brown, weathers same, shaly-bedded, unresistant, unfossiliferous	0.3
2. Sandstone, light grayish blue, stains red from above units, calcareous, cross-bedded, fine-grained, quartzose, mud cracks, rain-drop imprints(?), unfossiliferous, (97%)	0.8
1. Shale, medium reddish brown, some yellow stains, weathers same, shaly-bedded, hard, more resistant than other shales of section, blocky when breaks, calcareous, unfossiliferous, (100%)	2.5
Total exposed	18.0

Localities NO01 and NO02 combined

Unit

1. Sandstone, medium reddish brown to light brown, thin- to shaly-bedded, fine-grained, quartzose, moderately friable, unfossiliferous, (100%)	5 exposed
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GENERALIZED NORTH-SOUTH CROSS-SECTION OF WREFORD MEGACYCLOTHEM



EXPLANATION

Rock Types

- | | | | |
|--|--|--|--|
| | Algal Limestone | | Red Shale |
| | Algal-Molluscan Limestone | | Tan Quartzose Sandstone |
| | Chalky Limestone | | Grayish-Yellow Mudstone |
| | Cherty Limestone | | Intraformational Breccia |
| | Largely Molluscan and Related Limestones | | Channel Conglomerate |
| | Calcareous Shale | | Brachiopod-Molluscan Limestone interbedded with Calcareous Shale |
| | Coal and Black Shale | | Interbedded Red Shales and Red Channel Sandstones |
| | Green Shale | | |

Stratigraphic Units

- | | | |
|----|----------------------------|-------------------------|
| S | Schroyer Cyclothem | } Wreford Megacyclothem |
| T | Threemile Cyclothem | |
| Mw | Wymore Shale Member | } Matfield Shale |
| Ws | Schroyer Limestone Member | |
| Wh | Havensville Shale Member | } Wreford Limestone |
| Wt | Threemile Limestone Member | |
| Sp | Speiser Shale | |
- ==== Bed present - - - - Bed questionably present

LOCATION OF CROSS-SECTION

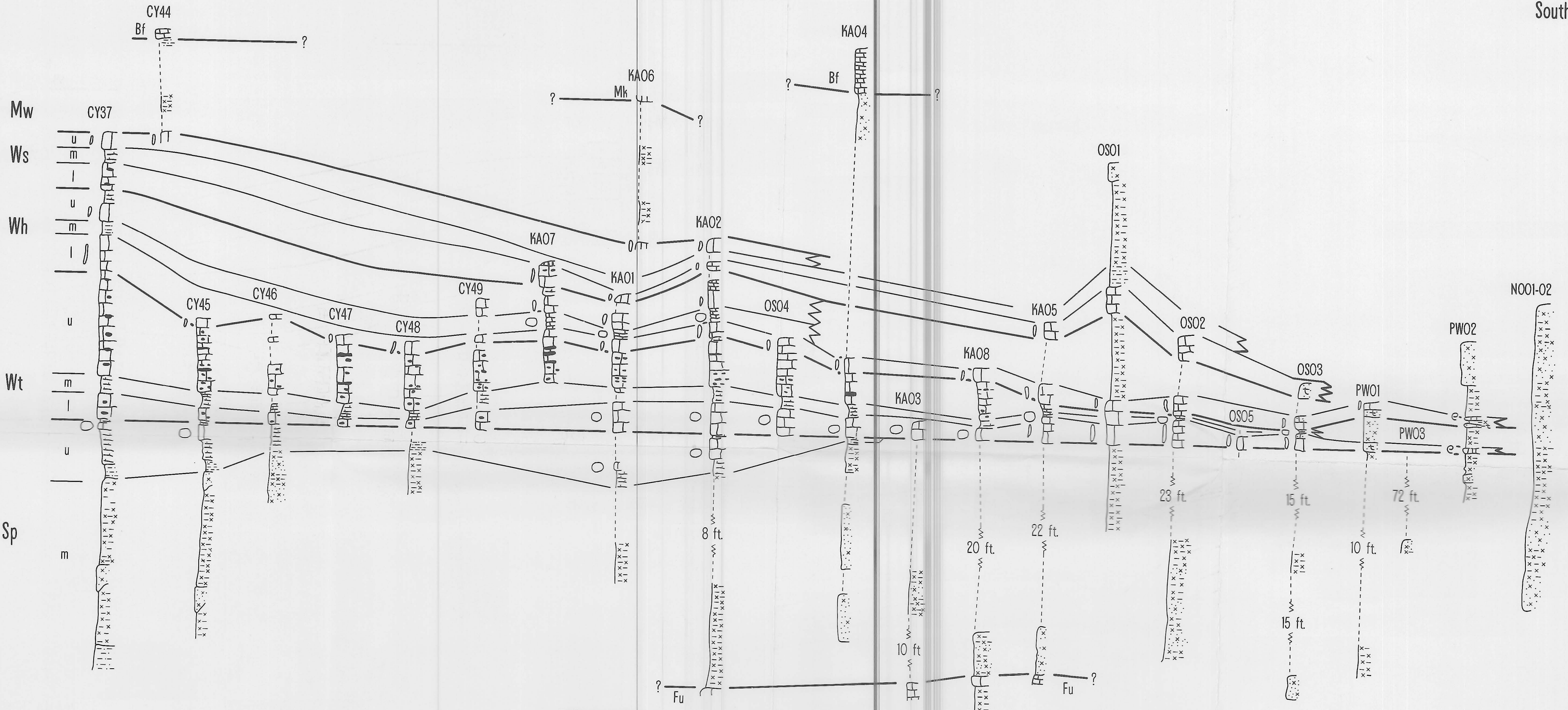


CORRELATION OF THE WREFORD MEGACYCLOTHEM IN SOUTHERNMOST KANSAS AND NORTHERN OKLAHOMA

North

KANSAS OKLAHOMA

South



EXPLANATION

- Rock Types**
- Algal-molluscan limestone
 - Algal limestone
 - Cherty limestone (with chert beds and nodules)
 - Brachiopod-molluscan limestone
 - Molluscan limestone
 - Calcareous shale
 - Grayish-yellow mudstone
 - Green shale
 - Red shale
 - Tan sandstone
 - Red sandstone

- Stratigraphic Units**
- Bf Florence Limestone Member
 - Mk Kinney Limestone Member
 - Mw Wymore Shale Member
 - Ws Schroyer Limestone Member
 - Wh Havensville Shale Member
 - Wt Threemile Limestone Member
 - Sp Speiser Shale
 - Fu Funston Limestone
 - Barneston Limestone
 - Matfield Shale
 - Wreford Limestone

u upper; m middle; l lower: informal subdivisions of the above units (see text)