PS Petrographic Characteristics of Maximum-Transgressive and Regressive Deltaic Sandstones of Upper-Pennsylvanian (Virgilian) Oread Cyclothem, NE Oklahoma*

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Abstract

Deltaic sandstones deposited during maximum-transgression and regression are expected to differ in composition and texture, because of different environmental conditions associated with sea-level changes. This hypothesis is tested by petrographic study of three sandstones from maximum-transgressive Heebner delta and 4 from regressive Elgin delta in NE Oklahoma. 300 point-counts of each sample document amount of matrix, and composition, grain size, sorting, and skewness of framework grains. The data are compared to display their similarities to interpret paleoenvironments. Heebner and Elgin samples are taken from adjacent locations except W30 (30km apart). Heebner has a coarsening upward trend (3-2.2Φ) while Elgin coarsens and then fines upwards (2.5-1.7-3.3Φ). Generally, coarser sandstones are better sorted. However, W32-5(3Φ) has a standard deviation (D) = 0.7, while W30, 262-15 7 and 8(3.4, 3.3 and33Φ) have D = 1.4, 1.7, and 1.8, respectively. W32-5 has the most feldspar. For samples of similar grain size, the ones with more feldspars are better sorted (comparing 262-13 with 262-11 and W32-6). When the QFL composition is plotted against grain size, the grain size distribution is nearly symmetrical for samples rich in feldspars (W32-5, 262-11, and 262-13, but not W30). The relatively large amount (10%) of lithics causes the strongly fine skewness of W30 (similarly 262-15 7 and 262-15 8). The QFL composition also reflects the tectonic setting of provenance (Dickinson, 1983). W32-5, 262-11, and 262-13 probably have similar source lithologies and tectonic settings, whereas W30, 262-15 7 and 8 the other. W30, which was deposited during maximum-transgression, is 30km south to 262-15 7 and 8 which were deposited during regression, but they have similar textures, suggesting the same provenance and deposition environment with a similar shoreline position. The results suggest that the composition and texture of sandstones can be used to aid in interpretation of provenance and paleoenvironments

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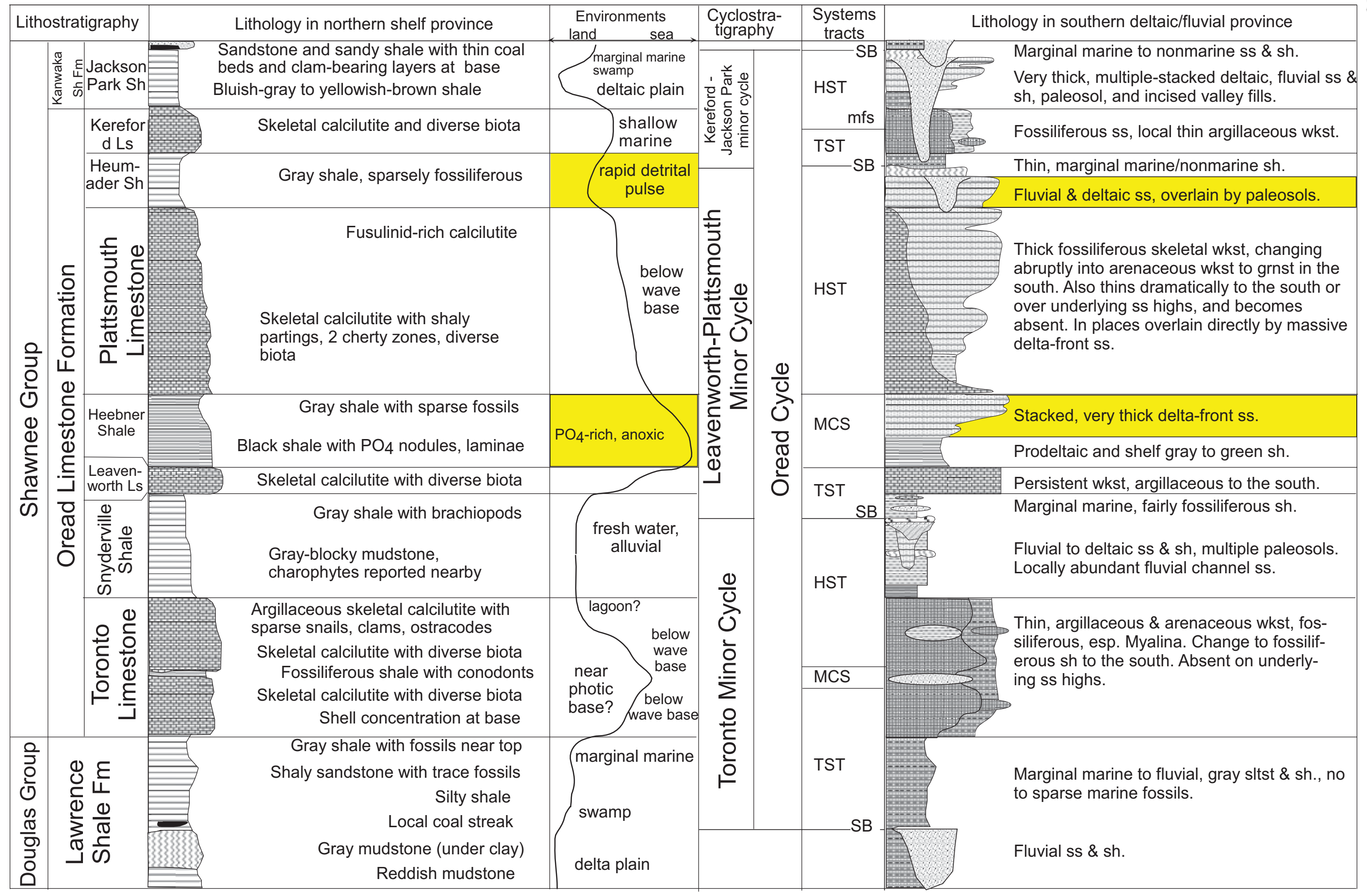
Abstract

Deltaic sandstones deposited during maximum-transgression and regression are expected to differ in composition and texture, because of different environmental conditions associated with sea-level changes. This hypothesis is tested by petrographic study of three sandstones from maximum-transgressive Heebner delta and five from late regressive Elgin delta in NE Oklahoma. 300 point-counts of each sample document amount of matrix, and composition, grain size, sorting, and skewness of framework grains. The data are compared to display their similarities to interpret paleoenvironments.

Heebner and Elgin samples are taken from adjacent locations except W30-14/15 (30 km apart). Heebner has a coarsening upward trend (3-2.2ϕ) while Elgin coarsens and then fines upward (2.5-1.7-3.3ϕ). Generally, coarser sandstones are better sorted. However, W32-N5 (3ϕ) has a standard deviation (D)=0.7ϕ, while W30-14/15, 262-15-7 and 262-15-8 (3.4, 3.3, and 3ϕ) have D=1.4, 1.7, and 1.8ϕ, respectively. W32-N5 has the most feldspar. For samples of similar grain size, the ones with more feldspars are better sorted (comparing 262-13 with 262-11 and W32-6). When the QFL composition is plotted against grain size, the grain size distribution is nearly symmetrical for samples rich in feldspars that are dominantly in the same size as quartz grains (W32-N5, 262-11, and 262-13, but not W30-14/15). The relatively large amount (10%) of lithics causes the strongly fine skewness of W30-14/15 (similarly 262-15 7 and 262-15 8). The QFL composition also reflects the tectonic setting of provenance (Dickinson, 1983). W32-N5, 262-11, and 262-13 probably have similar source lithologies and tectonic settings, whereas W30-14/15, 262-15-7 and 262-15-8 the other. W30-14/15, which was deposited during maximum-transgression, is 30 km south to 262-15-7 and 262-15-8 which were deposited during regression, but they have similar textures, suggesting the same provenance and depositional environment with a similar shoreline position. The results suggest that the composition and texture of sandstones can be used to aid in interpretation of provenance and paleoenvironments.



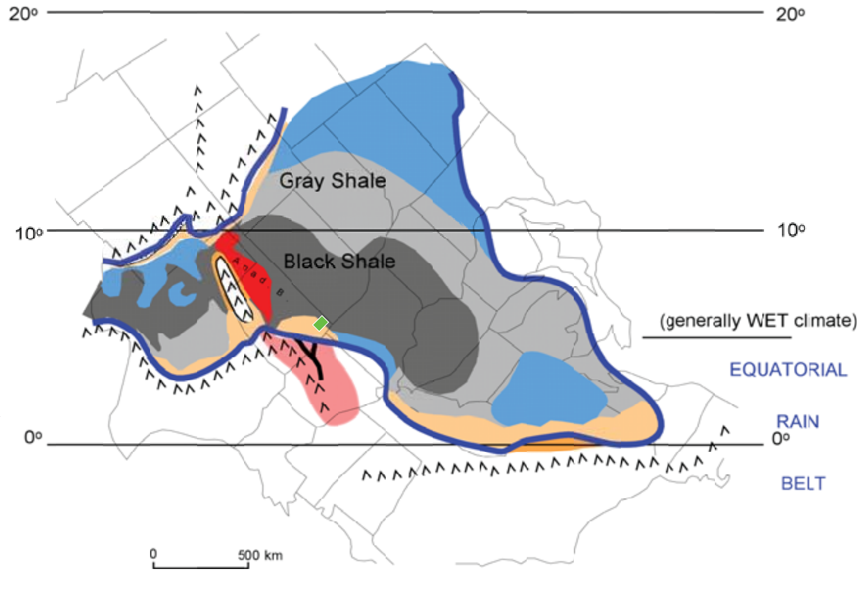


Figure 1. Midcontinent paleogeography during Late Pennsylvanian maximum transgression. Study area is in green rectangle. After Yang (2006).

Table 1. Stratigraphic successions of the Oread Cyclothem in contrasting northern shelf, SE Kansas and southern deltaic-fluvial province, NE Oklahoma. Study intervals are highlighted in yellow. After Yang (2006).

Introduction

Upper Pennsylvanian sandstones have been the target in petroleum exploration and production in Kansas and Oklahoma. A good understanding of the characteristics and depositional environments of those sandstones will help explore the correlative subsurface petroleum reservoirs efficiently.

The study area is in Osage County, Oklahoma, where Heebner Shale and Heumader Shale members are exposed. The area is on the Cherokee Platform on the Kansas Shelf, north of Ouachita thrustbelt during the Late Pennsylvanian time. It formed by cyclic sedimentation on epi-cratonic shelf during repetitive shoreline transgression and regression. Deltaic sandstones deposited during maximum-transgression and late regression are expected to be different in composition and texture, because of different environmental conditions associated with sea level changes. This hypothesis is tested by petrographic study of three sandstones from maximum-transgressive Heebner delta and five from late regressive Elgin delta.

Provenance interpretation based on composition and texture of sandstones also provides information on paleoenvironment, paleoclimate, and paleogeography study. This study investigates the provenance(s) of Heebner and Elgin deltas based on the relationship between framework composition of sandstones and tectonic setting using the model of Dickinson *et al.* (1983).

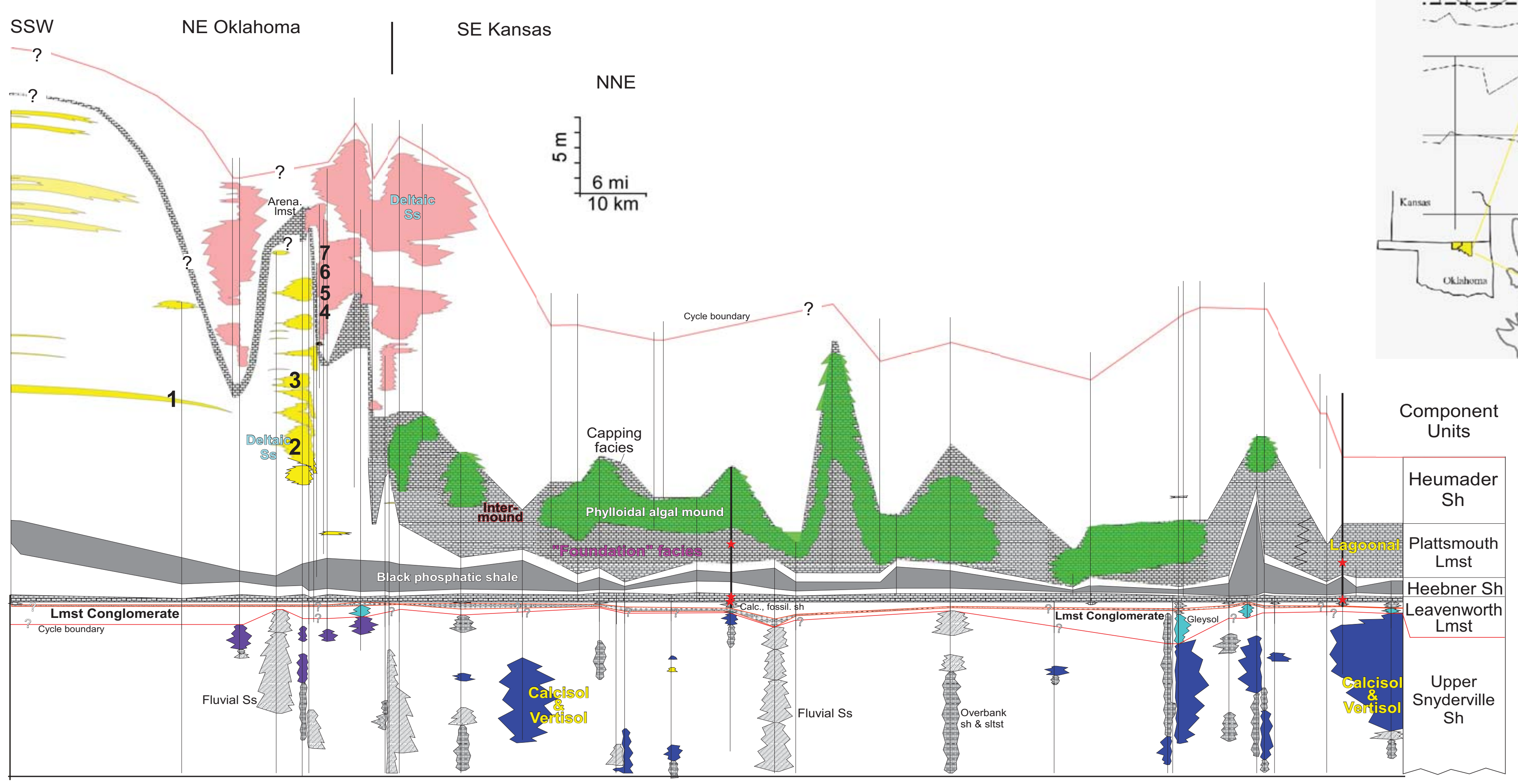


Figure 2. Stratigraphic architecture of Oread cyclothem. Lithofacies and thickness is well illustrated (Yang, 2006). Maximum-transgression deltaic sandstones: 1- W30-14/15; 2- W30-N5; 3- W30-6. Late regression deltaic sandstones: 4- 262-11; 5- 262-13; 6- 262-14; 7- 262-15-7 and 262-15-8.

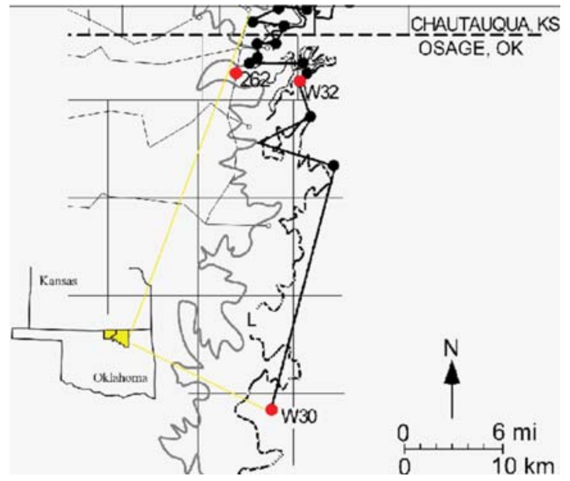


Figure 3. Locations of sampling sites. W30 is ~30 km south of W32 and 262.

Methodology

Petrographic study has been done using thin sections under polarized microscope. 300 points were counted along lines at an equal increment in each thin section to document amount of matrix and composition, grain size, sorting, and skewness of framework grains. Grain size distribution in percentage of abundance was constructed for each sample based on the raw point-counting data (Figs. 4 and 5). The distribution was then used to construct a cumulative curve for each sample. According to Folk's (1957) formulae (listed bellow), the graphic mean grain size, degree of sorting, and skewness of framework grains were calculated (Tables 2 and 3), assuming all grains are equi-dimensional and spherical, and have equal densities. The percentage in abundance of quartz, feldspar, and lithic fragments for each sample were calculated and plotted in diagrams (Figs. 6, 7). Last, QFL composition was interpreted with respect to tectonic setting of provenance using Dickinson *et al.*'s (1983) classification (Fig. 8).

Folk's (1957) formulae:

$$M_z = \frac{\phi_{16}+\phi_{50}+\phi_{84}}{3}$$

$$\sigma_i = \frac{\phi_{84}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6}$$

$$SK_i = \frac{\phi_{84}+\phi_{16}-2\phi_{50}}{2(\phi_{84}-\phi_{16})} + \frac{\phi_{95}+\phi_5-2\phi_{50}}{2(\phi_{95}+\phi_5)}$$

$$\phi = -\log_2 S$$

S = grain size in millimeters

Results and Discussion

Maximum-Transgression Deltaic Sandstones

1. Generally maximum-transgression deltaic sandstones are coarsening upward (Table 2. from W32-N5 to W32-6. Site W30 is 30 km south form Site W32, so it is not involved in the discussion about vertical trend). Grains include both quartz and feldspar. However, within this trend of coarsening upward, abundance of feldspar decreased significantly (Fig. 6 B and C).

2. W32-N5 and W32-6 are similarly sorted, but W32-N5 is near symmetrical distributed, while W32-6 is fine skewed (Table 2). W32-N5 has finer grains and much more matrix than W32-6 (Fig. 4), which contribute to a near symmetrical distribution. W32-6 has a coarser grain size but much less matrix (Fig. 4), whose fine skewed distribution is probably caused by the significant amount of fine feldspar grains (Fig. 6C).

3. W30-14/15 is the finest (Table 2) and with the most amount of matrix (Fig. 4) and lithic fragments (Fig. 6C) among the three maximum-transgression sandstones. It also has the worst sorting and strongest fine skewness (Table 4). However, in W30-14/15 quartz grains are the dominant small grains (< v. fine sand sized), while in W32-N5 and W32-6 there are more feldspar than quartz grains in the small size fraction (Fig. 6 A, B. and C).

Sample #	Mean	Sorting	Skewness
W30-14/15	3.4ϕ v. fine sand	1.46ϕ porly sorted	0.41 Strongly fine skewed
W32-N5	3.0ϕ v. fine sand	0.72ϕ moderately sorted	0.04 near symmetrical
W32-6	2.2ϕ fine sand	0.77ϕ moderately sorted	0.17 fine skewed

Table 2. Calculated graphic mean, inclusive graphic standard deviation, inclusive graphic skewness of framework grain size for maximum-transgression deltaic sandstones.

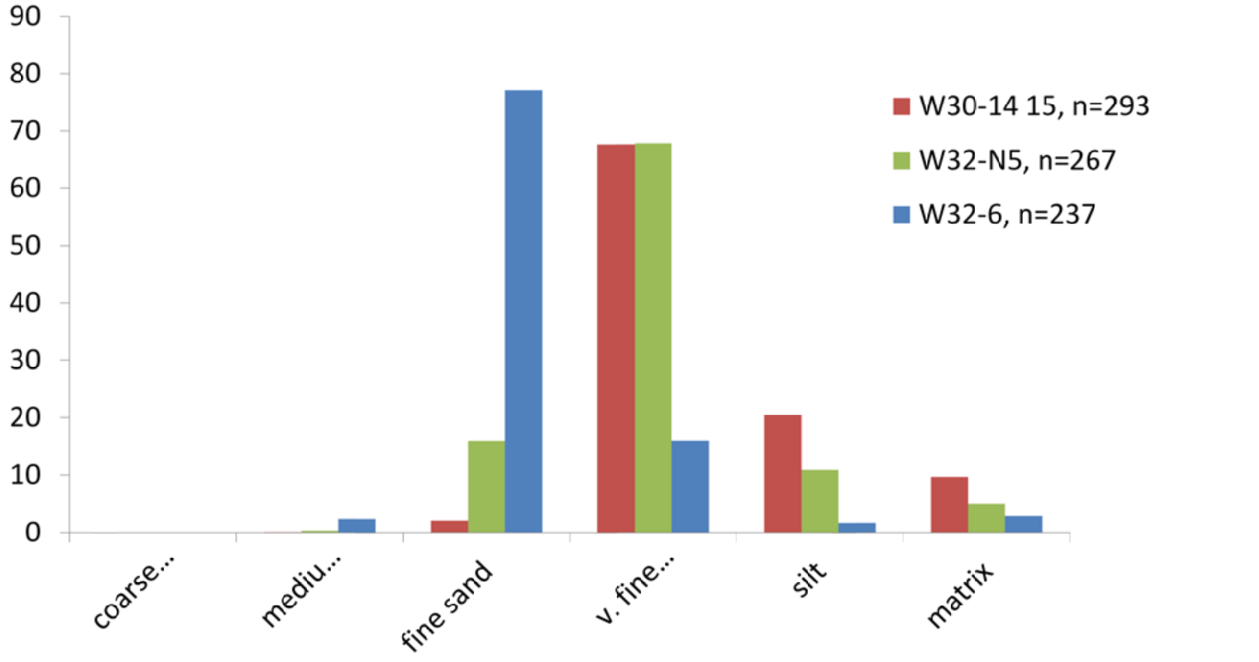


Figure 4. Distribution of framework grain size for maximum-transgression deltaic sandstones. y-axis is percentage in abundance, and increments for x-axis is one ϕ unit.

Late-Regression Deltaic Sandstones

1. Late-regression sandstones coarsen upwards and then fine again (Table 3, through 262-11 to 262-15-8).

2. Generally, coarser sandstones have better sorting (Table 3). However, comparing to 262-14, 262-13 is finer but better sorted (Table 3). This is probable cause is that 262-13 has both quartz and feldspar grains dominant in the size of very fine sand (Fig. 7), and 262-14 has more matrix than 262-13 (Fig. 5).

3. Late-regression sandstones in the upper position (262-15-7 and 262-15-8) are very fine sand sized, poorly sorted, and strongly fine skewed (Table 3), and they have significant amount of matrix (Fig. 5).

4. There is a trend of increasing abundance of lithic fragments through lower to upper late-regression deltaic sandstone. Generally the abundance of rock fragments is increasing, and the abundance of feldspar grains is decreasing through lower to higher stratigraphic positions (Fig. 7 A, B, C, D, and E).

Sample #	Mean	Sorting	Skewness
262-11	2.5ϕ fine sand	0.64ϕ moderately well sorted	-0.08 near symmetrical
262-13	2.1ϕ fine sand	0.47ϕ well sorted	0.08 near symmetrical
262-14	1.8ϕ medium sand	0.62ϕ moderately well sorted	0.17 fine skewed
262-15-7	3.3ϕ v. fine sand	1.73ϕ poorly sorted	0.40 strongly fine skewed
262-15-8	3.0ϕ v. fine sand	1.82ϕ poorly sorted	0.38 strongly fine skewed

Table 3. Calculated graphic mean, inclusive graphic standard deviation, inclusive graphic skewness of framework grain size for late-regression deltaic sandstones.

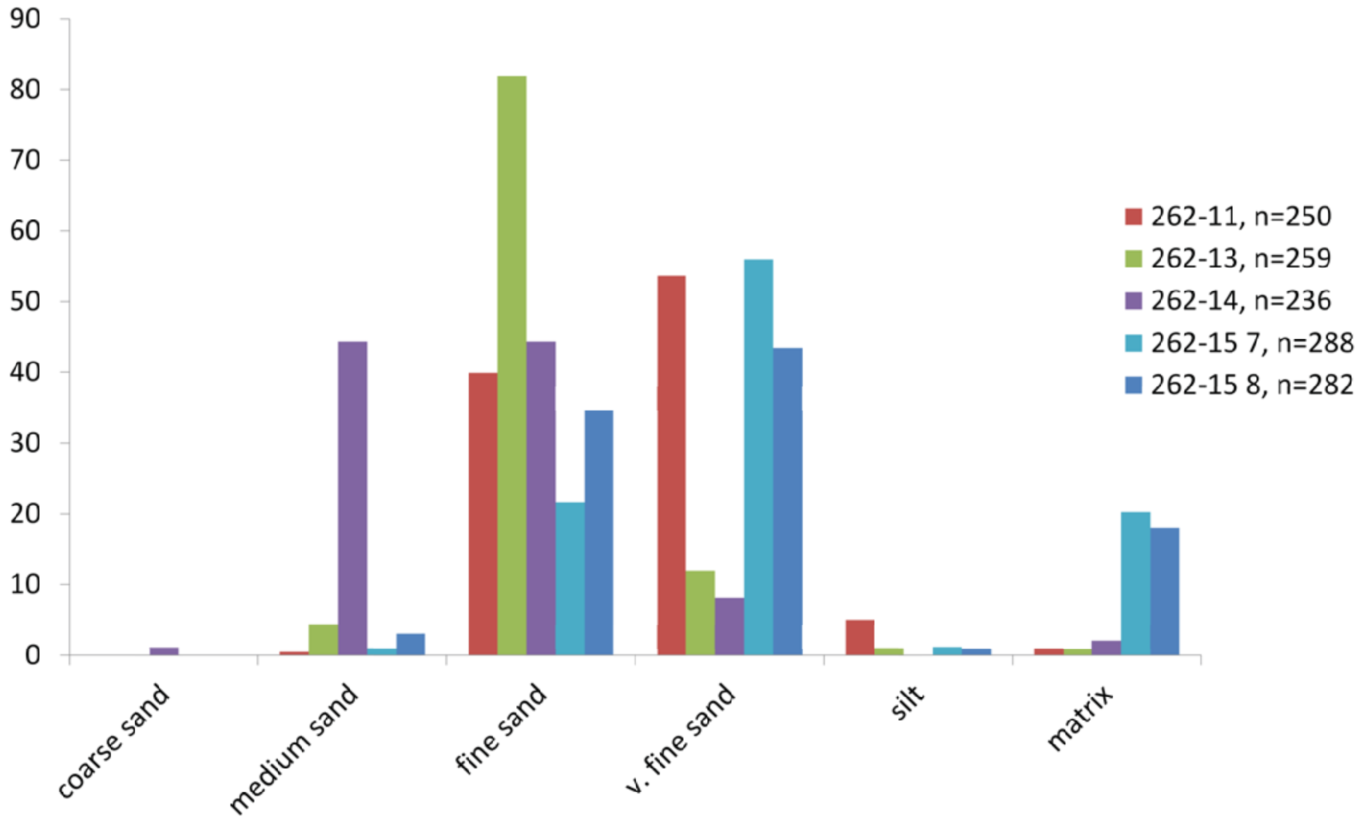


Figure 5. Distribution of framework grain size for late-regression deltaic sandstones. y-axis is percentage in abundance, and increments for x-axis is one ϕ unit.

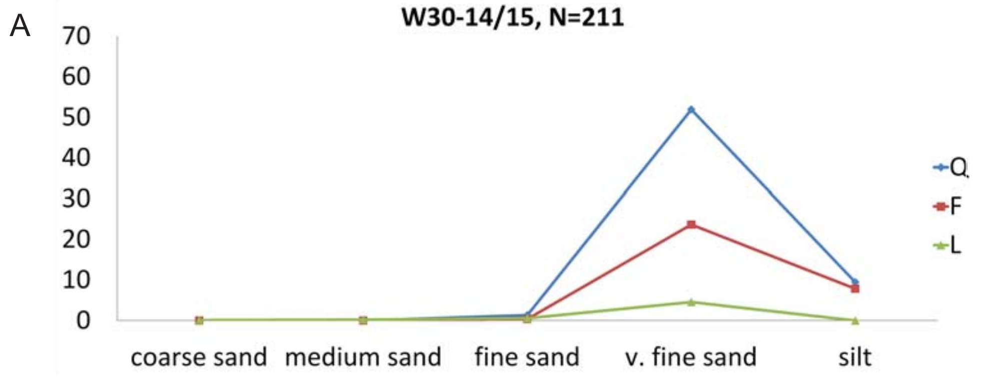
In general, maximum-transgression deltaic sandstones are finer than late-regression deltaic sandstones in the size of framework grains, though maximum-transgression sandstones are coarsening upward while late-regression sandstones coarsen and then fine upward.

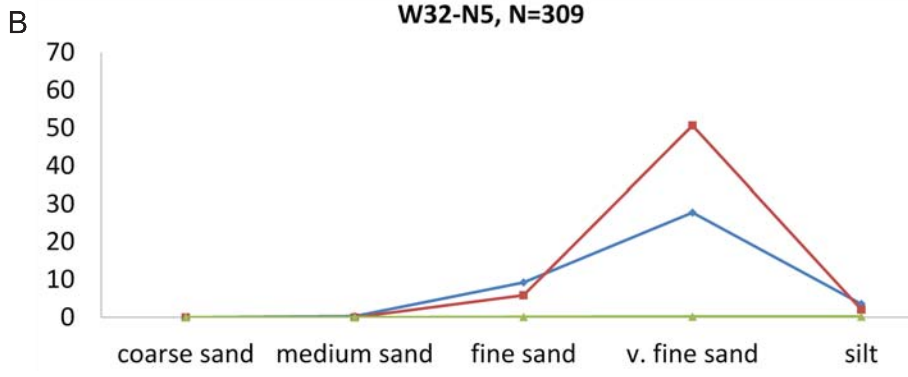
The abundance of matrix decreases upward in maximum-transgression sandstones, while increases in late-regressive sandstones. In general, maximum-transgression sandstones have less matrix than late-regression sandstones.

In both maximum-transgression and late-regression sandstones, the abundance of feldspar grains decreases upward. There are much more feldspar framework grains in maximum-transgression sandstones than in late-regression sandstones generally.

In maximum-transgression sandstones, only W30-14/15 has significant amount of lithic fragments as framework grains, either W32-N5 or W32-6 barely has any. However, in late-transgression sandstones, the abundance of lithic fragments increases upward, although lithics are rare in the lower delatic intervals.

Though W32-14/15 was deposited during maximum-transgression, its texture and framework grain size of different clasts are very similar to those of late-regression sandstones. W30-14/15 is 30 km south of Site W30 and Site 262, and its depositional environment at maximum transgression is probably similar to that of Site 262 during late regression.





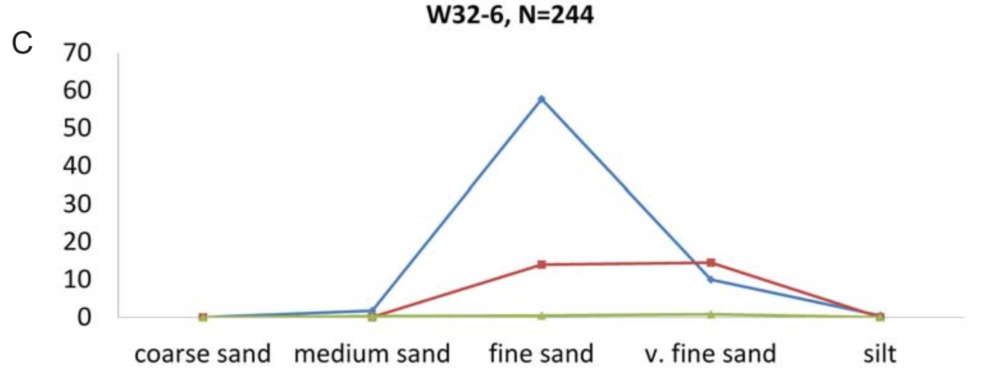
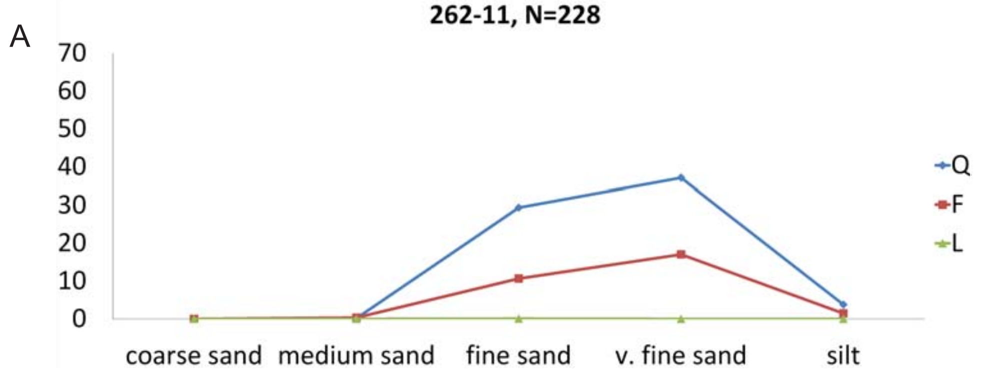
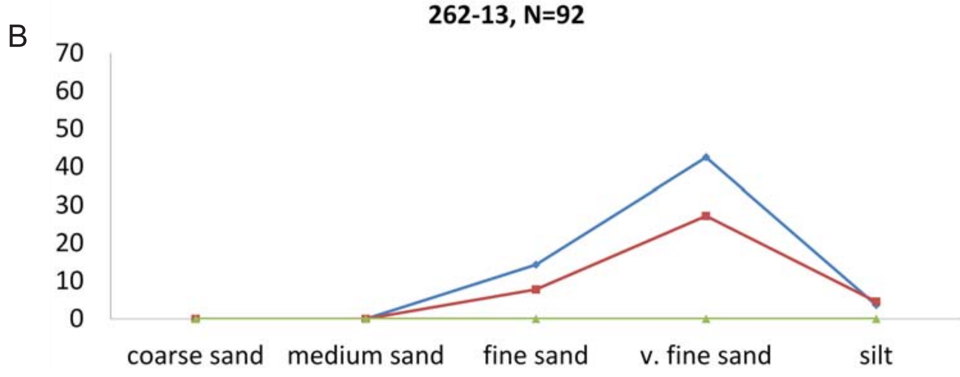
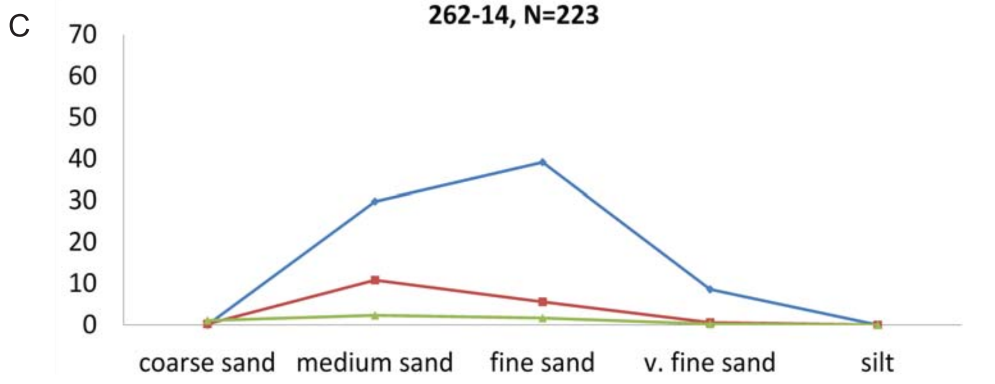
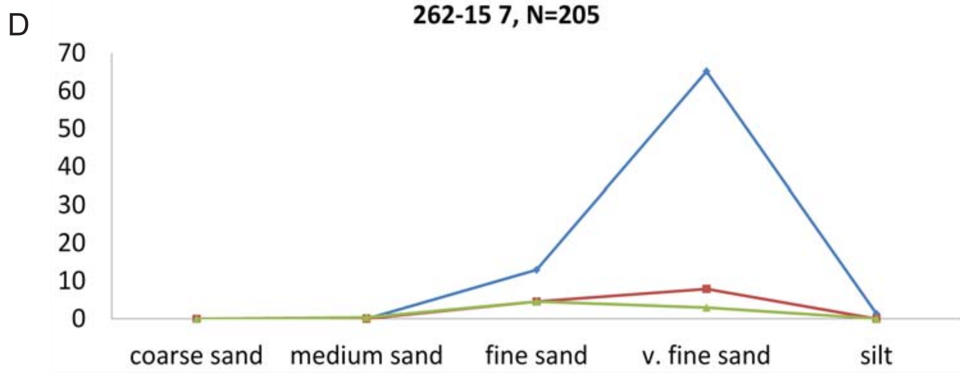


Figure 6. Grain size distribution of framework grains of quartz (Q), feldspar (F), and lithic fragment (L)) for maximum-transgression deltaic sandstones. y-axis is percentage in abundance, and the increment of x-axis is one ϕ unit. A- W30-14/15; B- W32-N5; C- W32-6.









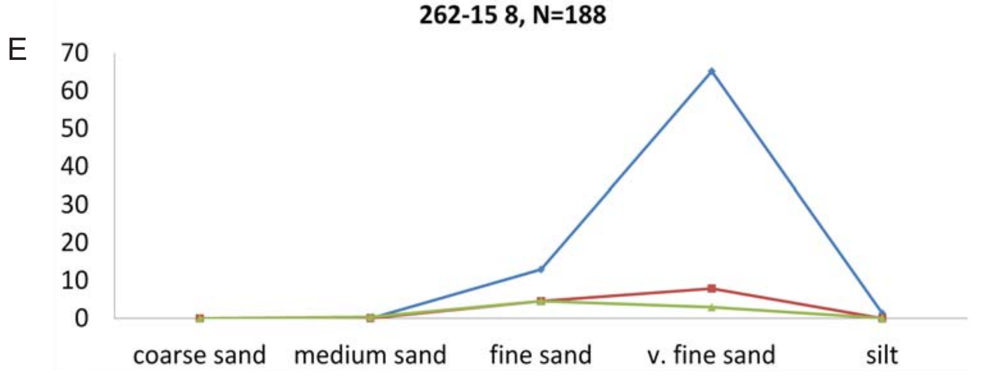


Figure 7. Grain size distribution of framework grains of quartz (Q), feldspar (F), and lithic fragment (L) for late-regression deltaic sandstones. y-axis is percentage in abundance, and the increment of x-axis is one ϕ unit. A- 262-11; B- 262-13; C- 262-14; D- 262-15-7; E- 262-15-8.

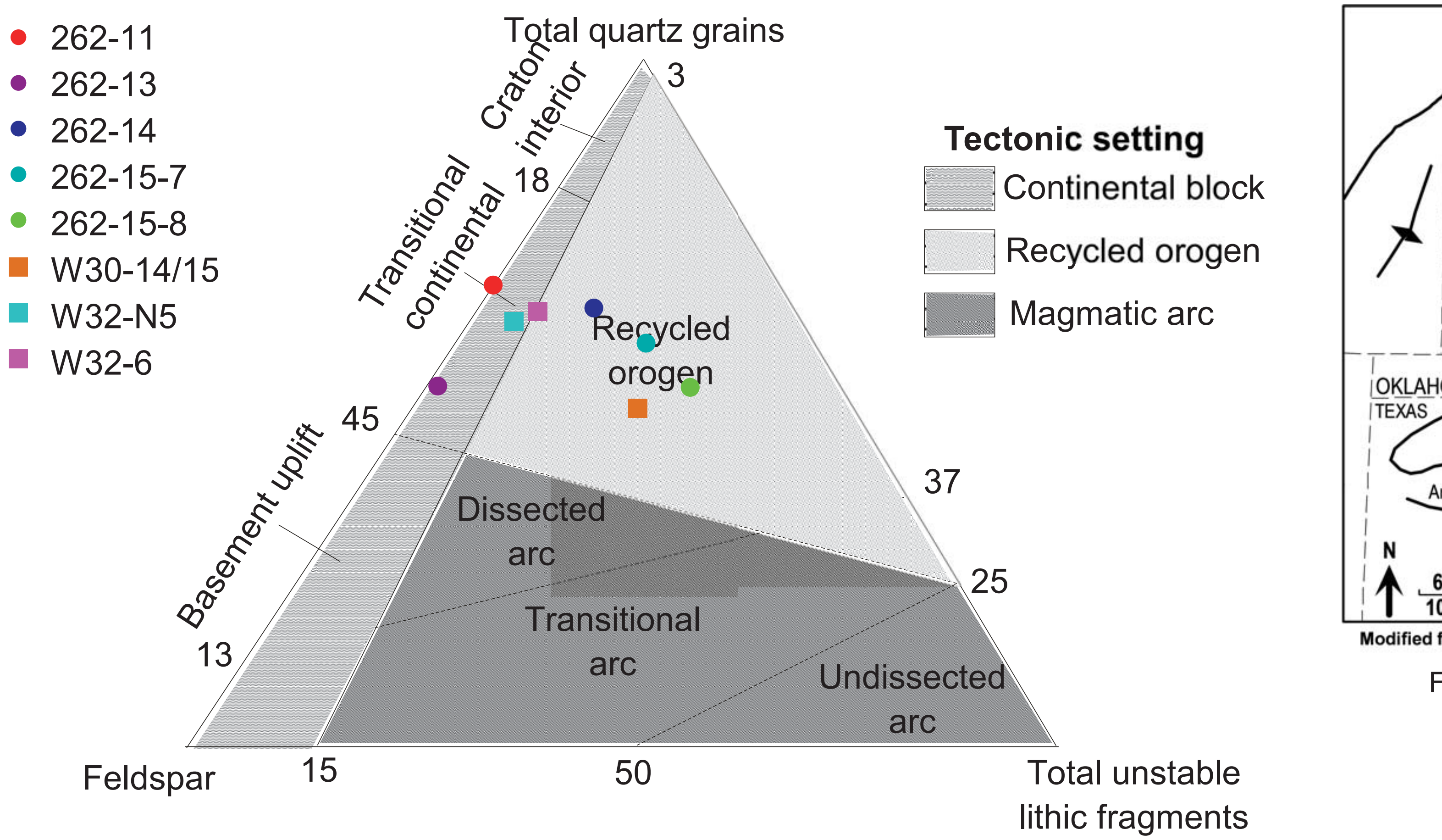


Figure 8. Tectonic classification of sandstones showing the possible tectonic settings of provenance(s) (after Dickinson *et al.*, 1983).

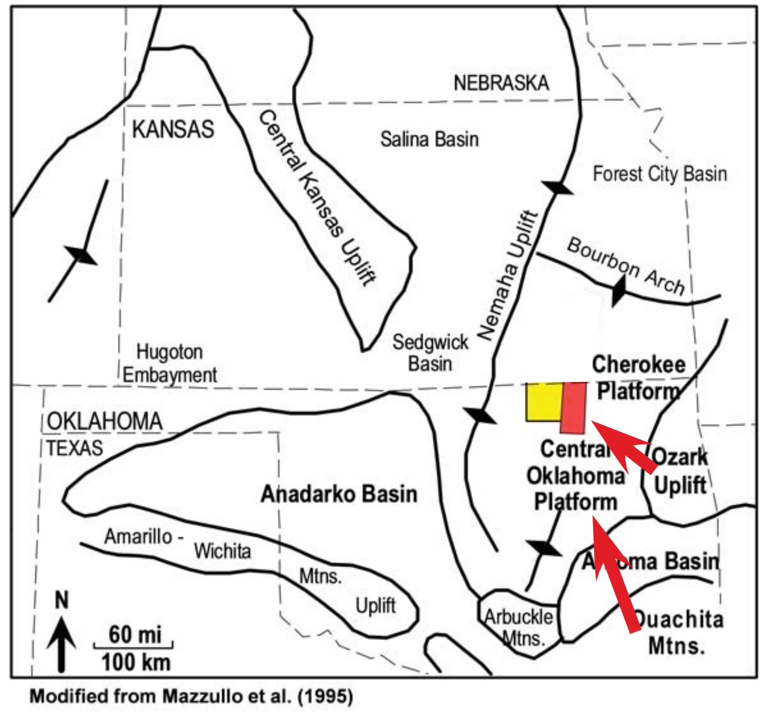


Figure 9. Tectonic elements around outcrop and subsurface study area in SE Kansas and NE Oklahoma.

The points on the ternary diagram indicate that maximum-transgressive sandstone W30-14/15 and late-regressive sandstones (262-14, 262-15-7, and 262-15-8) have similar provenances, as we expected, even though the latter is stratigraphically younger. It is also possible that they were in similar depositional facies during different time is spite of sea level changes.

Plots on ternary diagram of maximum-transgression sandstones (except W30-14/15) are more close to those of late-regression sandstones in a lower stratigraphic position (262-11 and 262-13). This suggests that there might be a change in main provenance during regression, from a transitional continental region to a cratonic region.

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References

Archer, A. W., and H. R., Feldman, 1995,Incised valleys and estuarine facies of the Douglas Group (Virgilian): Implications for similar Pennsylvanian sequences in the U. S. Mid-Continent, in Hyne, N. J., ed., Sequence stratigraphy of the Mid-Continent, The Tulsa Geological Society, Tulsa, Oklahoma, p. 119 - 140.

Bruemmer, M., 2003, Three-dimensional cyclo-stratigraphic architecture of nonmarine and marine mixed siliciclastic and carbonate Oread Cyclothem (Upper Pennsylvanian), SE Kansas and NE Oklahoma: MS thesis, Wichita State University, 338 pp.

Dickinson, W. R., Beard, L. S., Brakenridge, G. R., Erjavec, J. L., Ferguson, R. C., Inman, K. f., Knepp, R. A., Lindberg, F. A., and Ryberg, P. T., 1983, Provenance of North American sandstones in relation to tectonic setting: Geological Society of America Bulletin, v. 94, p. 222 - 235.

Folk, R. L., P. B. Andrews, and D. W. Lewis, 1970, Detrital sedimentary rock classification and nomenclature for use in New Zealand: New Zealand J. Geol. Geophys. p. 959.

Obrist, J. and Yang, W., 2011, Petrographic comparison and contrast of fluvial and deltaic sandstones, Upper-Pennsylvanian Oread Cyclothem, NE Oklahoma: Kansas Geological Society Bulletin, v. 86, p. 18 - 27.

Yang, W., 2007, Transgressive wave ravinement on an epicontinental shelf as recorded by an Upper Pennsylvanian soilnodule conglomerate - sandstone unit, Kansas and Oklahoma, USA: Sedimentary Geology, v. 197, p 189-205.

Yang, W., Bruemmer, M., and Williams, M. T., 2006, Coeval deltaic, platform carbonate, and condensed shelf sedimentation, Pennsylvanian Leavenworth Limestone-Heebner Shale-Plattsmouth Limestone-Heumader Shale depositional sequence, SE Kansas and NE Oklahoma, KGS Bulletin, v 81 No. 2, p. 12 - 24.