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Pennsylvanian Stratigraphy of Douglas County, Kansas: Glacioeustatically Modulated Cyclic Deposition on a Remarkably Smooth Shelf

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SIGMA GAMMA EPSILON
Centennial Field Trip
Lawrence, Kansas
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US 59 Roadcut, Pleasant Grove, Kansas

Pennsylvanian Stratigraphy of Douglas County, Kansas: Glacioeustatically Modulated Cyclic Deposition on a Remarkably Smooth Shelf

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Abstract

The Middle and Late Pennsylvanian succession of Kansas consists of two types of cyclothems, lithologic successions that consist of several members that repeat in a particular order. Cyclothems are a few meters to a few tens of meters thick. One type of cyclothem, the Kansas cyclothem, or here the limestone-rich cyclothem, consists of interbeds of limestone and shale, where the amounts of limestone are approximately equal to the amount of shale or dominate the succession. This trip will study one such cyclothem in the Oread Limestone at Stop 3 and possibly another cyclothem at the optional Stop 4. Siliciclastic cyclothems are dominated by shale and may contain an incised valley filled partly by fluvial or estuarine sandstone. The Lawrence Shale, which we will see at Stops 2 and 3, contains such features.

While many cyclothems are incomplete, both types of cyclothem may contain dark gray to black, fissile, phosphatic core shale beds, commonly a meter or less thick, and an underlying transgressive deposit beneath. Overlying deposits represent regression or progradation of the shoreline: either lime mudstone grading to grainstone or clay-rich marine shale grading to coarse siltstone or fine sandstone. Paleosols and fossils of marine invertebrates are common and indicate that deposition took place in both marine and non-marine conditions. Some marine deposits show a paleosol overprint.

The deposits indicate that the area was a shelf during the Late Pennsylvanian where relief was very low, and very laterally extensive deposits formed as sea level rose and fell. The alternation of shale-rich and limestone-rich intervals plus the feet-per-mile dip to the WNW create the characteristic topographic expression of cuestas with gently sloping caps that are underlain by limestone. While glacial deposits are mostly restricted to northern and east-central Douglas County, Pleistocene glaciers influenced the erosional and drainage patterns of the area.

KEY WORDS: cyclothem, paleosols, Kansas cyclothem, Lawrence Shale, Oread Limestone, Lansing Group, Plattsburg Limestone, Vilas Shale, Captain Creek Limestone, Eudora Shale, Stanton Formation

Driving directions.

The trip will drive south on US 59 from Lawrence and exit at Douglas County Rte 458. At Douglas County Rte 458, turn east and travel a little less than a mile to the turnoff for Wells Overlook. Turn right on the entrance road and continue to the park at the top of the hill.

The Road South

On the way, we will travel down a rather gentle slope from the ridge where the University of Kansas (KU) sits (Mount Oread), which underlain by the Oread Formation and Lawrence Shale, and pass onto the terraces and alluvium that overlie Pennsylvanian rocks along the Wakarusa River (fig. 1). South of the Wakarusa River, we will pass Shanks Hill on the right (west). Shanks Hill is underlain by Lawrence Shale, with Pleistocene outwash at its crest. Apocryphal tales tell of coal mines in the Lawrence Shale on Shanks Hill.

Stop 1: Wells Overlook County Park: Lunch and overview of the area.

Landscape of NE Kansas.

The landscape of Douglas County consists of the valleys of the Kansas River and the Wakarusa River, upland cuestas underlain by limestone with a thin coating of shale, and slopes cuestas underlain by shale beds that contain local lenses of sandstone. The limestone beds dip to the WNW at a few feet per mile, so that traversing I-70 from Kansas City westward through Lawrence to Topeka, one crosses successively younger rock units, ranging from early Late Pennsylvanian (Missourian) rocks of the Kansas City Group to later Late Pennsylvanian (Virgilian) rocks of the Shawnee Group.

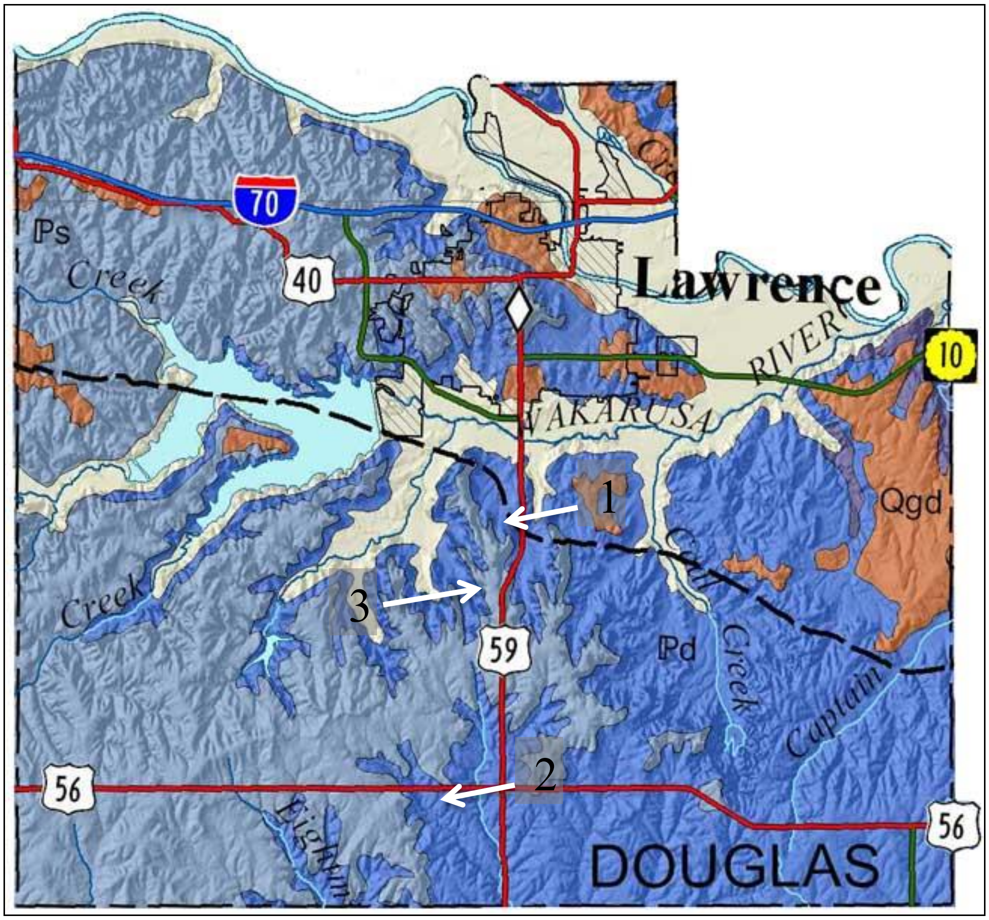


Figure 1. Geologic Map of Douglas County, Kansas. Qgd = glacial deposits, IPd = Douglas Group (includes Lawrence Shale), IPs = Shawnee Group (includes Oread Limestone), tan is alluvium. Locations of 3 stops shown. Alignment of US 59 has shifted since this map was made; Stop 3 is actually a roadcut along the new highway. Apparently, the Kansas Geological Survey feels that north arrows and scales are not necessary components of maps; north is at the top & E-W distance across Douglas County is very close to 24 miles.

http://kgs.ku.edu/General/Geology/County/def/douglas.html.

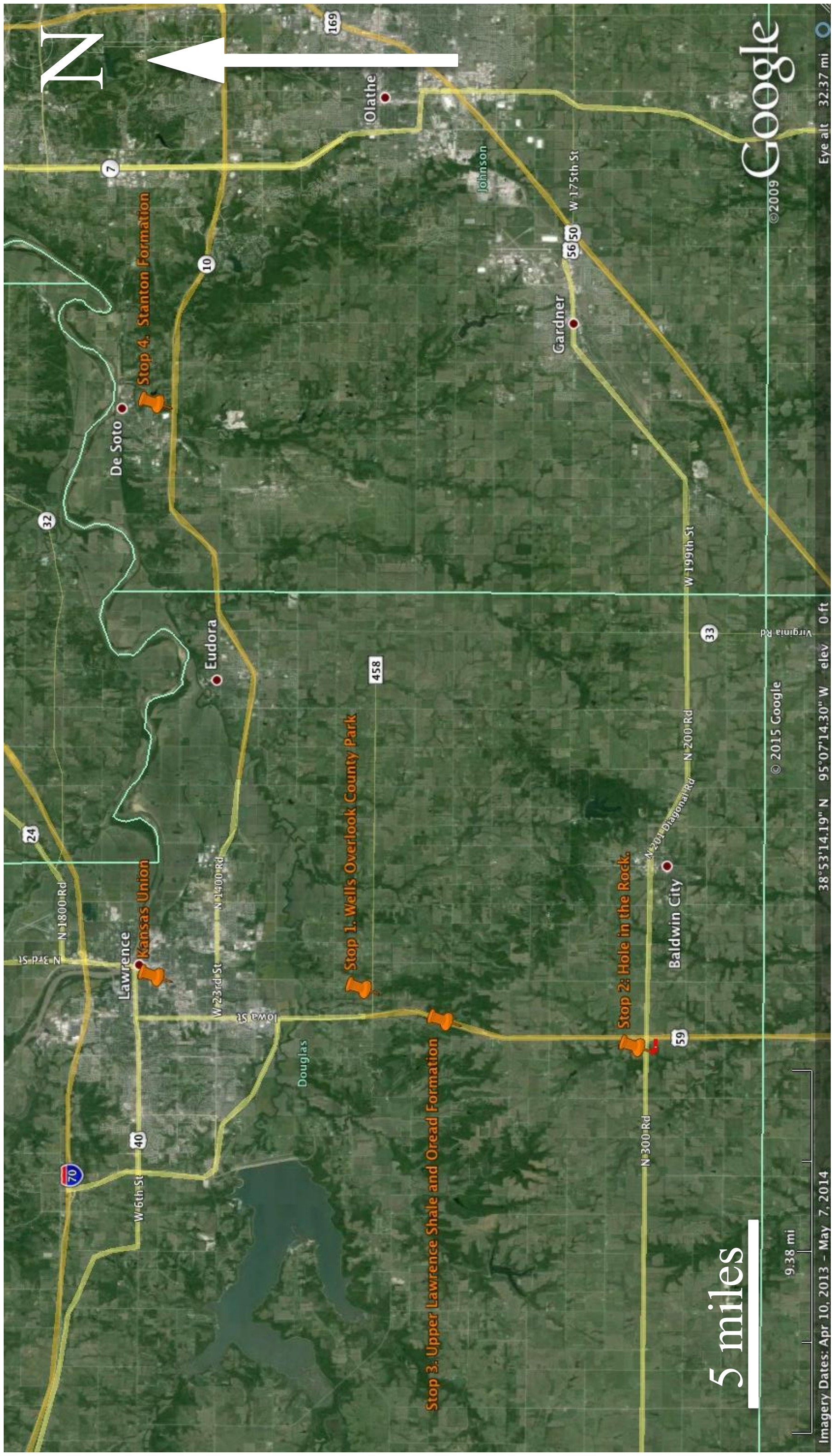


Figure 2. Field trip stops. North is to the left. The forested slopes extending to the west and southeast from Stop 3 mark the in-face of the cuesta of the Oread Limestone with uplands to the south underlain by the limestone beds. Lower land to the east and north of the cuesta is underlain by the Lawrence Shale and older strata. A forested slope east of Stop 4 marks the cuesta formed by the Lansing Group. © Google maps, 2015.

In the climate conditions in eastern Kansas, the limestone successions are more resistant to weathering than are the shale-rich successions. As the succession dips very gently to the WNW, the local landscape consists of a series of cuestas where limestone layers form caps on east-facing shaly slopes (fig. 2). As the dips of the strata are very low, the rule of Vs predicts that the outcrop pattern will be greatly affected by irregularities of topography. Indeed, each stream valley or drainage cuts a deep V into the course of the cuesta.

Wells Overlook Park, where we eat lunch, sits on a finger of the cuesta defined by the Oread Limestone, as does the KU campus, which is visible to the north across the valley of the Wakarusa River (fig. 2). The cuesta continues irregularly to the southeast out of the local valleys of the Wakarusa and Kansas Rivers and then to the SSW into northern Oklahoma - very irregularly because the dip is low and the Rule of Vs prevails. And, north of the Kansas River, north of Lawrence, the cuesta continues irregularly to the NNE.

The valleys along the aforementioned rivers represent dissection related to glacial activity and development of the Missouri River. The Missouri River is remarkable in that its course across South Dakota, between Nebraska and Iowa, and then between Kansas and Missouri as far south as Kansas City, cuts obliquely across the regional slope to the east. Rivers from the west, such as the Kansas River and the Platte River (of Nebraska; there is one in Missouri also), are much longer and carry more discharge that tributaries to the Missouri from the east, such as the Platte River (of Missouri). The western tributaries extend from the Rocky Mountains or from the large fan of material that spread east from the Rockies as they rose during the Pliocene. This fan, largely the Ogallala Formation, caps the High Plains of the Texas and Oklahoma panhandles, western Kansas, western Nebraska, eastern Colorado, and southern South Dakota.

In fact the Missouri River is a relatively recent development that occurred during Pleistocene ice ages, when ice sheets extended into Iowa and Missouri from the north and melt-water lakes formed in the westward valleys, upstream of the glacial margin. Those lakes spilled successively from one valley to the next to the south, carving a broad canyon that has remained as the course of the Missouri River long after the ice melted back. Previous to the glacial damming and formation of the Missouri River, rivers of the Great Plains flowed eastward directly to the Mississippi River.

This valley of the Missouri River was graded to that of the Mississippi River, which it joins near St. Louis. As the Mississippi River at times was graded to the low sea levels of the Pleistocene glacial ages, the Missouri valley and those of its tributaries, were cut down tens of feet below their present levels, especially where they passed through the restrictions formed by the limestone beds. The Mississippi valley aggraded owing to a rise in sea level and the immense discharge of water and sediment from the melting ice sheet. The valley of the Missouri River and its tributaries filled with sediment, aggrading to form the present gently sloping valley floors. The process was not linear, but cyclic, leaving terraces marking the level of filling of the valleys in ancient times. The valley-filling sediments are good aquifers.

This combination of resistant limestone, more easily eroded shale and siltstone, Pleistocene glaciation, Pleistocene changes of sea level, and erosion has formed the pleasantly rolling topography of Douglas County: nearly level uplands with limestone bedrock, shaly slopes and gentle hills, and terraced alluvial river valleys.

Cyclothems in Kansas

Now the question comes up about the alternation of limestone-rich and shale-rich successions that accounts for the caps and inner slopes of the cuestas. Middle and Late Pennsylvanian strata of Kansas consist of *cyclothems*. Many of the individual cyclothems consist of limestone beds of a few different types that alternate with relatively thin shale beds of a few different types. Other cyclothems are shaly, containing far less limestone, but have well-developed sandstone lenses and noticeable, though thin, beds of coal. Cyclothems are a few meters to a few tens of meters thick.

A complete "Kansas cyclothem", first recognized by Moore (1936; Figure 3), consists of an outer limestone; a shale bed, light gray, greenish gray, or reddened; a thin, persistent limestone bed (50 cm to 1 m); a dark gray to black, fissile, phosphatic shale a meter or less thick, a thicker (1 to 4 m) limestone bed, and an overlying light gray shale bed. Some such cyclothems were defined to contain a "super limestone" and a "fifth limestone" with intervening beds of shale. We can refer to this type of succession as a *limestone-rich cyclothem*.

This succession and its interpretation were modified somewhat by Heckel and Baesemann (1975), who recognized that some of the the outer limestone beds were incomplete or poorly developed cyclothems in and of themselves, and the essential components of the complete cyclothem are the thin "middle" limestone, the black core shale, and the overlying thicker "upper" limestone bed (fig. 3**).** Heckel and Baesemann indicated that the "middle" limestone represented a time of rising sea level, the black shale represented a time of high sea level and quasi-estuarine water circulation, and the "upper" limestone represented regression or progradation and a steady or falling sea level. Their interpretation is based upon lithologic characteristics that were not understood when Moore defined the cyclothems as well as paleontological characteristics.

More recent work on the Deer Creek Limestone has recognized paleosol features in several of the components (fig. 4), suggesting that the sea-level curve is oversimplified (Rader, personal communication, 2015). The Deer Creek is two megacyclothems above the Oread megacyclothem, and is well exposed nearby. Rader combined information from previous interpretations plus his information from trace fossils and paleosol features to recognize additional exposure surfaces. Noticeable especially is a paleosol in the Larsh-Burroak Shale Member, separating dark gray to black, fissile, phosphatic shale below from greenish gray shale above, and several paleosols within the Ozawkie Limestone Member. Just as Heckel and Baesemann (1975) applied information unavailable to previous workers, Rader has used features that earlier studies could not have considered. Interpretations are subject to change as time produces new techniques and new information.

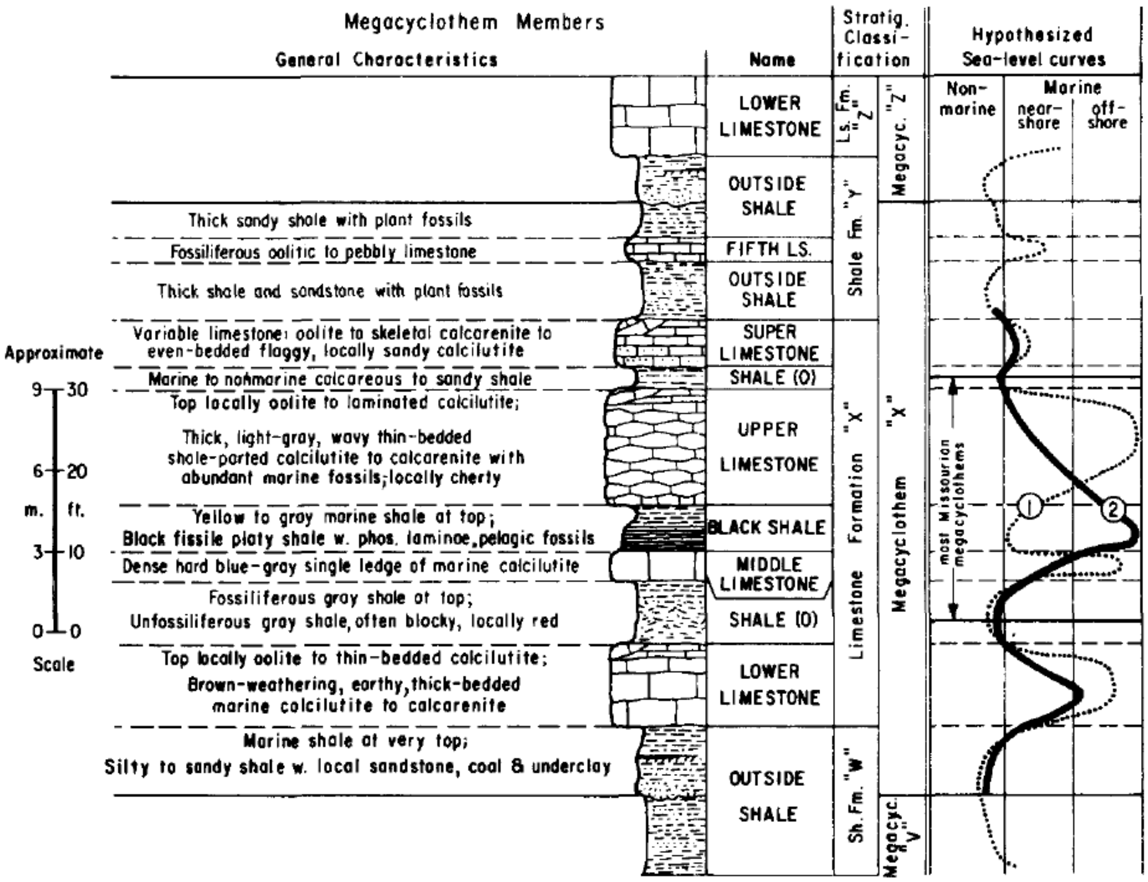


Figure 3. Description and two interpretations of Kansas (limestone-rich) cyclothems based upon the Oread megacyclothem (Virgilian, Upper Pennsylvanian). Interpretation of sea level curve 1 is by Moore (1936) and curve 2 is by Heckel & Baesemann (1975). After Heckel and Baesemann (1975). At Stop 3, the lower limestone is the Toronto Limestone Member, the Snyderville Shale Member overlies it, the middle limestone is the Leavenworth Limestone Member, the upper limestone in the Plattsmouth Limestone Member (at the top of the outcrop). Heckel & Baesemann (1975) argued that the black shale member represented an off-shore environment, with a transgressive (Leavenworth) limestone beneath and a regressive or progradational limestone (Plattsmouth in this case) above. The Lawrence Shale, at the bottom of the outcrop, is an outside shale in Moore's scheme, but is one or more of the shale-rich cyclothems described here with a thick, channel-filling sandstone cutting down into it.

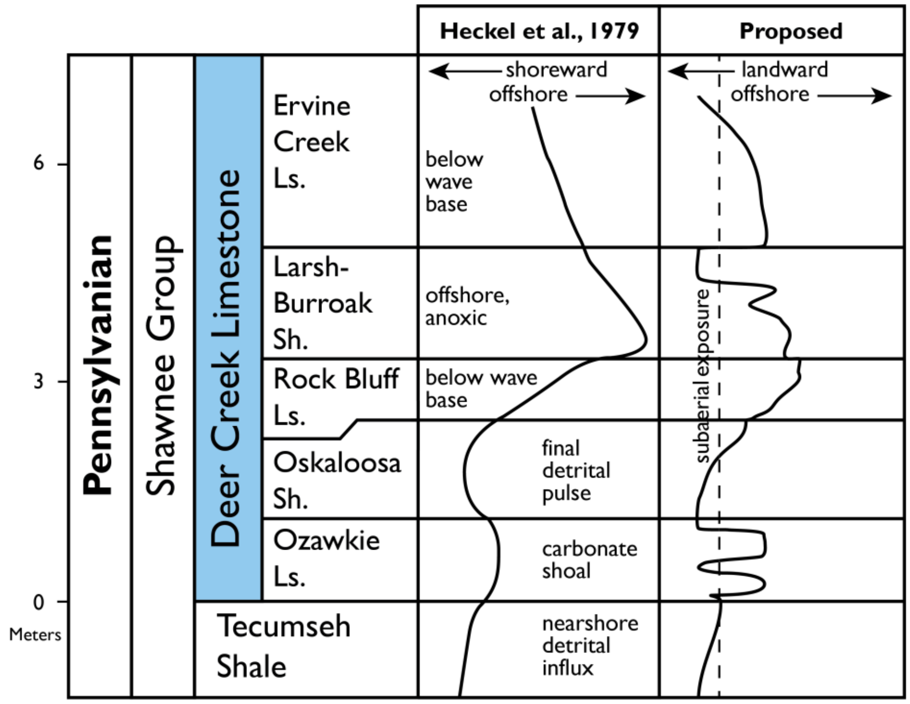


Figure 4. Sea-level interpretation of a limestone-rich cyclothem in the Deer Creek Limestone (Virgilian, Upper Pennsylvanian) of the Shawnee Group (Rader, personal communication, 2015). The proposed curve of depositional position relative to sea level is based partially upon information from paleosol features and ichnology that imply periods of subaerial exposure superimposed on the more generalized sea-level curve of Heckel et al. (1979).

Siliciclastic cyclothems

Siliciclastic cyclothems, the other type mentioned above, have some parallels with the limestone-rich variety that are useful for interpretation, and are also markedly different (Walton, 1996; fig. 5). Both varieties commonly contain beds of dark gray to black, fissile, phosphatic shale. In the shale-rich cyclothems, the black core shale commonly overlies a very thin limestone or fossiliferous and calcareous sandstone bed that, in turn, overlies a coal bed and an underclay or paleosol horizon. The thin limestone or sandstone bed is likely to represent a shelf deposit that overlies a ravinement surface that was cut by waves as the sea transgressed coal swamps. If so it is analogous to the transgressive middle limestone beds of the other type of cyclothem.

Figure 5 shows that bulk of the siliciclastic cyclothem consists of a coarsening upward succession of marine shale that grades into coarse siltstone or fine sandstone at the top. Some such sandstone beds contain hummocky cross-bedding, indicating wave activity. The top of the progradational or regressive interval is commonly overprinted by the paleosol processes and gleying associated with the next coal bed. This progression is analogous to the regressive upper limestone of the limestone-rich cyclothems, which grade from lime mudstones to packstone-wackestone and grainstone successively, with a paleosol overprint at the top in some examples.

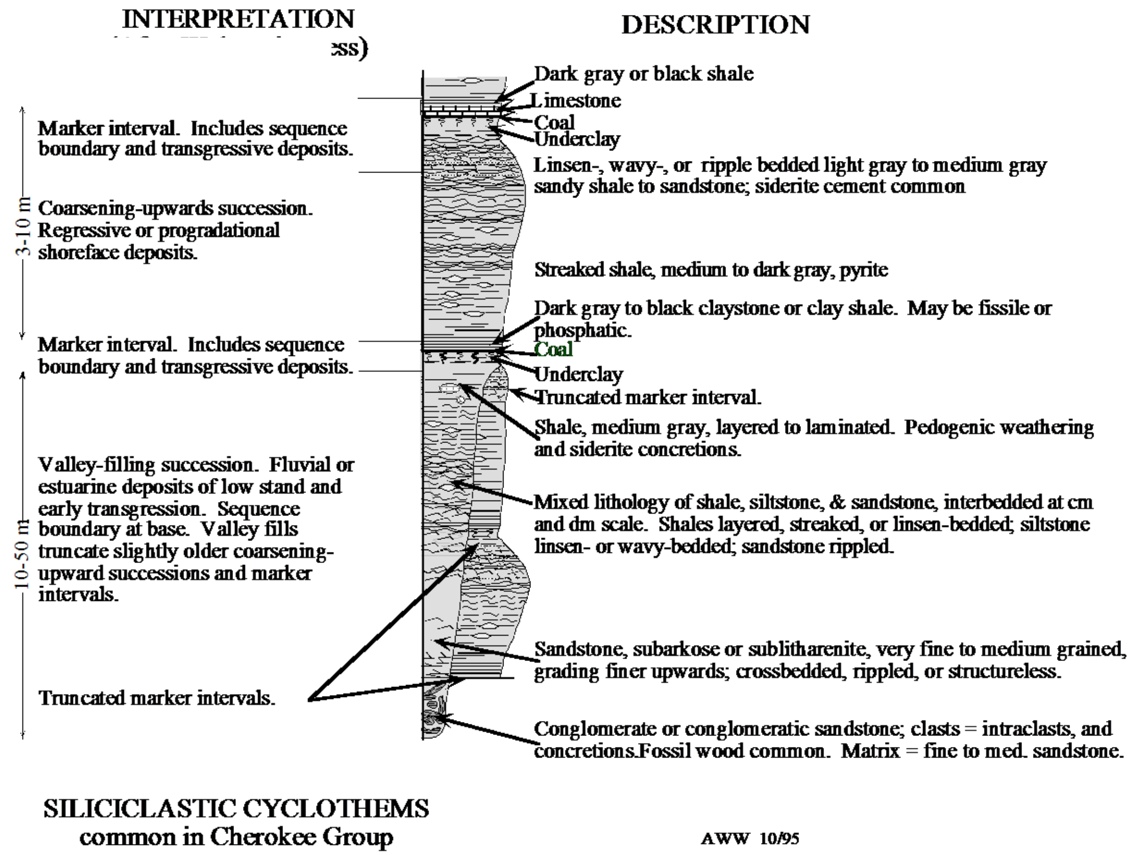


Figure 5. Siliciclastic cyclothems of the Cherokee Group (Desmoinesian) of southeastern Kansas. Lawrence Shale displays some of the same features even though the figure represents older rocks—late Middle Pennsylvanian rather than late Late Pennsylvanian. The marker intervals above include some or all of a coal bed with a sideritic underclay, a thin (cm to dm) limestone or shelly sandstone, and a dark gray to black shale. The analogy to the middle limestone and core shale of the limestone-rich cyclothem is strong, being strengthened by the presence of a paleosol horizon immediately beneath the middle limestone. The Lawrence shale, like several of the Cherokee cyclothems, includes a deeply incised valley partially filled with sandstone.

In the case of the Lawrence Shale, a dark-gray shale with fossils of fish skulls lies at the base, above a noticeable limestone, the Haskell Limestone Member, the top of the Stranger Formation. The Haskell Limestone is more analogous to a middle limestone bed of the limestone-rich cyclothem than the thin limestone or sandstone post-ravinement deposits of the Cherokee Group. Unfortunately those rocks are not exposed along the route of the trip. However, it is illustrative of the point that the two types of cyclothems are parts of a continuum that the lower part of the Lawrence Shale grades laterally into the Cass Limestone Member to the north, making the Haskell Limestone-lower Lawrence Shale-Cass Limestone succession a characteristic limestone-rich cyclothem where it occurs.

The siliciclastic cyclothems include lenticular, but elongate bodies of sandstone, and a number of beds of coal **(Figure 5**). These bodies of sandstone, which may be as little as half of a kilometer wide up to as much as several kilometers wide, overlie surfaces that are deeply incised into slightly older rocks. The deepest incision that I know of is about 50 m. Similar incision has been described by Archer et al. (1994) in the Stranger Formation, immediately below the Lawrence Shale, where the Tonganoxie Sandstone Member fills an incised valley that cuts from near the top of the formation into the Stanton Formation beneath. The Desmoinesian Cherokee Group contains several such incised-valley fills.

Lateral Extent

Some parts of the overall succession are rich in shale, with only thin limestone beds, other parts, the parts most easily seen at the outcrop, consist of limestone with thin, but very continuous beds of shale. In fact, the succession is remarkable in that beds of limestone or of certain kinds of shale are traceable for hundreds of kilometers both to the north and south in the outcrop belt (Iowa, NW Missouri, eastern Kansas, and into eastern Oklahoma) and to the west in the subsurface from the outcrop belt across the state of Kansas.

Driving Directions

Return to Douglas County Ret 458, turn left, and turn south on US 59. Continue to the intersection of US 56 at Baldwin Junction. Along the way the group will climb from the slopes of the Oread Cuesta through the Lawrence Shale and the several members of the Oread Limestone to a rather level upland. We will be passing through a nice road cut of Lawrence Shale and Oread Limestone that will be Stop 3. Before arriving at Baldwin Junction, US 59 drops back onto the Lawrence Shale. Exit US 59 at US 56 and turn right (west) on US 56. Immediately turn left (south) on the frontage road (formerly US 59) and get the vehicles as close to the white barn on the right as possible. The bus may not be able to turn off of US 59, but can drop off the passengers and find a suitable place to turn around. We will go back the way we came.

Stop 2: Hole in the Rock

This stop is on private property. Any future visitors should inquire with the owners about access.

Hole in the Rock features a small waterfall over a ledge of cross-bedded sandstone. Beneath the waterfall is a small cave that reportedly harbored Border Ruffians during the Bleeding Kansas days in the run-up to the Civil War. But this is a geology field trip.

The rock unit exposed here is a sandstone bed, generally referred to as the Ireland Sandstone Member, part of the Lawrence Shale, which is of Late Pennsylvanian (Virgilian) age (fig. 6). We can look at the character of the cross-beds to determine the processes that deposited it, and perhaps infer its environment of deposition.

Archer *et al*. (1994) described incised-valley fills in the Douglas Group, but concentrated on the Tonganoxie Sandstone Member in the underlying Stranger Formation. They did include reference to and outcrops of the Ireland Sandstone Member in the Lawrence Shale. Such valley-filling deposits have a lower part dominated by fluvial processes and overlying sandstone beds show evidence of tidal activity. The upper beds of the incised-valley-fill succession are shale and siltstone deposits of the estuary. Archer et al. (1994) did not report evidence of any estuary-mouth sandstone deposits. At stop 3 we will see the top of the Lawrence Shale, the part that overlies the sandstone shown here at Hole in the Rock.

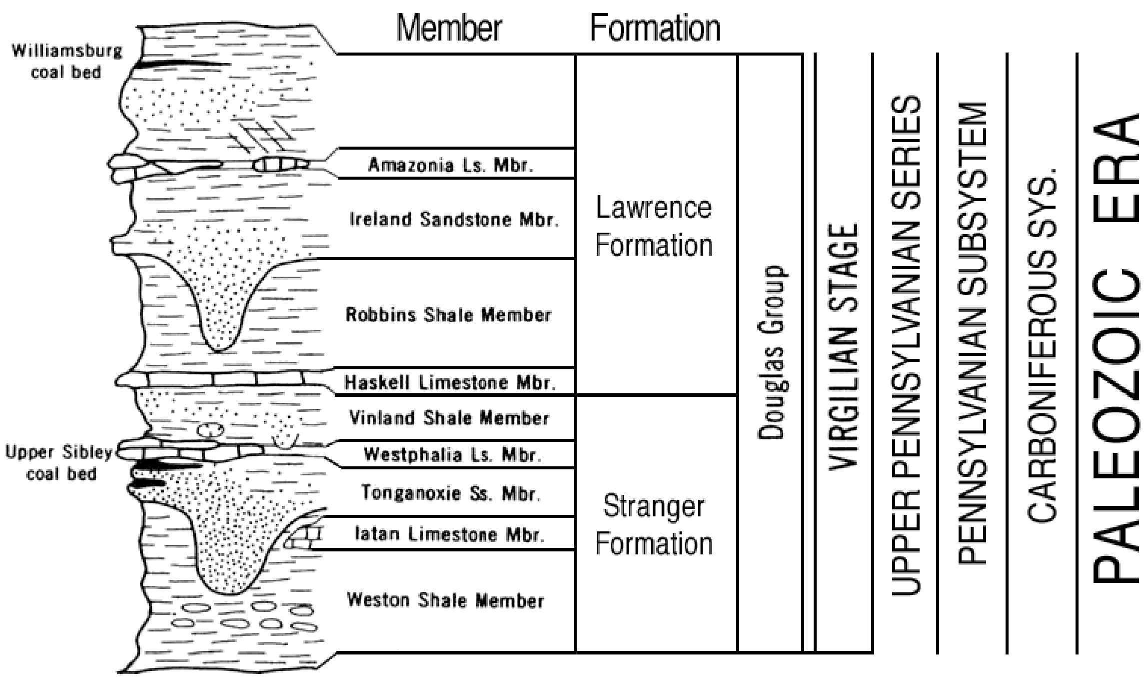


Figure 6. Stratigraphy of the Douglas Group, including the Lawrence Shale. The Ireland Sandstone Member, exposed here at Hole in the Rock (Stop 2), partially fills a channel eroded into slightly older beds. (http://www.kgs.ku.edu/General/Strat/Chart/index.html, downloaded 3/22/2015)

Driving Directions

Return to US 56 and turn left (north) onto US 59. Drive just over 4 miles to a large outcrop at Milepost 149. Stop near the lower (north) end of the outcrop. We will work our way to the south along the outcrop examining features of the rocks.

Stop 3. Roadside outcrops of the upper Lawrence Shale and the Oread Limestone along US 59.

Construction of a limited-access highway involved making a significant roadcut where the road ascends from the upper part of the Lawrence Shale (fig. 6) through the Oread Limestone (fig. 7) to the top of the local cuesta. The Lawrence Shale here is largely shale, but includes some coal beds and some reddened horizons that may be incipient paleosol horizons.

The Oread Limestone here contains the Toronto Limestone, which has both transgressive and regressive phases, making it an incomplete cyclothem as it lacks the core shale. The Snyderville Shale, where fresh and well exposed displays marked paleosol features, including large-scale curving, concave-up shrinkage cracks indicating vertisols where wetting and drying cycles were common. The Leavenworth Limestone is a middle limestone and represents transgression; the Heebner Shale is a core shale, but is unusually thick. The Plattsmouth Limestone represents the regressive phase of deposits.

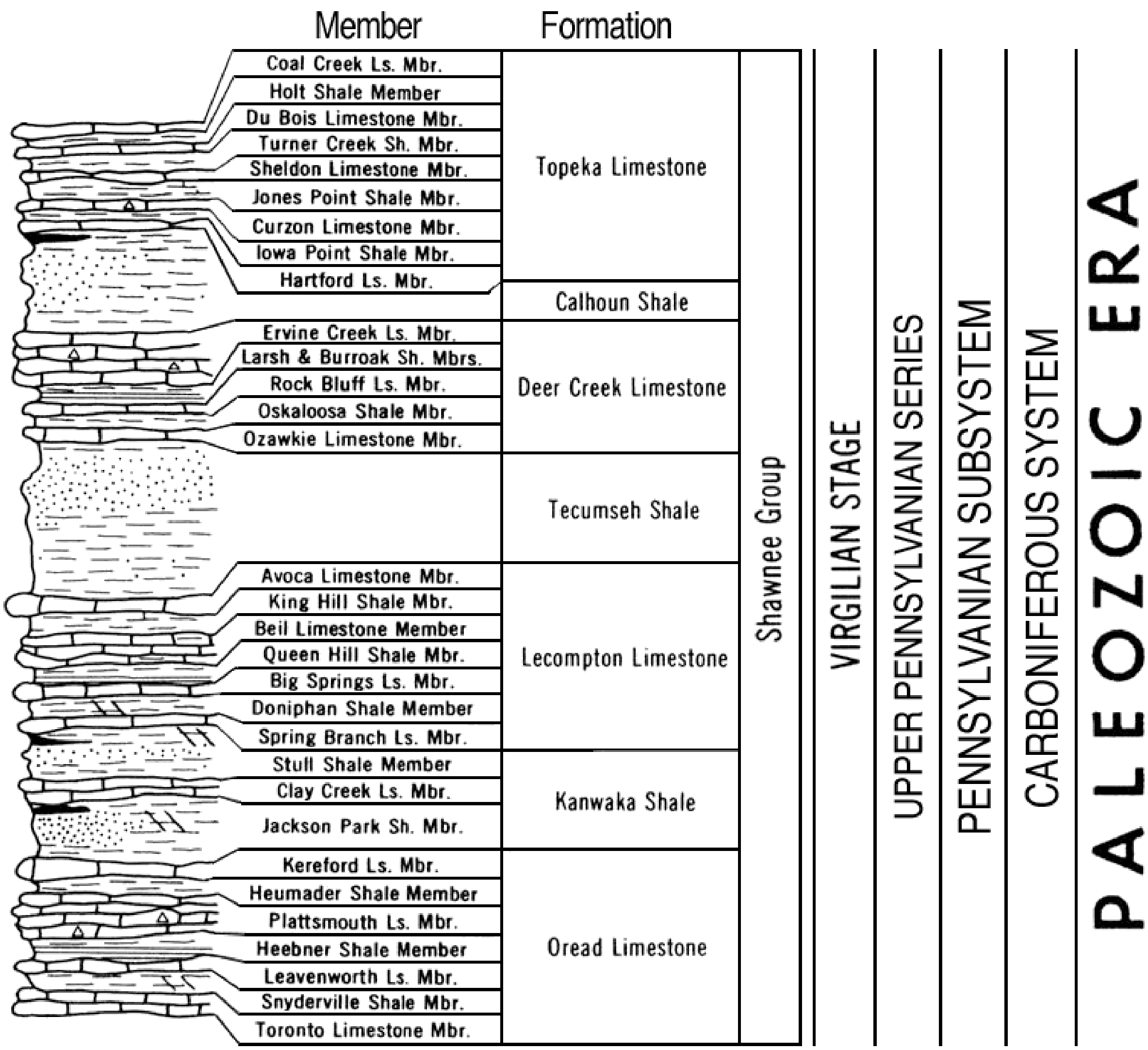


Figure 7. Stratigraphy of the Shawnee Group in Kansas. Stop 3 exposes the Plattsmouth Limestone Member of the Oread Limestone and underlying units (Heebner, Leavenworth, Snyderville, and Toronto) along with the upper portion of the Lawrence Shale. Some of these individual members of both the Oread Limestone and other units of the Middle and Upper Pennsylvanian of Kansas are less than a meter thick, but can be traced for hundreds of kilometers on the surface to the north and south, and in the subsurface to the west. (http://www.kgs.ku.edu/General/Strat/Chart/index.html, downloaded 3/22/2015)

What stories do these rocks tell?

A level playing field. One of the most impressive features of the Middle and Upper Pennsylvanian succession of Kansas is that very thin beds continue for very long distances (fig. 8). Admittedly, the character changes from place to place, especially in the limestone beds, where reef-like buildups mark the southern extent and oolites give way to fossil fragments as the dominant allochem to the north. Furthermore, some units pinch out to the north, and do undergo marked facies changes, generally in southern Kansas or northern Oklahoma. But beds that are 1 to 5 m thick extend 600 km north and south or to the west, and have aspect ratios of 1:120,000 to 1:600,000. If there were any significant contemporaneous tectonic activity or change of slope across the area, the units would either have marked local (not regional) facies changes, have noticeable thickness changes, or would simply terminate. The area of accumulation of these rocks was a smooth and nearly level shelf that passed gradually into deeper basins to the south.

Sea level rose and fell. Peat beds, which ultimately may form coal, accumulate in swamps that lie at or above sea level. Soils form above sea level; well-drained soils form significantly above sea level. Most limestone forms in the sea, some forms at significant depth. Transgression implies rise of sea level relative to the land; regression implies a fall of sea level, again relatively. Many features of the sedimentary succession indicate successively high or rising sea level and low or falling sea level. Sea-level change may result from rise or fall of the sea or fall or rise of the land. However, it is fairly safe to rule out rising and falling changes of the level of the land, where such extensive beds indicate little tectonic deformation. As the history of Pennsylvanian glaciation in the southern hemisphere is well known, most authors ascribe the change in sea level that are recorded in the rocks of eastern Kansas to glacioeustatic causes: as glaciers waxed, sea level fell; as glaciers waned, sea level rose.

A gradation cyclothem types. Clear analogies as well as obvious differences exist between limestone-rich and siliciclastic cyclothems. However, the two types seem to represent extremes of a gradation with intermediates common. The Lawrence Shale (with the Haskell Limestone Member of the Stranger Formation) illustrates this point well, because in most of Douglas County, that succession has features of the siliciclastic sequence. However the Haskell Limestone Member is similar to the middle (i.e. transgressive) limestone of the limestone-rich cyclothem, and the lower part of the Lawrence Shale grades laterally into the Cass Limestone to the north, making a limestone-rich cyclothem.

Driving Directions:

Either continue up US 56 to Lawrence and the end of the trip, or

Turn right (east) on Douglas County Route 458. Continue east for nearly 6 miles to Douglas County Route 1057. Turn north then, after about 2.5 miles, turn east on Kansas Route 10. Continue to the Kill Creek Road exit (about 10 miles), exit and return westbound to Milepost 19. There are two road cuts on the north side of the highway before the bridge over Kill Creek; stop at the second (more westerly) one.

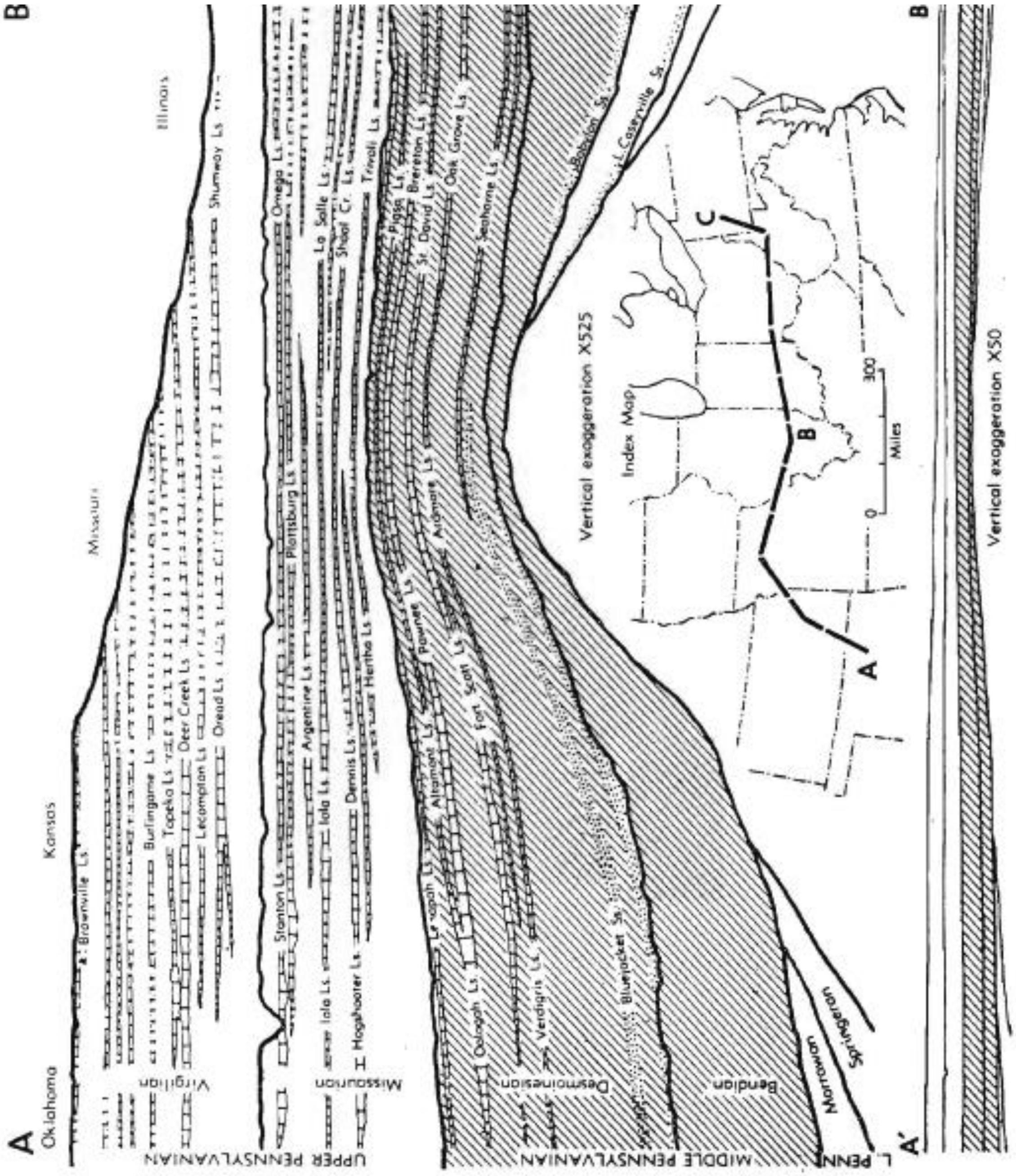
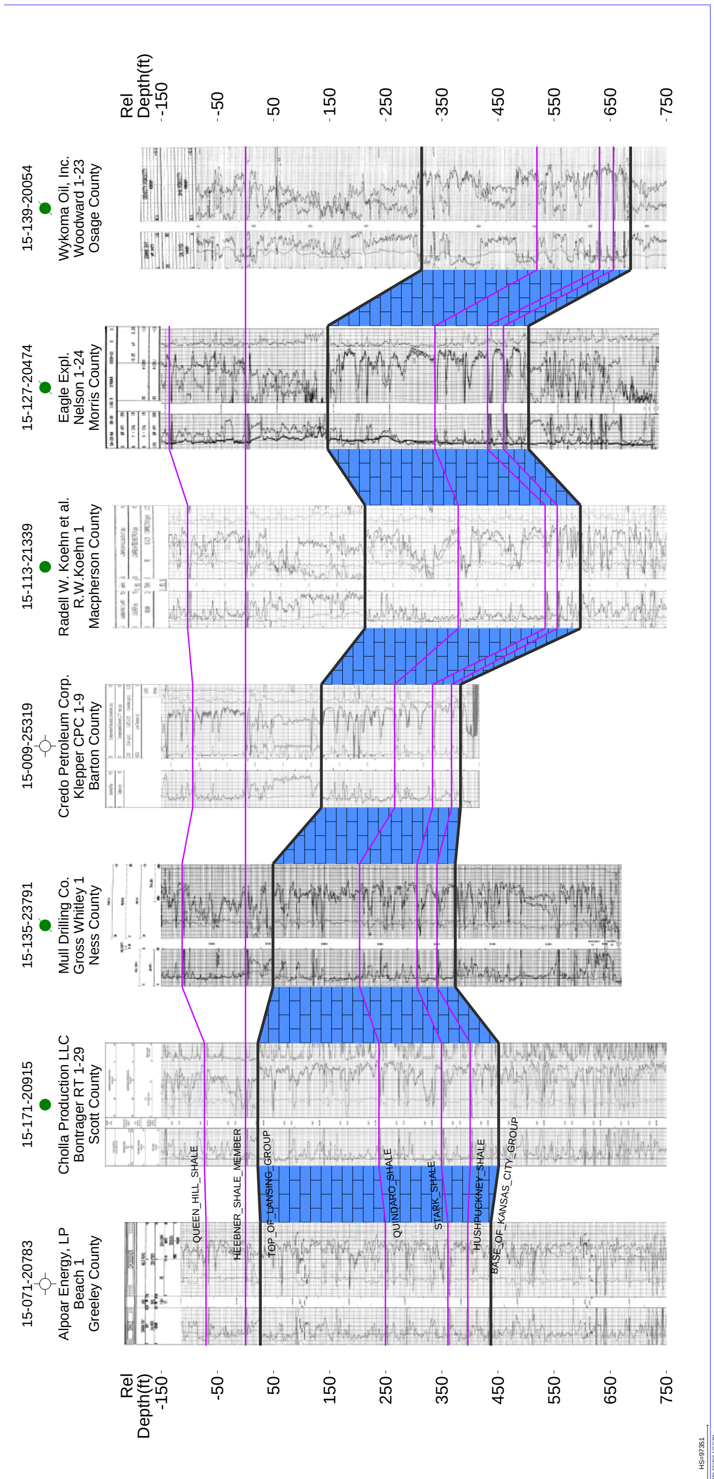


Figure 8. Very thin units can be traced for immense distances. Cross-section A-B-C: Moore's (1965) diagrammatic section of Middle and Upper Pennsylvanian rocks in the eastern interior (Oklahoma to Pennsylvania). Limestone beds, which are dominant in most cyclothems, are particularly persistent. Upper section is at 525X vertical exaggeration, lower image is at 50X VE. Original was spread across two pages, hence the imperfect fit. Moore omitted many named rock units. Facing Page: Subsurface geophysical log cross-section from Osage County to Greeley County, Kansas, a distance of about 380 miles (nearly 600 km). Several of the core shale beds are highlighted (Hushpuckney, Stark, Quindaro, Heebner, and Queen Hill) to help differentiate the different layers of limestone. Curves are gamma-ray and caliper logs in the left-hand track, and neutron porosity and density porosity, with or without photoelectric curves in

the right-hand track. Low gamma (deflected to the left) indicates limestone or sandstone, high gamma indicates shale, and very high gamma spikes are radioactive core shale beds. (Location map from http://www.netstate.com/states/maps/ks_maps.htm. Downloaded 3/26/2015.)



Stop 4. (Optional, if time permits)

This exposure of the upper part of the Lansing Group includes the top of the Spring Hill Member of the Plattsburg Limestone, the Vilas Shale, the Captain Creek Limestone, Eudora Shale, and Stoner Limestone members of the Stanton Formation **(**fig. 9**)**. The three members of the Stanton Limestone are the core of another limestone-rich cyclothem. In the Eudora Shale member here is not as pronounced as of a black core shale as the Heebner Shale is, in fact you will be able to collect fossils of small snails and brachiopods as well as see well laid-out branching calcite-filled burrows, probably of some arthropod. Here again the rocks tell a story of a rise then a fall of sea level.

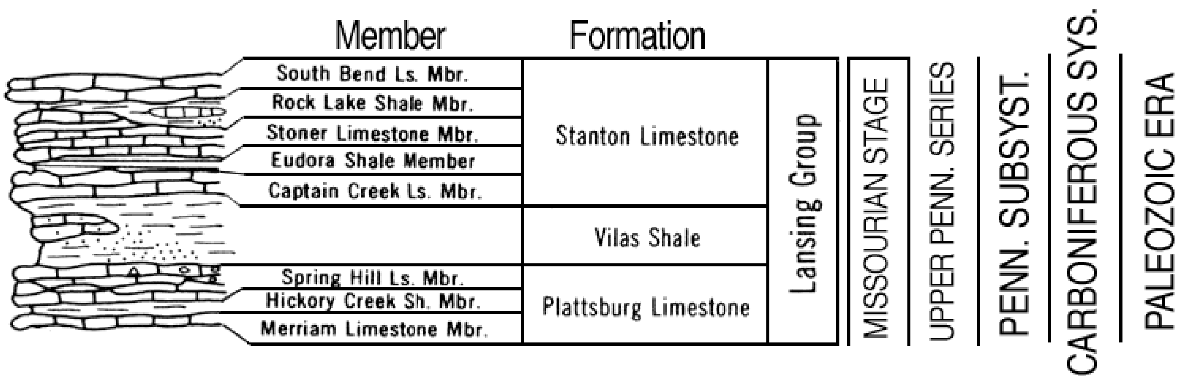


Figure 9. Stop 4 exposes the limestone and shale beds of the Lansing Group. The Captain Creek Limestone Member crops out just above road level. The Eudora Shale makes up the slope above it and below the Stoner Limestone Member. Bits of the Spring Hill Limestone Member of the underlying Plattsburg Limestone are exposed at the west end of the outcrop. This succession (Captain Creek, Eudora, Stoner) closely resembles the younger Leavenworth-Heebner-Plattsmouth succession of the Oread Formation and about a dozen other limestone-rich Kansas cyclothems of the Missourian and Virgilian of Kansas. (http://www.kgs.ku.edu/General/Strat/Chart/index.html, downloaded 3/22/2015)

Driving directions. Return to Lawrence along K-10.

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