HIGH RESOLUTION CORRELATION OF THE SHAWNEE GROUP (VIRGILIAN, PENNSYLVANIAN) CYCLOTHEMS FROM NORTHWESTERN MISSOURI TO EXPOSURES IN SOUTHERN KANSAS AND NORTHERN OKLAHOMA

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NORTHERN OKLAHOMA

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I.

INTRODUCTION

Problem and Purpose

Many studies have been conducted on the stratigraphy of Shawnee Group (Virgilian, Pennsylvanian) and its formations, with Condra (1927) and Moore (1936) being a foundation toward more recent research. R. C. Moore conducted research on the Shawnee group in terms of cyclothem theories, coining the term megacyclothem in 1936. Heckel (1977, 1980) modified the time interval and showed that in most cases only two limestones of Moore's megacyclothem are present in Kansas, renaming it as a Kansas cyclothem.

Within the Shawnee Group there are seven formations. In this study, only four of the formations of the Shawnee Group were studied, the Oread Limestone, Kanwaka Shale, Lecompton Limestone, and the Deer Creek (Figure1).

The primary purpose of this investigation is to correlate the Oread, Kanwaka, and Lecompton formations of Shawnee Group from a carbonate dominated shelf in northern Kansas and northwestern Missouri to a siliciclastic-dominated shelf in northern Oklahoma, using common terminology. A composite cross-section of the study region will be created along with two sea-level curves, one based on index fossils and the other on gamma ray curves.

Control outcrops, five in Missouri, that contain every member were sampled to create a database of conodonts for each member. From this a sea level curve was developed to compare to outcrop data in southern Kansas and northern

SYSTEM	SERIES	STAGE	GROUP	FORMATION	MEMBER
PENNSYLVANIAN	UPPER PENNSYLVANIAN	VIRGILIAN	WABAUNSEE	SEVERY SHALE	
			SHAWNEE	TOPEKA LIMESTONE	Coal Creek Limestone Holt Shale Du Bois Limestone Turner Creek Shale Sheldon Limestone Jones Point Shale Curzon Limestone Iowa Point Shale Hartford Limestone
				CALHOUN SHALE	
				DEER CREEK LIMESTONE	Ervine Creek Limestone Larsh Burroak Shale Rock Bluff Limestone Oskaloosa Shale Ozawkie Limestone
				TECUMSEH SHALE	
				LECOMPTON LIMESTONE	Avoca Limestone King Hill Shale Beil Limestone Queen Hill Shale Big Springs Limestone Doniphan Shale Spring Branch Limestone
				KANWAKA SHALE	Stull Shale Clay Creek Limestone Jackson Park Shale Elgin Sandstone
				OREAD LIMESTONE	Kereford Limestone Heumader Shale Plattsmouth Limestone Heebner Shale Leavenworth Limestone Snyderville Shale Toronto Limestone
			DOUGLAS	LAWRENCE FORMATION	

Figure 1. Formations of the Shawnee Group with the formations studied in yellow.

Oklahoma. A second sea level curve was generated using a gamma ray scintillometer, to compare and look for any discrepancies.

Location of Study Area

The Shawnee Group described in this research is located within a northeasterly, southwesterly trending outcrop belt that stretches from Osage county, Oklahoma, north to northwestern Missouri (Figure 2). Many of the outcrops in this research were located with the use of previous works done in the area by Mark W. Bryan (1999), James Carter Jr. (1954), and Patrick Shannon (1954). The total number of localities measured, sampled, and described is **?**. The northernmost five outcrops are located in the vicinity of St. Joseph, Missouri, comprising the complete Oread and Lecompton Limestone megacyclothems. These outcrops are being utilized as control outcrops to determine the conodont genera and species in each unit. Elk and Chautauqua counties, Kansas, contain **?** localities. The southernmost **?** localities are located in Osage county, Oklahoma, and show the sea level regressing. Appendix A contains descriptions of all localities along with pictures and topographic maps of the localities.

Methodology

A detailed analysis of the Shawnee Group was completed using lithostratigraphic, gamma-ray, and laboratory analysis. Included within this study are the Oread Limestone, Kanwaka Shale, and Lecompton Limestone formations. The Deer Creek Limestone is also included because in Oklahoma's geology the Lecompton and Deer Creek formations are considered one formation. Localities

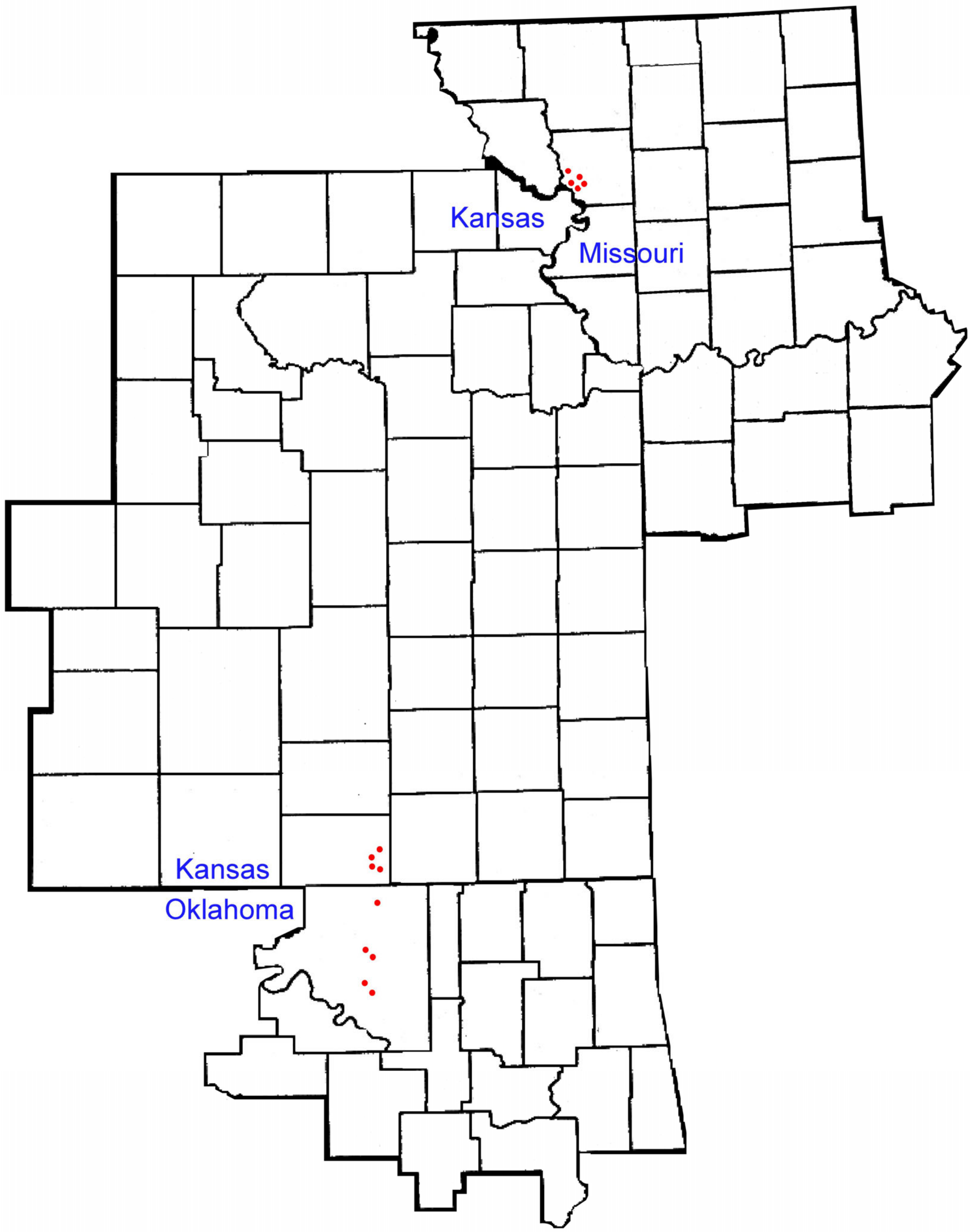


Figure 2. Map of Study area. Locality areas represented by red dots.

were chosen so both the formations and their members are represented and in most cases overlapped. Outcrops were chosen in Missouri based on their completeness and ability to provide conodont data which would help in the correlation between Kansas and Oklahoma.

Lithostratigraphic Analysis

Bed by bed descriptions of each surface exposure were taken in the field along with their measurements. These descriptions included type of bedding and contact between beds. Fossil content and lithology, from Dunham's (1962) carbonate classification (Figure 3), were noted along with the fresh and weathered color, based on the Geological Society of America Rock Color Chart (1951). Photographs of each location were taken along with close up photographs that show details of contacts, bedding surfaces, and fossil content.

Samples were collected of each bed, measuring 1-2 kilograms or enough to fill a 1-gallon Ziploc® bag. If the bed was more than 1/3 meter (1 foot) in thickness, multiple samples were taken. In these cases, the contacts between beds were most important and collected, especially limestones, in which the bottom, middle, and top were typically what was collected. Shales were collected in 1/3 meter (1 foot) intervals unless there was a change in lithology.

<table>
<tr><th colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</th><th rowspan="6">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE

<u>Crystalline Carbonate</u>

(Subdivide according to classifications designed to bear on physical texture or diagenesis.)</th></tr>
<tr><td colspan="4">Original Components Not Bound Together During Deposition</td><td rowspan="5">Original components were bound together during deposition... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.

<u>Boundstone</u></td></tr>
<tr><td colspan="3">Contains mud
(particles of clay and fine silt size)</td><td rowspan="4">Lacks mud and is grain-supported

<u>Grainstone</u></td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="3">Grain-supported

<u>Packstone</u></td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td><u>Mudstone</u></td><td><u>Wackestone</u></td></tr>
</table>

Figure 3. Dunham's Classification of Carbonate Rocks (from Dunham, 1962).

Gamma-Ray Scintillometer

A scintillometer was used to measure uranium, thorium, and potassium content and create a gamma ray curve. Readings were logged wherever a lithologic change occurred. For large sections of shale, in excess of 1 meter (3 feet), measurements were taken every 1/3 meter (12 inches). Sandstone and limestone bodies were measured less intensely, at every 1-2 meters (3-6 feet), unless a significant change in lithology was present.

The first step in using the scintillometer was to calibrate the settings based on the factory presetting. Next, the tool was placed against a fresh surface and the measurement was started. Each measurement lasted 60 seconds to get the most accurate reading. The reading was recorded for each locality based on the previously mentioned intervals. These numbers were then put into an Excel® spreadsheet to create the gamma-ray curve.

If the uranium, thorium, and potassium concentrations in the rock were measured in counts per minute, they first needed to be converted to parts per million using the following three equations:

$$U(ppm) = U(Ct) - 0.62 * Th(Ct) / 20.5$$

$$Th(ppm) = Th(Ct) / 7.5$$

$$K(wt\%) = K(Ct) - 0.68 * U(Ct) - 0.83 * Th(Ct) / 154$$

The uranium, thorium and potassium readings were then converted to API values using the equation from Klimentidis, Exxon Mobil:

$$API = 8 \pm 2 * U(ppm) + 4 \pm 1 * Th(ppm) + 16 \pm 2 * K(wt\%),$$

The API value was then plotted versus depth, in inches, creating a gamma-ray curve like the example seen in figure 4. Depth was measured from the top surface of the

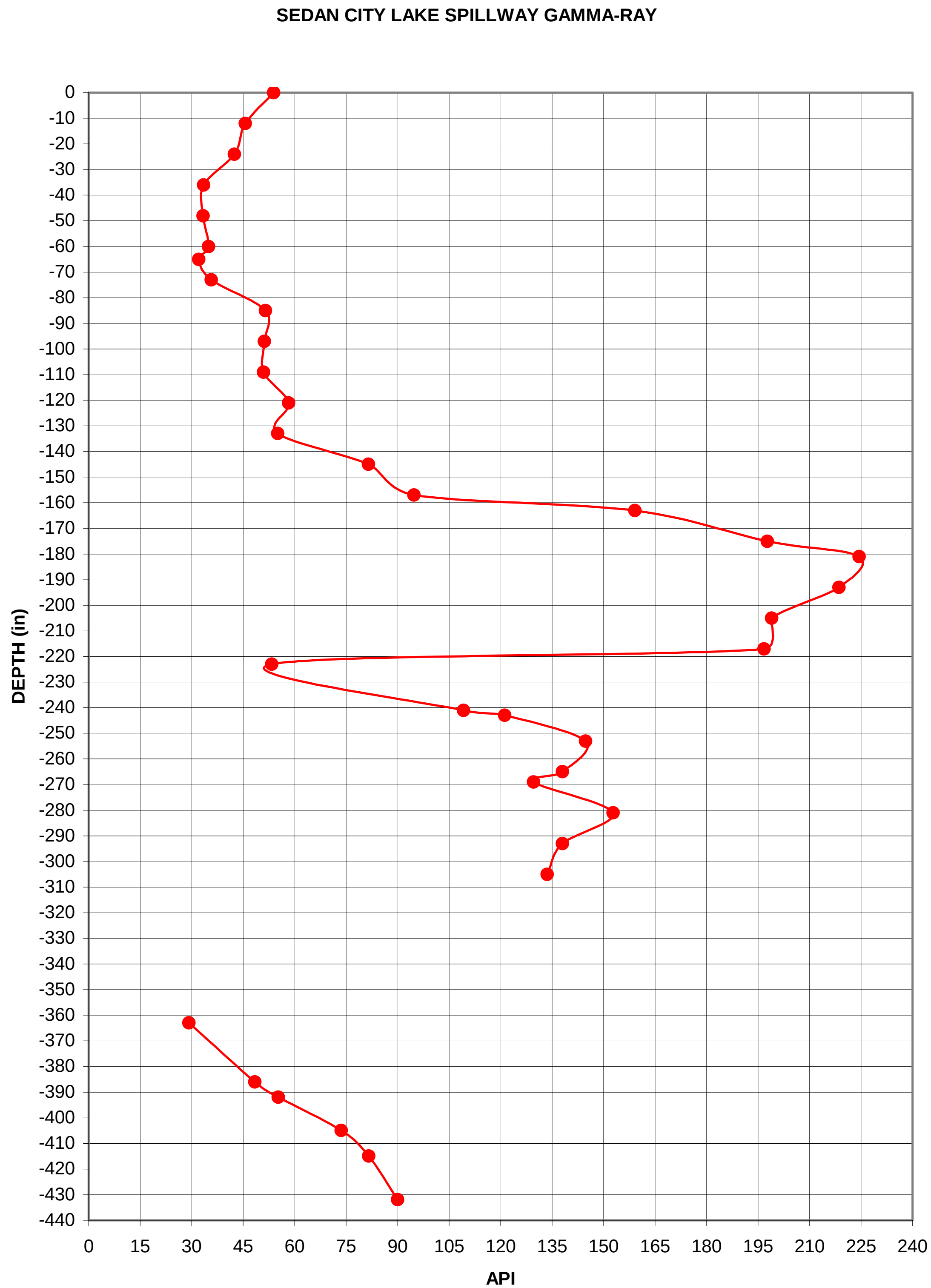


Figure 4. Example of Gamma-ray Curve.

outcrop as a negative number. All gamma-ray curves can be seen in Appendix C, where they are also shown in comparison to the stratigraphic columns.

Laboratory Analysis

Laboratory analysis performed on the samples collected in the field include processing and breaking down the rock, picking through remaining sediment for conodonts and other microfossils, scanning electron microscope (SEM) analysis, and computer analysis.

Processing was done in one of three ways, depending on the rock type, and then the remaining sediment was sieved through 45, 80, and 150 mesh sieves. Once sieved, the sediment was dried in an oven overnight and placed in labeled bags.

Calcareous material was broken down in a dilute formic acid solution. A sample of 500 grams was placed in a solution of 6L of water and 500mL of formic acid. This was allowed to break down for 24 hours. For carbonaceous shale, 500 grams of material were placed in enough hydrogen peroxide to cover the sample and allowed to break down for 1-24 hours. The variation in time is dependent on the ratio of organic material to inorganic material, as the peroxide breaks down organic material only. Clay shales were broken down with kerosene overnight and then washed with hot water for an average of six hours.

From the 45 and 80 mesh samples, fossil fauna was placed on micropaleontology slides. Conodonts, being the most important fauna, were more readily separated from the residue.

Sea level curves were generated for each locality using two methods. One curve was created using conodont distributions. From the scintilometer readings a second sea level curve was created in Excel®, based on total API values, as previously described.

The SEM was used to take photomicrographs of the conodonts found within samples. These pictures were then analyzed and used to correlate beds throughout the outcrop area.

Using the computer program Canvas®, stratigraphic sections were created based on the lithostratigraphic analysis done on every exposure. The stratigraphic sections were then combined to create a composite cross-section of the field area.

Geologic History of the Midcontinent

The collision of the North and South American plates from late Morrowan into early Desmoinesian time, resulted in the Wichita orogeny. This was responsible for the subsidence of the Arkoma basin, the folding and faulting of the Ouachita foldbelt, and the materialization of the Nemaha uplift (Rascoe and Adler, 1983)(Figure 5). This modification of the midcontinent basement rocks effectively controlled the sedimentation rates, duration and patterns (Heckel, 1977).

Sedimentation during the Virgilian, Shawnee Group depositional period, consisted of cyclic deposition of carbonates and shales on the Kansas shelf. Toward the south, near shoreline, clastic sediments were introduced due to the shallowing sea (Rascoe and Adler, 1983) (Figure 6).

During Pennsylvanian time, the paleoequator trended northeast-southwest along the Appalachian Mountains and across the northwestern part of what is now the Gulf of Mexico.

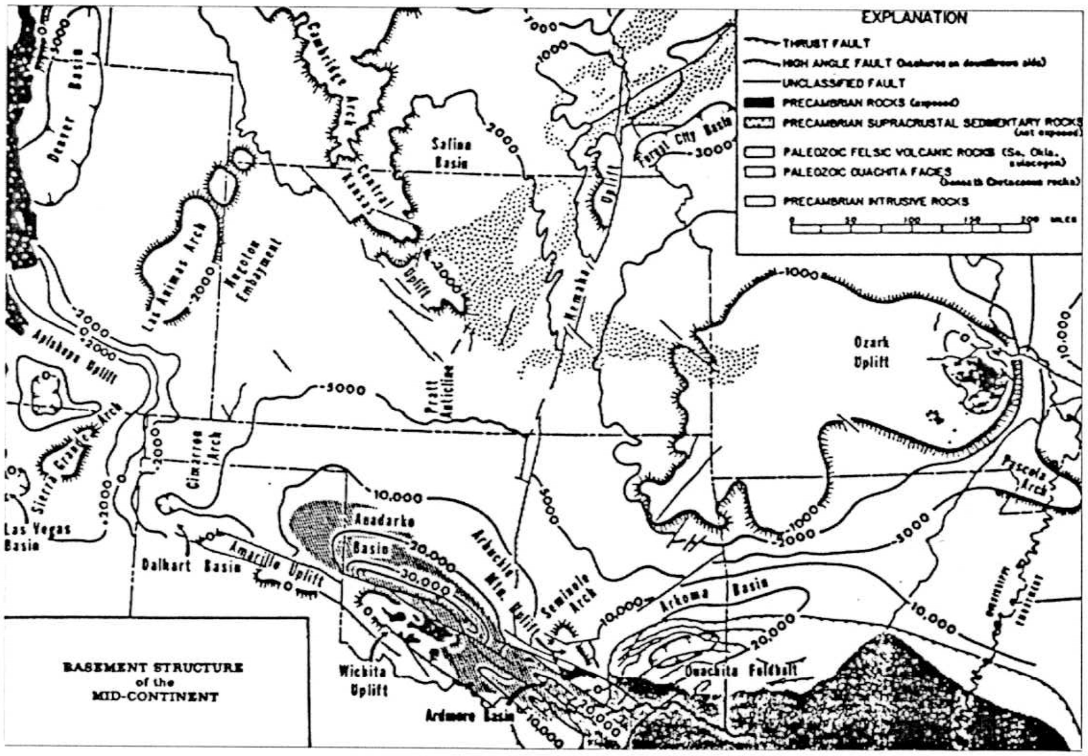


Figure 5. Basement structure of the MId-Continent (from Rascoe et al, 1983).

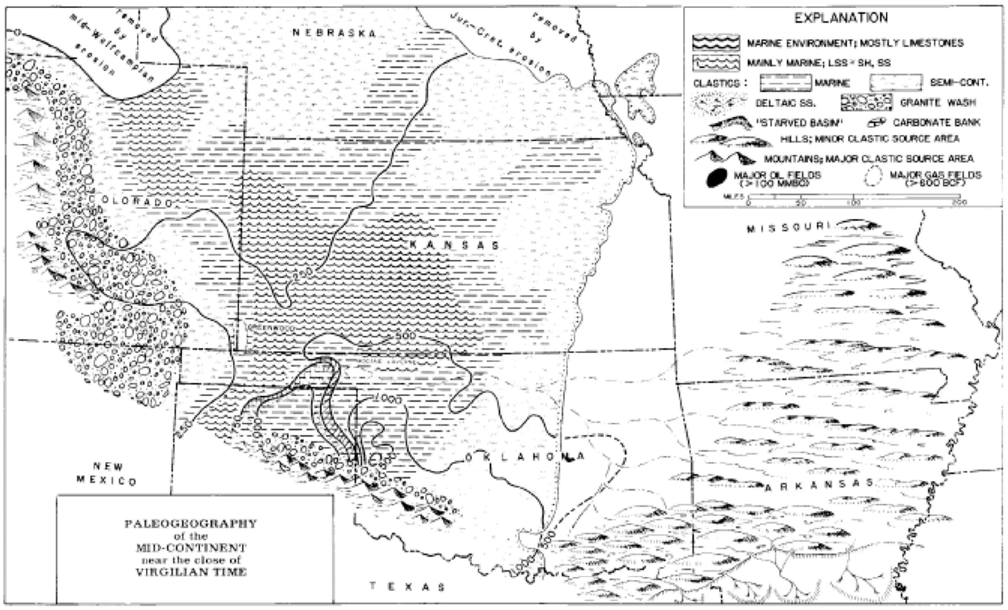


Figure 6. Paleogeography of the Mid-Continent during Virgilian time.

The location of the paleoequator allowed for the creation of large scale quasi-estuarine circulation in a midcontinent epicontinental sea, centered in was is now western Kansas. Major eustatic oscillations of sea level caused some transgressions to reach the Appalachians and some regressions shifted the shoreline to eastern Kansas (Heckel, 1977) (Figure 7).

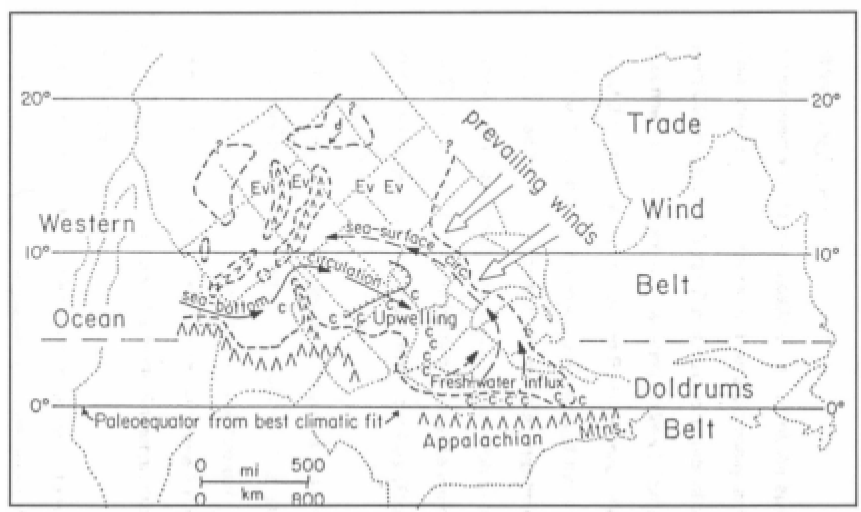


Figure 7. Location of the Paleoequator during Virgilian time.

II.

STRATIGRAPHY

Lithostratigraphic Nomenclature

The Shawnee Group was first defined and named in 1898, by E. Haworth as a formation name. It included the base of the Kanwaka Shale up to the top of the Scranton shale. Fath (1921) reclassified the Shawnee 'Formation' as the Shawnee group and R. C. Moore (1932) revised the upper and lower limits as the base of the Oread Limestone formation to the top of the Topeka Limestone formation.

Distribution and Thickness

The formations within the Shawnee Group, which are being examined in this study are the Oread Limestone, Kanwaka Shale, Lecompton Limestone, and Deer Creek Limestone. Northern Oklahoma equivalents would be the Nelagony Formation (Oread), Elgin Sandstone (Kanwaka), and the lower Pawhuska Formation (Lecompton and Deer Creek) (Moore, 1936). Moore (1948) tried to create an interstate classification system of rocks for the northern midcontinent. Figure 8 shows his interstate classification along with that used in Kansas, Missouri, Nebraska, Oklahoma, and Iowa.

The Shawnee Group stretches from Oklahoma through Kansas, Missouri, Iowa, and Nebraska within a northeasterly, southwesterly trending outcrop belt. Representing Virgilian time, it is persistent across Kansas, northwestern Missouri, southwestern Iowa, and southeastern Nebraska, and is easily recognized.

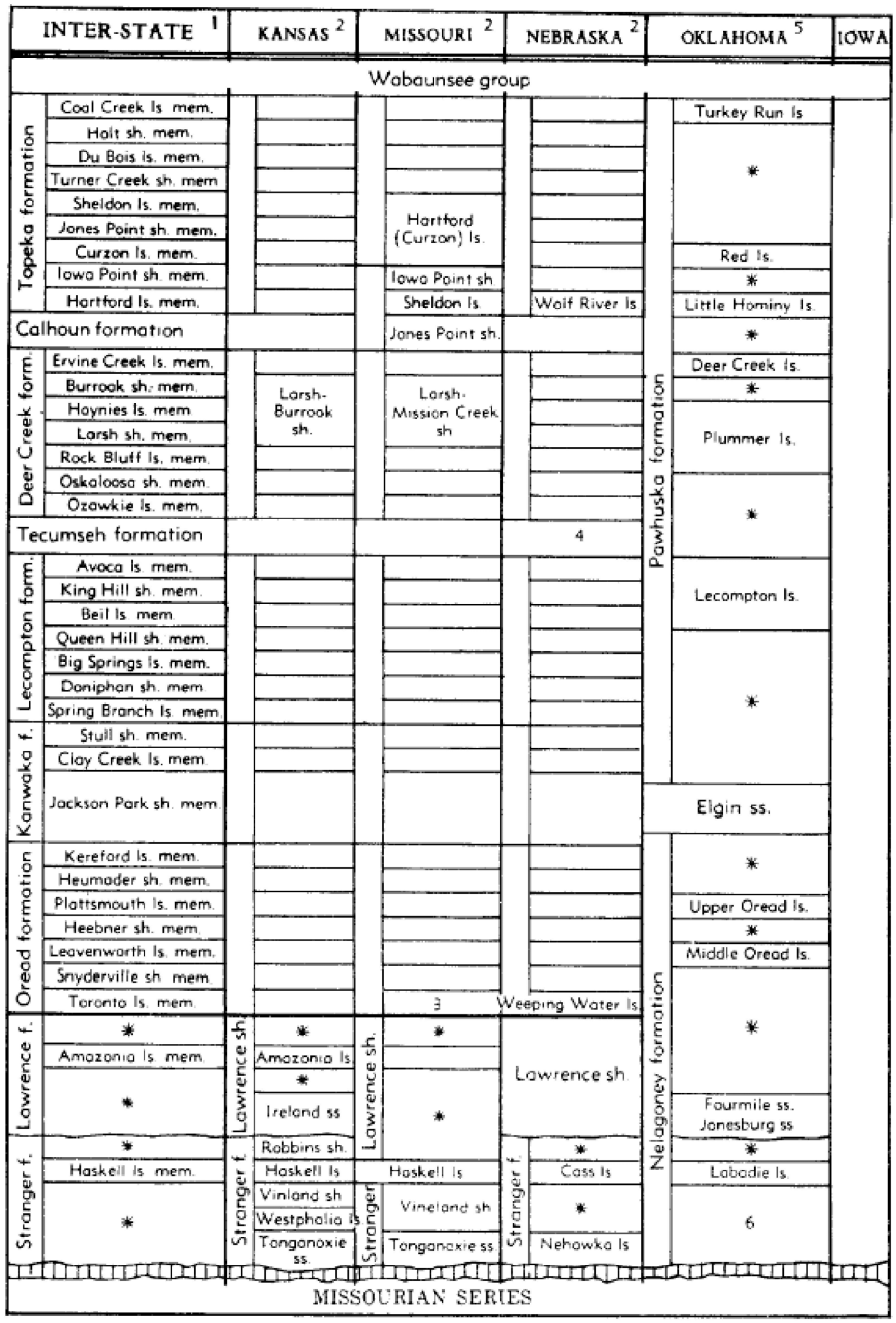


Figure 8. Interstate classification syatem of rocks for the Mid-Continent from Moore (1948)..

Consisting mostly of limestones and shales, there is an introduction of sandstones and siltstones toward the south in Oklahoma.

Although the thickness of individual beds of the Shawnee Group varies, the total thickness is typically 99 meters (325 feet)(Moore et al, 1951). In northern outcrop areas, the shales are thin (typically less than 2 meters (6 feet)), while the limestones make large escarpments. Toward southern Kansas, and most prominent in Oklahoma, the shales thicken, averaging fifty to one-hundred feet, and also include interbedded sandstones and siltstones, while the limestones thin or pinch out (Moore, 1932). The width of the Shawnee Group within the outcrop belt averages 32 kilometers (20 miles) (Condra and Reed, 1937).

Generalized regional tectonic dip is to the west, so the subsurface Shawnee Group is located west of the outcrop belt. The Shawnee Group underlies most of western Kansas and western Oklahoma.

Lithologic Character and Classification

Of the seven Shawnee Group formations, four are composed mostly of limestone, while the other three are mostly shales and sandstones. This is true revealed in the outcrop belt where the four limestones outcropped in Kansas become more clastic oriented in Oklahoma.

The limestone units are recognized by persistent and uniform features, both faunal and lithological. Also, associated with these limestones are thin, persistent shales, typically clayey, limey, or black and slaty (Moore, 1932).

Many of the shales and sandstones contain marine fossils, indicating original sediment deposition in marine environments. Black shales commonly contain phosphatic layers, indicating deposition in upwelling zones in deep marine waters, typically 50-200 meters (Heckel, 1977).

Regular alternation of the limestone and shale beds indicates the cyclicity of the deposition of the Shawnee units. Within these formations there are minor sequences present, indicating smaller scale cycles (Moore, 1932). The presence of nonmarine sandstones and shales containing terrestrial plant fossils, along with coals indicates the regression of sea level. As the sea transgresses, calcareous sediments, commonly containing marine invertebrates, were deposited in the warm, clear water. During the period of maximum flooding, the phosphatic sediments high in carbon were deposited. As the sea once again began to shallow, the next cycle was deposited.

Oread Limestone Formation

E. Haworth named the Oread Limestone Formation in 1894, because of its escarpments on Mount Oread, upon which the University of Kansas sits in Lawrence, Kansas. The Oread was first used to describe the lowest limestone of the formation, but in1895, Haworth included the Plattsmouth member. In 1927, the Kereford member was named, although it had been included as a member since 1896, by Bennett. The Oread is resistant to erosion and forms a prominent escarpment that is traceable from Doniphan County in the north to Chautauqua County in southern Kansas. In northern Kansas the shales are thin, but increase in thickness in the south. Therefore, in Oklahoma, the shales are more prominent than the limestones. The Oread is bounded below by the Lawrence Shale and above by the Kanwaka Shale (Moore, 1936).

At the type locality the thickness of the Oread is 14 meters (45 feet), but averages 16 meters (52 feet) throughout northern and central Kansas. Toward the south, the average thickness is around 30 meters (100 feet). (Moore et al, 1951)

The members of the Oread Limestone Formation are the Toronto Limestone, Snyderville Shale, Leavenworth Limestone, Heebner Shale, Plattsmouth Limestone, Heumader Shale, and the Kereford Limestone.

Toronto Limestone Member

The Toronto was named by E. Haworth and W. H. H. Piatt after the town of Toronto in Woodson County, Kansas, (Moore, 1936) and is the basal member of the Oread Limestone Formation. Typically it is 2-3 meters (6-10 feet) thick with few places being greater than 3 meters. It is usually yellow-brown in color and weathers brown. The Toronto exhibits massive bedding and breaks unevenly into slabs. With a distinctive upper layer, the top meter (3 feet), which is algal in some places and lacking fusulinids, the Toronto Limestone is fairly easy to distinguish. Locally it can be somewhat argillaceous to sandy (Troell, 1969) or contain numerous fossils like fusulinids, brachiopods, bryozoans, and crinoids. Also present are corals and mollusks, but less numerous. The Toronto has been traced from Oklahoma to Nebraska (Moore et al, 1951) where it has been considered equivalent to the Weeping Water limestone (Condra, 1927).

Snyderville Shale Member

The Snyderville Shale member was named for exposures east of the Snyderville Quarry, west of Nehawka, Nebraska (Condra, 1927), it lies above the

Toronto and below the Leavenworth. It is typically a bluish to grayish clayey shale, but sometimes red just above the Toronto. The red shale is more evident in southern outcrops, where it is also sandier with few limestone beds.

Thickness of the Snyderville Shale varies throughout the outcrop belt. In northern Kansas and Nebraska it averages 4 meters (12 feet) in thickness (Condra and Reed, 1937), whereas, in southern Kansas the average thickness is roughly 8 meters (25 feet), but can be as thick as 23 meters (75 feet) (O'Conner, 1955).

In northern Kansas and Nebraska, the top ½ meter (1-2feet) is a structureless gray clay that exhibits characteristics of an underclay. This top layer is also well laminated and contains brachiopods, bryozoans and pelecypods (Moore, 1936). Below this structureless clay, there is a more calcareous, gray to yellow-tan shale, siltstone, and argillaceous limestone (Moore et al, 1951). Within the lower Snyderville Shale there are some thin, impure limestone beds that are partially mud-cracked. They also contain sparser mollusks and less than a meter (3 feet) above the Toronto there is an algal bed (O'Conner, 1955). Von Bitter stated that beds in southern Kansas tend to be sandier locally with discontinuous, argillaceous limestone and calcareous shale nodules in the lowermost few centimeters (von Bitter, 1972).

Leavenworth Limestone Member

Condra and Reed (1937) named the Leavenworth Limestone member from an exposure northwest of the federal penitentiary at Leavenworth, Kansas, where the type location is found (Condra and Reed, 1937). It is rarely found to have a thickness less than 1/3 meter (1 foot) and more than 2/3 meter (2 feet) in over 480 kilometers (300 miles) of outcrop. This outcrop belt extends from central Iowa to Oklahoma with very little change in characteristics (Moore et al, 1951).

The Leavenworth Limestone is a single massive layer of a hard, dense, fine-grained limestone with prevalent vertical joints. It is dark bluish-gray when fresh and light- gray or slightly cream in color when weathered. Weathering also causes the edges of block surfaces to round. Fusulinids and molluscoids are numerous, with brachiopods and mollusks also being somewhat numerous (O'Conner, 1955).

Heebner Shale Member

The Heebner Shale is named for exposures at Heebner Creek and Heebner farm, west of Nehawka, Nebraska, Condra (1927). The thickness of this member varies very little from 1 2/3 meters (5 feet) in southern Kansas and Nebraska.

The lower part of the Heebner consists of a black, carbonaceous shale. This shale is very hard and fissile and contains conodonts but lacks megascopic fossils. The upper part is a bluish-yellowish gray, clayey shale that in many places contains many fossils.

Within the Oread Limestone Formation, there are no other occurrences of a black fissile shale. This makes the identification of the Heebner member easy (Moore, 1936).

Plattsmouth Limestone Member

Keyes (1899) first measured the Plattsmouth Limestone member. In 1915, Condra and Bengston named the rocks at the type location on the Missouri River Bluffs, Plattsmouth after the town to the southeast, Plattsmouth, Nebraska. Until 1927, the term "Plattsmouth" included the Spring Branch, Kereford, and Plattsmouth, when Condra restricted it as the name for the limestone between the Heebner Shale below and the Heumader Shale above. This is usually the topmost limestone because the Kereford is either missing or found at a distance from the escarpment (Moore, 1936).

As the thickest member of the Oread Formation, it averages 5 meters (15 feet), but locally can be up to 10 meters (30 feet). This limestone member is very light bluish gray in color and weathers light creamy yellow to nearly white. It forms thin, irregular beds with wavy, thin shale partings. Primarily the texture is fine, but there can be thin to coarse streaks or patches of clear crystalline calcite (Moore, 1936). There are also nodules of blue-gray chert occurring in parts of the member. Although these chert nodules occur mostly in the northern outcrops, they can be found throughout the outcrop belt (Moore, 1949).

Locally, algal remains, mostly Osagia, occur within the upper 1/3 meter (1 foot). This is underlain by a massive limestone bed with an abundance of fusulinids. In outcrops in Nebraska, there is a thin, dark gray, fossiliferous shale below the fusulinid layer. Under the shale is a meter (3 feet) bed of oölitic limestone. In Kansas, this is represented as a molluscan limestone. Most fossils in the Plattsmouth, including fusulinids, brachiopods, bryozoans, crinoids, corals and mollusks, have been replaced with crystalline calcite (Condra, 1927).

Heumader Shale Member

The Heumader Shale, which is the upper shale member of the Oread Formation, was named for exposures in the Heumader Quarry, north of St. Joseph, Missouri, Moore (1932). When the Kereford Limestone is not present, the

Heumader is also not considered present. Instead, the shale above the Plattsmouth is included as part of the Kanwaka Shale (Moore, 1936).

The Heumader Shale member is a clayey to sandy, dark gray shale. In some outcrops it is unfossiliferous, but in others it contains numerous mollusks. Bryozoans and brachiopods are also present, but much less abundant (Moore 1936, 1949). Thickness of the Heumader Shale ranges from almost nothing to more than 3 meters (10 feet), but the average is 1-1.5 meters (4-5 feet) (Moore 1936).

Kereford Limestone Member

In 1927, Condra named the Kereford Limestone from exposures in the Kereford Quarry, south of Atchison, Kansas. This unit was included in the Kanwaka Shale Formation but in 1932, Moore placed the Kereford with the Oread Formation as the uppermost unit.

Thickness of the Kereford Limestone member ranges from almost nothing to 3-4 meters (10-12 feet) within a few kilometers. Many outcrops do not have the Kereford present and have no indication of its development. Along with its variations in thickness, it also varies in fossil content and lithologic features (Moore, 1936).

In some outcrops, it is a massive bed of dense, hard, dark bluish, and somewhat siliceous limestone. Other outcrops possess a blue flagstone, with several feet of alternating, even-bedded, dense blue limestone layers and shale layers with equal thicknesses. Locally it can also be oölitic, slabby, and cross-bedded.

Mollusks are the predominant fossils within almost all of the Kereford, while fusulinids are absent (Moore, 1936). Associated with the oölitic layers in northern

Kansas, is an Osagia-bearing limestone. Locally plant remains are also present (Moore et al 1951).

Kanwaka Shale Formation

In 1898, Haworth named this member the Lecompton shale. Then in 1902, Adams renamed it the Kanwaka Shale from exposures east of Stull, Kanwaka Township, Kansas. This term refers to the beds between the Oread, top of Kereford Limestone (Plattsmouth where Kereford is not present) and Lecompton Formations (Moore, 1936). Thickness ranges from 2- 44 meters (7-145 feet), but the average tends to be around 21-24 meters (70-80 feet) (O'Conner, 1955).

The Kanwaka Shale contains both marine and nonmarine units. Both the upper and lower units consist of a sandy shale with land plant remains. About a meter (a few feet) below the Lecompton Limestone formation is the Elgin Sandstone, which thickens southward. Locally above the Elgin Sandstone is a coal bed. The middle unit is a marine limestone found in central and northern Kansas. In southern Kansas and northern Oklahoma, the possible equivalent for this middle limestone are sandstones and shales with marine fossils. The fossils found in these marine beds are brachiopods, bryozoans, mollusks, and fusulinids (Moore, 1936).

The basal member of the Kanwaka Shale is the Jackson Park Shale, followed by the Clay Creek Limestone and the Stull Shale (Moore, 1936).

Jackson Park Shale Member

The Jackson Park Shale was named from outcrops in a local park called Jackson Park in the southern part of Atchison, Kansas (Moore, 1932). This member of the Kanwaka Shale is a bluish-gray and yellowish-brown sandy shale. It contains carbonized land plants and locally coal seams are present (Moore, 1936, O'Conner, 1955). Thickness of the shale ranges from 8-17 meters (24-50 feet), although it is not always clearly defined. It is considered part of the undifferentiated Kanwaka Shale when the Clay Creek Limestone cannot be traced (Condra, 1927).

Clay Creek Limestone Member

In 1932, Moore named the Clay Creek Limestone from exposures on Clay Creek west of Atchison, Kansas. It is a thin, persistent, dark bluish-gray bed of medium fine-grained to granular and moderately hard limestone. It thickness is around 1 meter (2-3 feet) and contains vertical joints. During weathering, it breaks into shelly chips as it weakens (Moore, 1936). A thin shale parting is quite common in the upper middle part of the member, thickening southward (O'Conner, 1955).

The Clay Creek Limestone is only known from outcrops in northern Kansas, as it tends to disappear southward around Greenwood and Elk counties. Instead it is considered part of the undifferentiated Kanwaka Shale when it is 'absent' or too thin to trace (Moore et al, 1951).

Fusulinids are in the middle part of this very fossiliferous member. Usually this middle part is overlain by an algal layer (Condra, 1927). Mollusks, bryozoans, and brachiopods are less common, but do occur with crinoid stem plates and abundant fusulinids (Moore et al, 1951). At the top of the member, there is a thin crust a few centimeters (2-3 inches) in thickness that contains broken brachiopod, crinoid and bryozoan fragments (O'Conner, 1955).

Stull Shale Member

The Stull Shale member was named from exposures near the town of Stull, Kansas (Moore, 1932). Thickness ranges from 10-15 meters (30-45 feet), but averages 7 meters (21-23 feet). It is a yellowish-brown and bluish-gray colored, sandy shale. It can also be somewhat clayey or silty and contain limonite nodules (Moore 1936, O'Conner 1955). Locally there may be a soft, friable sandstone with a thin coal bed above, possibly the initial deposits of the Lecompton Limestone Formation. Carbonized land plants are numerous throughout this member (Moore, 1936). In northern Oklahoma and southern Kansas, the Elgin Sandstone may belong in the Stull Shale (Moore et al, 1951).

Lecompton Limestone Formation

This formation was first named the Strawn Limestone by Haworth and Kirk (1894). Bennett (1896) renamed it the Lecompton Limestone from exposures in the upland south of Lecompton, Kansas. Total thickness at the type locality is 12-13 meters (35-40 feet) (Moore, 1936), although throughout the entire outcrop area it ranges from 9-20 meters (30-60 feet), averaging 13 meters (43 feet) (Condra and Reed, 1937).

The Lecompton Formation forms a well defined escarpment in the Kansas River area as well as northern Kansas, which along with persistent lithologic and paleontologic characteristics, allows for easy identification of the formation. This is due to the thickness of the beds and their resistance to weathering. The shale formations at the base and the top of the formation, also aid in defining this escarpment. The escarpment thins and is less distinct and prominent toward southern Kansas and into northern Oklahoma, where the equivalent is found in the lower units of the Pawhuska Formation. This is from the thickening of the shale members and thinning of limestone members along with the thinning of the Tecumseh Shale above. Further south in Oklahoma some of the limestones disappear and eventually all limestones are gone (Moore, 1949, Moore et al, 1951).

The basal member of the Lecompton Formation is the Spring Branch Limestone followed by the Doniphan Shale, Big Springs Limestone, Queen Hill Shale, Beil Limestone, King Hill Shale, and the Avoca Limestone at the top of the formation (Moore, 1936).

Spring Branch Limestone Member

Named from exposures on Spring Branch, northeast of Big Springs, Kansas, the Spring Branch Limestone member is the basal member of the Lecompton Limestone Formation (Condra, 1927). In northern Kansas, the thickness of the limestone is about 2 meters (5 feet), but southward it decreases to a meter (2-3 feet) thick impure sandstone. Locally there may be a ½ meter (1-2 foot) coquinoid, somewhat conglomeratic, layer containing Osagia. In other localities the top ½ meter (1 foot) is somewhat nodular and algal, dense, and light drab gray (Moore, 1936).

This member is a massive, slightly unevenly bedded, grayish limestone that weathers strongly brown. There is an abundance of fusulinids, mostly occurring in the middle and upper beds. Along with being ferruginous, there are commonly sandy or silty impurities within this limestone. Southward, the Spring Branch Limestone becomes a sandy brown limestone with very few fossils or a very calcareous brown sandstone (Moore, 1936).

Doniphan Shale Member

This member of the Lecompton Limestone was named from exposures in northern Doniphan County, Kansas. It is a bluish, argillaceous, clay shale with some thin sandstone beds and rusty calcareous material (Condra, 1927). Overall thickness of this member is about 2-3 meters (5-10 feet). Fossils are typically not present, but locally can be sparse to abundant. In southeastern Shawnee County, Kansas, it exhibits blocky clay characteristics in the upper part, which could be an underclay (Moore, 1936). Beneath this possible underclay is a thin bed of carbonized plant material with numerous ostracods. Below this thin bed is a gray shale and unfossiliferous siltstone, about 1 meter (3-4 feet) thick. Central and northern Kansas beds are interbedded calcareous shales and shaley limestones with abundant fusulinids. Southward in Kansas, the middle beds contain a thin sand or conglomerate with molluscan fauna. Below this there is about 1 meter (3-4 feet) of silty shale and siltstone underlain by a molluscan limestone. The lowest beds in these southern exposures are gray or greenish in color, blocky to thin bedded shale (O'Conner, 1955). There are also red shale beds within the Doniphan Shale at these exposures (Moore et al, 1951).

Big Springs Limestone Member

Condra (1927) named the Big Springs Limestone member from exposures north of Big Springs, Kansas. Typically it is a single massive bed a meter or less (1-3 feet) thick, but locally it can be 2-3 beds separated by shale partings. Prominent vertical joints are found throughout the member and upon weathering it forms rounded bouldery blocks with a light yellowish-brown to bluish gray color. It is dark-bluish in color, dense and fine-grained, containing an abundance of fusulinids that resist weathering more so than the limestone itself (Moore, 1936). Other fossils found within the Big Springs Limestone are algae, brachiopods, echinoderm fragments, and mollusks (O'Conner, 1955). In northern exposures, the member can be somewhat argillaceous, but southward it is a sandy, impure limestone at some localities (Moore et al, 1951).

Queen Hill Shale Member

The Queen Hill Shale member is 1-2 meters (3-6 feet) thick and was named from Queen Hill, northeast of Rock Bluff, Nebraska, by Condra (1927). This member consists of a lower unit of hard, black, fissile shale containing conodonts overlain by a softer, blocky to thin-bedded, bluish-yellowish, argillaceous shale containing no fossils (O'Conner, 1955). In southern exposures the black shale is not always found, but throughout the rest of the outcrop belt it is present (Moore, 1949).

Beil Limestone Member

In 1915, Condra named this member the Cullom Limestone, but it was found to indicate a bed in the Kansas City Group. So, Condra (1930) renamed it the Beil Limestone from exposures on the Beil Farm south of Rock Bluff, Nebraska. Fossils present are corals and fusulinids in abundance, whereas brachiopods, bryozoans, and mollusks are less common. The thickness of the Beil Limestone ranges from 1-5 meters (3-15 feet), averaging 3 meters (10 feet). This member is easily identified from its distinct fossil assemblage and the black fissile shale below (Moore, 1949).

It outcrops as alternating layers of flaggy, hard limestone and very calcareous, fossiliferous shale in northern exposures. The top bed is a massive, Osagia-bearing bed that is less than a meter (1-1.5 feet) thick and coarsely granular or oölitic (Moore, 1936). The lower bed is an irregular to wavy bedded, massive fossiliferous limestone (Moore et al, 1951).

In southern Kansas and northern Oklahoma the member becomes more massive with wavy bedding. There are also less shale beds, making the Beil in southern exposures very similar to the Plattsmouth Limestone Member of the Oread Formation (Moore, 1936).

King Hill Shale Member

Named from exposures in King Hill, southeast of Rock Bluff, Nebraska, the King Hill Shale member is a bluish-green to reddish, argillaceous shale (Condra, 1927). It can be a blocky, clayey, and in places, sandy shale. In northern Kansas, it is 2-3 meters (5-7 feet) thick, but southward it reaches 5 meters (16 feet) or more. Fossils tend to be rare, except near the top where there are numerous brachiopods. In northern Kansas and Nebraska there may be 1-2 very irregular, nodular limestone beds that weather yellowish-brown (Moore, 1936). There may also be an impure, calcareous siltstone present in the lower part at few localities (O'Conner, 1955).

Avoca Limestone Member

Condra (1927) named the uppermost member of the Lecompton Limestone formation from an exposure 5 kilometers (3 miles) east of Avoca, Nebraska. The Avoca Limestone is a dense, dark bluish, somewhat earthy limestone that weathers yellowish brown. It usually occurs in 1 to 2 beds comprising a total thickness less than a meter (1-2 feet), separated by thin beds of fossiliferous shale. Although, the thickness near the town of Lecompton, Kansas, is slightly more than a meter (4.5 feet), it is very hard and massive (Moore, 1936, Condra, 1927).

Fusulinids in the Avoca Limestone are one of the characteristics used in identifying the member, as they are large and robust. Locally, there are algal-molluscan beds near the top (Moore, 1949). Not always abundant but also present are algae, brachiopods, crinoids and mollusks (O'Conner, 1955).

Tecumseh Shale Formation

Beede (1898) named the rocks from the top of the Avoca Limestone to the base of the Deer Creek Limestone the Tecumseh Shale Formation. It is mostly unfossiliferous and sandy to clayey. The upper part is sandstone, while the basal section is locally conglomeratic. In the north it is 23 meters (70 feet) thick, but southward it decreases in thickness to about 17 meters (50 feet) (Moore, 1936).

In Nebraska, the Tecumseh Shale is subdivided into 3 members: Kenosha Shale, Ost Limestone, and the Rakes Creek Shale. These subdivisions are not present in Kansas, due to the disappearance of the Ost Limestone, which makes it difficult to differentiate the Kenosha and the Rakes Creek (Moore, 1949).

The basal unit is 2-3 meters (6-10 feet) thick. It is bluish-purplish or dark gray in color and calcareous toward the north. There are thin lenses and nodules of limestone within the shale and fossils are fairly abundant. In Shawnee and Osage Counties, Kansas this is replaced by 15-18 meters (45-55 feet) of gray, silty, unfossiliferous shale. The middle unit, which is less persistent in the south, has a highly variable lithologic character. It is an oölitic, coquinoid, sandy, or conglomeratic limestone rich in Osagia. It may also contain numerous dense, light-gray limestone nodules. Thickness ranges from almost nothing to 2 meters (up to 5 feet), but averages less than a meter (2 feet). The upper unit is a light bluish-brownish, clayey and sandy shale, averaging 3 meters (10 feet) in thickness. At most exposures it includes a fairly persistent, mostly unfossiliferous sandstone (Moore, 1936).

Deer Creek Limestone Formation

This formation was first termed the Pawhuski Formation by Smith (1894), to describe the 43-60 meters (130-180 feet) of the Lecompton through Topeka Formations. Oklahoma now uses Lecompton and Deer Creek Limestone instead of the reclassified Deer Creek Formation. Bennett (1896) used the Deer Creek Formation to include the beds between the Tecumseh Formation below and the Calhoun Formation above. It includes 5 members, 3 limestones and 2 shales. The basal member is the Ozawkie Limestone, followed by the Oskaloosa Shale, Rock Bluff Limestone, Larsh-Burroak Shale, and at the top there is the Ervine Creek Limestone. In most exposures, the Deer Creek is more than 13 meters (40 feet) thick (Moore, 1936).

The Deer Creek Limestone forms prominent escarpments throughout the outcrop belt due to the shale formations above and below and its resistant weathering tendencies. Its lithologic characteristics are common throughout the outcrop belt, making it easily identifiable. Although it is easily identifiable, it is sometimes confused with the Oread Formation due to the similarities in lithologic character (Moore, 1949).

Ozawkie Limestone Member

This member of the Deer Creek Limestone formation was first considered by Moore (1932) as part of the Rock Bluff Limestone, but he later reclassified the basal member as the Ozawkie Limestone. It is a brown, massive to thick-bedded, ferruginous limestone that weathers in irregular shelly slabs. The Ozawkie is somewhat sandy and averages 2 meters (5 feet) in thickness, although it can be up to 5 meters (15 feet). Locally, there are numerous fusulinids, crinoid stem fragments, brachiopods, bryozoans, and corals (Moore, 1936).

Oskaloosa Shale Member

Moore first named this member the Larsh Shale in 1932, but in 1936 he renamed it Oskaloosa from exposures near Oskaloosa, Kansas. Normally, it is 2-3 meters (5-10 feet) thick in northern exposures, but southward it increases to more than 8 meters (25 feet). When the thickness of the Oskaloosa varies a lot from the average, the Ozawkie thickens similarly (Condra and Reed, 1937). In northern Kansas it is a bluish-gray or yellowish, blocky clay with 1 or 2 calcareous and somewhat ferruginous siltstones. In southern exposures, the Oskaloosa is sandy and micaceous with a red zone that may be marine in origin. There are also 1 or 2 beds of thin, nodular, light bluish gray impure limestone. Mostly it is unfossiliferous, except in the red marine zone (Moore, 1936).

Rock Bluff Limestone Member

This member was first classified as the Plummer Limestone, by Heald (19189), a term which is still used in Oklahoma. It was later renamed by Condra (1927) from exposures at Rock Bluff, south of Plattsmouth, Nebraska. Persistence of physical and lithological characteristics allow for the easy tracing of the member from Nebraska to Oklahoma. It is a dense, blue, massive limestone with 2 sets of vertical joints that break the unit into rectangular blocks. Normally it is less than a meter (1-2 feet) thick, but locally can exceed the average slightly. A zone a few inches from the surface may be purplish or brownish-blue from weathering processes, while surficial weathering colors tend to be light bluish-gray or creamy. Fossils within the Rock Bluff Limestone are not abundant, but fusulinids are the most common. Also present are brachiopods, bryozoans, crinoids and small mollusks (Moore, 1949).

Larsh-Burroak Shale Member

The Larsh-Burroak Shale is comprised of two beds of shale. Condra named the Larsh shale from exposures on the Larsh farm, northeast of Union, Nebraska. He named the Burroak Shale from road cuts and ravines near the Burr Oak School, south of Pacific Junction, Iowa (Condra and Reed, 1937).

Thickness of this member averages 1 meter (4 feet), but ranges from less than a meter to 2 meters (2.5-7 feet). The lower part is hard, black fissile shale containing conodonts, while the upper part is gray-yellowish, soft clay in which fossils are rare (Moore, 1936).

Ervine Creek Limestone Member

The Ervine Creek Limestone consists of an upper and lower unit, as defined by Moore (1936) and is the thickest member in most exposures.

The lower unit is light-gray to nearly white and locally bluish. It weathers mottled gray and yellowish brown and has a thickness of 1-10 meters (3-30 feet). Fine crystalline to dense, it may contain veinlets or irregularly distributed small masses of clear calcite. It exhibits thin and wavy bedding with clay shale partings, containing ostracodes and small forams, and locally, chert nodules. Fusulinids, calcareous brachiopods, corals, crinoid fragments, echinoid fragments, and bryozoans are most common. Less commonly there are mollusks, sponges, and trilobites (Moore, 1949).

The upper unit is not always present, but when present it may be separated from the lower unit by a meter (1-2 feet) of clayey to sandy, yellowish-gray shale. It is massive, moderately to finely granular, oölitic and contains many small Osagia. In some cases it is strongly coquinoidal with scattered mollusks, calcareous brachiopods, pelecypods, and bryozoans. There are some exposures in which this unit is a fine-grained, earthy to sandy limestone. Mostly it lacks fossils and may be either even-bedded or nodular. In this case it may be almost not present or up to 2 meters (6 feet) thick (Moore et al, 1951).

The upper limestone member of the Deer Creek Formation was named by Condra, from exposures along Ervine Creek, northeast of Union, Nebraska (Condra and Reed, 1937).

III.

CONODONTS

Previous Works

Early History

C. H. Pander was the first to describe conodont elements in 1856. He is also credited for creating the term conodont (Lindström, 1964). His belief was that the elements were teeth from and extinct group of fish (Robison, 1981). Since Pander's work, conodonts have been thought to be fragments of crustaceans (J. Harley, 1861), a fish-like animal's skeletal remains (H. Schmidt, 1934), or a jaw apparatus of a worm-like animal similar to annelids (F.H. T. Rhodes,1954) (Lindström, 1964). Today, the latter is the most commonly accepted explanation.

Many of the names that were created in the classification of conodonts are now considered invalid. This is due to early investigations not taking into consideration the possibility of variation of elements (Lindström, 1964). Although they worked independently, H. W. Scott in North America and H. Schmidt in Europe, were the first to discover that different elements occur in each conodont (Robison, 1981). Also, early researcher's studied embedded conodonts, which hindered their ability to understand what they looked like in three dimensions. In 1933-34, E. B. Branson and M. G. Mehl were the first to isolate the conodonts from their host rock.

In 1926, B. O. Ulrich and R. S. Bassler published a classification of American conodonts from the Devonian and Mississippian. Two years later, G. B. Holmes created a bibliography of conodonts. It includes 30 papers representing 35 conodonts genus names and 300 species, dating back to Pander in 1856. A catalogue of all conodonts known up to 1948, was created by R. O. Fay in 1952. It is very detailed and cross-indexes 620 conodont papers. The catalogue also gives the approximate place in succession of stratigraphic units. In 1961, another catalogue was created to include the conodonts discovered between 1949 and 1958 by S. R. Ash. In 1952, F. H. T. Rhodes published "A Classification of Pennsylvanian Conodont Assemblages." He studied Pennsylvanian conodonts of Illinois and classified them into 'form genera' and 'form species' (Rhodes, F. H. T., 1952).

Conodonts are known to have existed in North America, parts of Europe, Africa, and Australia. In North America, they are found in rock units dating from lower to mid Ordovician into the Permian. Conodonts found in Egypt, by D. B. Eicher in 1946, date back to the Triassic. After the Triassic Period, conodonts are rare or non-existent (Lindström, 1964).

Recent History (1960's – present)

More recent studies, have been geared more toward ecologic models and the distribution of conodonts environmentally. Müller (1962), states that conodonts are probably exclusively marine organisms because they have not been found in freshwater sediments.

Seddon and Sweet (1971) found that:

> "the conclusion that at least the majority of conodonts were not benthic is indicated most compellingly by the occurrence of representatives of the same species in a variety of lithofacies, including black shales of various ages that otherwise yield the remains only of planktonic or nektonic organisms."

Seddon and Sweet (1971) also created a model showing the marine depositional environment to which each conodont genera belonged. They determined the biofacies of each conodont genera and created the model as a vertical stratification of fauna. Since some deep water conodonts can be found in shallow water, Seddon and Sweet (1971) overlapped the zones of each genera.

Von Bitter (1972) studied the environmental control of conodont species within the Shawnee Group of eastern Kansas. Due to his intense study of the conodont assemblages within the Shawnee strata, he was able to provide for each member the typical conodont species found.

Heckel and Baesman (1975) modified this model (Figure 9) and used it to create living-depth zones for Missourian conodonts in Kansas. They use the conodont distribution to create an integrated environmental interpretation of the megacyclothems of the Missourian.

VonBitter (1972) conducted a study of conodont distributions within the Shawnee Group in eastern Kansas. He found that there were indicator species for the Heebner shale member, Plattsmouth limestone member, and Queen Hill shale member, while the remaining units contain primarily non-indicator species.

A depth-related model for the distribution of microfossils, including foramnifera, ostracodes, conodonts, and radiolarians, was created for Late Carboniferous to Early Permian cyclic strata within the Midcontinent region of the United States. Boardman et. al (1995) noted the microfaunal biofacies for nearshore marine, open mid-shelf marine, and deep-shelf marine strata. Figure 10 is a diagrammatic representation of their findings.

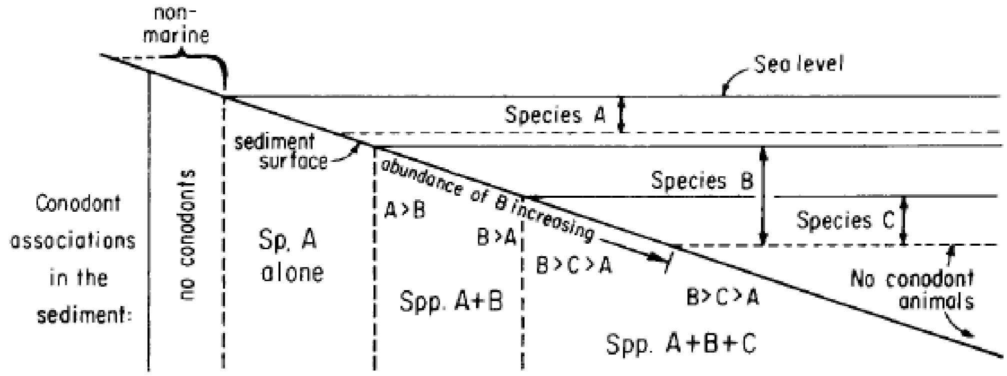


Figure 9. Living-depth zones of conodonts model. (From Heckel and Baeseman, 1975, modified from Seddon and Sweet, 1971)

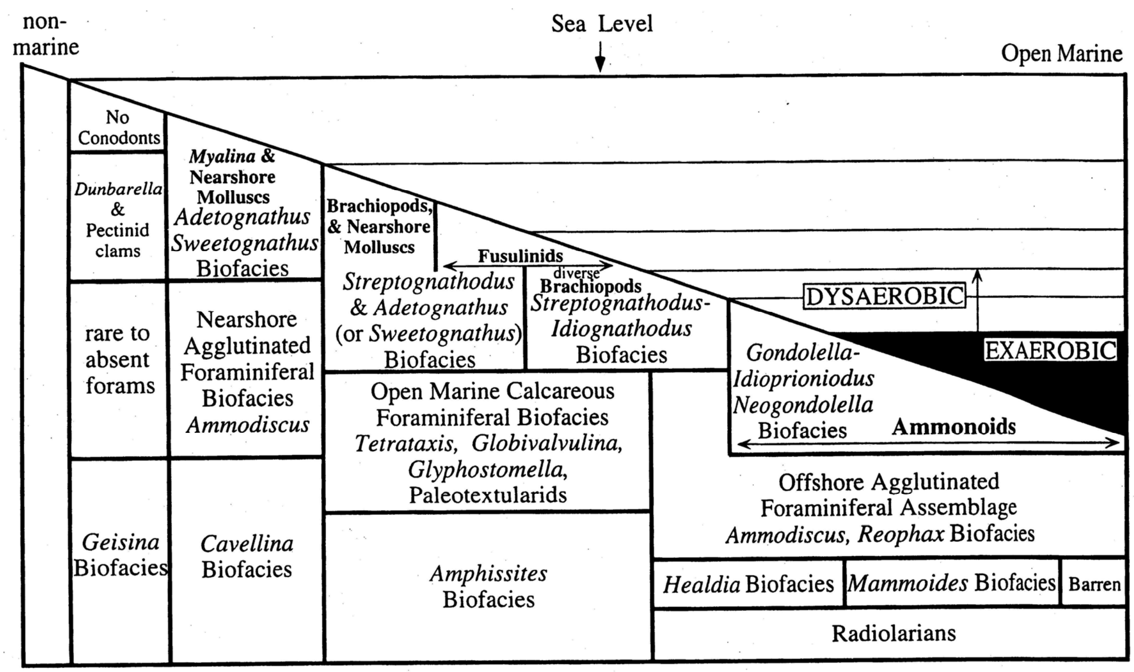


Figure 10. Microfaunal Biofacies of Marine Strata (from Boardman et. al., 1995).

Morphology

Haas (1941) confirmed Pander (1856) and Furnish (1938) by proving that conodonts grew centrifugally, one lamella outside another. Then in 1944, Ellison discovered that conodonts consist of calcium phosphate, or apatite.

It is now acknowledged that the conodont animal was composed of different conodont element shapes and sizes. Each was paired and created the internal support for major organs. There are three shape categories of these elements: coniform, ramiform, and pectiniform. Coniform elements are conical in shape, having a base and a cusp. Ramiform elements have a serrated edge that extends and out from the cusp. Blade-shaped, or platform, elements are of pectiniform shape (Robison, 1981).

Ecology and Environment of Virgilian Conodonts

Conodonts have yet to be discovered within terrestrial units or boundary units between marine and nonmarine environments. For this reason, conodont elements in this study were found only within limestones, calcareous shales, gray shales, and black shales. Heckel and Baesemann (1975) found that deep water units have the greatest diversity of conodont elements, while the lowest conodont element diversity is in shallow water units.

It is important to understand the depositional environment of individual conodont species in order to grasp and understanding of changes in assemblages during transgressive and regressive cycles. Unique assemblages in each depositional unit are created by these transgressive and regressive cycles.

Within the Shawnee Group, the common conodont genera are *Adentognathus*, *Hindeodus*, *Idiognathodus*, *Idioprioniodus*, *Lonchodina*, and *Streptognathodus*. *Gondolella* can be present, but is very rare.

Adentognathus preferred very shallow waters. *Lonchodina* lived in shallow waters, preferably in reefal areas. The surface dwelling *Hindeodus* lived in both shallow and deep waters. *Idiognathodus* and *Streptognathodus* preferred warm, offshore waters, while *Idioprioniodus* and *Gondolella* preferred deep, offshore waters (Robison, 1981).

IV.

CYCLOTHEMS

History of the Cyclothem Theory

Early Theories

J. A. Udden (1912) was one of the first to notice the cyclical nature of formations in the Pennsylvanian of the Midcontinent. In Peoria, Illinois, he subdivided the Pennsylvanian strata into a series of four beds, each of which included four stages:

> "(1) accumulation of vegetation, (2) deposition of calcareous material, (3) sand importation, and (4) aggradation to sea level and soil making."

Although he devised this theory for cyclicity, not much attention was paid to it.

It was later proposed, by J. M. Weller (1930), that each cyclical repetition of beds be considered a formation. The boundaries of each formation were the two periods of diastrophism bounding normal depositional periods:

> "(1) at the close of the period of peat accumulation when subsidence resulted in extensive transgression by sea (formation of the underclay), (2) before the development of the unconformity beneath the sandstone when uplift occurred and the sea withdrew from its shallow basin."

Weller, for the most part, agreed with Udden's theory except for where the bottom boundary lay. Weller felt that the unconformity beneath the sandstone made the best boundary, whereas Udden placed the boundary at the top. The problem with Weller's theory on diastrophism is that he did not provide a mechanism by which all of the uplift and subsidence cycles (100's) could occur. Weller's typical Pennsylvanian formation is described as:

"marine
8. shale, containing 'ironstone' bands in upper part and thin limestone layers in lower part
7. limestone
6. calcareous shale
5. black fissile shale
continental
4. coal
3. underclay, not uncommonly containing concretionary or bedded fresh-water limestone
2. sandy and micaceous shale
1. sandstone
unconformity"

Moore (1932) noted that most cycles of the Pennsylvanian in Kansas and Nebraska contained three or four limestones. He called them "lower, middle, upper, and super" limestones and gave a complete description of each using the Oread Limestone as an example (Moore, 1932, p.251-253).

The term cyclothem was coined by Wanless and Weller (1932), from the Greek words *cyclos* and *thema* meaning cycle and deposit respectively. The definition for a cyclothem is to "designate a series of beds deposited during a simple sedimentary cycle of the type that prevailed during the Pennsylvanian period."

Along with creating the term cyclothem, Wanless and Weller (1932), tried to correlate the Pennsylvanian cyclothems across the Midcontinent. They found that " (1) the entire Pennsylvanian system in the Eastern Interior and northern Appalachian basins and the lower Pennsylvanian strata in the northern part of the Western Interior basin consist of a similar succession of cyclothems, (2) that individual cyclothems are persistent, and (3) that correlation of cyclothems at widely separated localities is possible."

A new, somewhat simpler cycle classification was developed by Wanless and Shepard (1936). They proposed grouping cyclic sediments by: "(a) piedmont facies, composed wholly or very largely of non-marine sediments, but often including a small thickness of marine sediments, (b) delta facies, containing records both of non-marine and marine deposition, and (c) neritic facies, consisting predominately of marine sediments, though containing some non-marine sediments."

A new mechanism for the control of cyclothem deposition was also proposed by Wanless and Shepard (1936), suggesting that sea level would increase approximately one foot if the temperature of the world rose 10ºC. Their theory on eustatic sea level changes is much more believable than Weller's diastrophic control theory. They proposed that glaciers in the Southern Hemisphere retreated and shrank in size, causing a worldwide rise in sea level. This rise in sea level allowed the deposition of limestones and shales to occur. When the glaciers went through a period of growth, the sea level dropped, allowing for the deposition of terrestrial units.

Moore (1936) developed the term megacyclothem, "a cycle of cyclothems," while studying the Shawnee Group in Kansas. He observed that within the Shawnee Group there are major cyclothems, characterized by the presence of three or four fusulinid-bearing limestones, and minor cyclothems, similar to the "ideal" cyclothem. The description of the "ideal", Wabaunsee, cyclothem is as follows:

".9. shale (and coal).
.8. shale, typically with molluscan fauna.
.7. limestone, algal, molluscan, or with mixed molluscan and molluscoid fauna.
.6. shale, molluscoids dominant.
.5. limestone, contains fusulinids, associated commonly with molluscoids.
.4. shale, molluscoids dominant.
.3. limestone, molluscan, or mixed molluscan and molluscoid fauna.
.2. shale, typically with molluscan fauna.
.1.c. coal
.1.b. underclay
.1.a. shale, may contain land plant fossils.
.0. sandstone."

Moore (1936) used this “ideal” cyclothem to compare and contrast the Shawnee Group, although the Shawnee Group units are much more complex. Nonmarine subunits are .0, .1, and .9. Subunit .9 represents the regression. Marine subunits are .2-.8. Moore’s interpretation of the Shawnee Megacyclothem is as follows:

> “Minor Cyclothem
> .8-.9. shale, marine or nonmarine (thick).
> .7. limestone, light-gray, *algal*, sandy to conglomeratic, oölitic, may contain mollusks, brachiopods, bryozoans, etc.
> .6. shale, may contain abundant mollusks, brachiopods, bryozoans, etc.
> .5. limestone, contains fusulinids.
> .2-.4. shale, marine, thin or absent.
> .0-.1. shale and sandstone, nonmarine, not definitely differentiated.
> Major Cyclothem
> .9. shale, nonmarine, thick, commonly with plant fossils.
> .8. shale, with molluscan fauna.
> .7. limestone, dark-blue or gray, like .7 member of Wabaunsee cyclothem, but less persistent and more irregular in thickness (the “super” limestone of field classification).
> .6. shale, thin or absent.
> .5.h. limestone, blue or gray, even-bedded, contains fusulinids, absent in many sections (and where present it has generally been classed with the “fourth” or “super” limestone).
> .5.g. shale, commonly somewhat sandy, marine.
> .5.f. limestone, light-gray, fine-grained, wavy-bedded, locally cherty, thickness generally 12 feet or more, contains abundant *fusulinids* and other fossils, at top in some cases contains algal? “super” type limestone lacking in fusulinids (the “upper” limestone).
> .5.e. shale, yellow or gray, clayey.
> .5.d. shale, black, fissile.
> .5.c. limestone, dark-blue, dense, single massive bed, 1 to 2 feet thick, vertical joints, contains numerous *fusulinids* and other fossils (the “middle” limestone).
> .5.b. shale, gray, clayey, 10 feet or more, in southern areas contains a red zone and subordinate thin sandstone and nodular limestone beds.
> .5.a. limestone, blue-gray weathering strongly brown, ferruginous, somewhat sandy or earthy, massive, 5 to 10 feet in average thickness, contains numerous fusulinids and other fossils (the “lower” limestone).
> .2-.4. shale, sandy to clayey, contains brachiopods and mollusks, may include zone with brachiopods and pelecypods at base of 5a.
> .1.c. coal, thin and very local.
> .1.ab. shale, yellowish, sandy, may contain plant fossils.
> .0. sandstone, yellow-brown, fairly persistent, 5 to 10 feet in average thickness, base locally conglomeratic.

An alternate classification was also provided by Moore (1936) listing the subdivisions of the Shawnee Megacyclothem. A major flaw in this interpretation is the placement of the black, fissile shales. Black, fissile shales in the subdivisions were designated .1 of the “ideal” cyclothem, “c. coal, b. underclay, a. shale, may contain land plants,” and considered nonmarine. Moore (1932) originally thought the black shales to be marine in origin, but gives no explanation as to this change in depositional environment. Another conflict, if one refers to the description of the Shawnee Megacyclothem, Moore (1936) places the black fissile shale in a marine depositional environment, .5.d., of the major cyclothem.

Recent History

The depositional environment of black fissile shale became the focal point of research in the 1950s until the late 1970s. Moore (1950) observed that the only clastic member of a cycle not to thicken toward a source is the black shale and thought that it was deposited in a marine swamp. In the early 1960s, J. K. Evans and P. E. Schenk came to independent conclusions that black shales were deposited at the maximum depth of the transgressing sea and were the most offshore of any facies of a cyclothem (Heckel, 1984).

In the 1970s, conodonts helped in determining that black shales were deep water units. Using Devonian and Ordovician conodonts, zones of the water column in which specific conodont genera lived were modeled by Seddon and Sweet (1971). Later, Heckel and Baesman (1975) discovered that black fissile shale contained *Idioprioniodus and Gondollela*, deep water conodonts, while studying the Missourian of Kansas (Figure 11). They determined that the limestones bounding the black fissile shale above and below must represent part of a transgressive/regressive

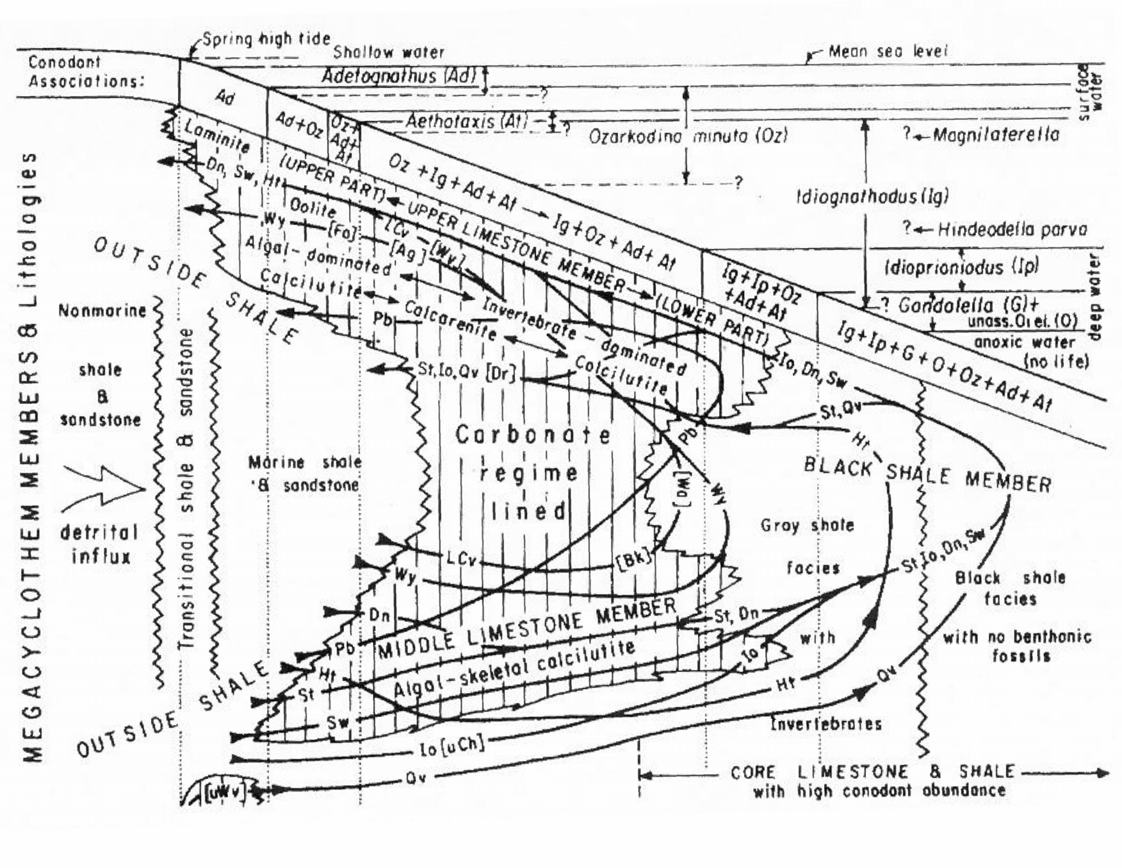


Figure 11. Model for Missourian Conodonts from Heckel and Baeseman (1975).

cycle. The limestone below was deposited during the transgression, the black fissile shale during maximum transgression, and the limestone above represents a regression.

Heckel (1977) introduced a new model for a transgressive/regressive cycle. His model included: "outside (nearshore) shale, middle (transgressive) limestone, core (offshore) shale, upper (regressive) limestone" (Figure 12). This is also known as a Kansas Cyclothem. Outside shales are primarily nonmarine in origin, including: coals, underclays, channel sandstones, red beds, and land-plant fossils. The middle limestone lies beneath the core shale and contains an abundant, diverse marine fauna. The core shale contains black fissile shale with phosphate nodules, which indicates anoxic bottom conditions. Also represented within the core shale is a gray shale containing phosphate nodules, which indicates slightly more oxygen within the system. Lastly, the upper limestone overlies the core shale and contains abundant, diverse marine fauna. Along with this model, Heckel 1977 redefined Moore (1936)'s definition of a megacyclothem. Heckel (1977) uses it to define the more complex sequences of cycles in Kansas and Illinois.

Heckel (1977) also noted the lateral change in the Upper Pennsylvanian cyclothems across facies belts from Oklahoma in the south to Iowa and Nebraska in the north (Figure 13). During the Upper Pennsylvanian, the open marine facies existed in northern Kansas, while the terrigenous detrital facies existed in Oklahoma.

Heckel (1977) created a model to explain the deposition of the phosphatic black shales, termed core shales. His theory is most accepted and considers the water circulation due to the trade winds (Figure 14). Heckel (1977) proposed that the water depth needed to be deep enough to create a thermocline, approximately 50-200 meters (150-600 feet). The winds carried the warm waters out of the

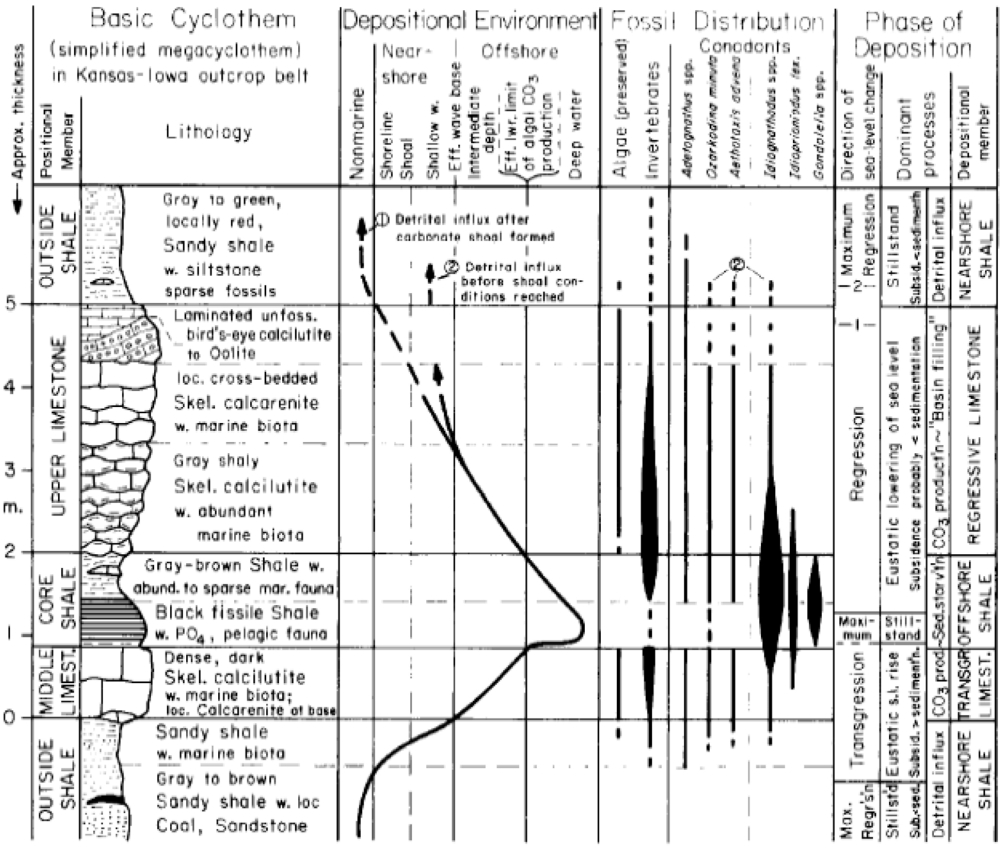


Figure 12. A typical Kansas cyclothem from Heckel (1977).

epicontinental sea's basin, allowing cooler waters to move up to the surface to replace them. Along with cooler water, phosphate was carried toward the surface. Surface dwelling organisms thrived on this supply of phosphate. Eventually it was depleted and the animals died, creating a tremendous amount of organic debris on the bottom of the sea. All of these organics along with anoxic conditions, allowed the deposition of black shale.

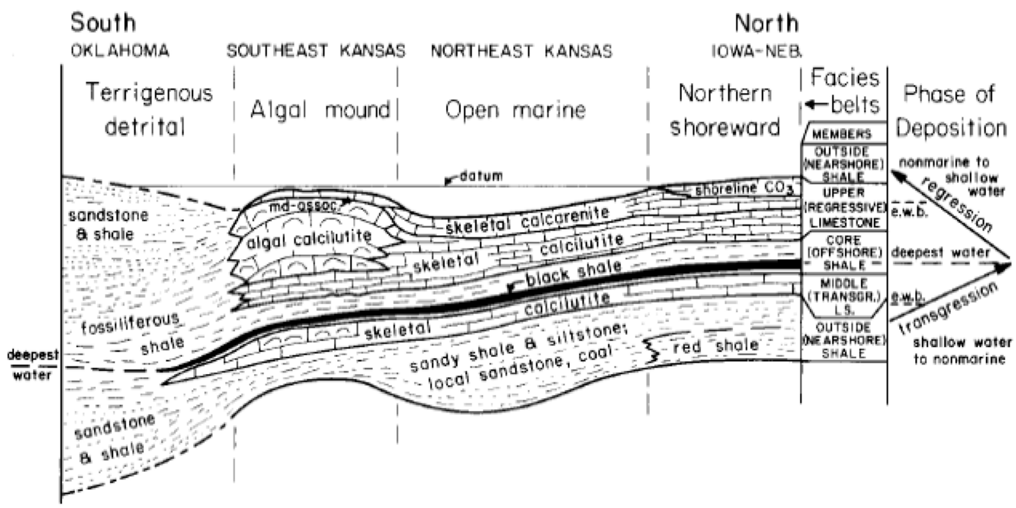


Figure 13. Facies belts from Oklahoma to Iowa and Nebraska from Heckel (1977).

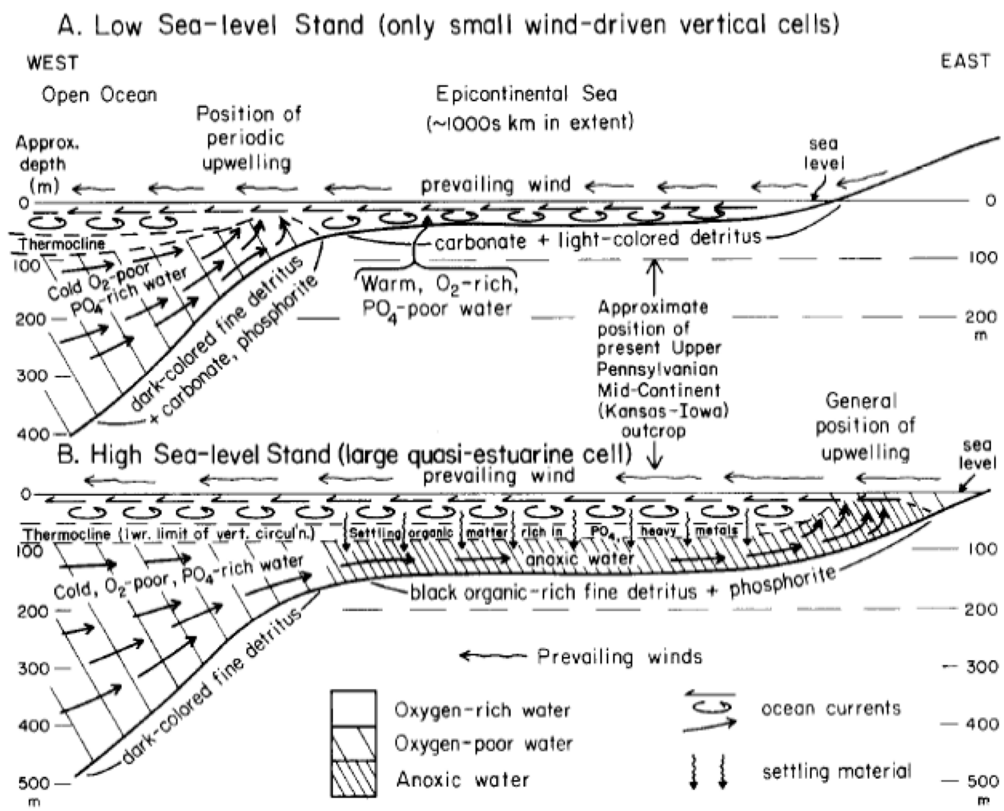


Figure 14. Model for the explanation of the formation of black phosphatic shale from Heckel (1977).

V.

DISCUSSION OF RESULTS

Within the region of study, the Shawnee Group lithology varies greatly. In Missouri it is carbonate dominated, while toward the south and especially in Oklahoma it siliciclastic dominated with increasing shale thicknesses and a decrease in limestone thicknesses. The most probable reason for this is the influx of clastic sediments being shed from the Ouashita Orogeny. In the vicinity of the localities in Oklahoma, the Nemaha uplift may have caused the sea-level to be shallower, but probably only a minor factor. This allowed for the deposition of less limestone and offshore (core) shale and more nearshore clastic strata.

Stratigraphic sections of all localities can be seen in Appendix A, and show the variations in thicknesses and lithologies of all members of the Shawnee Group. A composite cross section of the field area can be viewed on plate 1.

Variations in Core Shale Characteristics

Core shales of the Missouri section are black and extremely fissile at the base. These shales break down in less than 24 hours do to a high percentage of carbon. The top sections of these core shales are gray shale containing phosphate nodules.

As the outcrops move into southern Kansas, less carbon exists within the black shales. This causes them to loose some of their fissility and take 1-2 or more weeks to break down. Also, instead of the black shales lying directly upon the underlying limestone, there is 2-3 inches of gray, clayey, shale. This shale layer typically contains more conodonts per sample than the overlying black fissile shale.

Thickness of the core shale increases by approximately 2 feet , do to an increase of clastics from the distant south.

In a distance of approximately 20 miles, the Heebner Shale thickness increases from 6 feet at locality 13 to 50 feet at locality 14, along with an associated sandstone comprising the top layer. There is no apparent sign of a black, fissile shale, but in its place there is a gray shale containing limonite nodules at the base, grading into silty shale toward the top. During Heebner time, there was a significant influx of clastic sediment into the northern Oklahoma region. The most probable reason for this is the uplifting Ouashita Mountains. This influx of clastic sediments, geologically speaking, lasted a short period of time because, although the Queen Hill Shale does increase in thickness from southern Kansas, to northern Oklahoma, it is in no way as significant as in the Heebner shale. One other difference in these two core shales is that the Queen Hill Shale does keep its black color. It is by no means fissile, being more of a clay shale. It breaks down very easily in Kereosene, whereas black, fissile shales break down easily in hydrogen peroxide and not at all in Kerosene.

Due to these changes in fissility, it can be seen that the deepest water within the study area covered the Missouri outcrop area. Higher fissility and in return higher carbon content means that there needed to be anoxic waters present (50-200 m). Oklahoma outcrops would represent an area closer to shore, but in a region where maximum transgressions reached a depth in the vicinity of at least 50 meters.

Conodont Distribution within the Formations Studied

Within the examined formations of the Shawnee Group, there are three core shales. Each of these core shale has distinctive conodont fauna. Within the Heebner Shale Member, the species *Idiognathodus simulator* is the identifier. The identifying species within the Queen Hill Shale is typically *Idiognathodus tersus*, but in Oklahoma it is not present. Instead we find that the species *Streptognathodus ruzhencevi* can be traced from Oklahoma into Kansas and to the outcrops in Missouri. *Streptognathodus ruzhencevi* is also the identifier species within the Larsh-Burroak Shale in Kansas and Oklahoma. These two core shales can be differentiated, although they contain the same key species because within the Larsh-Burroak Shale, *Streptognathodus ruzhencevi* is evolutionarily advanced compared to the *Streptognathodus ruzhencevi* of the Queen Hill Shale.

Within the Heebner Shale, the highest concentration of conodonts per sample was at the base. In some cases, it wasn't within the black, fissile shale, but within a three inch layer of gray clay shale. Typically the Heebner Shale Member contained 200-500+ conodonts per 1 kilogram of sample. This high concentration is expected in a core shale, but it does decrease in Oklahoma where the black, fissile shale facies has not been found present.

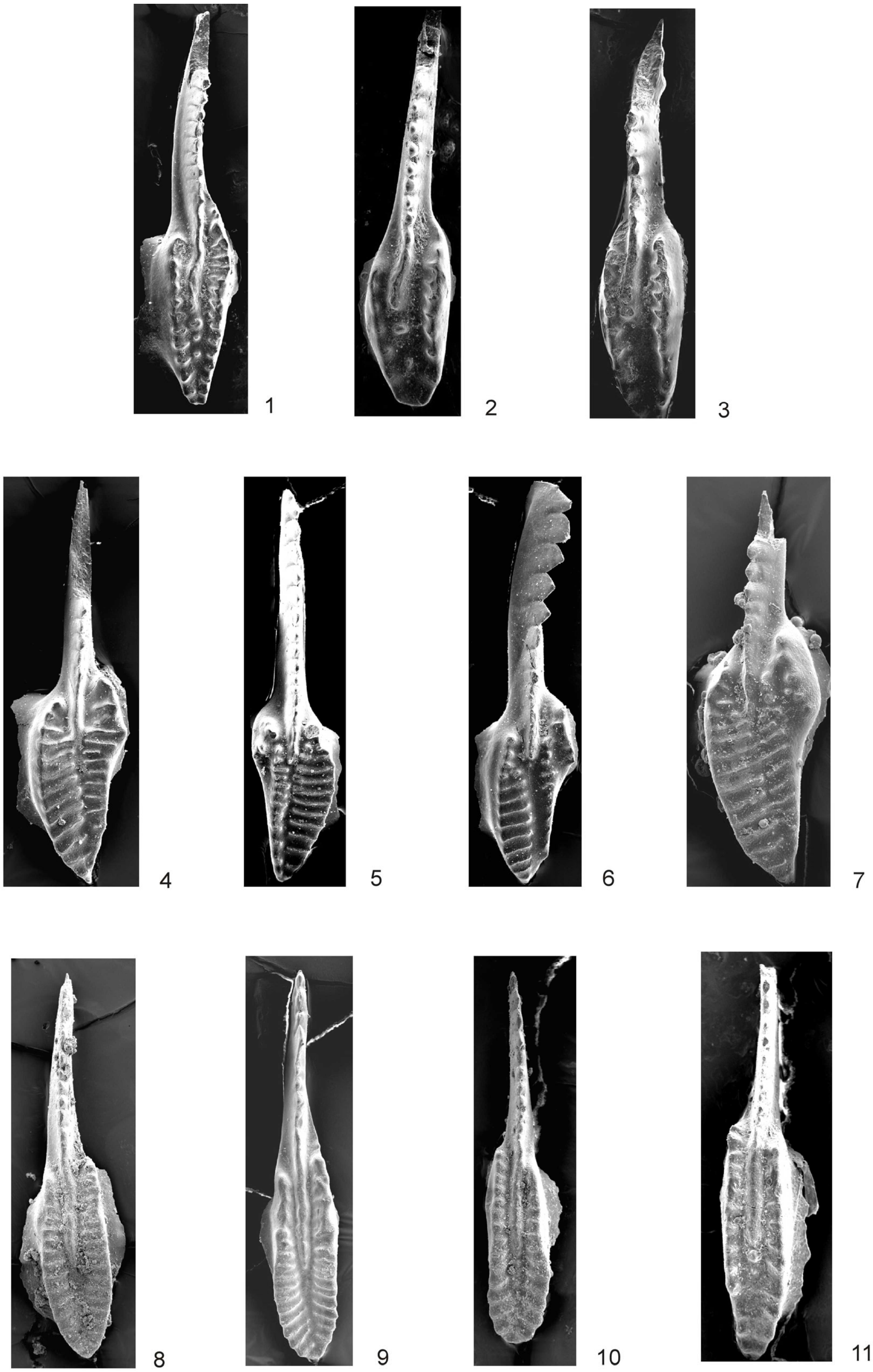


Plate 1.

Plate 1
Missouri Sections Conodont Photomicrographs

1-3 *Streptognathodus bitteri* from locality 1, sample 2.
4-6 *Idiognathodus simulator* from locality 5, sample 1.
7 *Idiognathodus lobulatus* from locality 5, sample 1.
8-10 *Streptognathodus* sp A. 8 and 10 are from locality 5, sample 5. 9 is from locality 4, sample 11.
11 *Streptognathodus* sp. A from locality 4, sample 1.

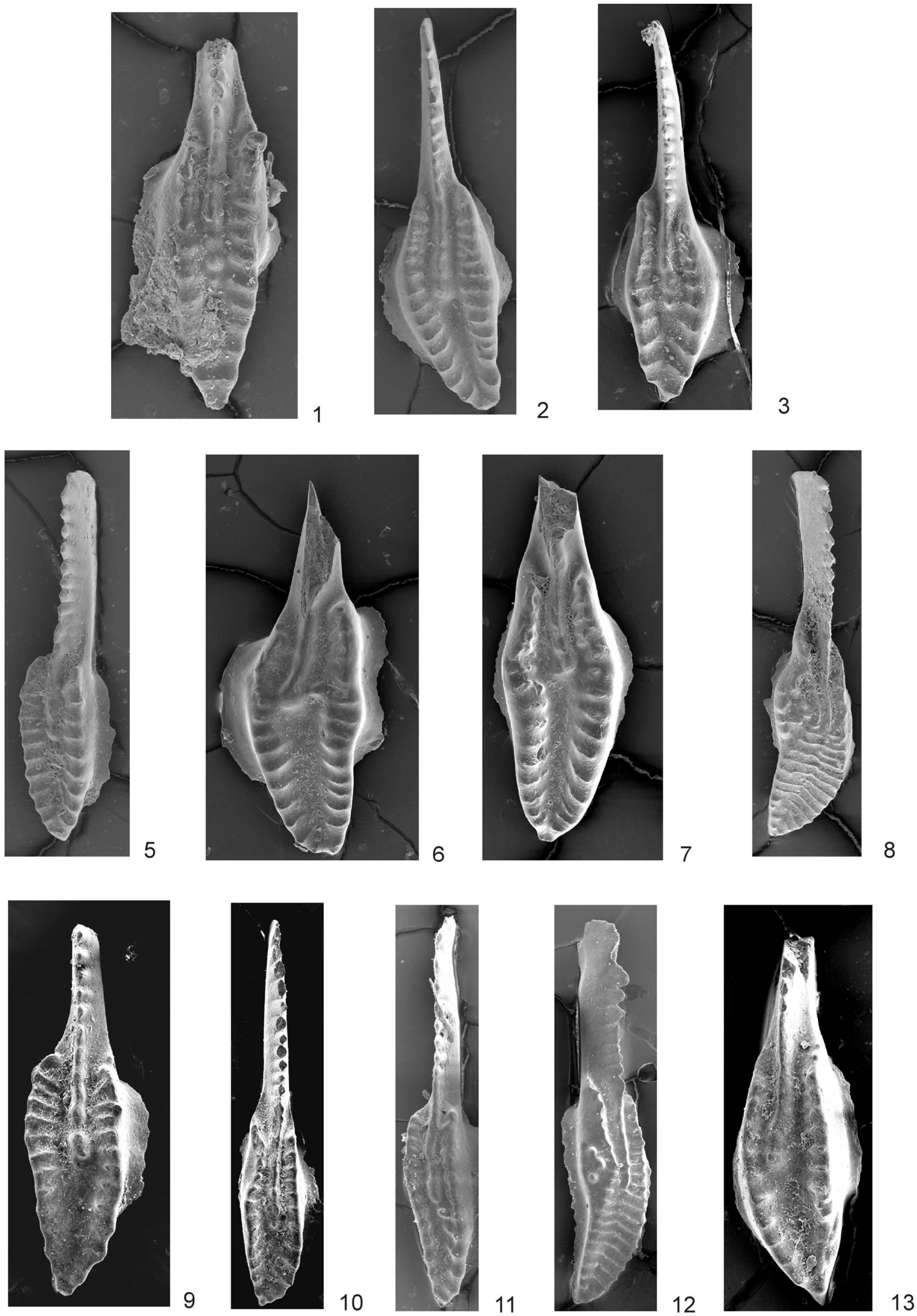


Plate 2.

Plate 2
Missouri and Kansas Sections Conodont Photomicrographs

1 *Streptognathodus* cf. *Ruzhencevi* from locality 3, sample 7.
2-3 *Streptognathodus* sp. B. from locality 3, sample 7.
4-5 *Streptognathodus deflectus* from locality 3, sample 8.
6 *Idiognathodus lobulatus* from locality 3, sample 6.
7-10 *Streptognathodus* sp. B from locality 2, sample 13.
11 *Idiognathodus lobulatus* from locality 2, sample 13.
12 *Streptognathodus deflectus* from locality 7, sample 4.

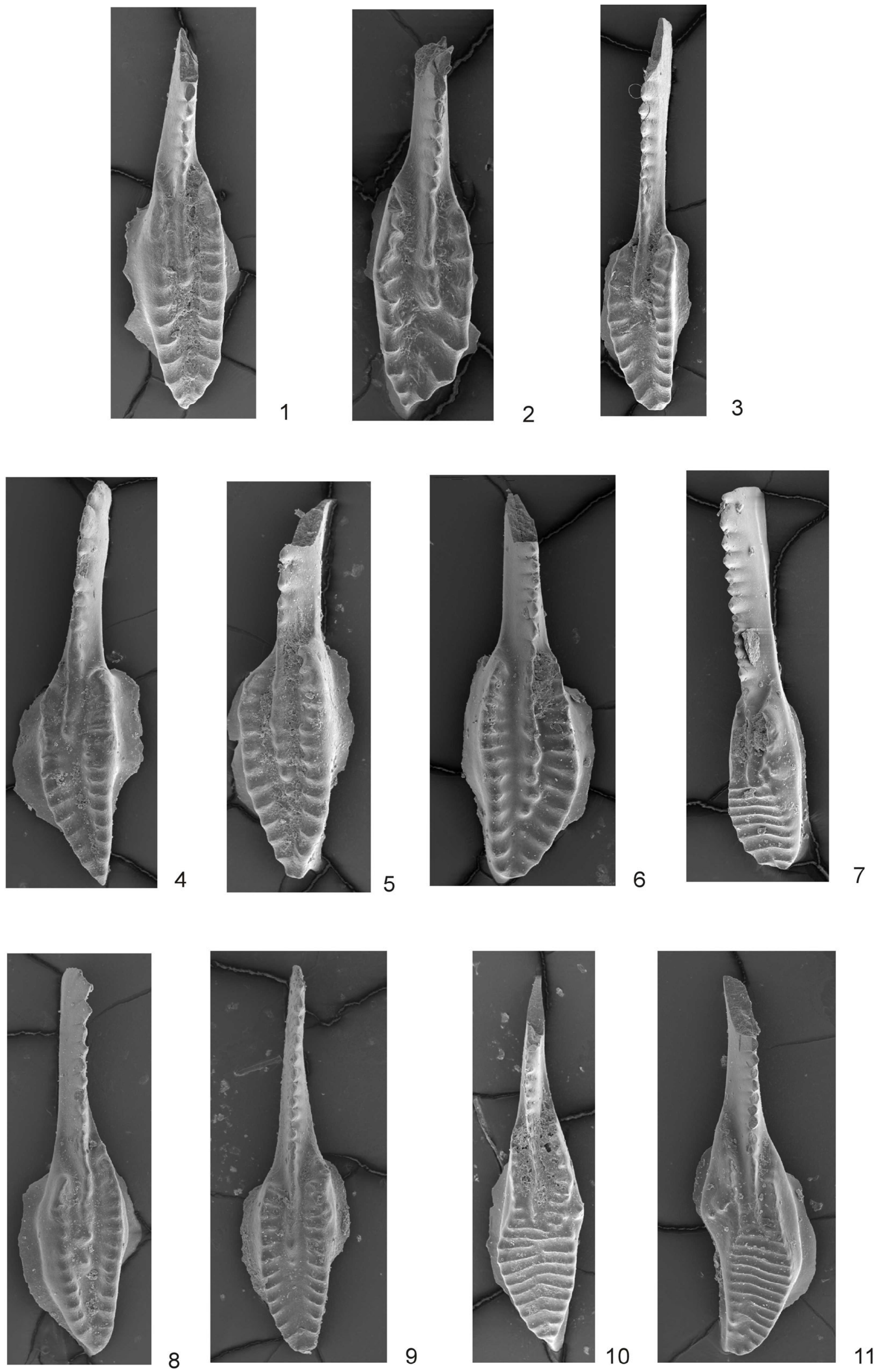


Plate 3.

Plate 3
Missouri and Kansas Sections Conodont Photomicrographs

1. *Streptognathodus* sp. B from locality 3, sample 28.
2. *Streptognathdous* sp. C from locality 3, sample 28.
3 *Streptognathodus pawhuskensis* from locality 3, sample 28.
4 *Streptognathodus pawhuskensis* from locality 3, sample 25.
5-6 *Streptognathodus ruzhencevi* from locality 3, sample 25.
7 *Idiognathodus tersus* from locality 3, sample 25.
8-9 *Streptognathodus* sp. B from locality 11, sample 3.
10 *Idiognathodus lobulatus* from locality 11, sample 3.
11 *Idiognathodus lobulatus* from locality 3, sample 23.

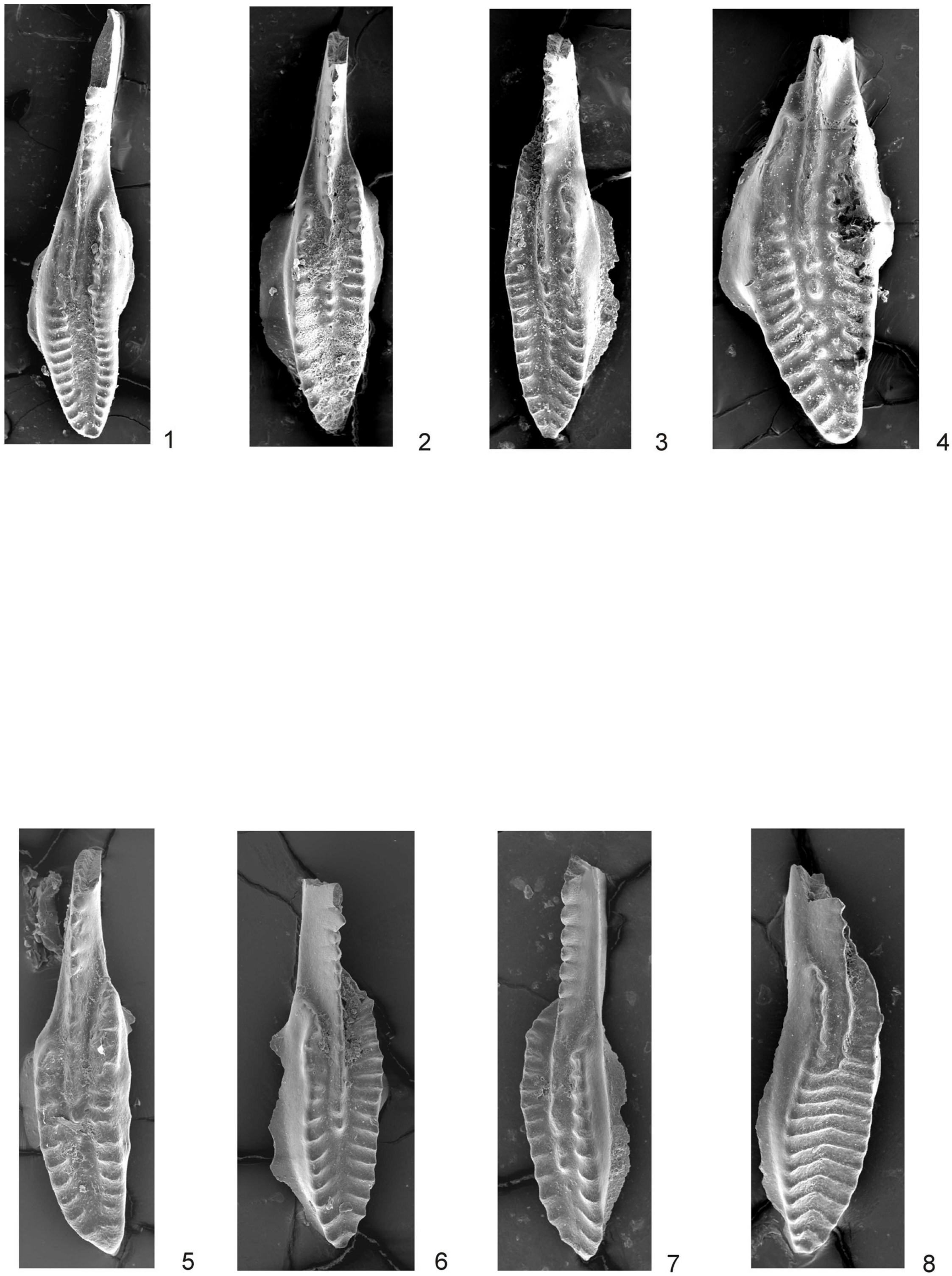


Plate 4.

Plate 4
Missouri and Kansas Sections Conodont Photomicrographs

1 *Streptognathodus pawhuskensis* from locality 13, sample 1.
2-4 *Streptognathodus ruzhencevi* from locality 13, sample 1.
5-6 *Streptognathodus* sp. B from locality 6, samples 11 and 12 respectively.
7 *Streptognathodus ruzhencevi* from locality 6, sample 12.
8 *Idiognathodus tarsus* from locality 6, sample 12.

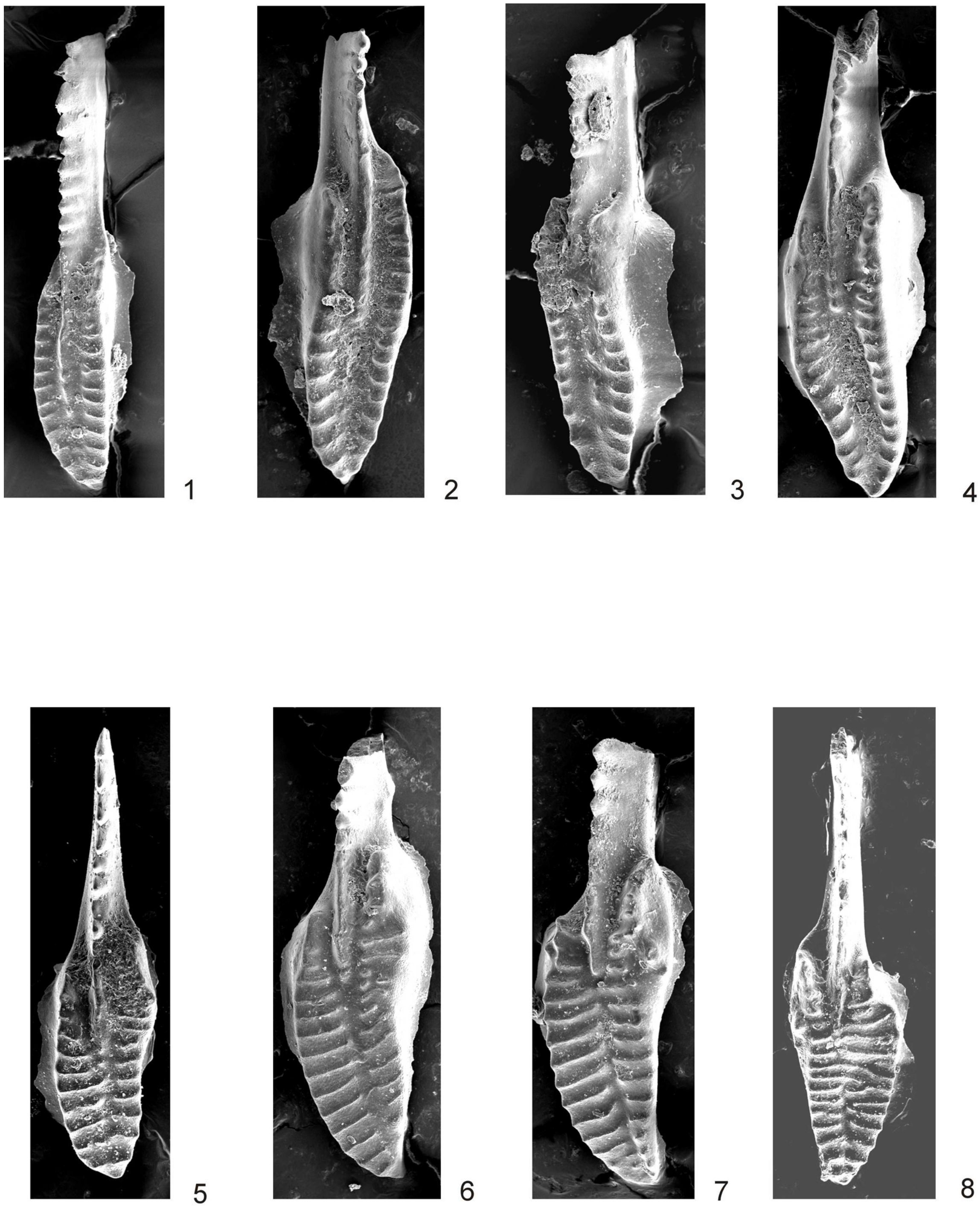


Plate 5.

Plate 5
Oklahoma Sections Conodont Photomicrographs

1-3 *Streptognathodus cf. Ruzhencevi* from locality 20, sample 5.
4 *Streptognathodus* cf. Sp. B from locality 20, sample 5.
5-8 *Idiognathodus simulator* from locality 19, samples 1-3.

Gamma-ray Interpretations

Due to malfunctioning equipment, gamma-ray signatures are unavailable for many of the localities. In the gamma-ray signatures that were measured, similar curves to those found in subsurface gamma-ray well logs were produced. These curves along with measured values for uranium, thorium, and potassium can be found in Appendix C. Also found in Appendix C are the sea level curves generated from the API values plotted next to the measured section of the locality.

The most notable signatures came from locality 13, where the Heebner Shale has its distinguishable hot kick in surface exposures. Within the Heebner shale, the most radioactive layers contain phosphate nodules. This is to be expected since phosphate nodules are sinks for uranium.

Also seen in the locality 13 signatures, is the low API values in regressive limestones and increasing API values in transgressive limestones. The Toronto Limestone at this location exhibits both characteristics, perhaps showing that during the deposition of the Toronto sediments, there was both a transgression and a regression.

VI.

CONCLUSIONS

Within the Missouri sections, two maximum flooding surfaces are represented by black fissile shale containing phosphate nodules. The Lecompton Limestone formation contains the Queen Hill shale member and the Oread Limestone formation contains the Heebner shale member. These contain condensed sections with high concentrations of conodonts (500+) per kilogram of sample. There are also three flooding surfaces, within the Beil Limestone member, the Plattsmouth Limestone member, the Toronto Limestone member. These flooding surfaces occur as shale partings and are recognized by the presence of phophotized and glaucony replaced fossils, glauconite, and a concentration of 100+ conodonts per kilogram of sample.

In Kansas, the Deer Creek formation was also sampled, due to its inclusion as one formation with the Lecompton Limestone Formation in Oklahoma. Due to this inclusion in Kansas, there are three maximum flooding surfaces: the Heebner shale member, the Queen Hill shale member, and the Larsh-Burroak shale member (within the Deer Creek formation). All are black, fissile shales containing phosphate nodules and 500+ conodonts per kilogram of sample. Other flooding surfaces aren't present in southern Kansas and may be a regional occurrence in the north.

In Oklahoma, the Queen Hill shale is the only core shale that keeps some black color. The Heebner shale thickens and in some locations there is an included deltaic sandstone at the top. Conodonts per sample decrease, but are still abundant and include indicator species.

Gamma-ray analysis has shown that surface to subsurface correlation of the Shawnee Group could be possible in the future. The core shales have prominent kicks in radiation in surface outcrops that can also be seen in subsurface gamma-ray logs.

REFERENCES

Boardman, Darwin R., II, Nestell, Merlynd, K. and Knox, Larry W., 1995. Depth-related Microfaunal Biofacies Model for Late Carboniferous to Early Permian Cyclothemic Sedimentary Sequences in Midcontinent North America, *in* Hyne, N. J. (ed.), Sequence Stratigraphy of the Midcontinent: Tulsa Geological Society Special Publication 4, p. 93-118.

Bryan, M. W., 1999. Sequence Stratigraphy of the Shawnee Group (Virgilian, Pennsylvanian) in Southeastern Kansas: Published M.S. Thesis, Oklahoma State University, 173 p

Carter, James A. Jr., 1954. The Geology of the Pearsonia Area, Osage County, Oklahoma: M. S. thesis, University of Oklahoma, 114p.

Condra, G. E., 1927. The Stratigraphy of the Pennsylvanian System in Nebraska: Nebraska Geological Survey, 2nd series, Bulletin 1, 291p.

Condra, G. E., 1930. Correlation of the Pennsylvanian Beds in the Platte and Jones Point Sections of Nebraska: Nebraska Geological Survey, Bulletin 3, 2nd Series, 57p.

Condra, G. E. and Bengston, 1915. The Pennsylvanian Formations of Southeastern Nebraska: Nebraska Academy of Science, Pub. 9, No. 2, p. 1-60

Condra, G. E. and Reed, E. C., 1937. Correlation of the Members of the Shawnee Group in Southeastern Nebraska and Adjacent Areas of Iowa, Missouri and Kansas: Nebraska Geological Survey, Bulletin11, 2nd Series, 64p.

Dunham, R. J., 1962. Classification of Carbonate Rocks According to Depositional Texture: *in* Classification of Carbonate Rocks – A Symposium: AAPG memoir 1, p. 108-121.

Haworth, E., 1894. Résumé of the Stratigraphy of Eastern Kansas: Kansas Univ. Quart., vol. 2, p. 126-129.

Haworth, E., 1895. Stratigraphy of the Kansas Coal Measures: American Journal of Science, volume 50, no. 3, p. 452-466.

Haworth, E., 1898. Special Report on Coal: Kansas Geological Survey, vol. 3, p. 1-347.

Haworth, E. and Kirk, 1894. A Geologic Section Along the Neosho River from the Mississippian Formation of the Indian Territory to White City, Kansas and Along the Cottonwood River from Wyckoff to Peabody: Kansas University Quarterly, vol. 2, p. 102-115.

Heckel, P. H., 1977. Origin of Phosphatic Black Shale Facies in Pennsylvanian Cyclothems of Midcontinent North America, AAPG Bull., v. 61, no. 7, p. 1045-1068.

Heckel, P. H., 1984. Changing Concepts of Midcontinent Pennsylvanian Cyclothems, North America: International Congress on Carboniferous Stratigraphy and Geology, v. 9, no. 3, p. 535-553.

Heckel, P. H. and Baesemann, J. F., 1975. Environmental Interpretation of Conodont Distribution in Upper Pennsylvanian (Missourian) Megacyclothems in Eastern Kansas, AAPG Bull., v. 59, no. 3, p. 486-509.

Keyes, C. R., 1899. The Missourian Series of the Carboniferous, The American Geologist, volume 23, p. 298-316.

Lindström, M., 1964. "Conodonts", Elsevier, Amsterdam.

Moore, R. C., 1929. Correlation of Pennsylvanian Formations of Texas and Oklahoma, AAPG Bull., v. 13, no. 8, p. 883-901.

Moore, R. C., 1932. Pennsylvanian Cycles in the Northern Midcontinent Region: Illinois Geologic Survey Bulletin, No. 60, p.247-258.

Moore, R. C., 1936. Stratigraphic Classification of the Pennsylvanian Rocks of Kansas: State Geological Survey of Kansas Bulletin, No.22, 256p.

Moore, R. C., 1949. Divisions of the Pennsylvanian System in Kansas: State Geological Survey of Kansas Bulletin, No. 83, 223p.

Moore, R. C., 1950. Late Paleozoic Cyclic Sedimentation in Central United States: 18th International Geol. Congr. Rept. (Great Britain 1948) part 4, p.5-16.

Moore, R. C., 1962. Treatise on Invertebrate Paleontology, Part W, Miscellanea, GSA and University of Kansas Press.

Moore, R. C., Frye, John C., Jewett, J. M., Lee, Wallace and O'Conner, Howard G., 1951. The Kansas Rock Column: State Geological Survey of Kansas Bulletin: No. 89, 132p.

Müller, K. J., 1962. Taxonomy, Evolution, and Ecology of Conodonts, *in* R. C. Moore (ed.), Treatise on Invertebrate Paleontology, Part W, Miscellanea, GSA and University of Kansas Press, W83-W91.

O'Conner, H. G., 1955. Geology, Mineral Resources and Ground-Water Resources of Osage County, Kansas, 1955, University of Kansas Publication State Geological Survey of Kansas, Volume 13, Part 1, p. 14-19.

Rascoe, B. Jr. and Adler, F. J., 1983. Permo-Carboniferous Hydrocarbon Accumulations, Midcontinent, USA: AAPG Bulletin, v. 67, p. 979-1001.

Rhodes, F. H. T., 1952. A Classification of Pennsylvanian Conodont Assemblages, Journal of Paleontology, v. 26, no. 6, p. 886-901.

Robison, R. A., ed., 1981. Treatise on Invertebrate Paleontology, Part W, Supplement 2, Conodonta, GSA and University of Kansas Press.

Seddon, G. and Sweet, W. C., 1971. An Ecologic Model for Conodonts, Journal of Paleontology, v. 45, no. 5, p. 869-880.

Shannon, Patrick Joseph, 1954. The Geology of the Pawhuska Area, Osage County, Oklahoma: M.S. thesis, University of Oklahoma, 98p.

Troell, A. R., 1969. Depositional Facies of Toronto Limestone Member (Oread Limestone, Pennsylvanian), Subsurface Marker Unit in Kansas: Kansas State Geological Survey Bulletin, No. 197, 29p.

Udden, J. A., 1912. Geology and Mineral Resources of the Peoria Quadrangle, Illinois: U.S.G.S Bulletin, No. 506, 103 pp.

von Bitter, P. H., 1972. Environmental Control of Conodont Distribution in the Shawnee Group (Upper Pennsylvanian) of Eastern Kansas: University of Kansas Paleontological Contributions, Article 59, 105p.

Wanless, H. R. and Shepard, F. P., 1936. Sea-level and Climatic Changes Related to Late Paleozoic Cycles, GSA Bull., v. 47, p. 1177-1206.

Wanless, H. R. and Weller, J. M., 1932. Correlation and extent of Pennsylvanian Cyclothems, GSA Bull., v. 43, p. 1003-1016.

Weller, J. M., 1930. Cyclical Sedimentation of the Pennsylvanian Period and its Significance, Journal of Geology, v. 38, no. 2, p.97-135.

Weller, J. M., 1956. Argument for Diastrophic Control of Late Paleozoic Cyclothems, AAPG Bull., v. 40, no. 1, p. 17-50.

Weller, J. M., 1958. Cyclothems and Larger Sedimentary Cycles of the Pennsylvanian, Journal of Geology, v. 66, p. 195-207.

APPENDIX A

Outcrop Descriptions

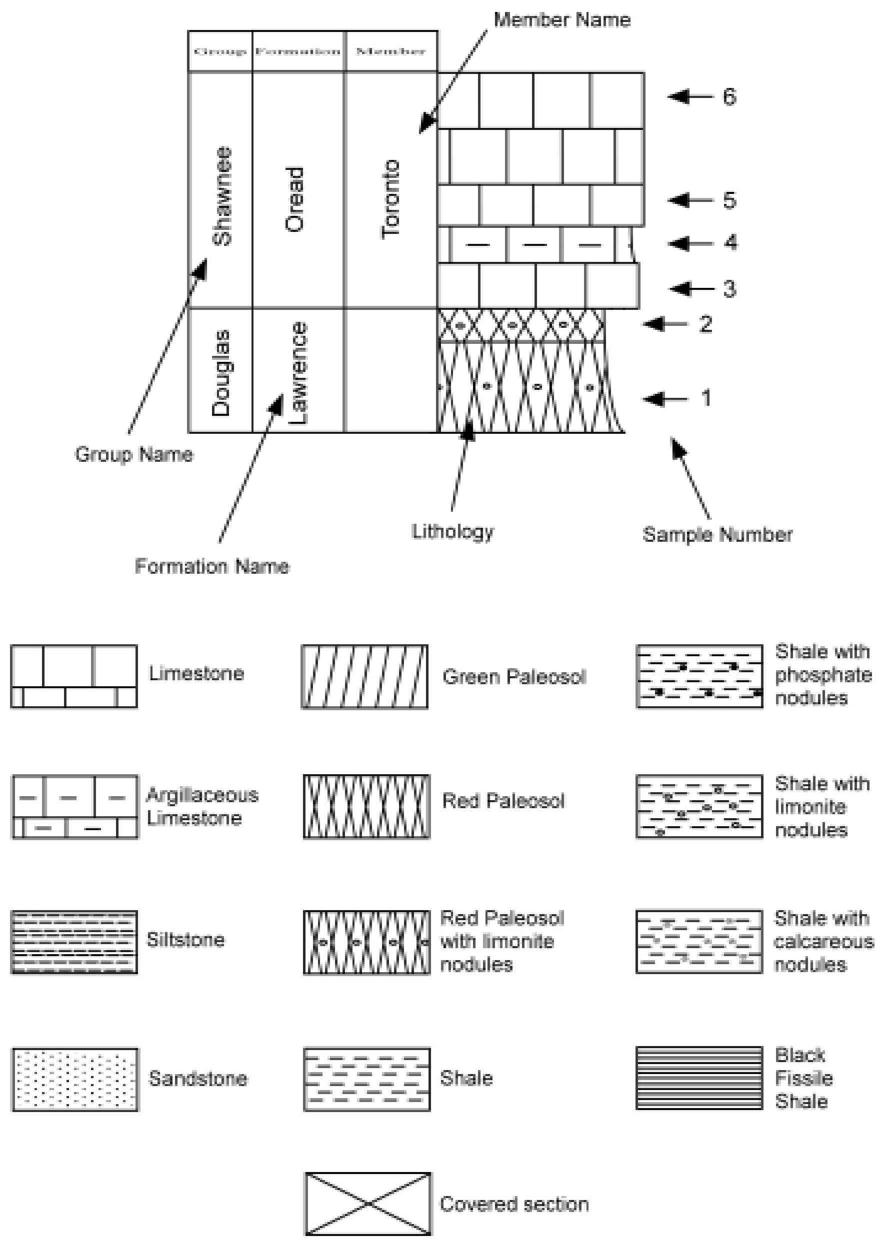


Figure 15. Key to symbols used in measured sections.

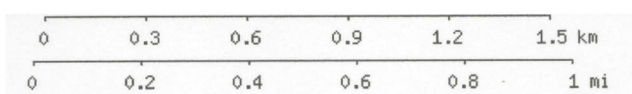


Figure 16. Location map of locality 1.

LOCATION 1: Quarry 1.8 miles west of Amazonia, Missouri, on highway T
NW/4 SW/4 NE/4 sec. 28 T59N R36W
LONGITUDE: N39°54'14.7"
LATTITUDE: W94°56'45.2"

Lecompton Limestone Formation

Plattsmouth Limestone Member

1 Wackestone, massive, wavy beds, hard, fossiliferous, very light gray N8, yellowish gray 5Y7/2 fresh, weathers pale yellowish orange10YR8/6 – 185cm/74 inches

2 Shale, slight laminations, calcareous, medium dark gray N4, medium gray N5 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y7/2 – 10cm/4 inches

3 Wackestone, massive, wavy beds, hard, fossiliferous-crinoids, very light gray N8, yellowish gray 5Y7/2 fresh, weathers pale yellowish orange10YR8/6 – 150cm/60 inches

4 fusulinid packstone, wavy bedded, hard, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y7/2, moderate brown 5YR4/4 – 7.5cm/3 inches

5 wackstone/packstone, massive, wavy beds, hard, fossiliferous-fusulinids, pelecypods, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y7/2, moderate brown 5YR4/4, dark yellowish orange 10YR6/6 – 185cm/74 inches

Heumader Shale Member

6 shale, clayey, very thinly bedded, medium light gray N6, light olive gray 5Y6/1, dark yellow orange 10YR6/6, light brown 5YR5/6, moderate brown 5YR4/4 – 15cm/6 inches

7 shale, very thinly bedded, light olive gray 5Y6/1, medium light gray N6, grayish yellow 5Y8/4 – 15cm/6 inches

8 shale, thinly bedded, faintly laminated, pale yellowish orange 10YR8/6, medium light gray N6, light gray N7 – 45cm/18 inches

9 shale, very fossiliferous-composita, myalina, bryozoans, calcareous, very thinly bedded, light olive gray 5Y6/1, light gray N7, pale yellowish orange 10YR8/6 – 10cm/4 inches

Kereford Limestone Member

10 massive, recrystallized calcite on surface, base is wackstone/packstone, hard, fossiliferous-brachiopods, pelecyopods, and crinoids, top is packstone, hard, pale brown 5YR5/2, pale yellowish brown 10YR6/2, pale yellowish orange 10YR8/6 fresh, weathers grayish orange 10YR7/4, yellowish gray 5Y7/2, grayish yellow 5Y8/4, dark yellowish orange 10YR6/6 – 90cm/36 inches

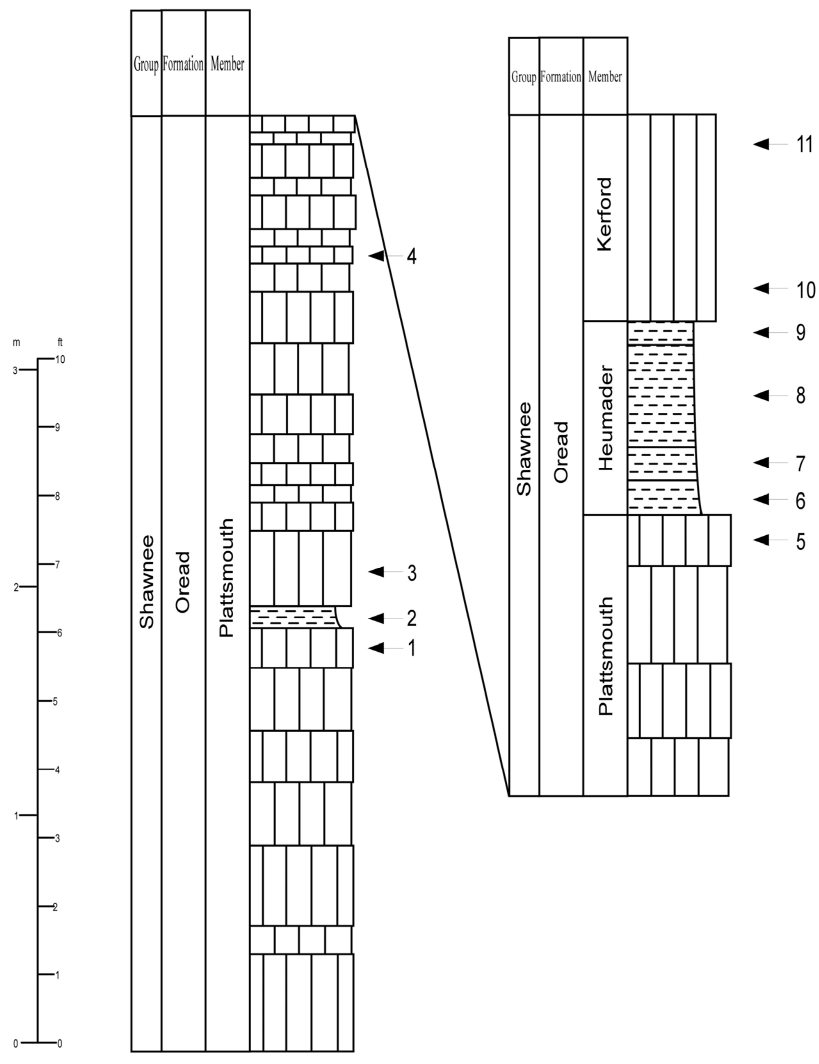


Figure 17. Stratigraphic section of locality 1.

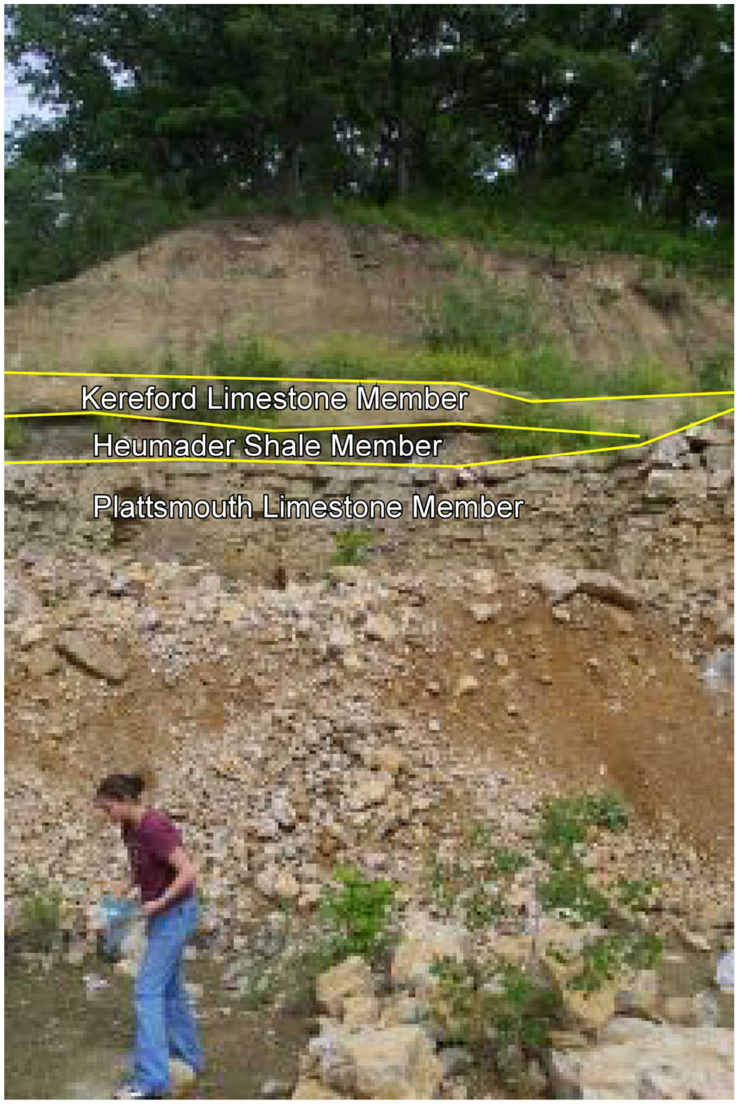


Figure 18. Photograph of locality 1.

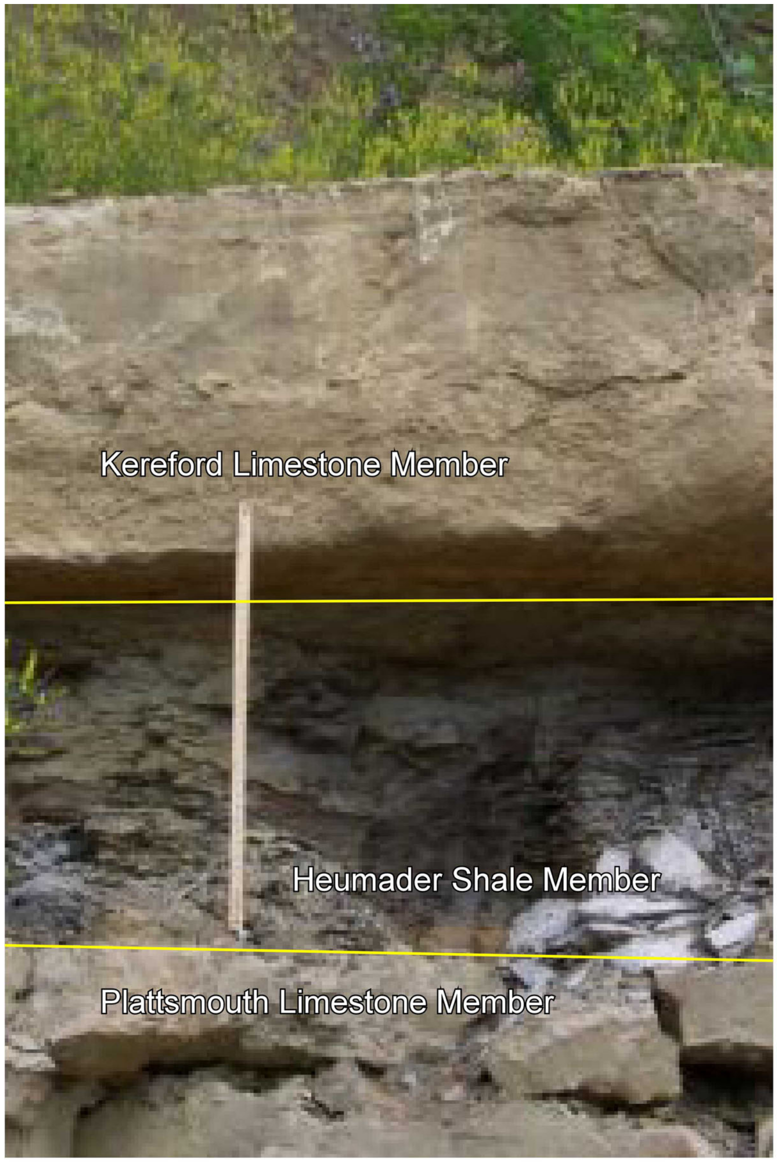


Figure 19. Kereford Limestone, Heumader Shale, and the top of the Plattsmouth Limestone.

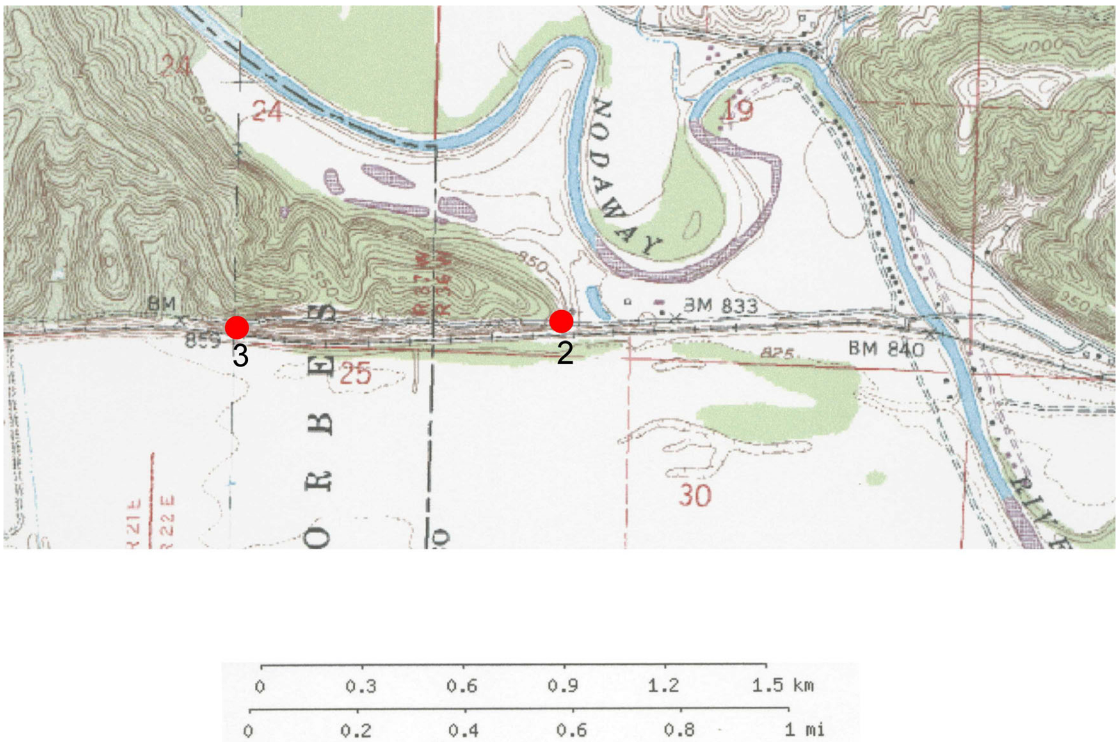


Figure 20. Map of locality 2.

LOCATION 2: North backslope of highway T, 1.2 miles west of Nodaway, Missouri SW/4 SW/4 sec. 19 T59N, R36W and SE/4 SE/4 sec. 24 T59N R37W
LONGITUDE: N39°54’37.7”
LATTITUDE: W94°59’20.4”

Oread Limestone Formation

Plattsmouth Limestone Member

1 Poorly exposed – 275cm/110 inches

2 Packstone, massive, fossiliferous – fusulinids, pelecypods, recrystallized calcite on the surface, hard, medium light gray N6, light olive gray 5Y6/1 fresh, weathers moderate brown 5YR4/4, pale yellowish orange 10YR8/6, grayish yellow 5Y8/4 – 25cm/10 inches

Heumader Shale Member

3 shale, fossiliferous, yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 – 15cm/6 inches

4 shale, calcareous, fossiliferous, pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6 – 15cm/6 inches

5 shale, calcareous, pale yellowish orange 10YR8/6 – 20cm/8 inches

Kereford Limestone member

6 wackestone, massive, hard, crystalline, fossiliferous, medium dark gray N4 fresh, weathers pale yellowish orange 10YR8/6, light brown 5YR5/6, yellowish gray 5YR7/2 – 25cm/10 inches

7 wackestone, massive, hard, argiliceous base, light olive gray 5Y6/1, yellowish gray 5Y7/2, grayish yellow 5Y8/4 fresh, weathers pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6, moderate brown 5YR4/4 – 45cm/ 18 inches

8 wackestone, massive, recrystallized calcite on surface, olive gray 5Y4/1, light olive gray 5Y6/1, grayish yellow 5Y8/4, medium gray N5, medium dark gray N4 fresh, weathers dark yellowish orange 10YR6/6, dusky yellowish brown 10YR2/2, pale yellowish orange 10YR8/6, yellowish gray 5Y7/2 – 35cm/14 inches

Kanwaka Shale Formation

Jackson Park Shale Member

9 shale, slightly calcareous, yellowish gray 5Y7/2 – 30cm/12 inches

10 shale, interbedded with siltstone and sandstone – 555cm/222 inches

11 shale, bioturbated, plant debris, interbedded sandstones, slightly calcareous, pale yellowish orange 10YR8/6, light gray N7, medium light gray N6 – 70cm/28 inches

12 shale, calcareous, yellowish gray 5Y7/2, light olive gray 5Y6/1 – 35cm/14 inches

Clay Creek Limestone Member

13 packstone, wavy beds, argillaceous, fusulinids, medium gray N5, medium dark gray N4 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y7/2, grayish yellow 5Y8/4 – 45cm/18 inches

14 wackestone/packstone, massive, hard, fusulinids, pelecypods, light olive gray 5Y6/1, medium light gray N6 fresh, weathers yellowish gray 5Y7/2, grayish yellow 5Y8/4, pale yellowish orange 10YR8/6, moderate brown 5YR3/4 – 45 cm/18 inches

Stull Shale Member

15 shale, calcareous, medium gray N5, medium light gray N6, yellowish gray 5Y7/2 – 12.5cm/5 inches

16 shale, calcareous, yellowish gray 5Y7/2, grayish yellow 5Y8/4 – 30cm/12 inches

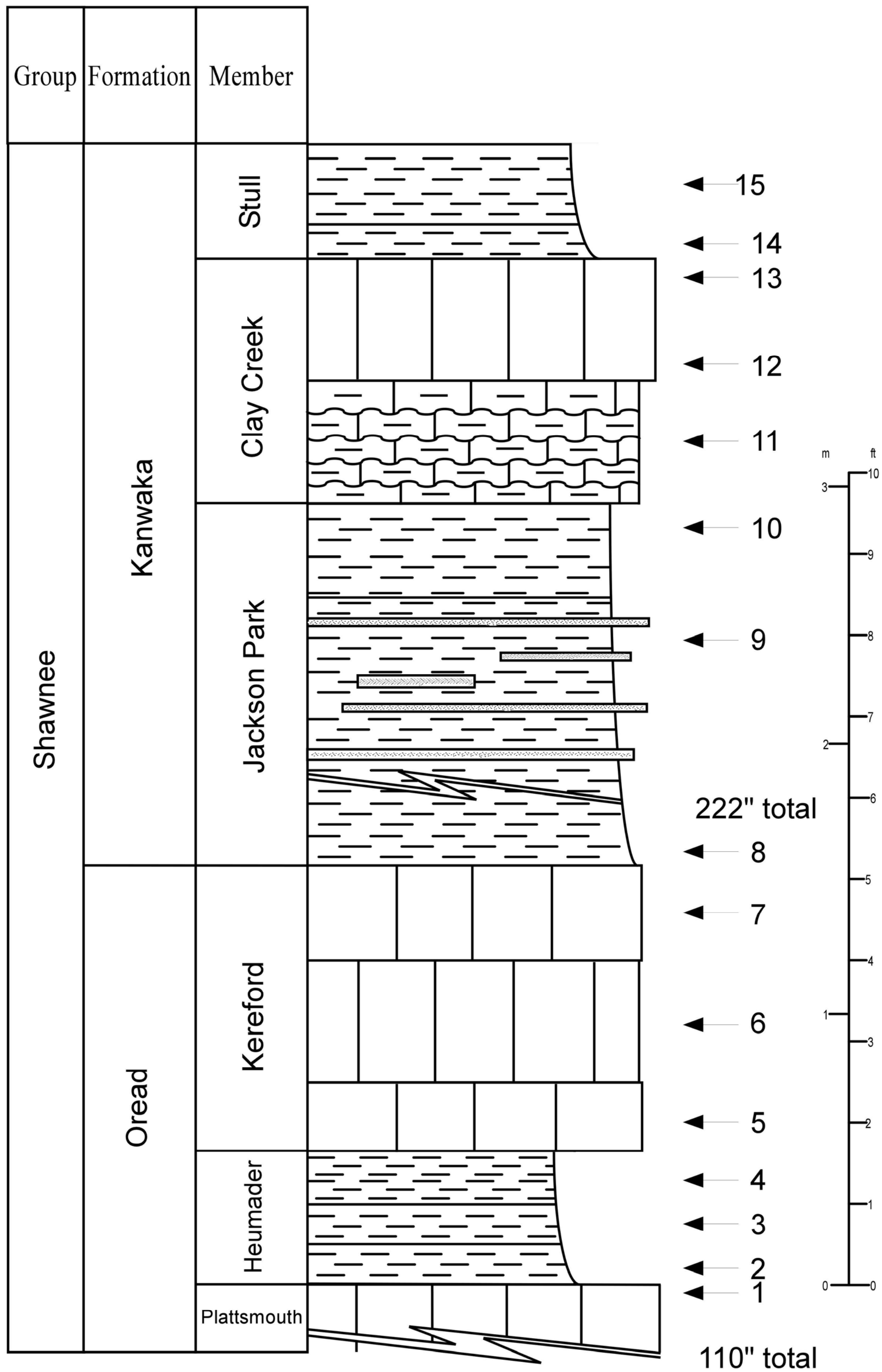


Figure 21. Stratigraphic section of locality 2.

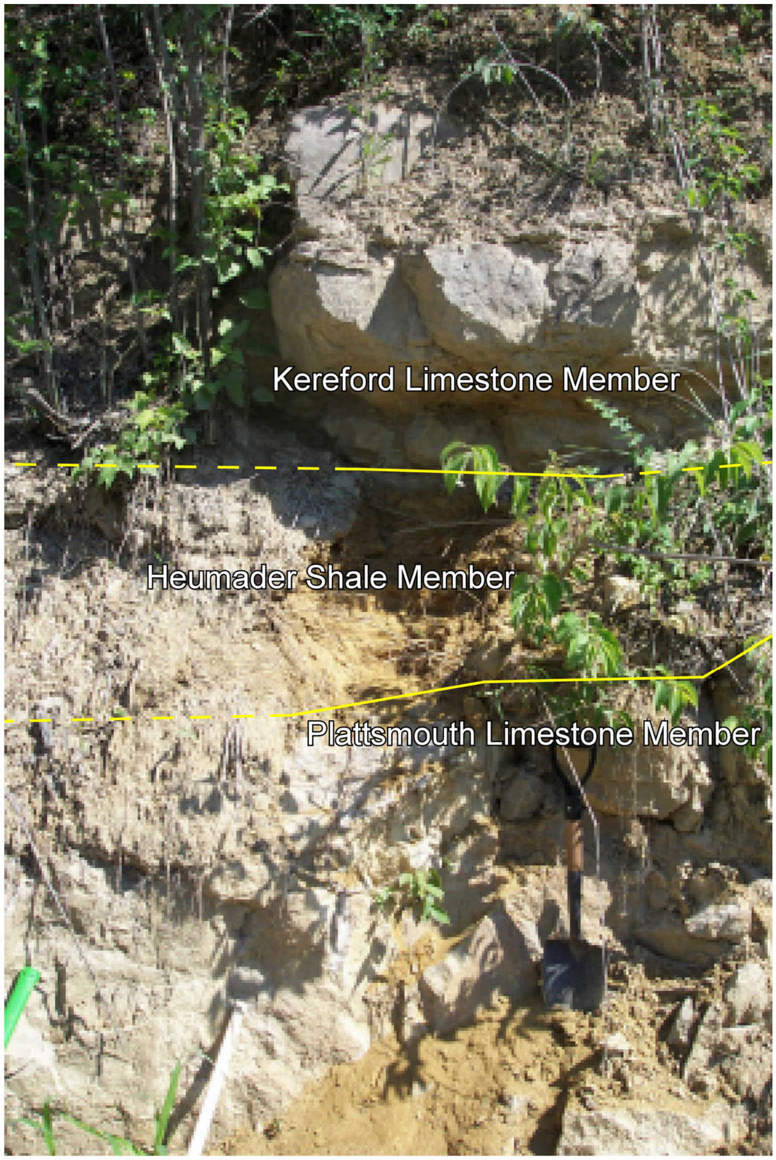


Figure 22. Basal section of locality 2.

Figure 23. Upper section of locality 2.

Figure 24. Clay Creek Limestone.

LOCATION 3: North backslope of highway T, 1.7 miles west of Nodaway, Missouri
SE/4 SE/4 sec. 23 T59N R37W
LONGITUDE: N39°54'36.5"
LATTITUDE: W95°00'01.6"

Kanwaka Shale Formation
Stull Shale Member

1 Poorly exposed shale with lenses and beds of very fine sandstone and silstone – 510cm/204 inches

2 Shale, silty, plant debris, yellowish gray 5Y7/2, moderate brown 5YR3/4 – 20cm/8 inches

3 Shale, fossiliferous, yellowish gray 5Y7/2, medium light gray N6, moderate brown 5YR4/4 near top – 85cm/34 inches

4 Shale, fossiliferous, moderate brown 5YR3/4, pale yellowish brown 10YR6/2, yellowish gray 5Y7/2, light gray N7 – 32.5cm/13 inches

5 Shale, abundant fossils, calcareous, yellowish gray 5Y2/2, grayish yellow 5Y8/4 – 25cm/10 inches

Lecompton Limestone Formation
Spring Branch Limestone Member

6 Wackestone, massive, hard, crystalline, fossiliferous, recrystallized calcite on surface, medium gray N5, medium light gray N6, yellowish gray 5Y7/2 fresh, weathers dark yellowish orange 10YR6/6, grayish yellow 5Y8/4, grayish brown 5YR3/2 – 45cm/18 inches

7 Shale parting, somewhat platy, calcareous, contains solitary rugose corals, grayish yellow 5Y8/4, yellowish gray 5Y7/2, medium dark gray N4, medium gray N5 – 5cm/2 inches

8 Wackestone, massive, argillaceous at base, fossiliferous – fusulinids, crinoids, pelecypods, hard, recrystallized calcite on surface, moderate yellowish brown 10YR5/4, pale yellowish orange 10YR8/6, yellowish gray 5Y7/2, medium light gray N6, weathered surface is the same color as the fresh surface – 100cm/40 inches

9 Very argillaceous nodular limestone, possibly caliche, calcareous, highly weathered, pale yellowish orange 10YR8/6, yellowish gray 5Y7/2, grayish yellow 5Y8/4 – 150cm/60 inches

Doniphan Shale Member

10 Mudstone, blocky, medium gray N5, dark gray N3 fresh, weathers light olive gray 5Y6/1, dark yellow orange 10YR6/6 – 30cm/12 inches

11 Mudstone, blocky to thinly bedded, silty laminations, calcareous, pale yellow orange 10YR8/6, – 40cm/16 inches

Big Springs Limestone Member

12 Mudstone/wackestone, slightly laminated, soft, fossiliferous – 55cm/22 inches

13 Shale, faintly laminated, calcareous, pale yellowish orange 10YR8/6, pale yellow brown 10YR6/2 – 7.5cm/3 inches

14 Mudstone/wackestone, argillaceous, chalky, mudcracks, burrows, fossiliferous, soft, yellowish gray 5Y7/2 fresh, pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6, grayish orange 10YR7/4 – 150cm/60 inches

15 shale, silty, calcareous, dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6, yellowish gray 5Y7/2 – 7.5cm/3 inches

16 fusulinid packstone, pelecypods, iron stained fossiliferous streak near top, hard, very light gray N8-light gray N7, yellowish gray 5Y8/1 fresh, weathers pale yellowish orange 10YR8/6, very pale orange 10YR8/6 – 22.5cm/9 inches

Queen Hill Shale Member

17 shale, thinly bedded, fossiliferous-crinoids, brachiopods, fusulinids, calcareous, light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 10cm/4 inches

18 black fissle shale, less fissile near top, phosphatic, very thinly bedded, grayish black N2, dark gray N3 fresh, weathers olive gray 5Y4/1, light olive gray 5Y6/1, dark yellowish orange 10YR6/6, brownish gray 5YR4/1 – 55cm/ 22 inches

19 shale, thinly bedded, blocky, slightly calcareous, medium gray N5, medium light gray N5, light olive gray 5Y6/1, dark yellowish orange 10YR6/6, yellowish gray 5Y7/2, grayish yellow 5Y8/4, olive gray 5Y4/1 – 50cm/20 inches

Beil Limestone Member

20 wackestone, thin bed, hard, crystalline in places, large crinoids, brachiopods-mostly composita, fusulinids are not abundant, medium light gray N6, yellowish gray 5Y7/2 fresh, weathers grayish yellow 5Y8/4, dark yellowish orange 10YR6/6, yellowish gray 5Y7/2 – 10cm/4 inches

21 shale, calcareous, yellowish gray 5Y7/2, pale yellowish orange 10YR8/6 – 5cm/2 inches

22 wackestone/packstone, massive, top 45cm/18 inches contains fusulinids and abundant syringopora, pelecypods, crystalline, hard, medium light gray N6, yellowish gray 5Y7/2, light gray N7, light olive gray 5Y6/1 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y8/1, dark yellowish orange 10YR6/6 – 75cm/30 inches

23 wackestone/packstone, wavy discontinuous beds, pelecypods, abundant fusulinids, light gray N7, yellowish gray 5Y7/2 fresh, weathers grayish yellow 5Y8/4, pale yellowish orange 10YR8/6 – 25cm/10 inches

24 argillaceous mudstone/wackestone, massive, hard, brachiopods, fusulinids, pelecypods, yellowish gray 5Y7/2, light gray N7 fresh, weathers pale yellowish orange 10YR8/6, grayish yellow 5Y8/4, moderate brown 5YR4/4 – 30cm/12 inches

25 shale, calcareous, grayish yellow 5Y8/4, yellowish gray 5Y7/2 – 5 cm/2 inches

26 wackestone, hard, massive, fossiliferous, light gray N7, yellowish gray 5Y8/1 fresh, weathers yellowish gray 5Y7/2, grayish yellow 5Y8/4 – 25cm/10 inches

King Hill Shale Member

27 shale, blocky, calcareous, yellowish gray 5Y7/2, yellowish gray 5Y8/1 – 15cm/6 inches

28 shale, blocky, calcareous, pale yellowish orange 10YR8/6, light gray N7, light greenish gray 5GY8/1 – 7.5cm/3 inches

29 shale, blocky, calcareous, medium light gray N6, light olive gray 5Y6/1, grayish yellow 5Y8/4 – 30cm/12 inches

30 shale, blocky, calcareous, yellowish gray 5Y7/2, medium light gray N6, light gray N7 – 35cm/14 inches

31 shale, thinly bedded, nodular in middle, calcareous, grayish yellow 5Y8/4 – 30cm/12 inches

32 fusulinid wackestone, hard, blocky, medium light gray N6, light olive gray 5Y6/1 fresh, weathers dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6, pale brown 5YR5/2 – 20cm/8 inches

33 shale, calcareous, dark yellowish orange 10YR6/6, pale olive 10Y6/2, greenish gray 5GY6/1 – 5cm/2 inches

34 shale, calcareous, pale yellowish orange 10YR8/6, grayish yellow 5Y8/4 – 25cm/10 inches

35 shale, fossiliferous, calcareous, dark yellowish orange 10YR6/6, grayish brown 5YR3/2 – 5cm/2 inches

Avoca Limestone Member

36 wackestone/packstone, argilliceous, contains small shale partings, fusulinids, olive gray 5Y6/1, medium light gray N6, moderate brown 5YR3/4, medium gray N5 fresh, weathers grayish yellow 5Y8/4, yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 – 60cm/24 inches

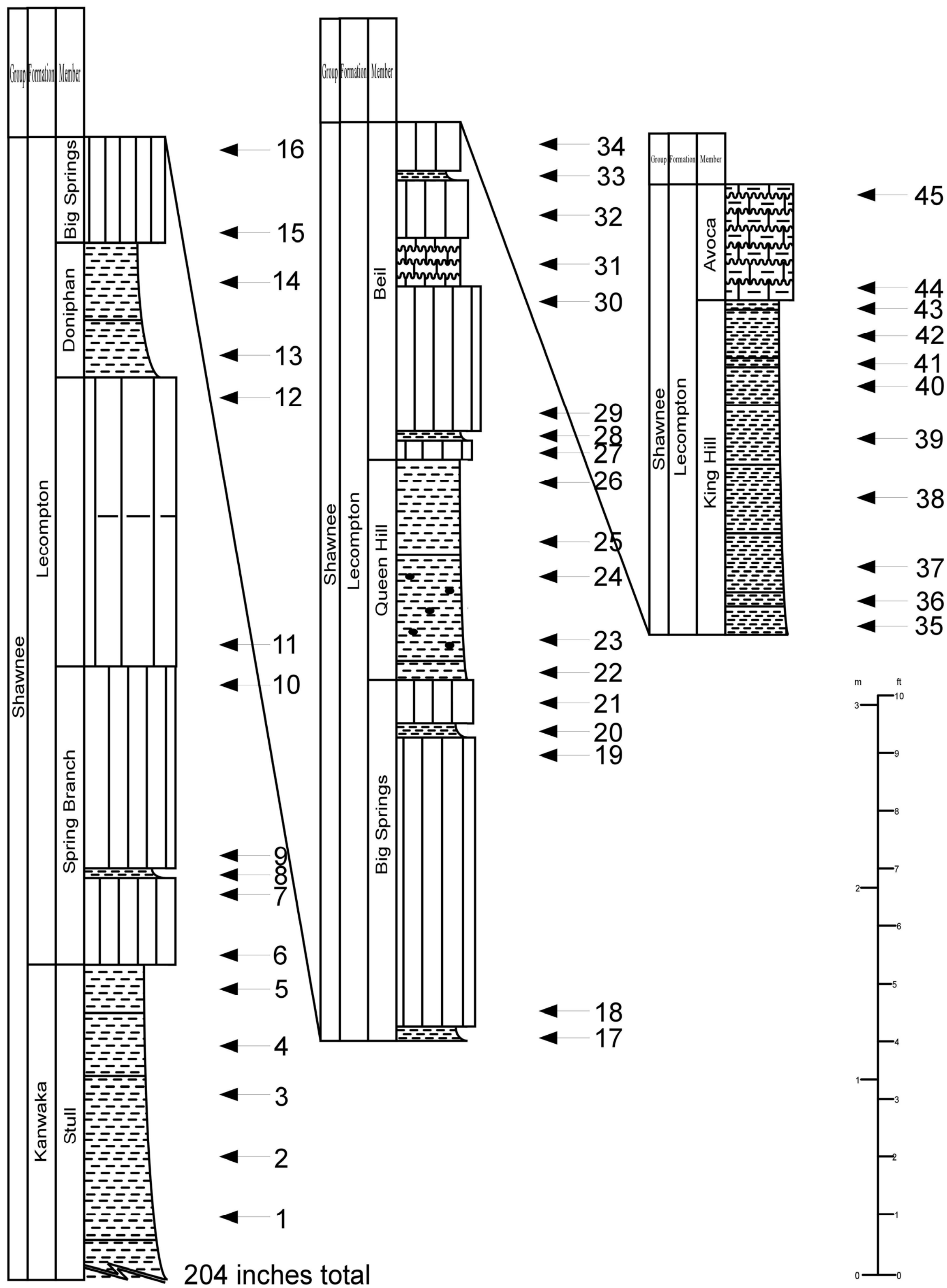


Figure 25. Stratigraphic section of locality 3.

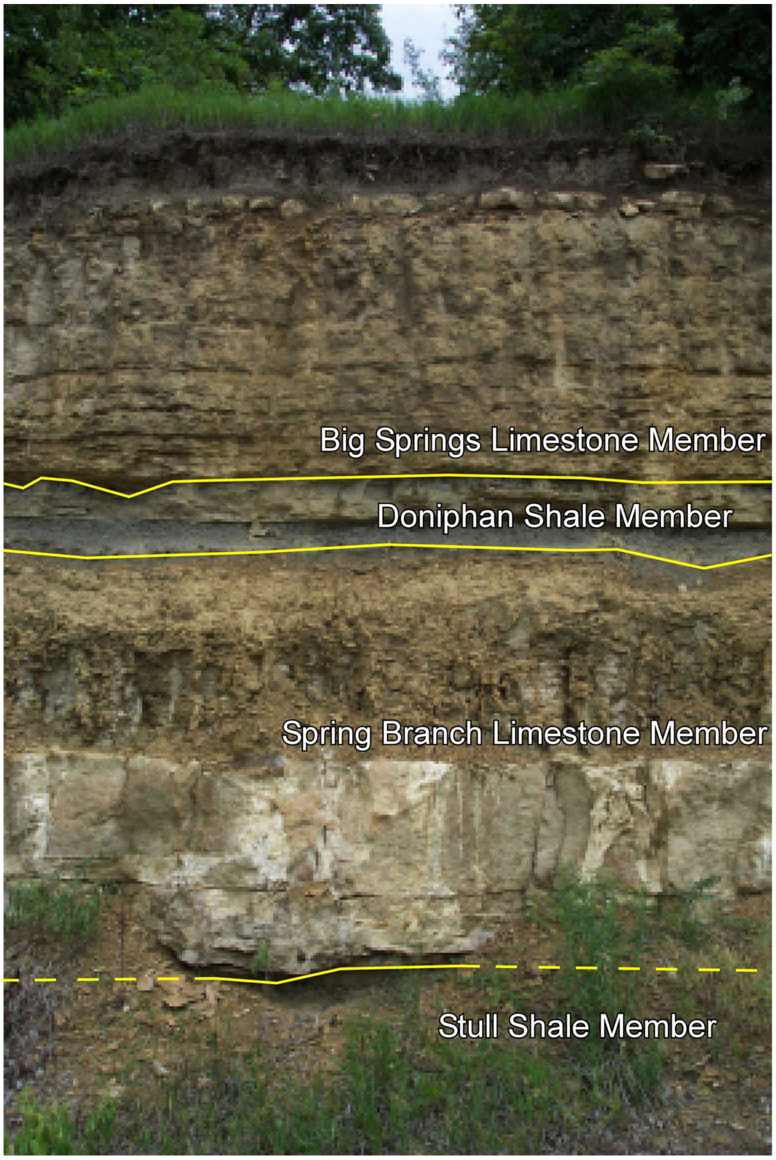


Figure 26. Stull Shale, Spring Branch Limestone, Doniphan Shale, and Big Springs Limestone.

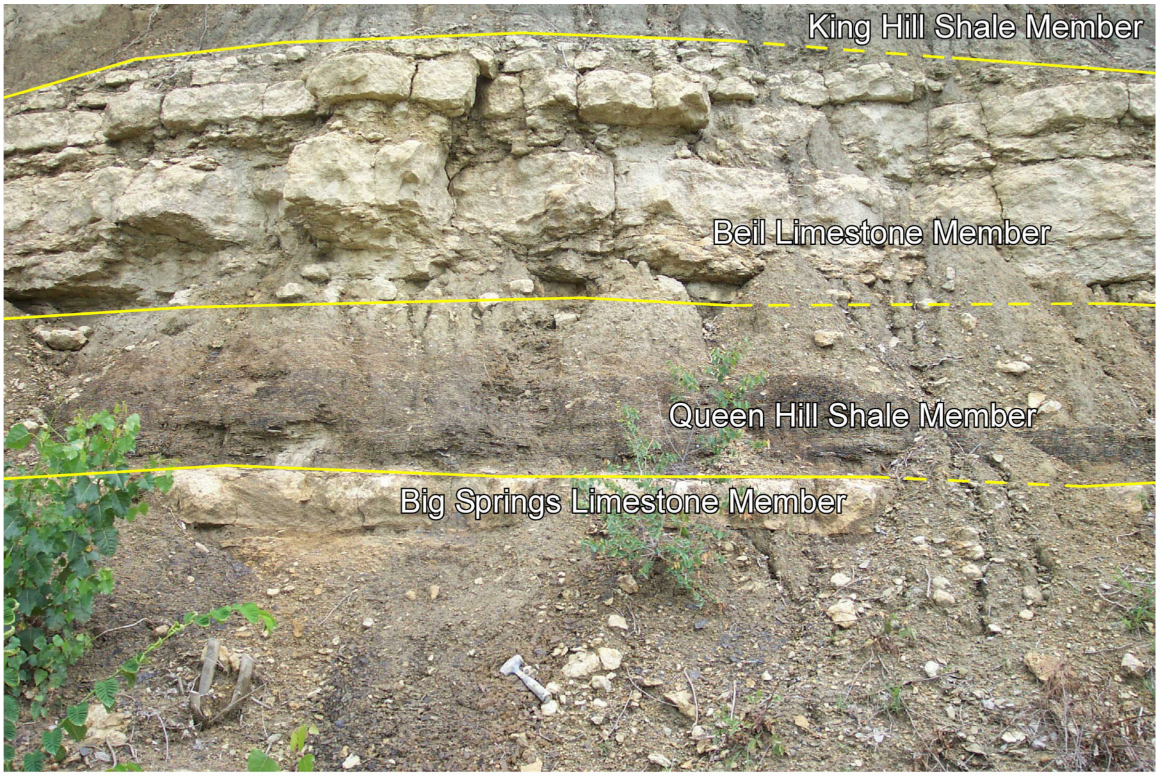


Figure 27. Big Springs Limestone, Queen Hill Shale, Beil Limestone, and King Hill Shale.

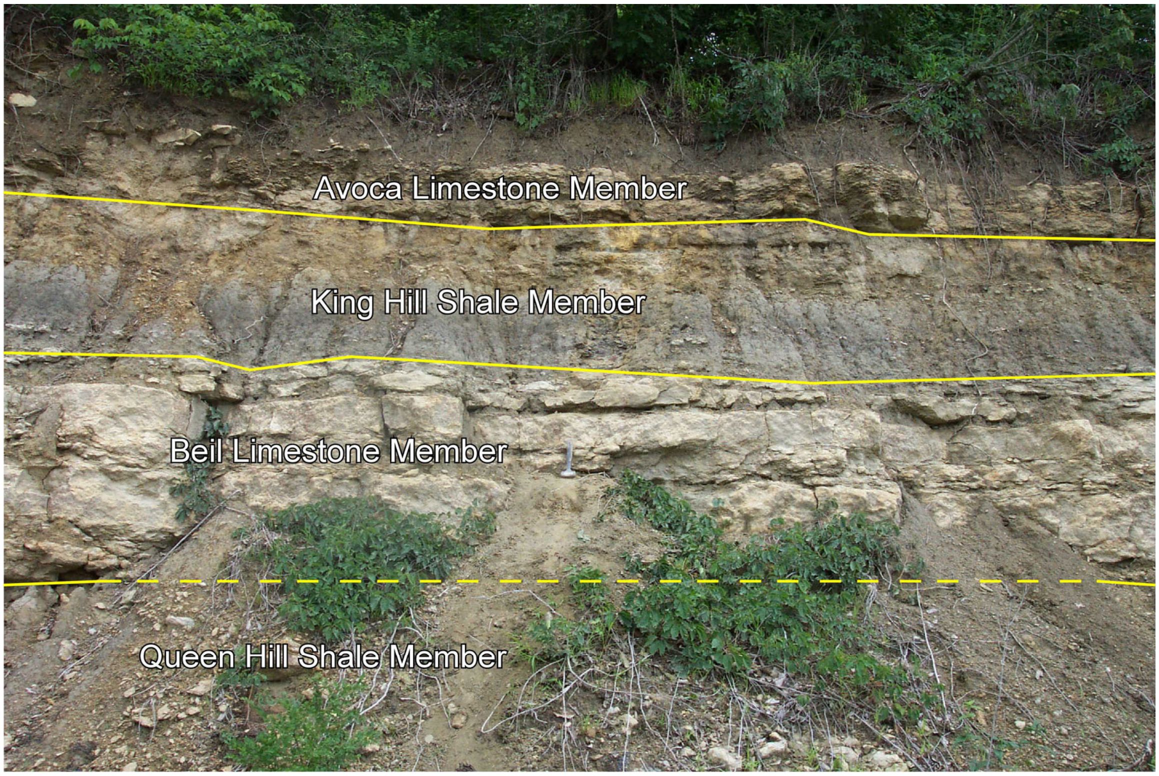


Figure 28. Queen Hill Shale, Beil Limestone, King Hill Shale, and Avoca Limestone.

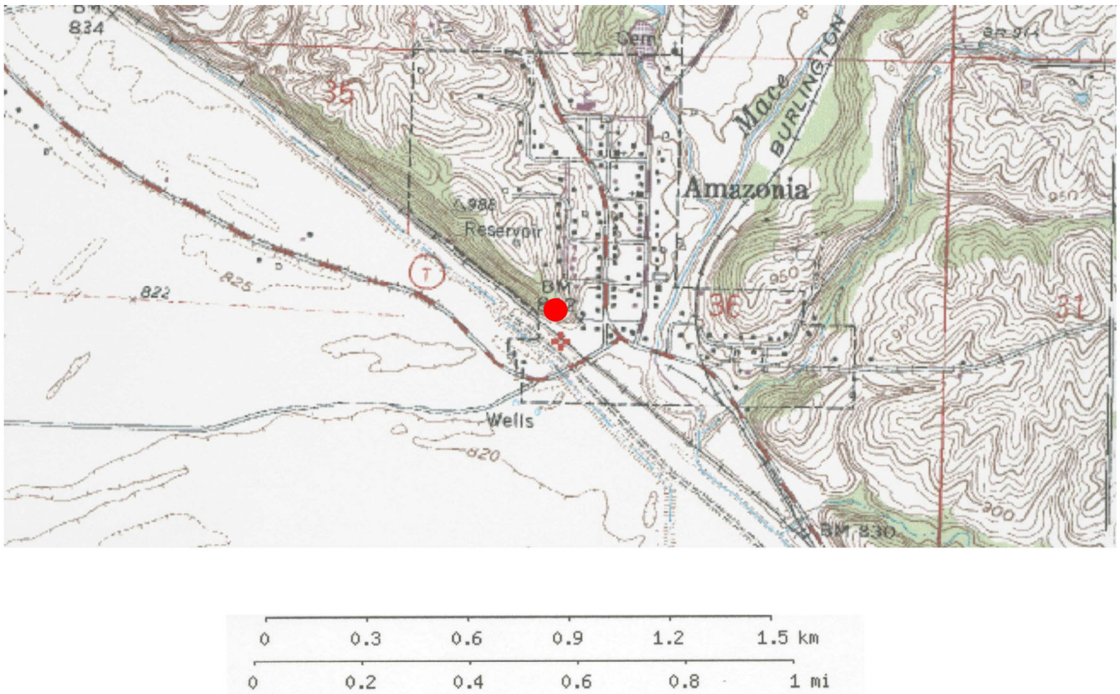


Figure 29. Location map of locality 4.

LOCATION 4: Railroad cut on southwest corner of Amazonia, Missouri, on highway T
SW/4 SE/4 NW/4 sec. 36 T59N R36W
LONGITUDE: N39°53'10.3"
LATTITUDE: W94°53'40.2"

Douglas Group
Lawrence Shale Formation

1 Slightly brecciated, calcareous, light olive gray 5Y6/1, yellowish gray 5Y8/1, dark yellowish orange 10YR6/6 – 20cm/8 inches

2 Shale, calcareous, greenish gray 5GY6/1 – 30cm/12 inches

3 Shale, calcareous, greenish gray 5GY6/1 – 12.5cm/5 inches

4 Shale, dark yellowish orange 10YR6/6, dark yellowish brown 10YR4/2, moderate brown 5YR3/4 – 7.5cm/3 inches

5 Shale, calcareous, dark yellowish orange 10YR6/6, light olive gray 5Y6/1 – 185cm/74 inches

Shawnee Group
Oread Limestone Formation
Toronto Limestone Member

6 Fusulinid wackestone/packstone, hard, massive beds, crinoids, brachiopods, bryozoans, medium gray N5, light olive gray 5Y6/1 fresh, weathers pale yellowish orange 10YR8/6 – 89.5cm/35.5 inches

7 Shale parting, pale yellowish orange 10YR8/6, yellowish gray 5Y7/2 – 1.25cm/.5 inches

8 Wackestone/packestone, thickly bedded, few fusulinids, crinoids, brachiopods, and bryozoans, filled burrows, hard, yellowish gray 5Y7/2, grayish yellow 5Y8/4, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, pale yellowish brown 10YR6/2 – 60cm/24 inches

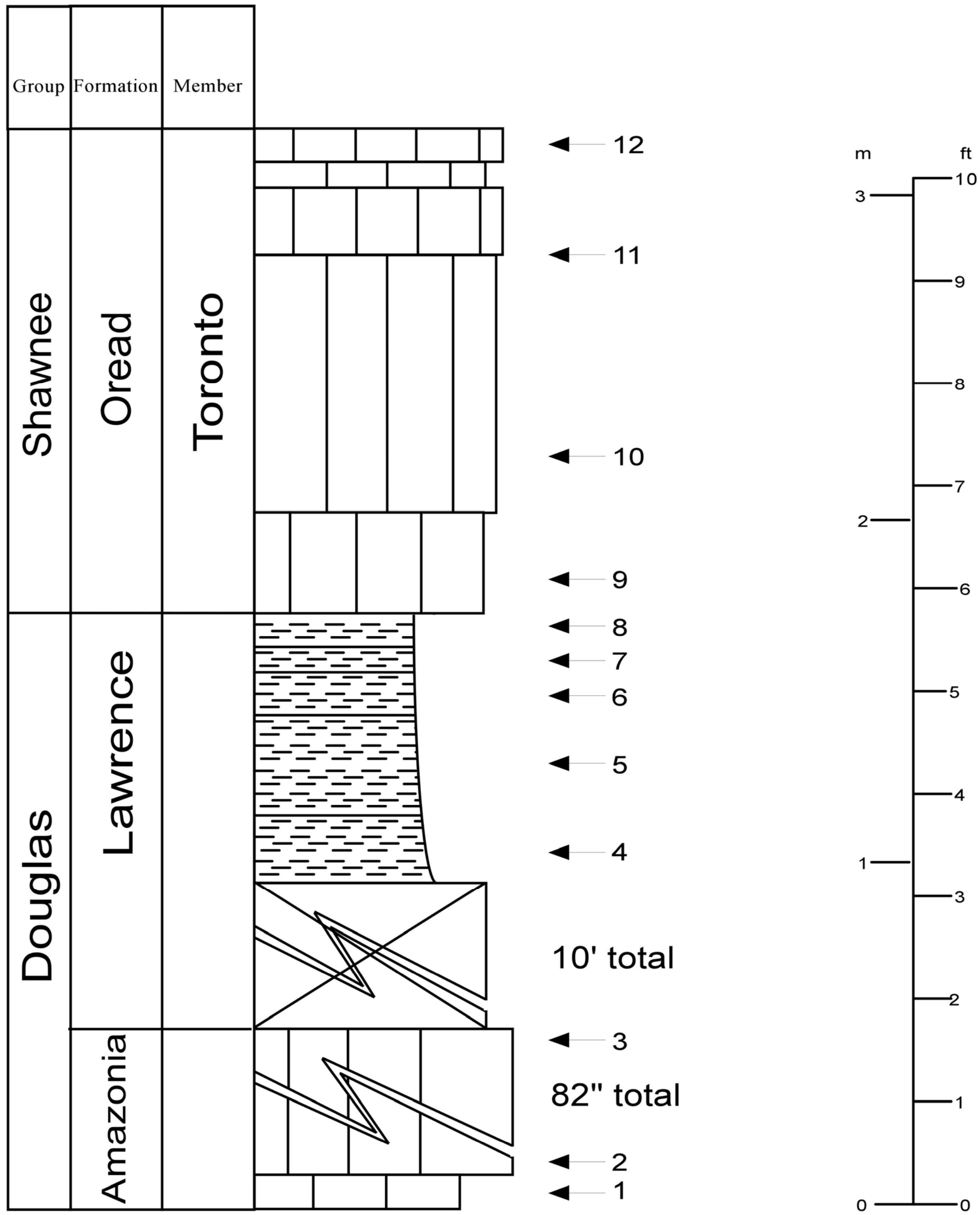


Figure 31. Stratigraphic Section of locality 4.

Figure 31. Lawrence Shale and Toronto Limestone.

Figure 32. Photograph of Amazonia limestone at locality 4.

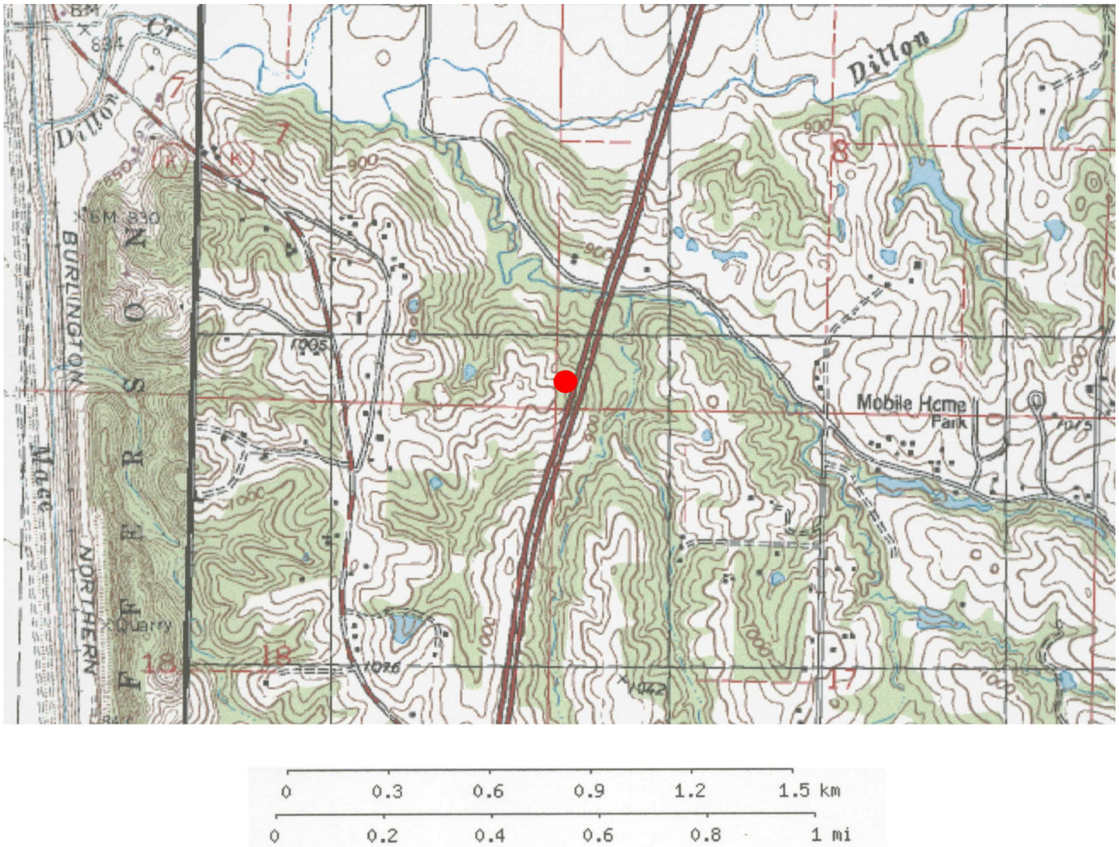


Figure 33. Location map of locality 5.

LOCATION 5: North backslope of I-229, 2.6 miles west of exit 56B of I-29 and approximately 1 mile east of highway K

LONGITUDE: N39°51'03.1"
LATTITUDE: W94°51'44.6"

Oread Limestone Formation

Toronto Limestone Member

1 Packstone, 6 thick-massive beds, weathers flaggy, hard, crystalline, fossiliferous – crinoids, pelecypods, medium light gray N6, yellowish gray 5Y7/2 fresh, weathers dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6, moderate brown 5YR4/4, moderate brown 5YR3/4 – 91cm/36 inches

2 shale, calcareous, medium gray N5 fresh, weathers yellowish gray 5Y7/2, dark yellowish orange 10YR6/– 12.5cm/5 inches

3 mudstone, massive, chalky, weathers blocky, bioturbated, calcite filled burrows and vugs, very pale orange 10YR8/2, grayish yellow green 5GY7/2 fresh, weathers pale yellowish orange 10YR8/6, dark greenish gray 5GY4/1 – 60cm/24 inches

Snyderville Shale Member

4 shale, possible paleosol, weathers pale green 10G6/2, grayish green 5G5/2 fresh, conglomeratic, calcareous – 15cm/6 inches

5 shale, calcareous, dark gray N3-grayish black N2 – 30cm/12 inches

6 shale, calcareous, medium dark gray N4 – 30cm/12 inches

7 shale, calcareous, medium gray N5-medium light gray N6 – 90cm/36 inches

8 shale, calcareous, medium light gray N6 – 30cm/12 inches

9 shale, abundant fossils – myalina, calcareous, olive gray 5Y4/1, brownish gray 5YR4/1 – 7.5cm/3 inches

10 covered – approximately 30cm/12 inches

Leavenworth Limestone member

11 wackestone, massive, hard, fossiliferous, medium light gray N6 fresh, weathers dark yellowish orange 10YR6/6, yellowish gray 5Y7/2, very pale orange 10YR8/2 – 30cm/12 inches

12 wackestone, massive, hard, crystalline, fusulinids, medium light gray N6, medium dark gray N4 fresh, weathers yellowish gray 5Y7/2, dark yellowish orange 10YR6/6, very pale orange 10YR8/2 – 25cm/ 10 inches

Heebner Shale Member

13 shale, fissile, platy, black N1 – 90cm/36 inches

14 shale, slightly bedded, calcareous, light olive gray 5Y6/1, medium dark gray N4 – 27.5cm/11 inches

15 shale, limey, calcareous, vertical burrows, greenish gray 5GY6/1, weathers light greenish gray 5GY8/1, dusky yellow 5Y6/4 near top – 12.5cm/5 inches

Plattsmouth Limestone Member

16 wackestone, wavy beds, thick-massive, hard, crinoids, light olive gray 5Y6/1, light gray N7 fresh, weathers pale yellowish orange 10YR8/6 – 46.25cm/18.5 inches

17 shale parting, fossiliferous with very thin limestone streamers, calcareous, yellowish gray 5Y7/2 fresh, weathers pale yellowish orange 10YR8/6 – 5cm/2 inches

18 wackestone, wavy beds, hard, pelecypods, 1.25cm (.5 inch) weathering rine, light olive gray 5Y6/1, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, white N9, grayish yellow 5Y8/4 – 45cm/18 inches

19 shale parting, calcareous, thinly bedded, yellowish gray 5Y7/2 fresh, pale yellowish orange 10YR8/6 – 5cm/2 inches

20 wackestone, wavy beds, thick-massive, slightly crystalline, hard, pelecypods, brachiopods, light olive gray 5Y6/1, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, grayish yellow 5Y8/4 – 98.75cm/39.5 inches

21 shale parting – 10cm/4 inches

22 wackestone, wavy beds, massive, hard, pelecypods, light olive gray 5Y6/1, medium light gray N6 fresh, weathers pale yellowish orange 10YR8/6, grayish yellow 5Y8/4 – 25cm/10 inches

23 shale parting – 12.5cm/5 inches

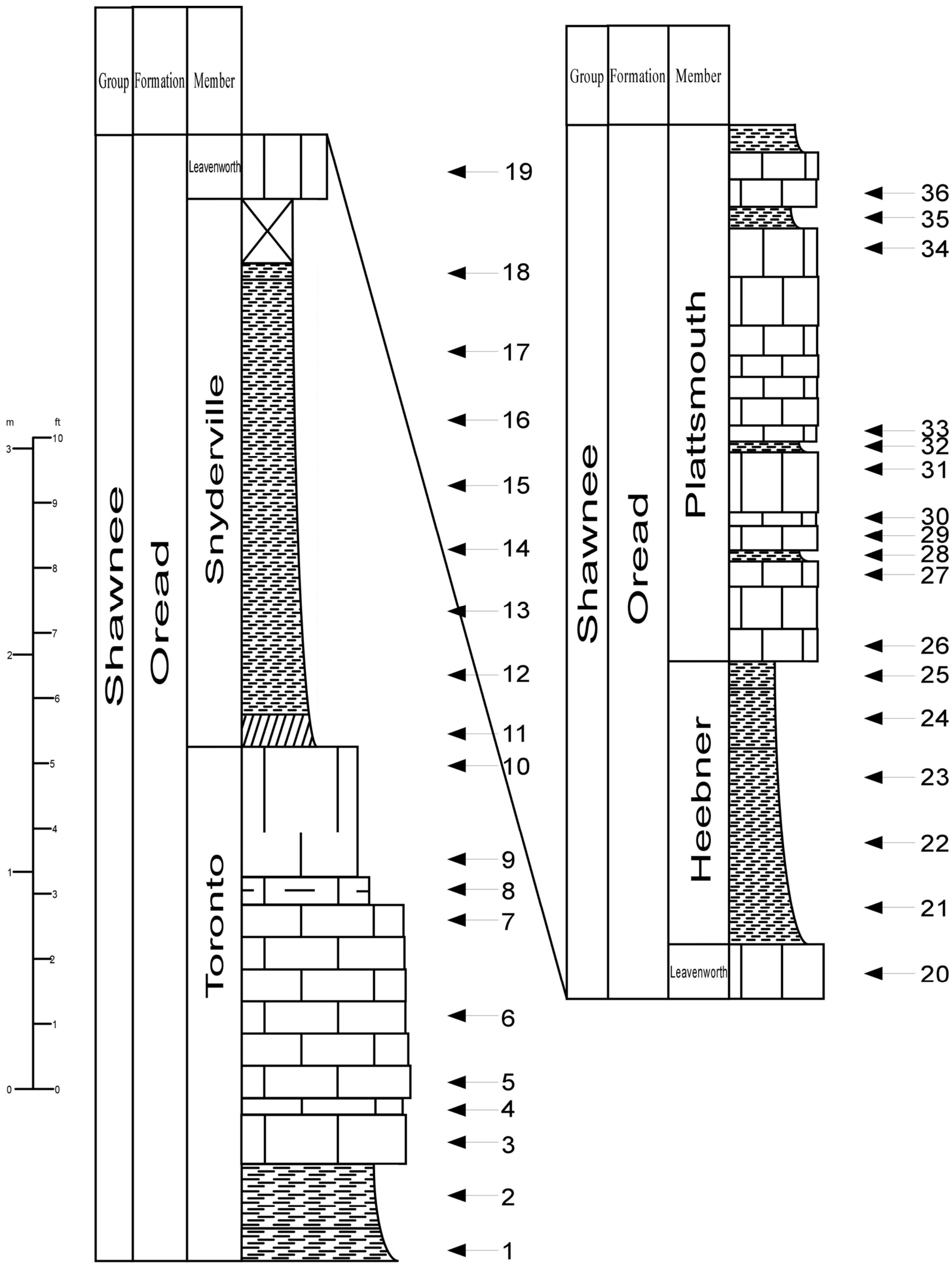


Figure 34. Stratigraphic section of locality 5.

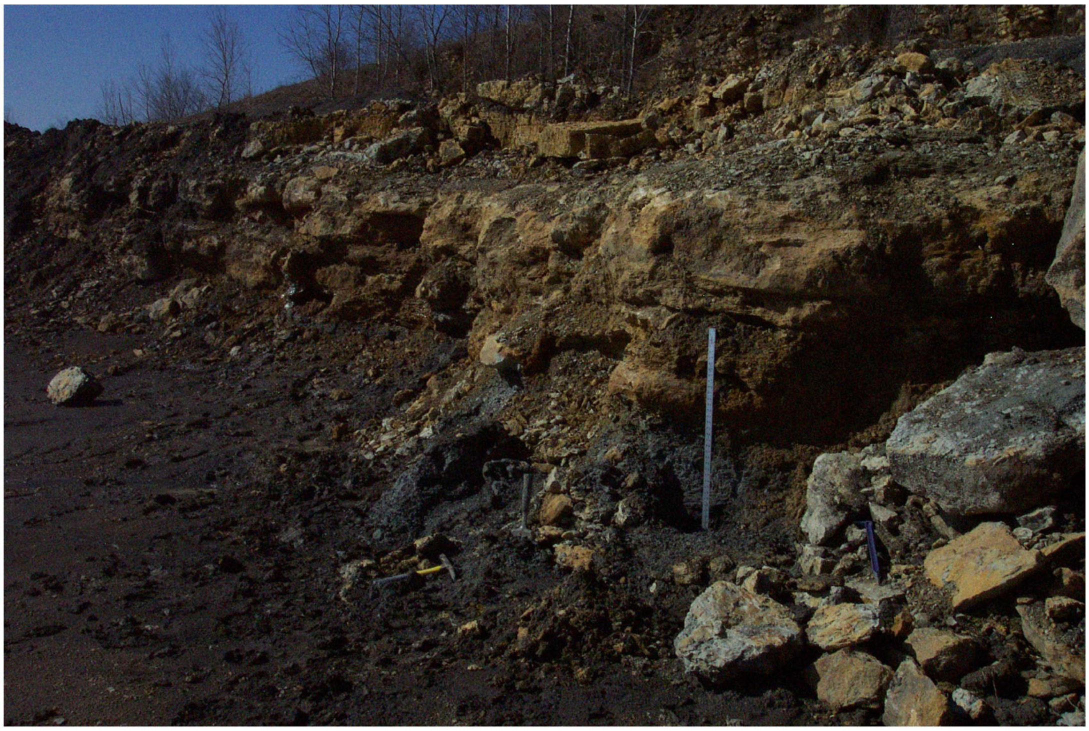


Figure 35. Toronto Limestone.

Figure 36. Snyderville Shale.

Figure 37. Leavenworth Limestone and Heebner Shale.

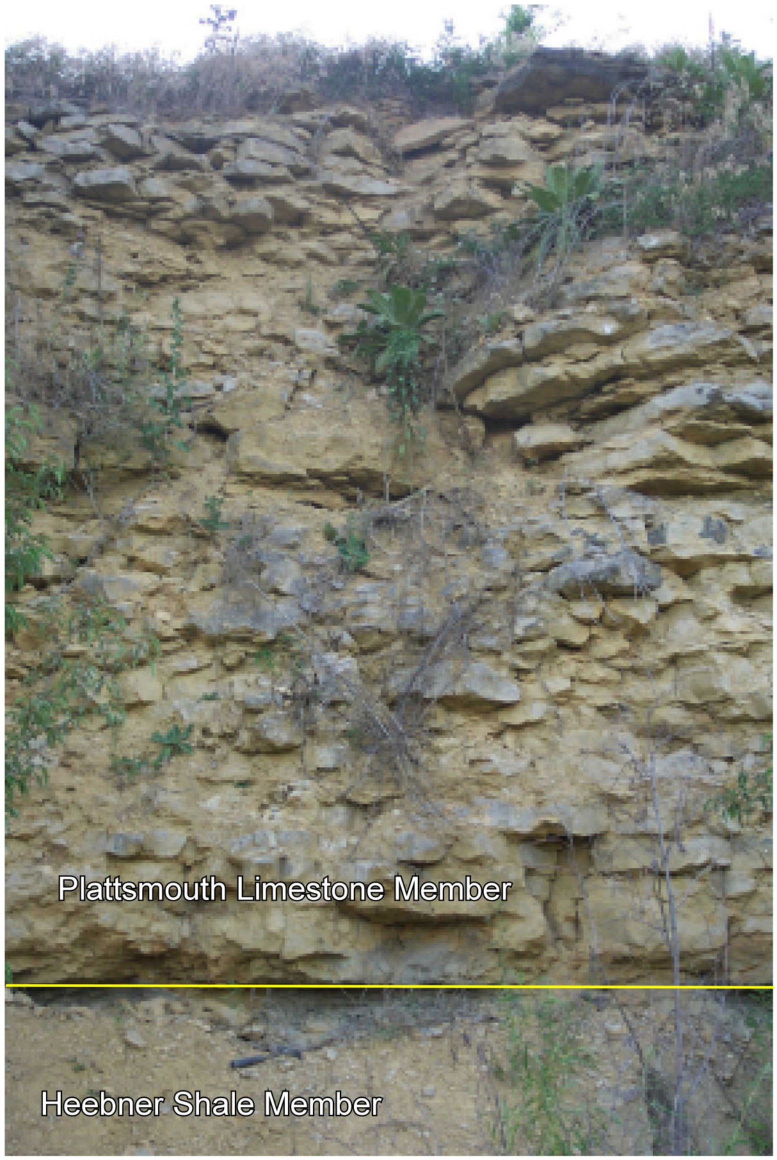


Figure 38. Plattsmouth Limestone.

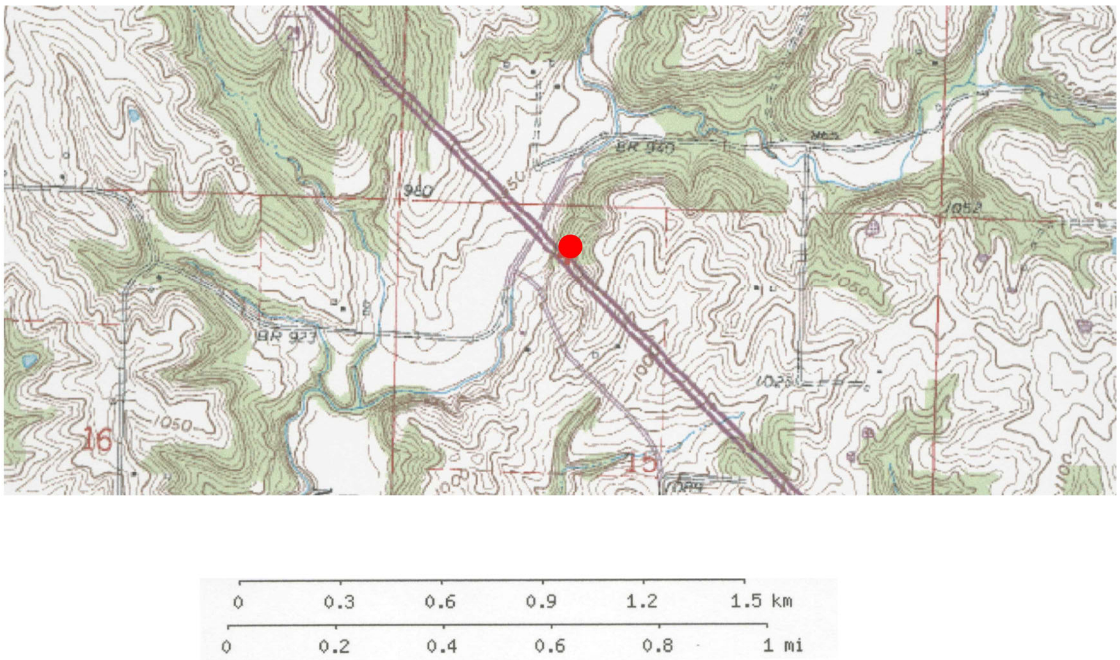


Figure 39. Location map of locality 6.

LOCATION 6: East backslope of I-29 north, just south of Mill Creek and CR422 near mile marker 62, Andrew County, Missouri
E/2 NW/4 NE/4 NW/4 sec. 15 T59N R36W
LONGITUDE: N39°56'11.2"
LATTITUDE: W94°55'51.7"

Lecompton Limestone Formation

Beil Limestone Member

1 Argillaceous – 60cm/24 inches

2 Wackestone, fusulinids, coated grains, yellowish gray 5Y7/2, very light gray N8 fresh, weathers pale yellowish orange 10YR8/6, grayish yellow 5Y8/4 – 15cm/6 inches

3 calcareous shale, calcareous nodules, very light gray N8 fresh, weathers grayish yellow 5Y8/4,` dark yellowish orange 10YR6/6 – 22.5cm/9 inches

4 wackestone/packstone, coated grains, fossiliferous-contains pelecypods, fusulinids, brachiopods, recrystallized vugs, hard, yellowish gray 5Y7/2, yellowish gray 5Y8/1 fresh, weathers dark yellowish orange 10YR6/6, grayish yellow 5Y8/4 – 25cm/10 inches

5 mudstone/wackestone with small shale partings, yellowish gray 5Y7/2 fresh, weathers light olive gray 5Y5/2, dusky yellow 5Y6/4 – 75cm/30 inches

King Hill Shale Member

6 shale, blocky, slightly calcareous, greenish gray 5G6/1 – 30cm/12 inches

7 shale, blocky, calcareous, light olive gray 5Y6/1, greenish gray 5G6/1 – 30cm/12 inches

8 mudstone, cracks/tubes, spar-filled insitu brecciation, pinkish gray 5YR8/1, yellowish gray 5Y8/1 fresh, weathers yellowish gray 5Y7/2 – 20cm/8 inches

9 shale, calcareous, greenish gray 5G6/1, medium light gray N6 – 30cm/12 inches

10 shale, brecciated, calcareous, medium gray N5, light olive gray 5Y6/1 – 30 cm/12 inches

Avoca Limestone Member

11 fossiliferous packstone, thin, argillaceous, wavy discontinuous beds, crinoids, chonetes, fusulinids, medium dark gray N4, olive gray 5Y4/1 fresh, weathers yellowish gray 5Y8/1, light gray N7 – 55cm/22 inches

Kenosha Shale Member

12 fossiliferous, calcareous shale, light olive gray 5Y6/1, yellowish gray 5Y7/2 – 15cm/6 inches

13 platy clay shale, dark gray N3 – 40cm/28 inches

Ost Limestone Member

14 wackestone, very hard, slumped, fusulinids, thick bed, light olive gray 5Y6/1, yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 fresh, weathers brownish gray 5YR4/1, dark greenish gray 5GY4/1, medium light gray N6 – 20cm/8 inches

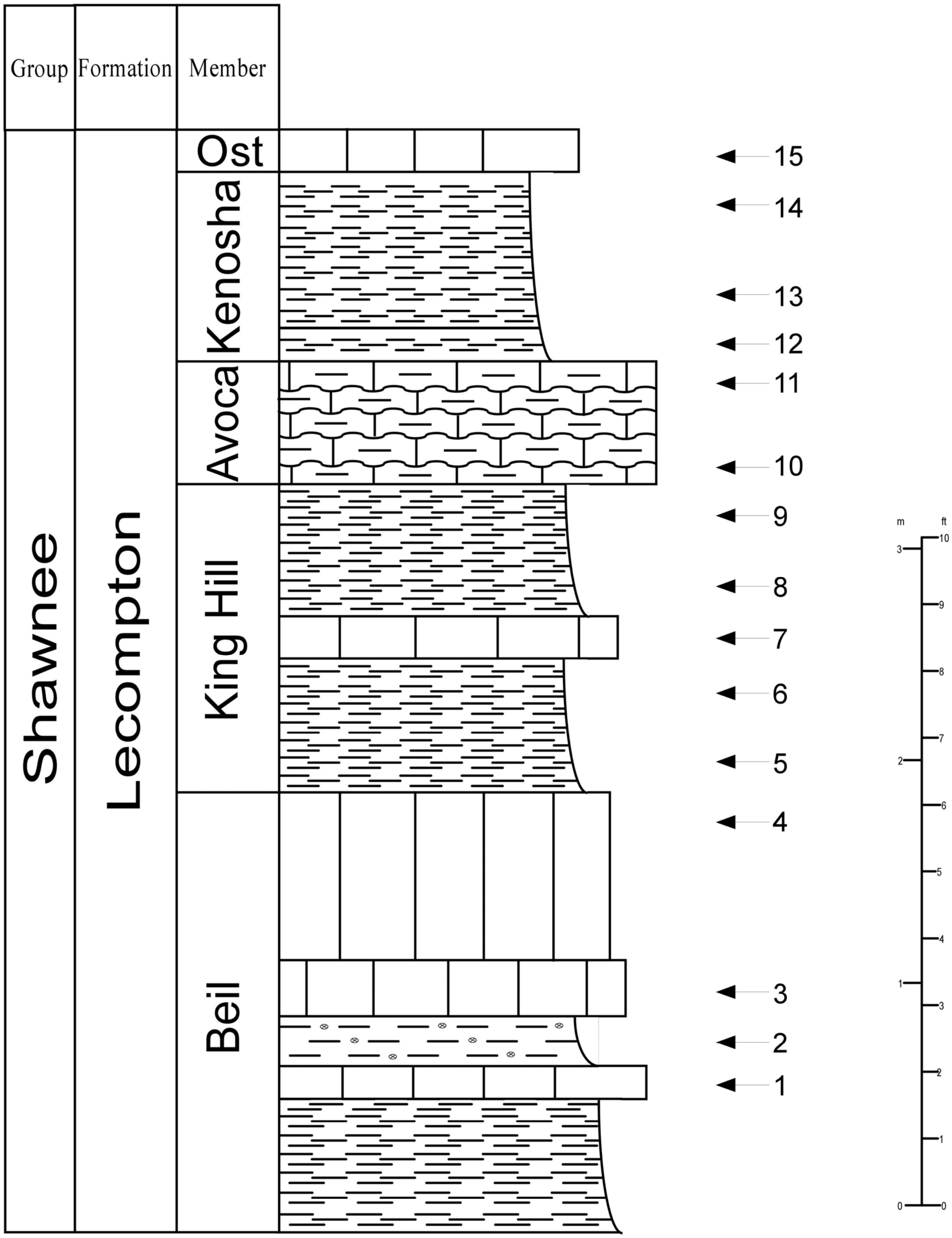


Figure 40. Stratigraphic section of locality 6.

Figure 41. Beil Limestone.

Figure 42. King Hill Shale and Avoca Limestone.

Figure 43. Kenosha Shale.

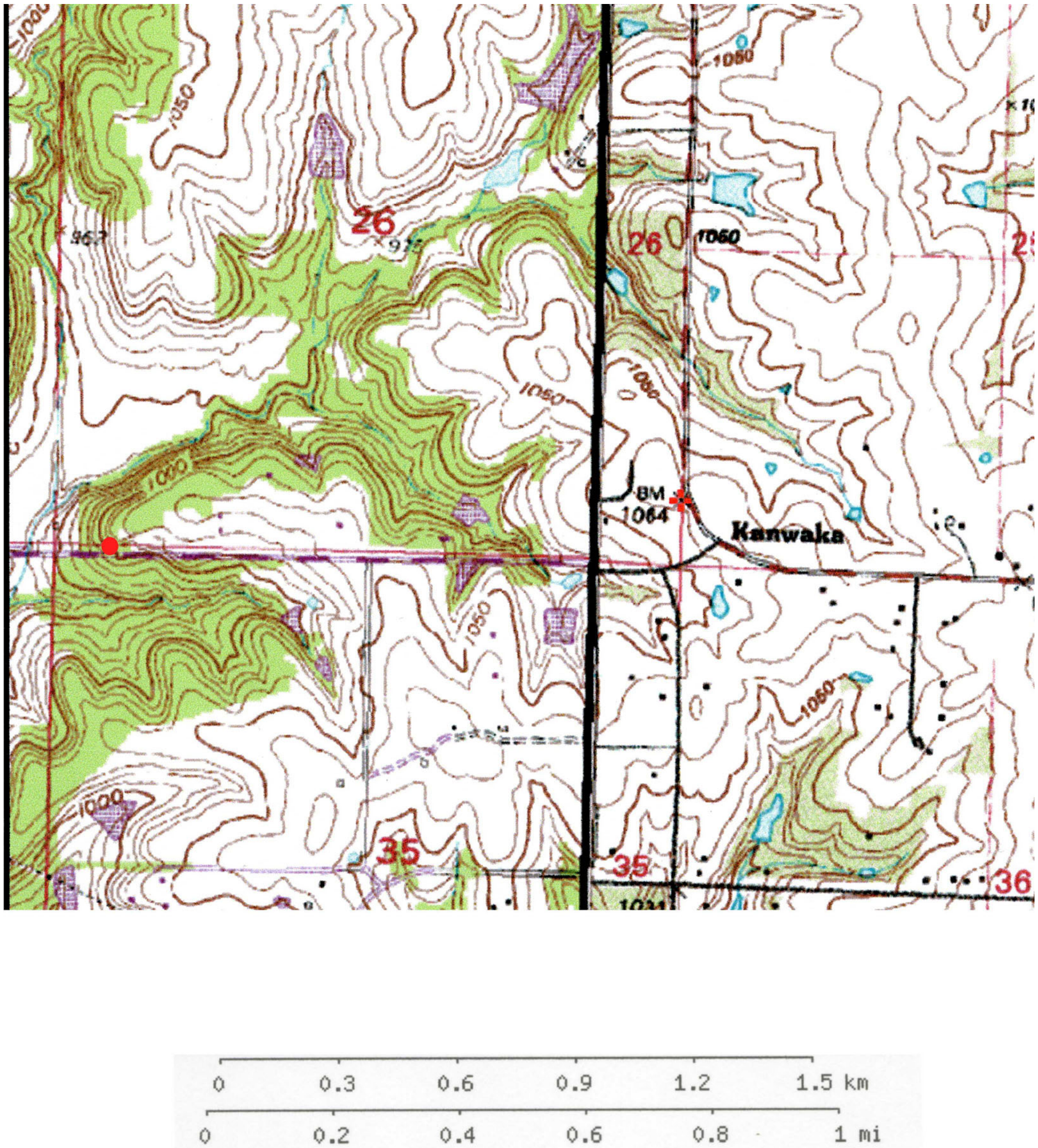


Figure 44. Location map of locality 7.

Location 7: approximately .6 miles west of Kanwaka Corners, Kansas on county road.

Lattitude: N38°58'16.8"
Longitude: W95°23'23.4"

Kanwaka Shale Formation

Jackson Park Shale Member

1 Shale, thinly bedded to laminated, land plant fragments, medium dark gray N4, dark gray N3, dark yellowish orange 10YR6/6, light brown 5YR5/6, grayish brown 5YR3/2 – 37.5cm/15 inches

Clay Creek Limestone Member

2 Mudstone, shaley, soft, argillaceous, dark gray N3, medium dark gray N4 fresh, weathers dark yellowish orange 10YR6/6, light brown 5YR5/6, grayish brown 5YR3/2, and yellowish gray 5Y7/2 – 15cm/6 inches

3 Shale, thinly bedded, calcareous, grayish yellow 5Y8/4, yellowish gray 5Y7/2, pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6, medium light gray N6 – 8.75cm/3.5 inches

4 Mudstone, argillaceous, few fusulinids, medium gray N5 fresh, weathers yellowish gray 5Y7/2, pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6 – 20cm/8 inches

5 Mudstone to wackestone, fusulinids, brachiopods, hard, medium gray N5, light olive gray 5Y6/1 fresh, weathers pale yellowish orange 10YR8/6, yellowish gray 5Y7/2 – 30cm/12 inches

6 Mudstone, fusulinids, argillaceous, medium gray N5, light olive gray 5Y6/1 fresh, weathers dark yellowish orange 10YR6/6, yellowish gray 5Y7/2, moderate yellowish brown 10YR5/4 – 20cm/8 inches

7 Shale, thinly bedded, contains lenses of packstone, dark gray N3, grayish black N2 fresh, weathers medium light gray N6, light olive gray 5Y6/1, and dark yellowish orange 10YR6/6 – 25cm/10 inches

8 Wackestone to packstone, thin bed, fossiliferous, contains a weathering rine: brownish gray 5YR4/1, grayish red 5R4/2, dark yellowish orange 10YR6/6, and medium gray N4. Fresh surfaces are light olive gray 5Y6/1 – 12.5cm/5 inches

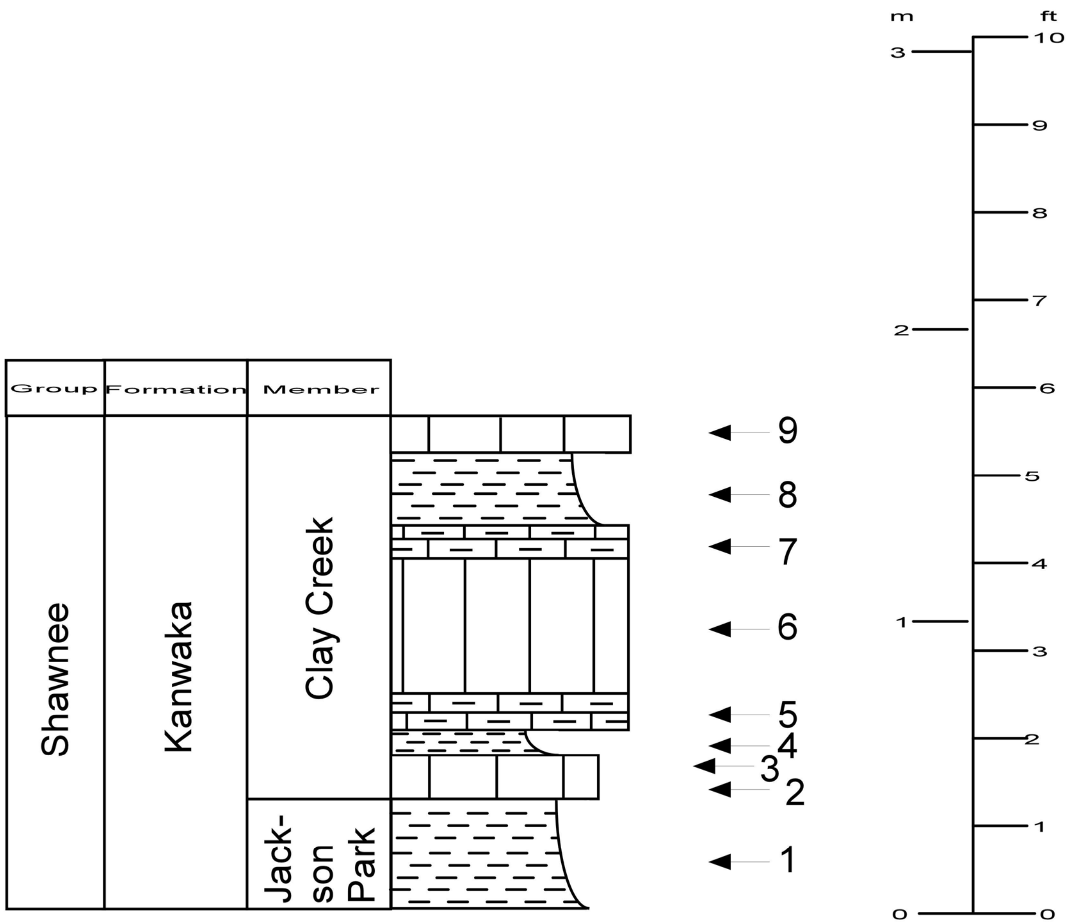


Figure 45. Stratigraphic section of locality 7.

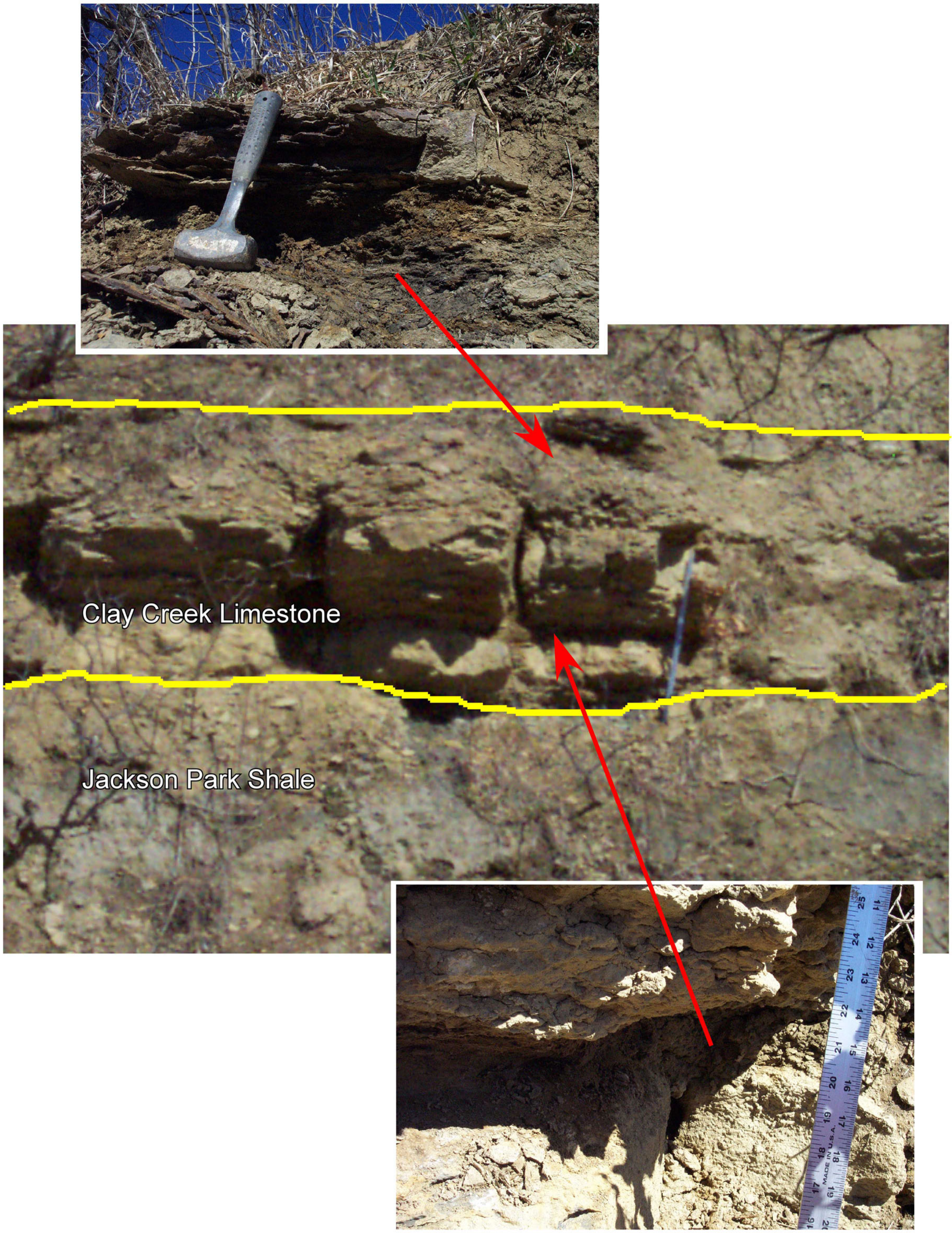


Figure 46. Clay Creek Limestone.

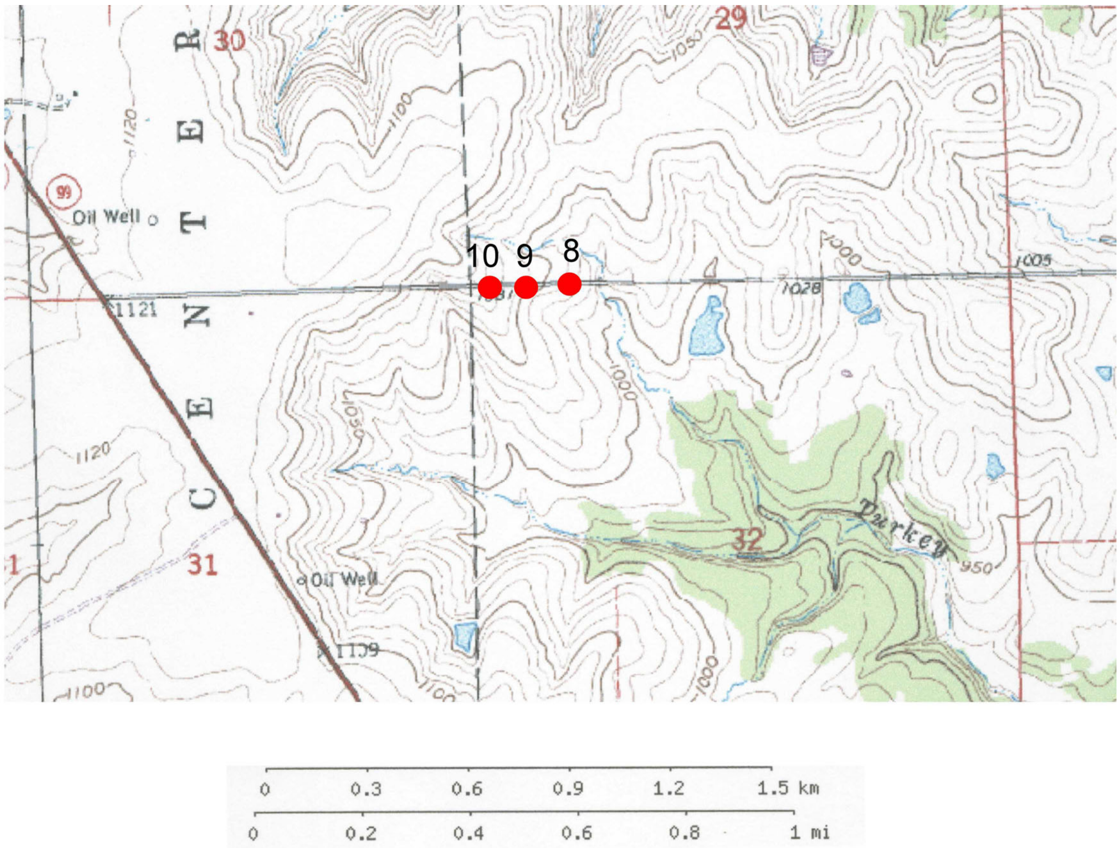


Figure 47. Location map for localities 8, 9, and 10.

LOCATION 8: Outcrop on south side of county road, north of Sedan, Kansas
E1/2 W1/2 sec. line between sec. 29 and sec. 32, T32S, R11E
LONGITUDE: N37º13.709'
LATTITUDE: W96º13.941'

Lecompton Limestone Formation

Stull Shale Member

1 Very fine-grained sandstone and siltstone – 30cm/12 in

2 Shale, calcareous, yellowish gray 5Y8/1, yellowish gray 5Y7/2, pale yellowish orange 10YR8/6 – 25cm/10 in

Spring Branch Limestone Member

3 Wackestone/packstone, more argillaceous at base with less fossils, top 8-10 inches has burrows and many productid brachiopods – 65cm/26 in

Doniphan Shale Member

4 Shale, clayey, calcareous, light gray N7, light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 85cm/34 in

5 shaley paleosol, grayish red 10R4/2 at base grading into pale yellowish green 10GY7/2 at top – 30cm/12 inches

6 shale, clayey, light olive gray 5Y6/1 – 47.5/19 inches

7 shale, sandy, very thin sandstone bed near base, limonitic, pale yellowish brown 10YR6/2 – 40cm/16 inches

Big Springs Limestone Member

8 packstone, thinly bedded, fusulinids, crinoids, bivalves, brachiopods, ferruginous, crystalline, hard, weathers dark yellowish orange 10YR6/6, light brown 5YR5/6, fresh grayish yellow 5Y8/4 with moderate brown 5YR4/4 streaks – 5cm/2 inches

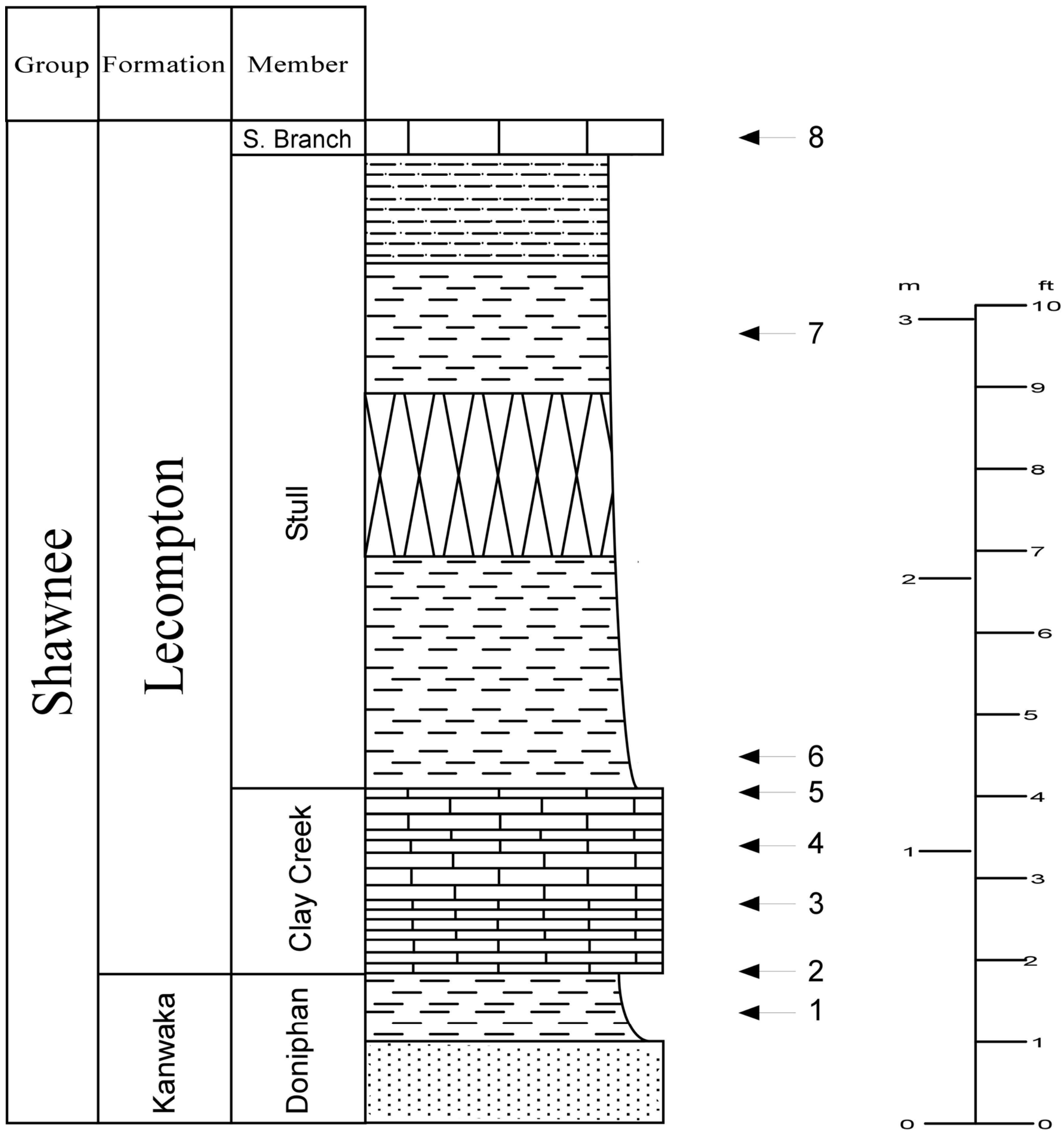


Figure 48. Stratigraphic section or locality 8.

Figure 49. Stull Shale and Spring Branch Limestone.

Figure 50. Paleosols within Stull Shale.

LOCATION 9: Outcrop on south side of county road, north of Sedan, Kansas
Center W1/2 section line between sec. 29 and sec. 32, T32S, R11E
LATTITUDE: N37º13.708'
LONGITUDE: W96º14.000'

Lecompton Limestone Formation
Queen Hill Shale Member

1 shale, platy, clayey, medium dark gray N4 – 60cm/24 inches

2 clay shale, blocky, phosphate nodules, slightly calcareous, medium gray N5 – 30cm/12 inches

3 clay shale, calcareous, light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 30cm/12 inches

Beil Limestone Member

4 wackestone, 2 to 3 beds, hard, caninia torqua, top is more fossiliferous with a pitted surface, weathers dark yellowish orange 10YR6/6, moderate brown 5YR4/4, fresh moderate yellowish brown 10YR5/4 – 20-30cm/8-12 inches

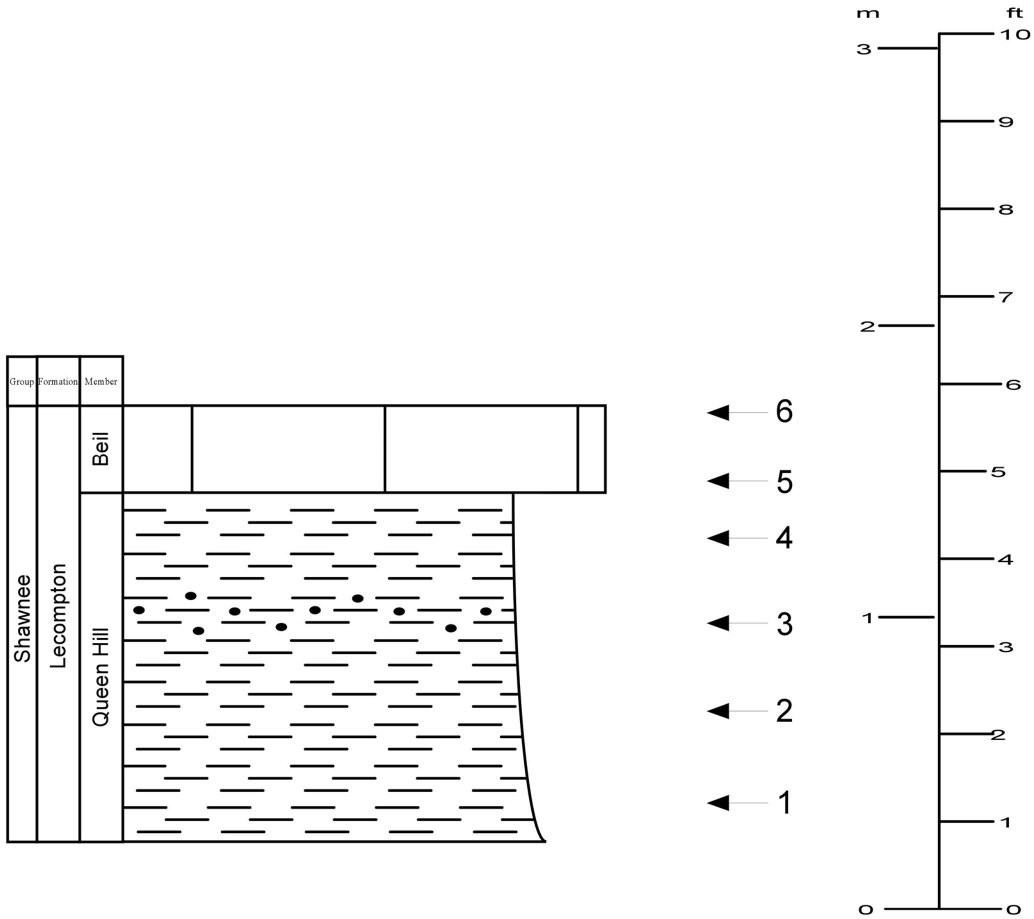


Figure 51. Stratigraphic section of locality 9.

Figure 52. Beil Limestone and Queen Hill Shale.

LOCATION 10: Outcrop on south side of county road, north of Sedan, Kansas
W1/2 W1/2 section line between sec. 29 and sec. 32, T32S, R11E
LATTITUDE: N37º13.709'
LONGITUDE: W96º14.080'

Lecompton Limestone Formation
King Hill Shale Member

1 shale, clayey, calcareous, dark yellowish brown 10YR4/2 – 50cm/20 inches

Avoca Limestone Member

2 wackestone, massive, hard, bivalves, fusulinids, weathers dark yellowish orange 10YR6/6, light olive gray 5Y6/1, fresh medium gray N5, olive gray 5Y4/1 – 22.5cm/9 inches

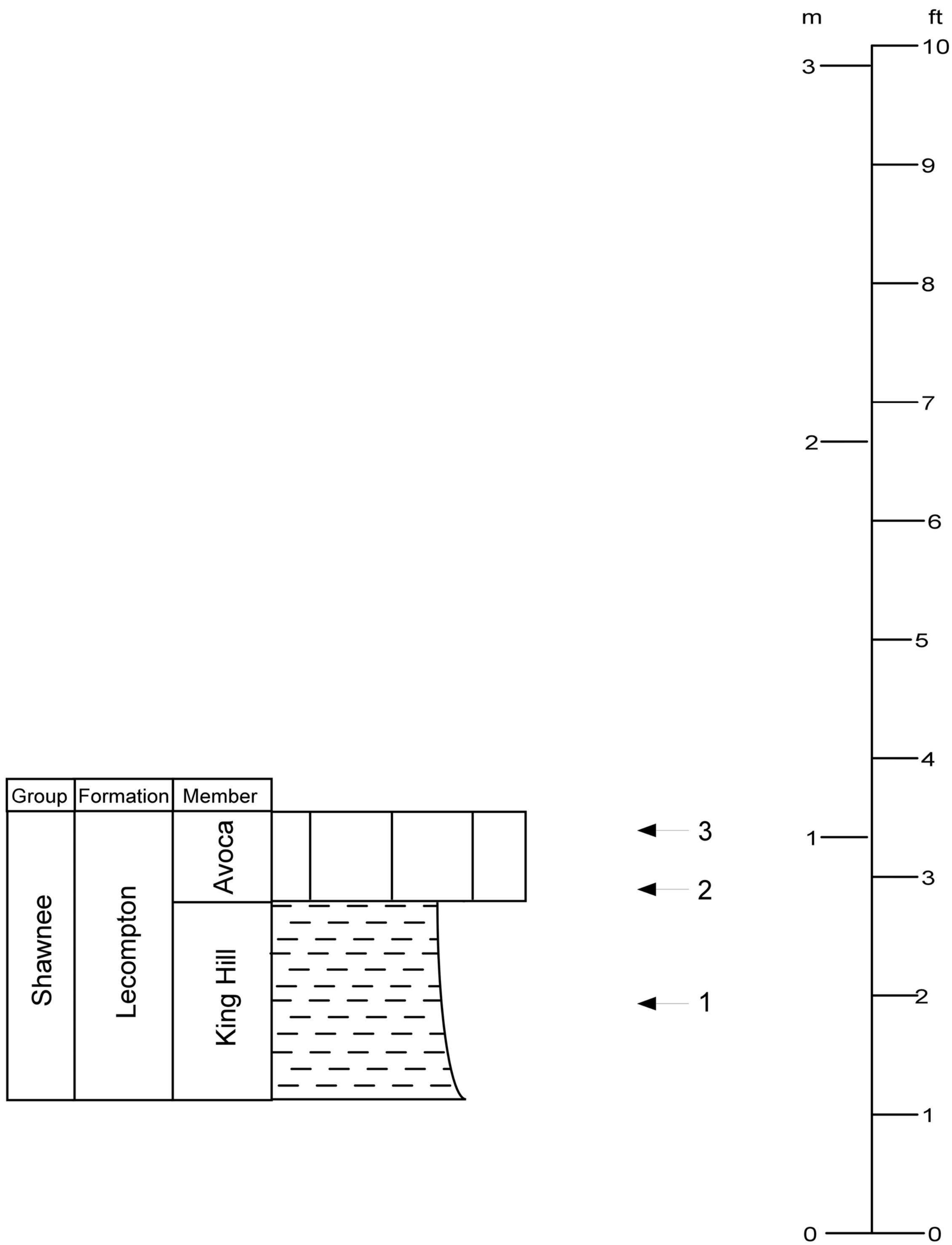


Figure 53. Stratigraphic section of locality 10.

Figure 54. Avoca Limestone.

Figure 55. Location map for localities 11 and 12.

LOCATION 11: Road outcrop on the west side of highway 99, near mile marker 14.4
E1/2 SW1/4 sec. 8, T33S, R11E
LATTITUDE: N37º11.237'
LONGITUDE: W96º13.590'

Lecompton Limestone Formation

Big Springs Limestone Member

1 wackestone-packstone, hard, crystalline, fossiliferous-crinoids, brachiopods, massively bedded, fusulinids, fresh medium gray N5, medium dark gray N4, weathers olive gray 5Y4/1, dusky yellow 5Y6/4, dark yellowish orange 10YR6/6 – 25cm/10 inches

2 wackestone, hard, thinly bedded, very fossiliferous, weathers dark yellowish orange 10YR6/6, moderate brown 5YR4/4, fresh medium gray N5, light olive gray 5Y6/1 – 20cm/8 inches

Queen Hill Shale Member

3 covered – 130cm/52 inches

4 fissile shale, platy, calcareous, brachiopods, dark gray N3 – 12.5cm/5 inches

5 fossiliferous mudstone, hard, thin bed, fresh dark gray N3, weathers olive gray 5Y4/1 – 6.875cm/2.75 inches

6 fissile shale, platy, grayish black N2 to black N1 – 30cm/12 inches

7 fissile shale, platy, black N1 – 55cm/22 inches

8 shale, blocky, phosphate nodules, medium gray N5 – 20cm/8 inches

9 shale, clayey, slightly calcareous, limonitic, light gray N7, pale yellowish orange 10YR8/6 – 30cm/12 inches

10 covered – 42.5 inches

11 clay shale, calcareous, light olive gray 5Y6/1, dark yellowish orange 10YR6/6 – 45cm/18 inches

Beil Limestone Member

12 wackestone, 12-16 thin, wavy, discontinuous beds, caninia torqua, ferruginous, crystalline, hard, fresh medium gray N5, medium light gray N5, weathers dark yellowish orange 10YR6/6, light olive gray 5Y5/2 – 90cm/36 inches

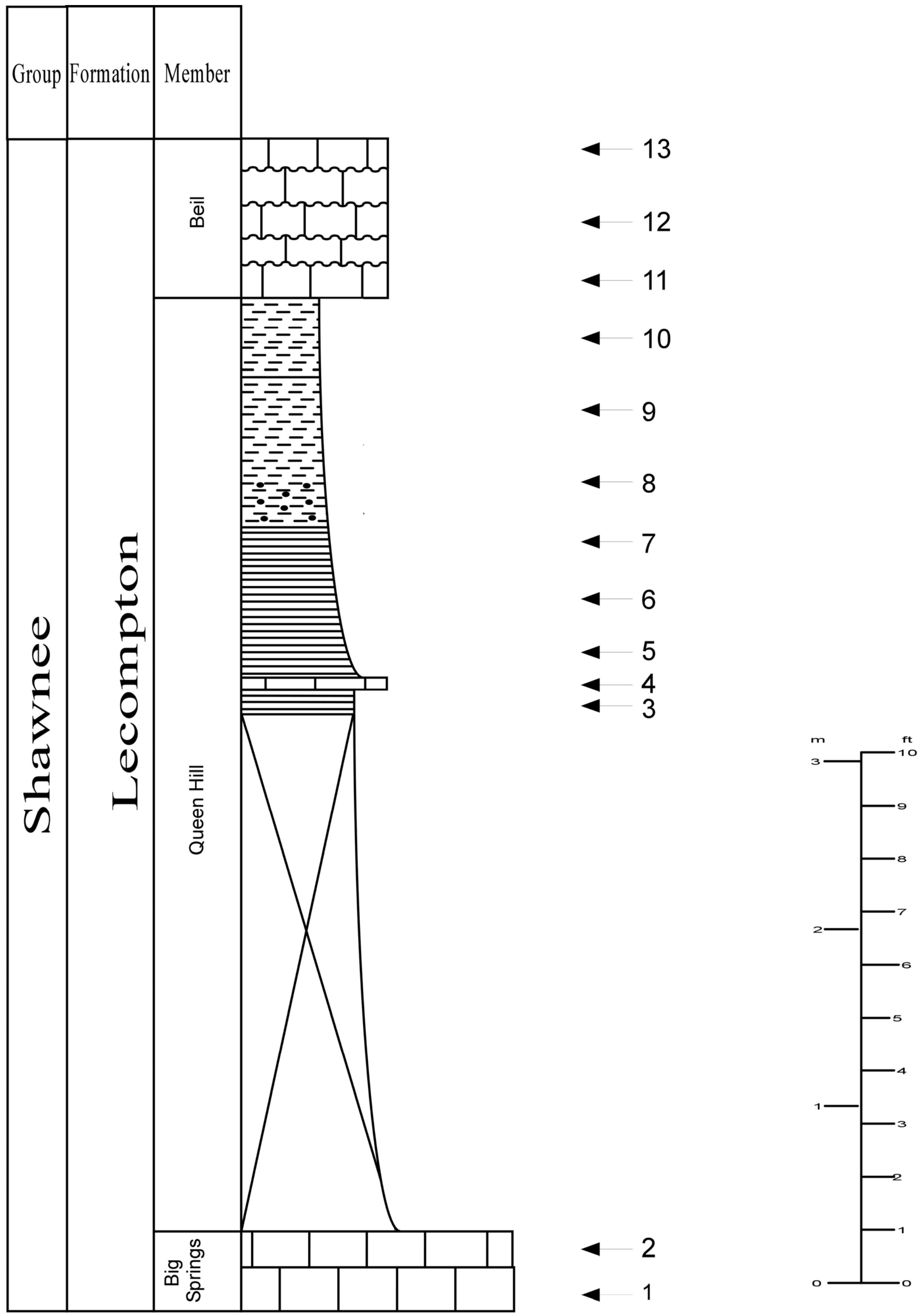


Figure 56. Stratigraphic section of locality 11.

Figure 57. Queen Hill Shale.

Figure 58. Beil Limestone.

LOCATION 12: Road outcrop on the west side of highway 99, near mile marker 15
E1/2 NW1/4 sec. 8, T33S, R11E
LATTITUDE: N37º11.762'
LONGITUDE: W96º13.590'

Lecompton Limestone Formation

King Hill Shale Member

1 calcareous clay shale, moderate olive brown 5Y4/4 – 37.5cm/15 inches

2 calcareous clay shale, limonitic streak 4 inches from top, light olive gray 5Y6/1, yellowish gray 5Y8/1

Avoca Limestone Member

3 fossiliferous wackestone, crinoids, weathers dark yellowish orange 10YR6/6, olive gray 5Y4/1, fresh light olive gray 5Y5/2, medium gray N5

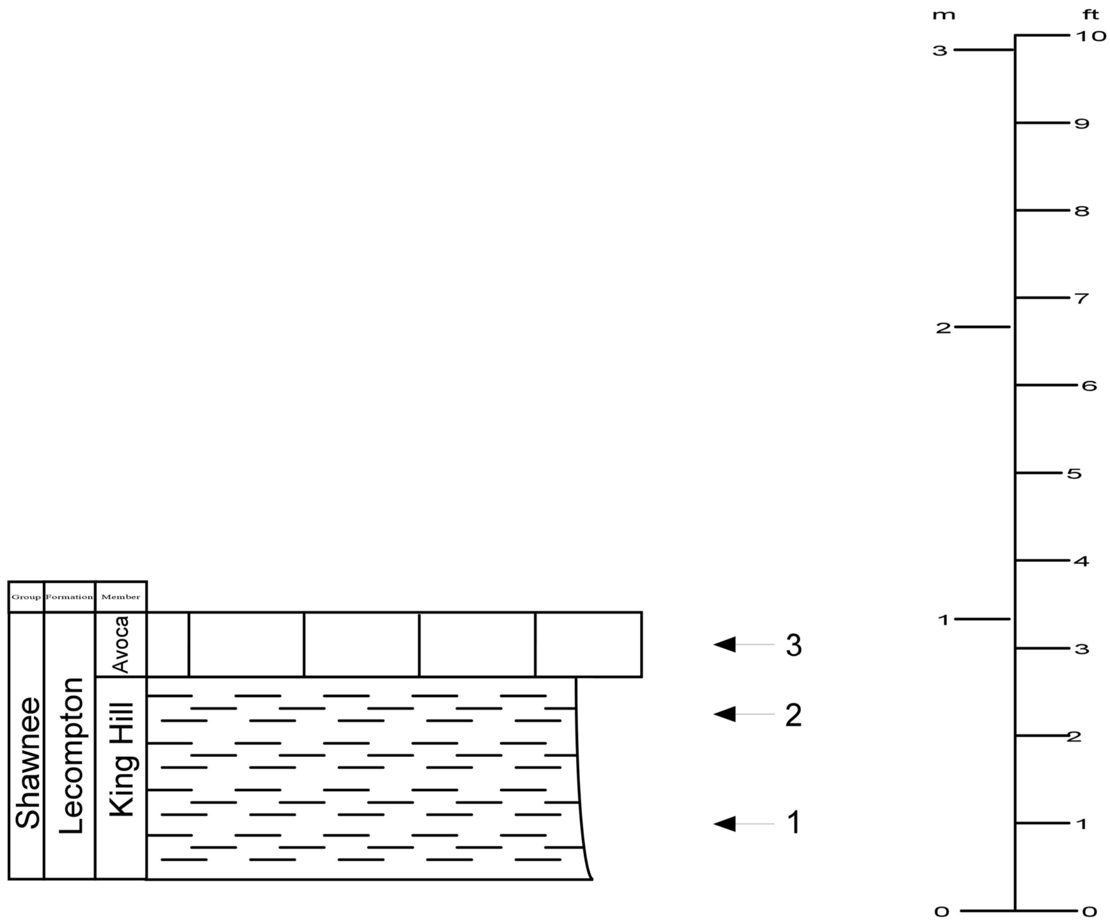
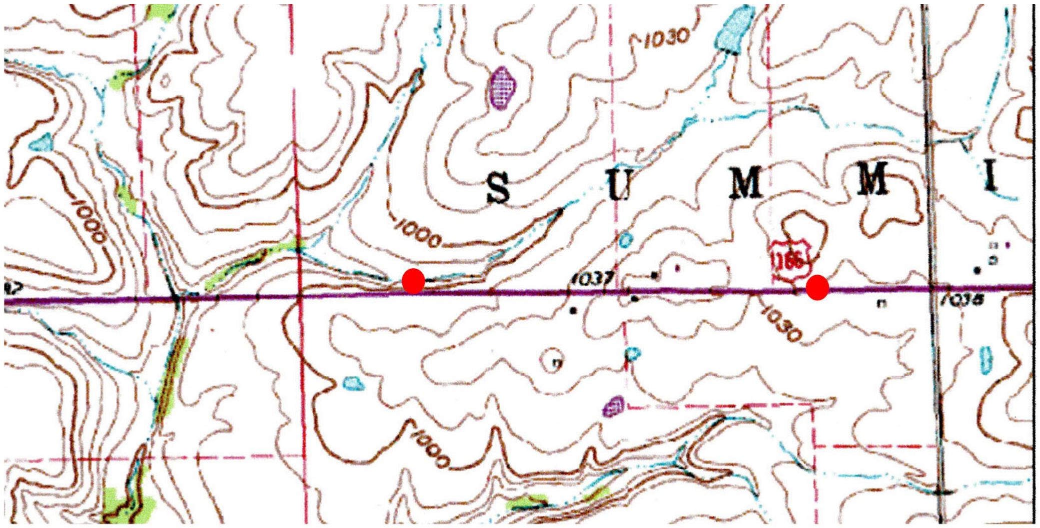


Figure 59. Stratigraphic section of locality 12.

Figure 60. Avoca Limestone and King Hill Shale.



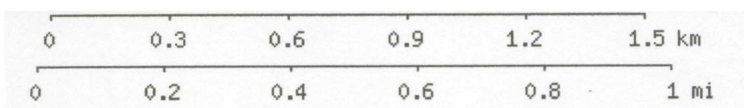


Figure 61. Location map for locality 13.

LOCATION 13: Road outcrop on higheway 166, near mile marker 62
S/2 SE/4 sec. 4 T34S R10E
LATTITUDE: ?
LONGITUDE: ?

Deer Creek Limestone Formation

Rock Bluff Limestone Member

1 Wackestone, only the top surface is exposed

Larsh Burroak Shale Member

2 shale, clayey, slightly platy, calcareous, light olive gray 5Y5/2, yellowish gray 5Y7/2, moderate yellow 5Y7/6, dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6, medium gray N5, light gray N7 – 5cm/2 inches

3 shale, fissile, phosphate nodules near top, grades to platy and blocky at top, black N1, grayish black N2 fresh, weathers medium gray N5 to dark gray N3, olive gray 5Y4/1, pale yellowish orange 10YR8/6 – 27.5cm/11 inches

4 shale, clayey, grainy, light gray N7, light olive gray 5Y6/1, brownish gray 5YR4/1, dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6, dark yellowish brown 10YR4/2 – 10cm/4 inches

Ervine Creek Limestone Member (eposed less than one mile west of first outcrop)

5 wackestone, very hard, abundant fossils – brachiopods, sponges, crinoids, and coral, contains styolites approximately 30 cm (12 in) from base, medium gray N5 - 138.75cm/ 55.5 inches

6 shale parting, clayey, grainy, calcareous, grayish brown 5YR3/2, moderate brown 5YR4/4 and 5YR3/4, light brown 5YR5/6, dark yellowish orange 10YR6/6 – 5cm/2 inchees

7 Wackestone, sparse fossils, calcite recrystallization, extremely styolitic at base, then to medium wavy beds, light olive gray 5Y6/1 fresh, weathers dark yellowish orange 10YR6/6, pale yellowish orange 10YR8/6 contains an arenaceous 2.5 cm (1 inch) thick shale parting 31.25cm (12.5 inches) from base, grayish brown 5YR3/2, moderate brown 5YR4/4, dark yellowish brown 10YR4/2 – 73.75cm/ 29.5 inches

8 wackestone/packstone, dense, hard, abundant fusulinids, light gray N7to medium gray N5 – 75cm/30 inches

9 wackestone, dense, fossil abundance increases upwards – fenestrate, brachiopods, fusulinids, solution channels in bottom 80 cm (32 inches) dark bluish gray. Contains a shale parting 42.5 cm (17 inches) from top, very thinly bedded, calcareous, dark yellowish brown 10YR4/2, pale brown 5YR5/2, dark yellowish orange 10YR6/6 – 130cm/52 inches

Calhoun Shale Formation

10 shale, possible paleosol, reddish orange – 3.75cm/1.5 inches

11 shale, thinly bedded, platy, very slightly calcareous, medium light gray N6 to medium dark gray N4, weathers yellowish gray 5Y7/2 – 23.75cm/9.5 inches

12 calcareous mudstone, thinly bedded, light gray N7-medium gray N5 – 12.5cm/5 inches

Topeka Limestone Formation
Hartford Limestone Member

13 wackestone, fossil fragments, oolitic, very hard, medium dark gray N4 – 25cm/10 inches

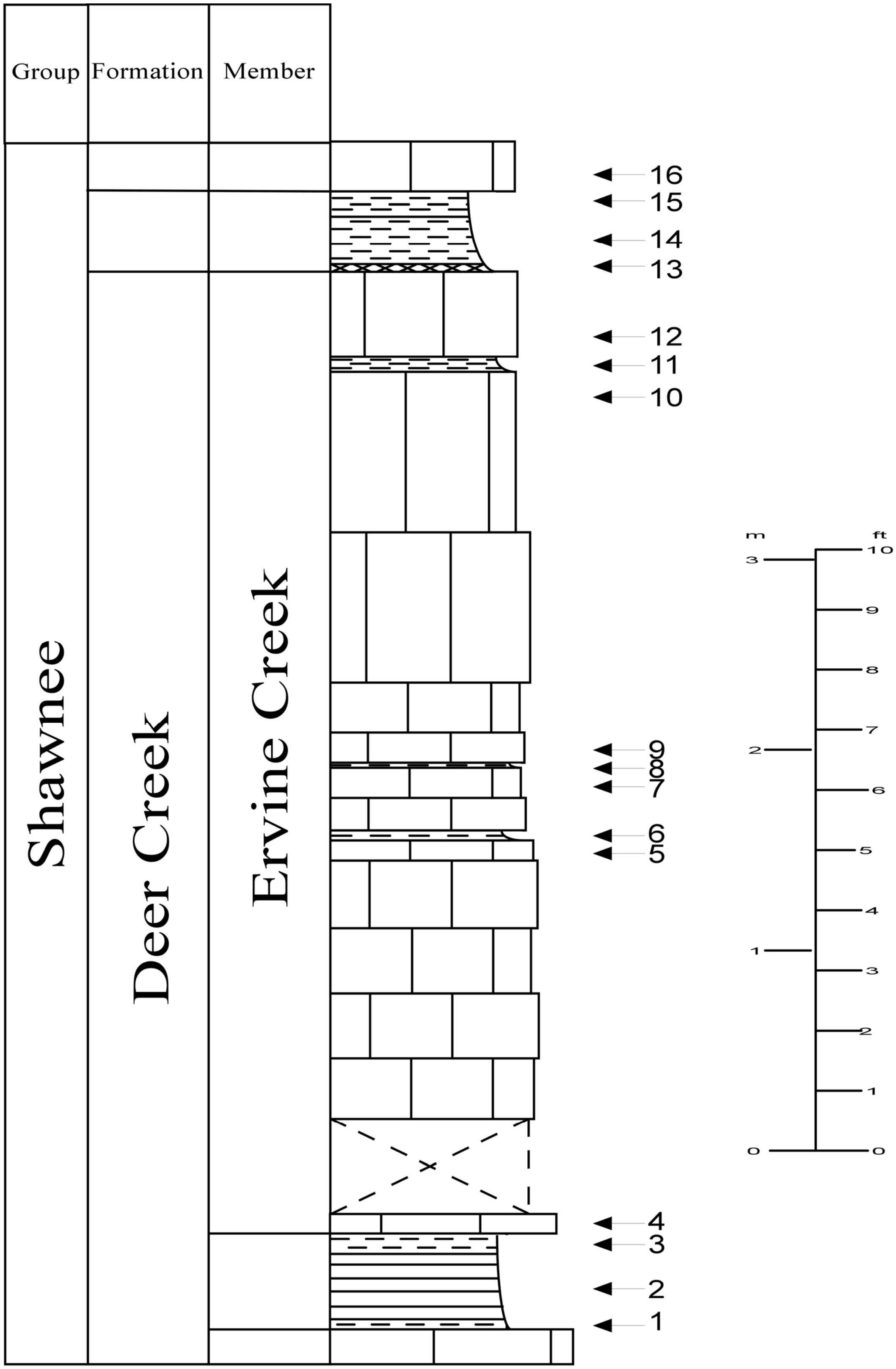


Figure 62. Stratigraphic section of locality 13.

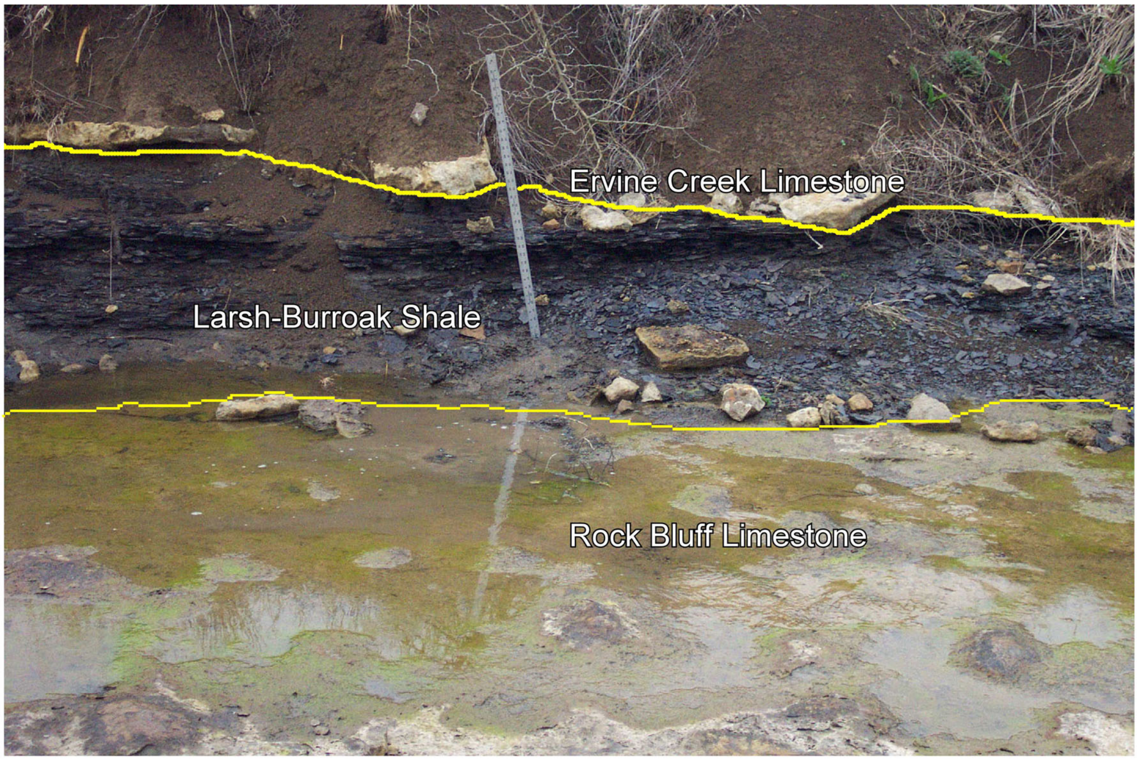


Figure 63. Larsh-Burroak Shale.

Figure 64. Basal section of the Ervine Creek Limestone.

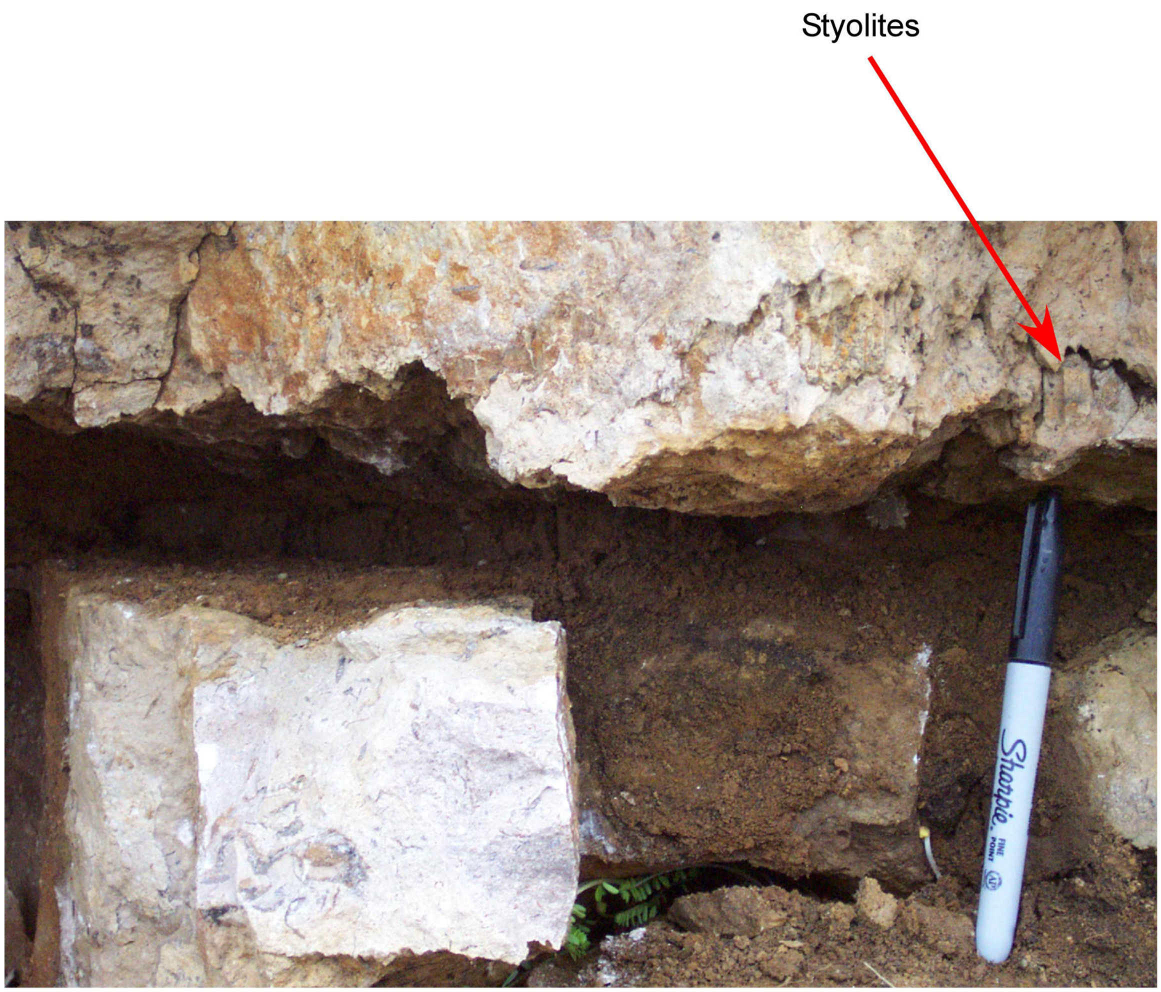


Figure 65. Shale parting within the lower section of the Ervine Creek Limestone.

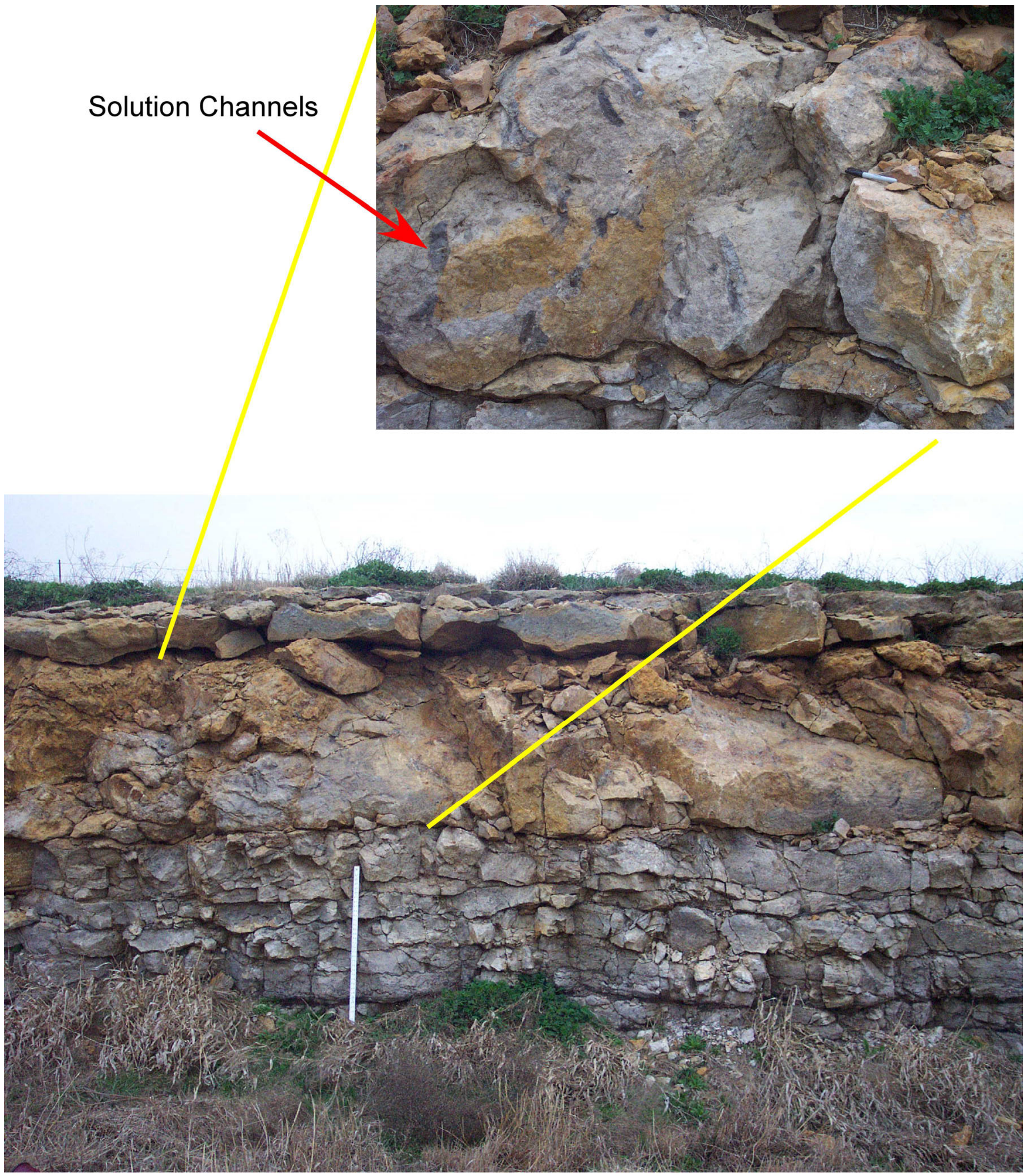


Figure 66. Solution channels within the upper section of the Ervine Creek Limestone, evidence for subarial exposure.

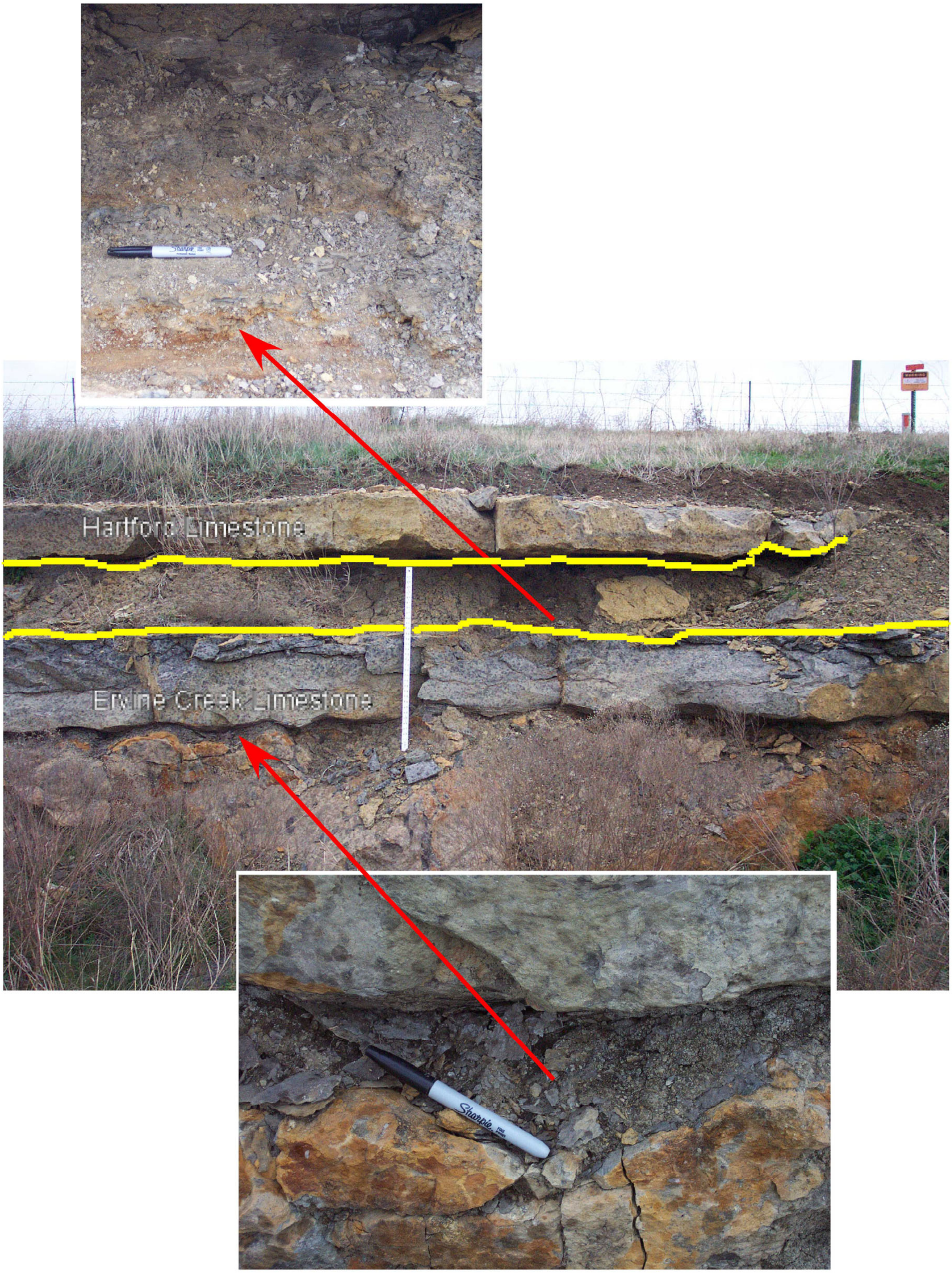


Figure 67. Top of the Deer Creek Formation.

Figure 68. Location map of locality 14.

LOCATION 14: Sedan City Lake Spillway and approximately ¾ mile downstream from the spillway
NW1/4 SW1/4 NW1/4 NW1/4 sec. 21, T33S, R11E (spillway)
NW1/4 NW1/4 SW1/4 sec. 21, T33S, R11E (downstream)
LATTITUDE: N37º10.094' (spillway) N37º09.665' (downstream)
LONGITUDE: W96º13.039' (spillway) W96º13.017' (downstream)

Douglas Group
Lawrence Shale Formation

1 Paleosol, limonite concretions, calcareous, very dusky red 10R2/2, dark yellowish orange 10YR6/6, greenish gray 5GY6/1 – 30cm/12inches

2 Paleosol, limonite concretions, calcareous, very dusky red 10R2/2, dark yellowish orange 10YR6/6, greenish gray 5GY6/1 – 30cm/12inches

Shawnee Group
Oread Limestone Formation
Toronto Limestone Member

3 Wackestone, wavy, thinly bedded, crystalline, hard, fossiliferous, pitted surface, medium light gray N6 fresh, weathers yellowish gray 5Y7/2, pale yellowish orange 10YR8/6, light brown 5YR5/6 – 15cm/6 inches

4 Wackestone, argillaceous, crystalline, pitted, fossiliferous, medium gray N5, weathers yellowish gray 5Y7/2, pale yellowish orange 10YR8/6, light brown 5YR5/6 – 12.5cm/5 inches

5 Wackestone/packstone, wavy, thin beds, crystalline, hard, fossiliferous, medium gray N5, medium light gray N6 fresh, weathers dark yellowish orange 10YR6/6, light brown 5YR5/6, olive gray 5Y4/1 – 57.5cm/23 inches

Snyderville Shale Member

6 Covered – 121.25cm/48.5 inches

7 red and green paleosol, thinly bedded, fractured – 90cm/36 inches

8 covered – approximately 60cm/24 inches

9 very thinly bedded shale, slightly calcareous, dark gray N3 – 22.5cm/ 9 inches

10 very thinly bedded shale, calcareous, medium dark gray N4 – 60cm/24 inches

11 conglomeratic carbonate, fossiliferous, fresh medium dark gray N4, weathers medium gray N5 – 5-7.5cm/2-3 inches

12 shale parting, calcareous, medium light gray N6 – 5cm/2 inches

13 conglomeratic carbonate, slightly crystalline, fossiliferous, fresh dark gray N3, weathers yellowish gray 5Y7/2 – 2.5cm/1 inch

14 thinly bedded shale, fossiliferous, calcareous, medium gray N5 – 45cm/18 inches

15 thinly bedded shale, fossiliferous, chonetes, calcareous, medium light gray N6 – 30cm/12 inches

Leavenworth Limestone Member

16 mudstone-wackestone, hard, fossiliferous, fresh olive gray 5Y4/1, medium gray N5, weathers light olive gray 5Y5/2, pale greenish yellow 10Y8/2, dark yellowish orange 10YR6/6 – 50cm/20 inches

Heebner Shale Member

17 shale, clayey, platy, calcareous, abundant chirithirus, dark gray N3, medium dark gray N4 – 7.5cm/3 inches

18 fissile shale, grayish black N2 – 30cm/12 inches

19 fissile shale, dark gray N3, brownish black 5YR2/1, light olive brown 5Y5/6 – 30cm/12 inches

20 phosphatic shale, grayish black N2, light brown 5YR5/6, dark yellowish orange 10YR6/6 – 30cm/12 inches

21 shale, contains very few phosphate nodules, dark gray N3, moderate yellowish brown 10YR5/4 – 30cm/12 inches

22 phosphatic shale, fossiliferous, medium dark gray N6 mottled with light olive gray 5Y6/1 – 15cm/6 inches

23 very thinly bedded shale, fossiliferous, limonite replacement of some fossils, brachiopods, pelecypods, medium dark gray N6 – 30cm/12 inches

24 very thinly bedded shale, fossiliferous, slightly limonitic, medium dark gray N4, olive gray 5Y4/1, light olive gray 5Y6/1 – 30cm/12 inches

Plattsmouth Limestone Member

25 wackestone, approximately 27 wavy, medium-thick, discontinuous beds, hard, fossiliferous, bivalves, crinoids, fresh medium light gray N6, weathers dark yellowish orange 10YR6/6, yellowish gray 5Y8/1, light olive gray 5Y6/1 – 215cm/86 inches

26 bindstone, fossiliferous - predominately phylloid algae, mound structure, 10-15 somewhat discontinuous, thick-massive wavy beds, crystalline, hard, vugular with some calcite recrystallization, fresh very light gray N8, light gray N7, yellowish gray 5Y8/1, grayish orange 10YR7/4, weathers light brown 5YR5/6, olive black 5Y2/1 – 265cm/106 inches

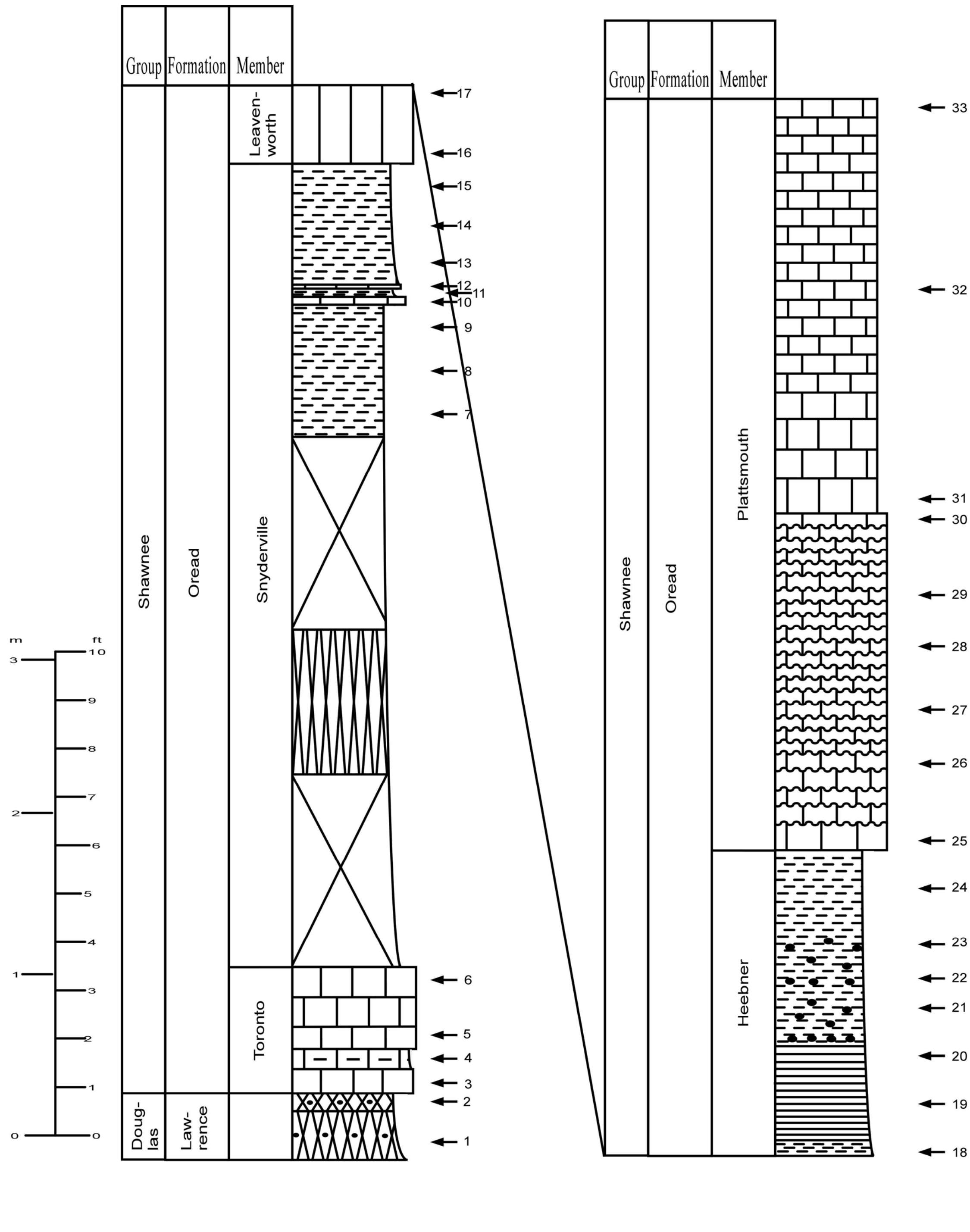


Figure 69. Stratigraphic section of locality 14.

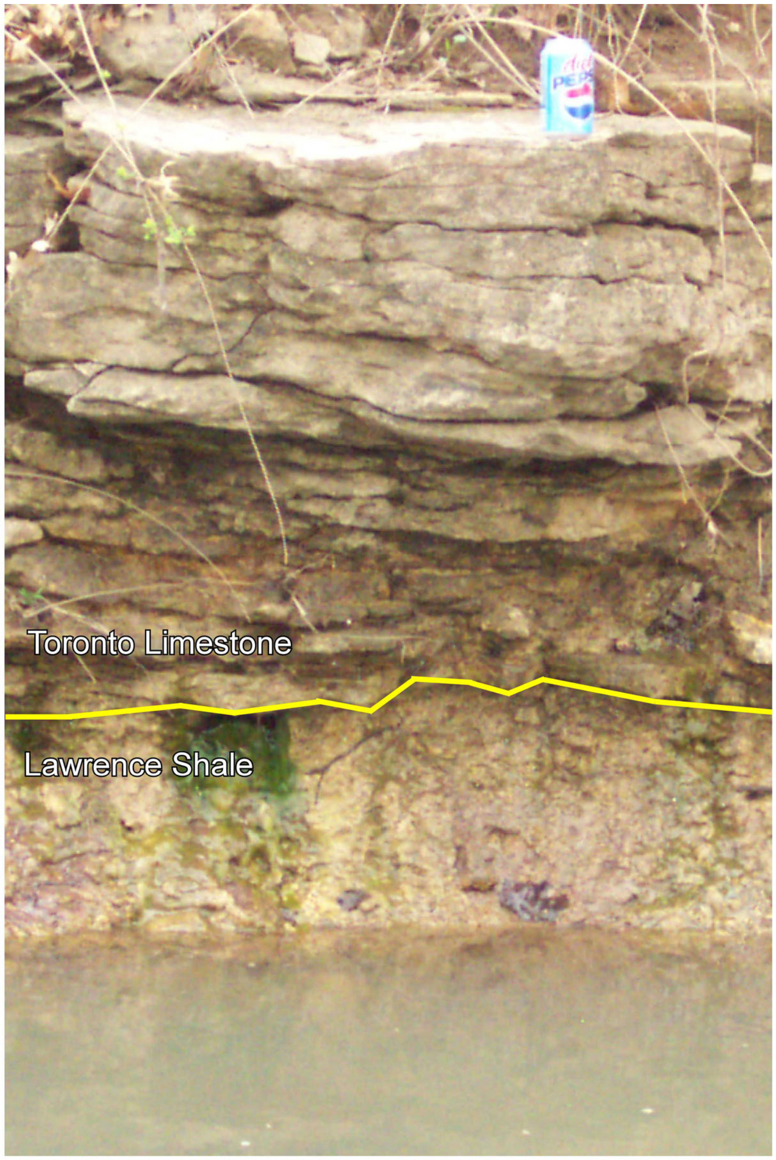


Figure 70. Lawrence Shale and Toronto Limestone.

Figure 71. Paleosol at the base of the Snyderville Shale.

Figure 72. Leavenworth Limestone and Snyderville Shale.

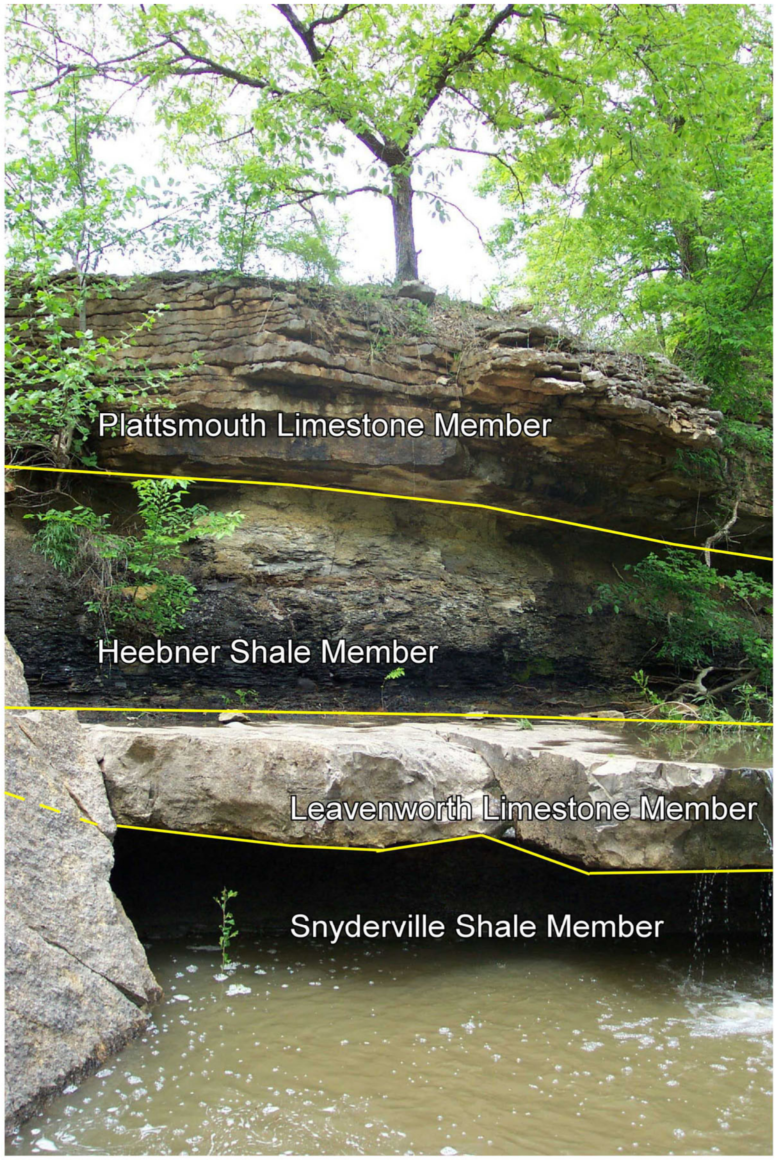


Figure 73. Plattsmouth Limestone, Heebner Shale, and Leavenworth Limestone.

Figure 74. Algal section of the upper Plattsmouth Limestone.

Figure 75. Location map of location 15.

LOCATION 15: Tributary canyon of Buck Creek, west of the county road.
SW1/4 NE1/4 sec. 14, T29N, R9E
LATTITUDE: N36º59.352'
LONGITUDE: W96º17.680'

Oread Limestone Formation
Snyderville Shale Member

1 Shale, clayey-blocky, calcareous, medium gray N5, light olive gray 5Y6/1, dusky yellow 5Y6/4 – 30cm/12 inches

Leavenworth Limestone Member

2 Wackestone/packstone, hard, crystalline, possible lag at base, pelecypods, crinoids, brachiopods, bryozoans, medium gray N5 fresh, weathers light olive gray 5Y6/1, moderate yellowish brown 10YR5/4 – 10cm/4 inches

3 Packstone, hard, crystalline, bryozoans, crinoids, pelecypods, brachiopods, medium gray N5 fresh, weathers moderate yellowish brown 10YR5/4, moderate brown 5YR4/4, dark reddish brown 10R3/4 (spotty) – 15cm/6 inches

Heebner Shale Member

4 Shale, clayey-blockey, calcareous, large limonite nodules (approximately 10cm/4 inches in diameter), light olive gray 5Y6/1, medium gray N5 – 30cm/12 inches

5 Shale, clayey, thinly bedded, calcareous, limonite nodules, medium light gray N6, light olive gray 5Y6/1fresh, weathers yellowish gray 5Y7/2 – 90cm/36 inches

6 Shale, clayey, calcareous, thin limonite wedges, medium light gray N6, light gray N7 fresh, weathers light olive gray 5Y6/1, grayish yellow 5Y8/4 – 30cm/12 inches

7 Shale, clayey, calcareous, mottled dark yellowish orange 10YR6/6, grayish red 10R4/2, very dusky red 10R2/2, and yellowish gray 5Y7/2 – 30cm/12 inches

8 Covered section, probably shale – 1320cm/44 feet

9 Sandstone, slabby, limonitic, dense, friable, tan with brown spots – 150cm/60 inches

Plattsmouth Limestone Member

10 Wackestone, hard, fossiliferous – pelecypods, brachiopods, fusulinids weather in relief, light olive gray 5Y6/1, medium gray N5 fresh, weathers yellowish gray 5Y7/2, moderate yellowish brown 10YR5/4 – 75cm/30 inches

Kanwaka Shale Formation

11 Covered section, probably shale – 120cm/48 inches

12 Sandstone, tan, impure, medium grained, cross-bedded – 600cm/20 feet

13 Paleosol, alternates between green and maroon approximately every 1/3 meter (1 foot) with a siltstone 1 meter (3 feet) from the base that weathers white and is yellow on a fresh surface – 450cm/15 feet

14 Sandstone, tan, impure, medium grained, cross-bedded, multiple channels visible, friable, contains rust spots – 450cm/15 feet

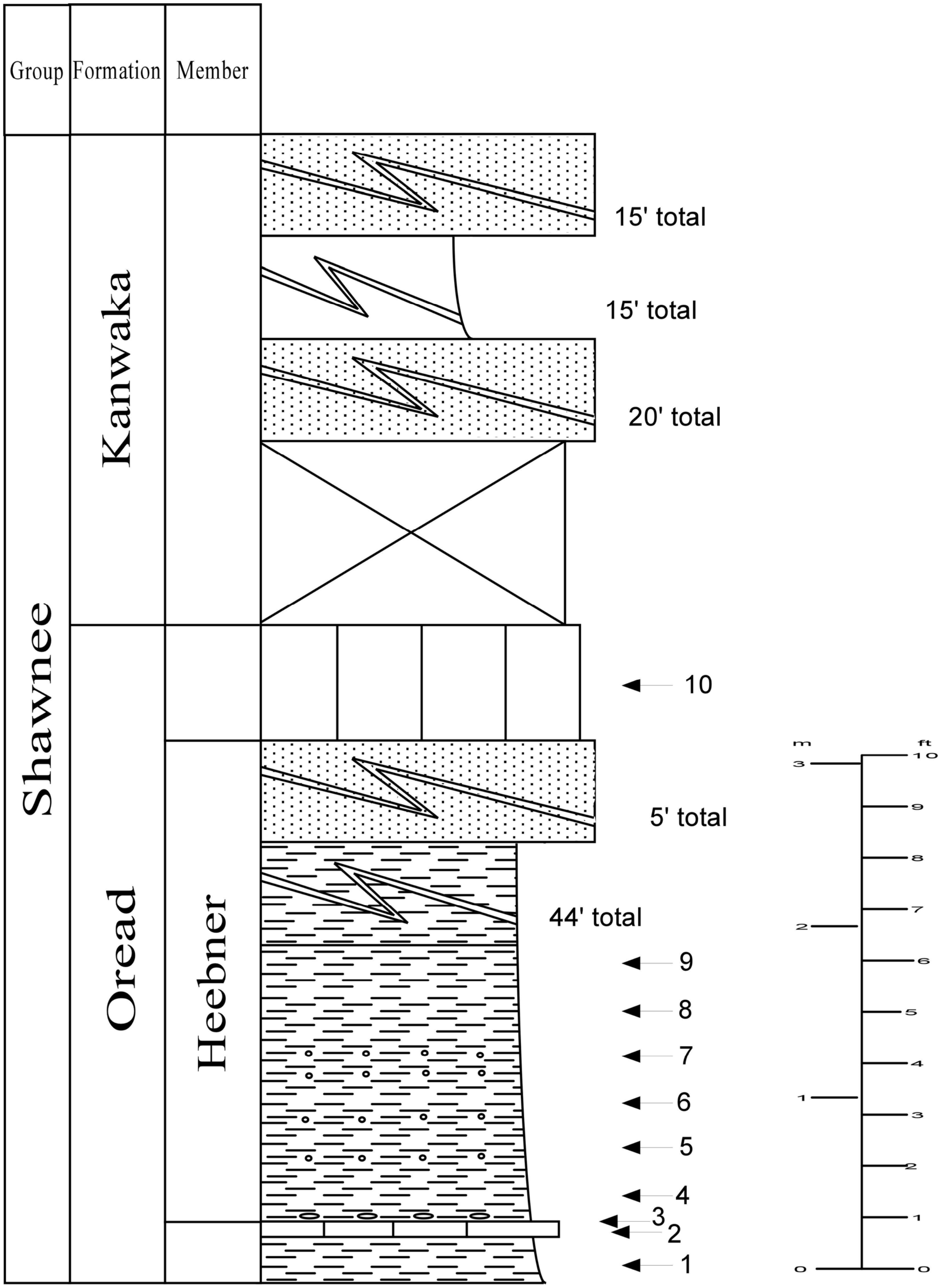


Figure 76. Stratigraphic section of locality 15.

Figure 77. Snyderville Shale and Leavenworth Limestone.

Figure 78. Heebner Shale.

Figure 79. Paleosols within the Elgin Sandstone.

Figure 80. Deltaic sandstone within the Elgin Sandstone.

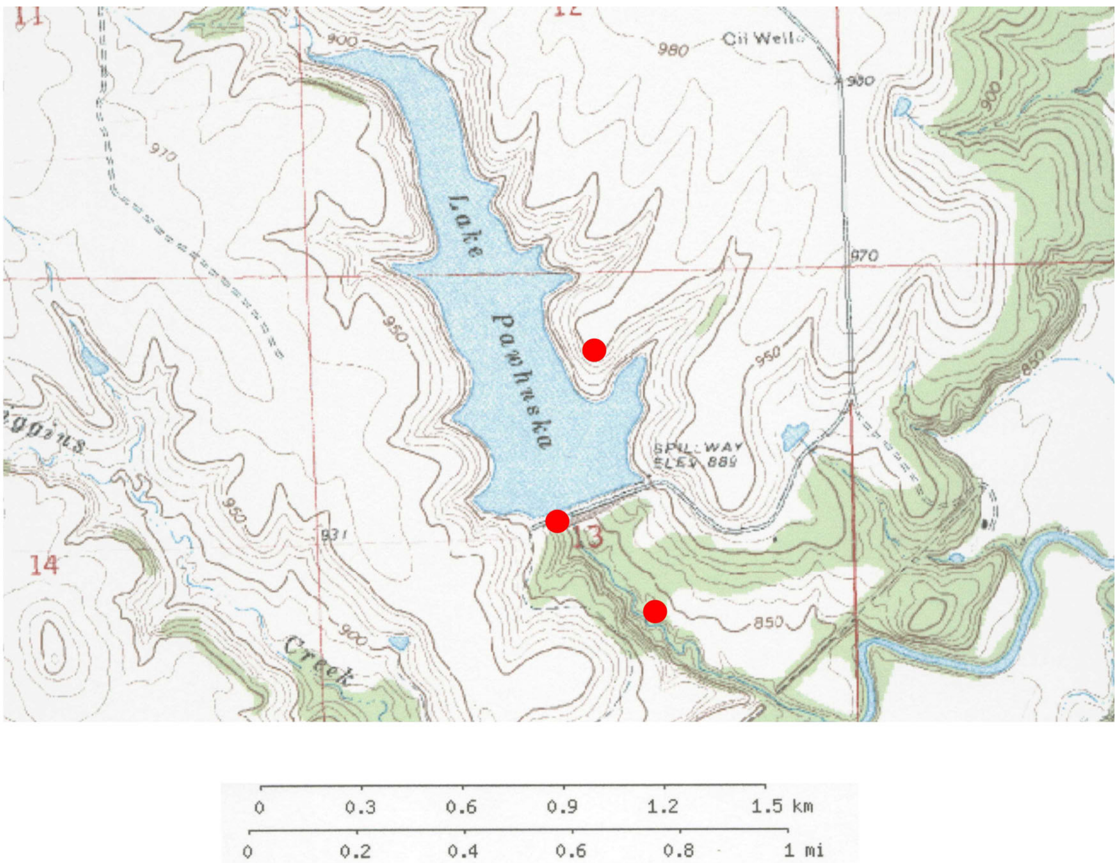


Figure 81. Location map of locality 16.

LOCATION 16: Lake Pawhuska Spillway and escarpment on east side of the lake
Center sec. 13, T25N, R8E
LATTITUDE: 36º38.671'
LONGITUDE: 96º23.747'

Kanwaka Shale Formation

Elgin Sandstone Member

1 Sandstone, massive, soft, poorly cemented, medium-grained, large cross beds, forms prominent cliffs, weathers grayish brown, fresh surfaces are reddish orange – 1275cm/42.5 feet

2 Shale, poorly exposed – 300cm/10 feet

3 Sandstone, massive, small cross beds, medium-grained, friable, yellowish brown fresh, weathers pink with and orange rine – 600cm/20 feet

4 Shale, very poorly exposed, maroon – 195cm/6.5 feet

5 Sandstone, medium to course grained, white N9, dark yellowish orange spots fresh, weathers pale brown 5YR5/2, moderate brown 5YR3/4 – 20cm/8 inches

6 Shale parting, light tan, calcareous, silty – 10cm/4 inches

Clay Creek Limestone member

7 Wackestone, pitted surface, calcite filled vugs, fusulinids, moderate brown 5YR4/4, pale yellowish orange 10YR8/6, grayish yellow green 5GY7/2 fresh, weathers moderate brown 5YR3/4, dark yellowish orange 10YR6/6 – 45cm/18 inches

Stull Shale member

8 Shale, platy, calcareous, grayish red 10R4/2, light gray N7, medium gray N5 – 30cm/12 inches

9 Shale, platy, calcareous, yellowish gray 5Y7/2, light gray N7, grayish red 10R4/2 – 30cm/12 inches

10 Shale, platy, slightly calcareous, yellowish gray 5Y7/2, pale brown 5YR5/2, pale red 5R6/2, blackish red 5R2/2 – 45cm/18 inches

Lecompton Limestone Formation

Spring Branch Limestone Member

11 Fusulinid packstone/grainstone, contains shaly zones, hard, pale yellowish orange 10YR8/6, pale olive 10Y6/2 fresh, weathers grayish red 5R4/2, dark yellowish orange 10YR6/6 – 15cm/6 inches

12 Wackestone, impure, silty, fossiliferous, yellowish gray 5Y7/2, grayish yellow 5Y8/4 fresh, weathers grayish red 10R4/2 – 30cm/12 inches

Doniphan Shale Member

13 Sandstone, fine-grained, poorly cemented with calcite, soft, yellow fresh, weathers black – 30cm/12 inches

14 Covered shale – 450cm/15 feet

Big Springs Limstone Member

15 Fusulinid packstone, shaly, pale red 10R6/2, pale yellowish brown 10YR6/2 fresh, weathers grayish red 10R4/2, brownish black 5YR2/1, pale yellowish orange 10YR8/6 – 17.5cm/7 inches

Queen Hill Shale Member

16 Covered green shale – 105cm/3.5 feet

Beil Limestone Member

17 Wackestone, fossiliferous – caninia torqua, hard, flaggy, light gray N7, medium light gray N6 fresh, weathers light olive gray 5Y6/1, dark yellowish orange 10YR6/6 –

Deer Creek Limestone Formation

18 Shale, buff, fossiliferous – 120cm/48 inches

19 Covered – 300cm/10 feet

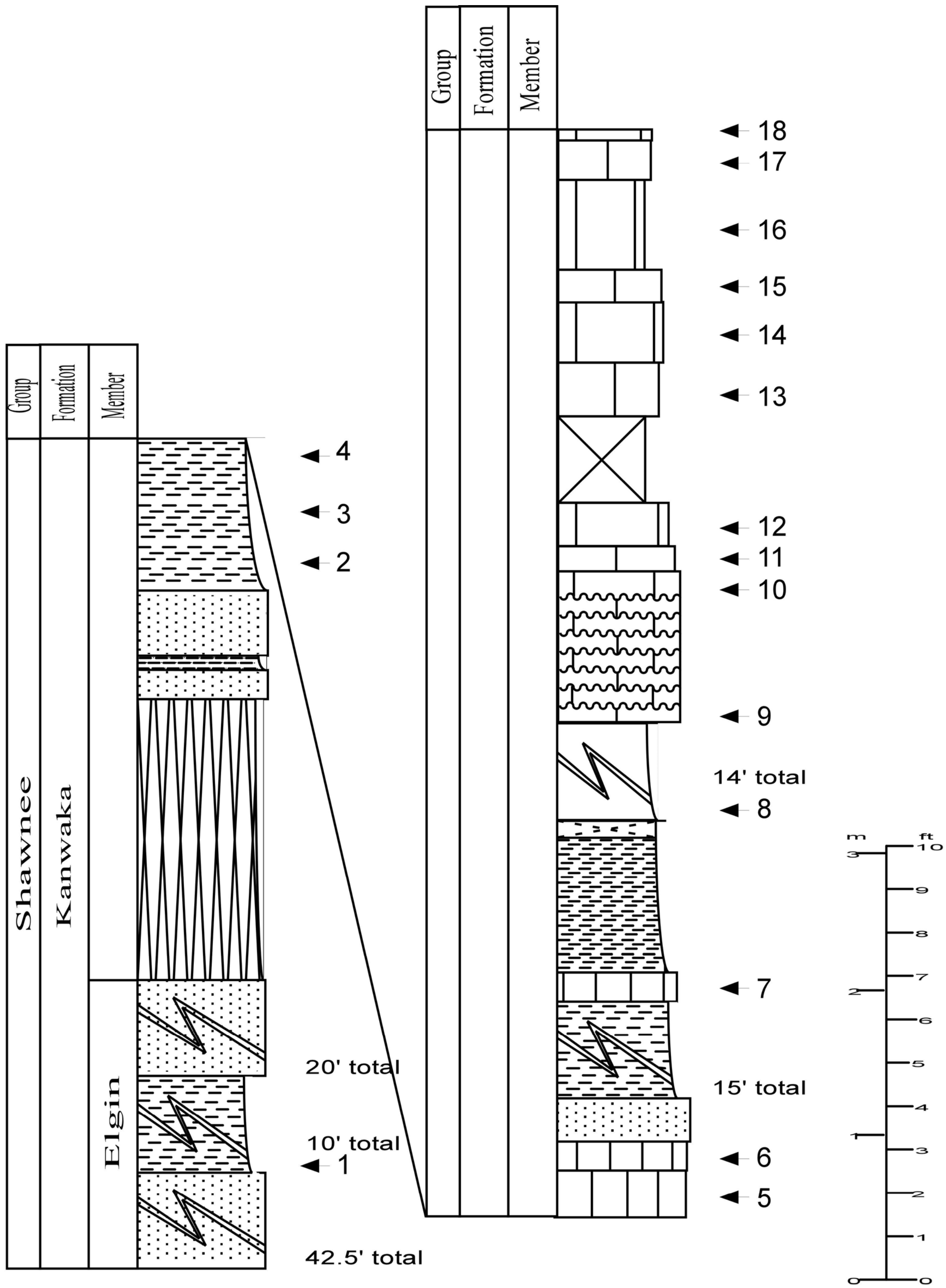


Figure 82. Stratigraphic section of locality 16.

Figure 83. Elgin Sandstone.

Figure 84. Stull Shale.

Figure 85. Ervine Creek Limestone.

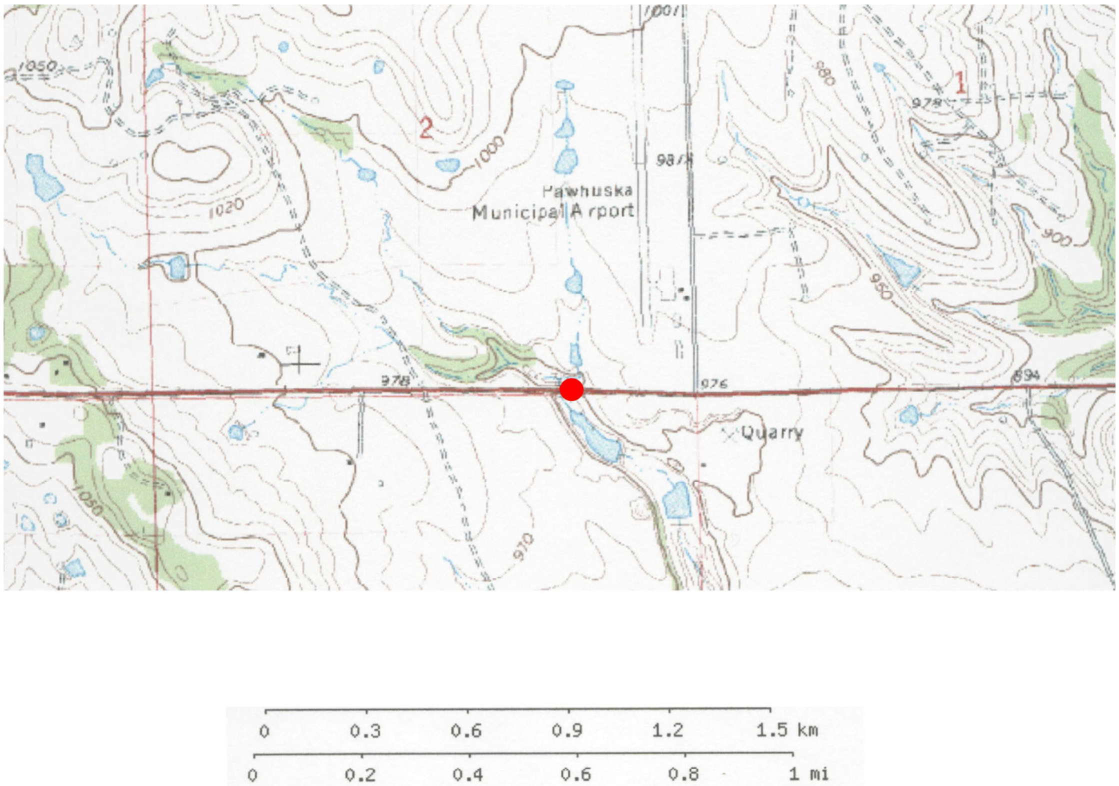


Figure 86. Location map of locality 17.

LOCATION 17: Road outcrop on highway 60, across from Bellco Materials Quarry
Very SW corner SE1/4 SE1/4 sec. 2, T25N, R8E
LATTITUDE: N36^{o}39.955'
LONGITUDE: W96^{o}24.485'

Deer Creek Limestone Formation

Larsh-burroak Shale Member

1 Shale, clayey, limonitic streaks, olive gray 5Y3/2, dark gray N3, grayish black N2 – 37.1 cm/ 14.6 inches

Ervine Creek Limestone Member

2 Massive mudstone, crystalline, fossils weather in relief, brachiopods, weathers dark yellowish orange 10YR6/6 and medium gray N5, fresh surfaces are olive gray 5Y4/1, dark gray N3, pale yellowish brown 10YR6/2 – 36.6 cm/14.4 inches

3 Shale parting, clayey, calcareous, light olive gray 5Y5/2, dusky yellow 5Y6/4, dark gray N3 – 3 cm/1.2 inches

4 Slightly fossiliferous wackestone, fine-grained, hard, thin to massive bedding, pitted surface, weathers moderate yellowish brown 10YR5/4, brownish gray 5YR4/1, and medium dark gray N4, fresh surfaces are white N9, medium gray N5, moderate yellowish brown 10YR5/4 – 113.3 cm/44.6 inches

5 Very fossiliferous wackestone, hard, contains crinoids, fusulinids, brachiopods, possible coral fragments, fossils weather in relief, weathers light brown 5YR5/6, pale yellowish brown 10YR6/2, and medium gray, fresh surfaces are light gray N7, medium light gray N6, and light olive gray 5Y6/1 – 73.7 cm/29 inches

- Upper bedding is hummocky and somewhat discontinuous – 25.9cm/10.2 inches
- Middle four beds are discontinuous and wavy – 18.8 cm/7.4 inches
- Lower beds exhibit massive bedding – 29 cm/11.4 inches

6 Fossiliferous wackestone to packstone, two thick beds, brachiopods, quartz grains, pitted surface, weathers dark gray N3, dark greenish gray 5GY4/1, and moderate brown 5YR3/4, fresh surfaces are grayish orange pink 5YR7/2, pale yellowish brown 10YR6/2, and medium light gray N6 – 19.8 cm/7.8 inches

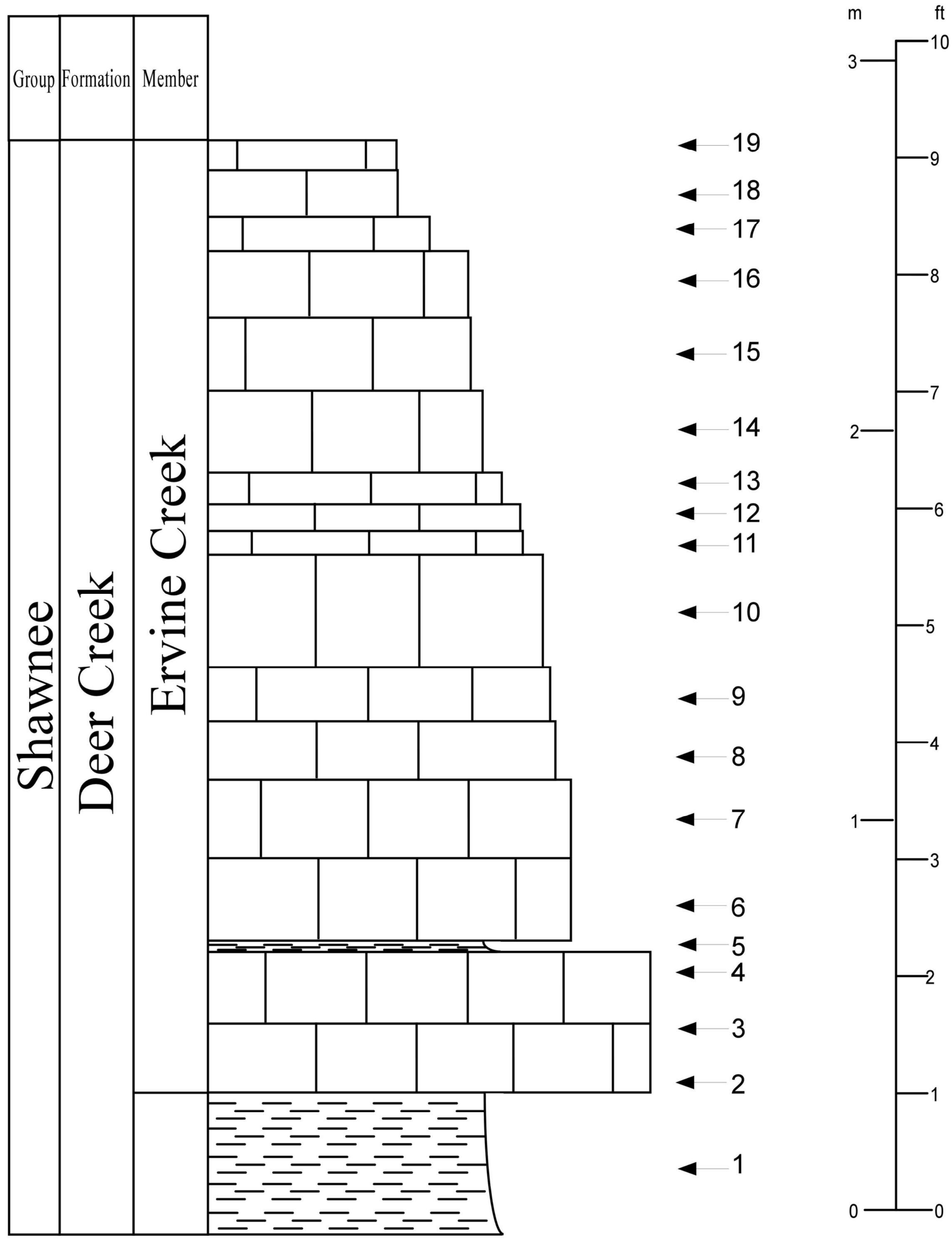


Figure 87. Stratigraphic section of locality 17.

Figure 88. Larsh-Burroak Shale.

Figure 89. Ervine Creek Limestone.

Figure 90. Location map of locality 18.

LOCATION 18: Shale pit on south side of the city of Pawhuska
NW1/4 SE1/4 NW1/4 SE1/4 sec. 9, T25N, R9E
LATTITUDE: N36°39.337'
LONGITUDE: W96°20.294'

Oread Shale Formation
Heebner Shale Member

1 Shale, blocky, limonite wedges, dark yellowish orange 10YR6/6, grayish brown 5YR3/2, dark gray N3, black N1 fresh, weathers light olive gray 5Y6/1, dark yellowish orange 10YR6/6, medium gray N5 – 152.4cm/60 inches

2 Shale, blocky, limonite laminations, limonite nodules containing fossils in basal 2/3meters (2 feet) – trilobites, archeogastropods, ammonoids, and brachiopods, medium gray N5, dark yellowish orange 10YR6/6 fresh, weathers grayish brown 5YR3/2, pale yellowish orange 10YR8/6, light olive gray 5Y6/1 – 90cm/36 inches

3 Shale, very thinly bedded, limonite streaks, light brown 5YR5/6, pale yellowish brown 10YR6/2, medium gray N5, medium light gray N6 – 30cm/12 inches

4 Shale, brown, sandy – 106.7cm/42 inches

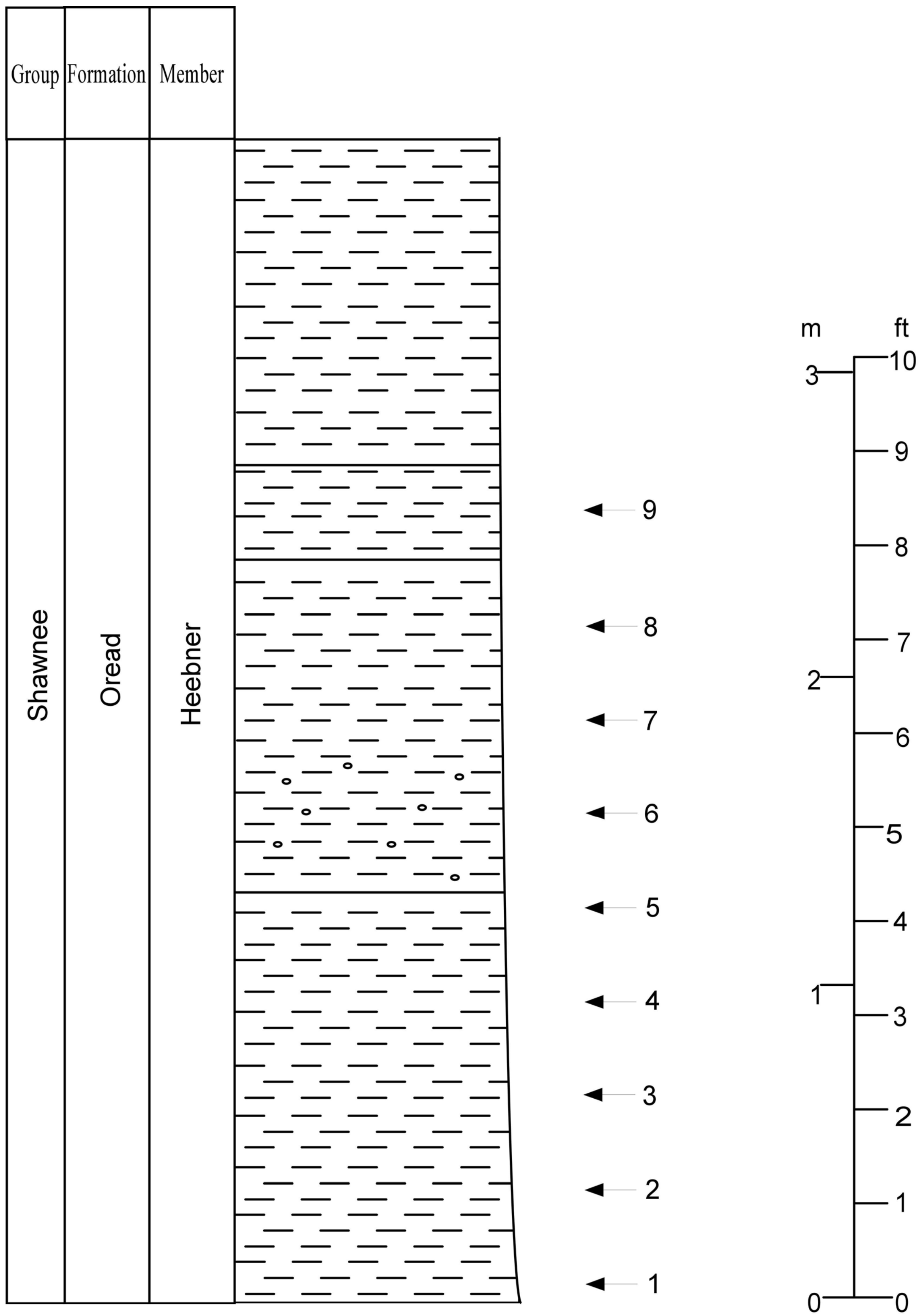


Figure 91. Stratigraphic section of locality 18.

Figure 92. Heebner Shale.

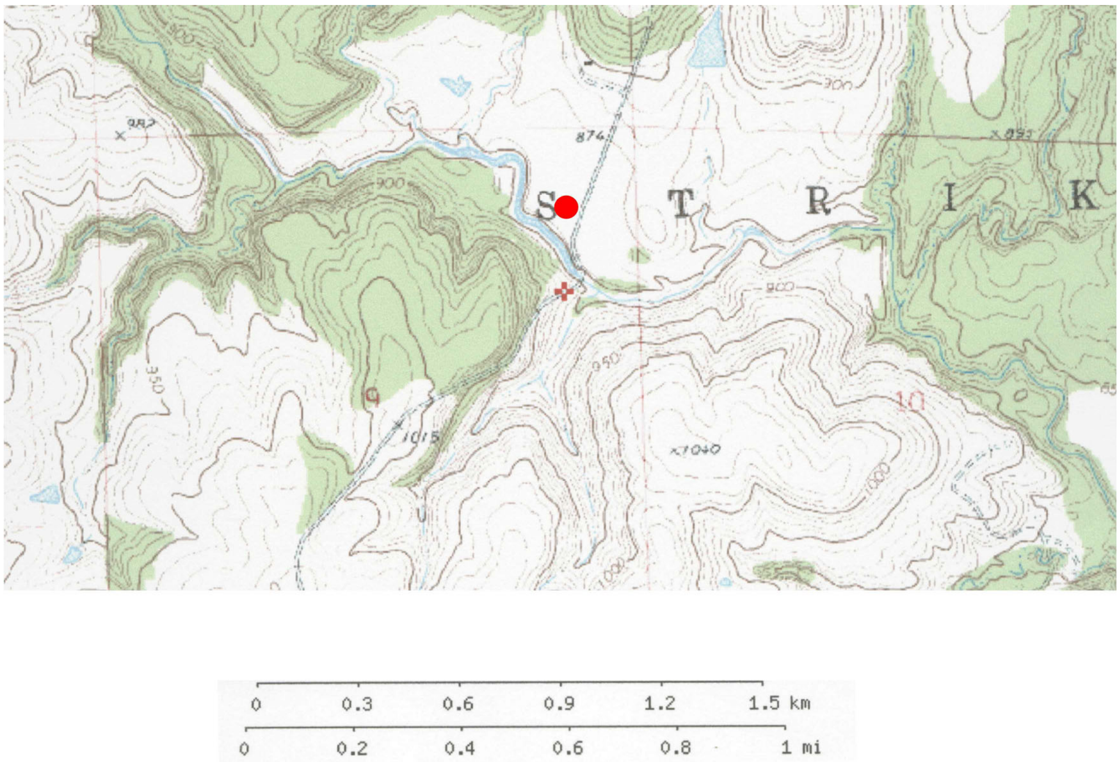


Figure 93. Location map of locality 19.

LOCATION 19: County road outcrop on Kyler Ranch
E1/2 NE1/4 SE1/4 NE1/4 sec. 9, T24N, R8E
LATTITUDE: N36^{o}34.491'
LONGITUDE: W96^{o}26.756'

Kanwaka Shale Formation

Elgin Sandstone Member

1 Sandstone, cross-bedded, - 240cm/96 inches

2 Covered – 150cm/60 inches

Lecompton Limestone Formation

Spring Branch Limestone Member

3 Calcareous sandstone at base, very pale orange 10YR8/6 fresh, weathers moderate brown 5YR3/4. Top is sandy, impure wackestone with calcite filled vugs, very pale orange 10YR8/6, light greenish gray 5G8/1 fresh, weathers moderate brown 5YR3/4, dark yellowish orange 10YR 6/6 – 52.5cm/21 inches

Doniphan Shale Member

4 Covered section, probably shale – 150cm/60 inches

Big Springs Limestone Member

5 Wackestone, bioturbated, fossiliferous, ferruginous, ripple cross-bedding, impure, pale brown 5YR5/2, dark yellowish orange 10YR6/6, moderate brown 5YR3/4 fresh, weathers moderate yellowish brown 10YR5/4, pale yellowish orange 10YR8/6, light brown 5YR5/6 – 5cm/2 inches

Queen Hill Shale Member

6 Covered, probably shale – 60cm/24 inches

7 Shale, slightly calcareous, limonitic streaks, light olive gray 5Y6/1, yellowish gray 5Y7/2 – 30cm/12 inches

8 Shale, clayey, fissile, grayish black N2, Black N1 – 30cm/12 inches

9 Shale, very thinly bedded, clayey, medium gray N5, medium dark gray N4, olive gray 5Y4/1 – 30cm/12 inches

10 Shale, calcareous, medium gray N5, light olive gray 5Y6/1 – 30cm/12 inches

11 Shale, clayey, calcareous, limonitic, medium light gray N6, light olive gray 5Y6/1 – 30cm/12 inches

12 Shale, clayey, calcareous, yellowish gray 5Y7/2, light olive gray 5Y6/1 – 30cm/12 inches

Beil Limestone Member

13 Wackestone, massive, dense, weathers into rounded boulders, fossils less abundant in middle of bed, cania torqua most abundant at top, fresh surface has bands of the following colors: dark gray N3, medium dark gray N4, medium gray N5, medium light gray N6, light brown 5YR5/6, dark yellowish orange 10YR6/6, weathers grayish yellow 5Y8/4, yellowish gray 5Y7/2, light olive gray 5Y6/1 – 62.5cm/25 inches

Shale Member

14 Covered – 900cm/30 feet

15 sandstone – 90cm/36 inches

16 covered – 195cm/6.5 feet

17 shale, clayey, calcareous, very dusky red 10R2/2, dusky brown 5YR2/2, grayish brown 5YR3/2, moderate yellowish brown 10YR5/4 – 60cm/24 inches

18 shale, clayey, silty, calcareous, grayish brown 5YR3/2, dusky yellowish brown 10YR2/2, dark yellowish orange 10YR6/6, moderate yellowish brown 10YR5/4 – 30cm/12 inches

19 sandstone with silty shale partings, bulbous at base, calcite cement, weathers with pitted surfaces and dark grayish brown, fresh surface is tanish yellow with rust spots – 225cm/7.5 feet

20 shale, sandy, calcareous, moderate yellowish brown 10YR5/4, grayish orange 10YR7/4, pale yellowish orange 10YR8/6 – 30cm/12 inches

21 shale, clayey, calcareous, medium gray N5, yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 – 30cm/12 inches

22 shale, clayey, calcareous, moderate yellowish brown 10YR5/4, grayish orange 10YR7/4, pale yellowish orange 10YR8/6, dark yellowish orange 10YR6/6, medium gray N5 – 30cm/12 inches

23 shale, clayey, light gray N7, light bluish gray 5B7/1, pale yellowish orange 10YR8/6 – 30cm/12 inches

Ervine Creek Limestone Member

24 mudstone, calcite filled fractures, limonite pebbles, impure, hard, wavy bedded, dark yellowish orange 10YR6/6, moderate brown 5YR3/4, medium light gray N6, light gray N7 fresh, weathers moderate yellowish brown 10YR5/4, dark yellowish orange 10YR6/6, dark yellowish brown 10YR4/2 –

25 mudstone, wavy bedded, impure, crystalline, hard, ferruginous, light olive gray 5Y6/1, pale yellowish orange 10YR8/6, moderate brown 5YR3/4 fresh, weathers grayish black N2, olive gray 5Y4/1, yellowish gray 5Y7/2 –

26 wackestone/packstone, wavy bedded, crystalline, fossiliferous, medium gray N5, medium light gray N6, light olive gray 5Y6/1, yellowish gray 5Y7/2 fresh, weathers medium dark gray N4, dark yellowish orange 10YR6/6 –

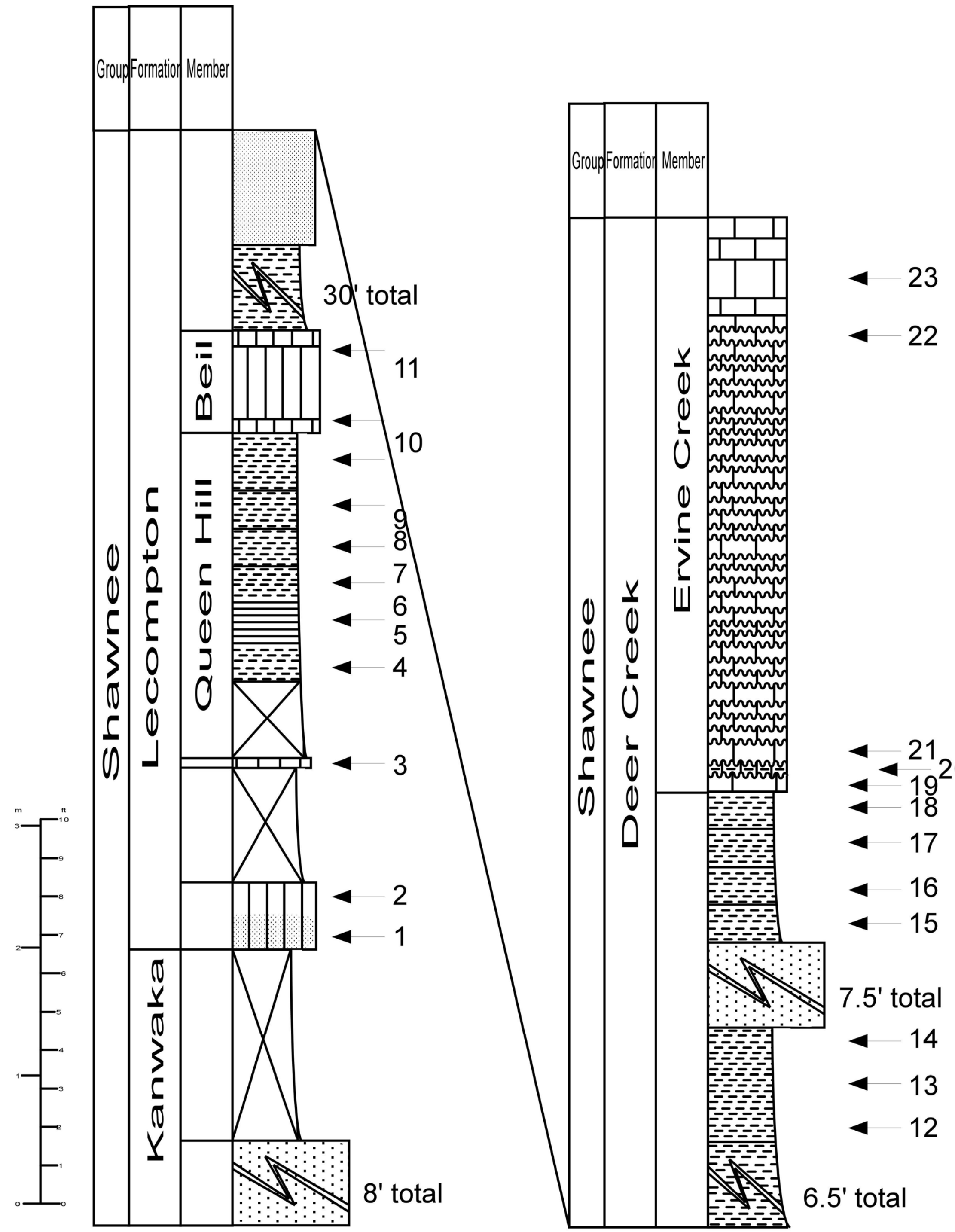


Figure 94. Stratigraphic section of locality 19.

Figure 95. Spring Branch Limestone.

Figure 96. Queen Hill Shale.

Figure 97. Beil Limestone.

Figure 98. Sandstone at the base of the Deer Creek Limestone.

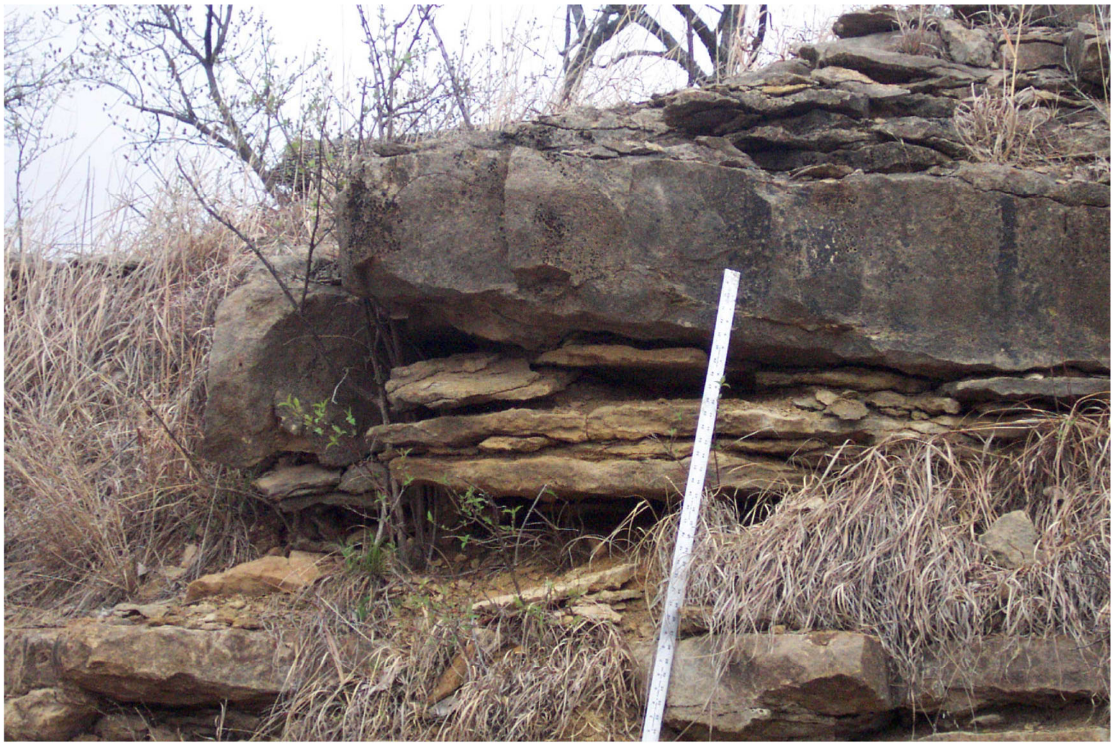


Figure 99. Deer Creek Limestone.

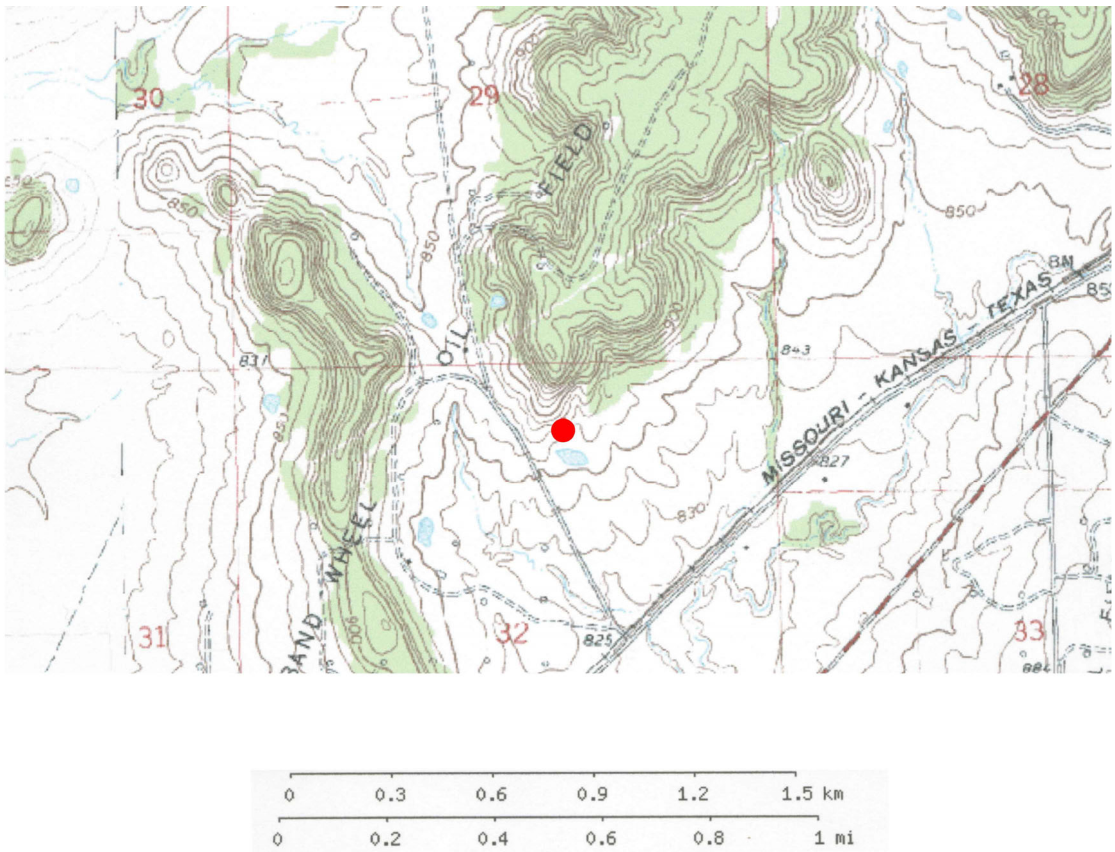


Figure 100. Location map of locality 20.

LOCATION 20: Hill in the Band Wheel Oil Field on Holcomb Ranch, on the north side of the farm road, near Wynona, Oklahoma
NW1/4 NW1/4 NE1/4 sec. 32, T24N, R9E
LATTITUDE: N36°31.154'
LONGITUDE: W96°21.647'

Oread Limestone Formation

Heebner Shale Member

1 Shale, blocky, fossiliferous – gastropods, pelecypods, ammonoids, limonite nodules, medium gray N5, medium dark gray N4 fresh, weathers light olive gray 5Y6/1 – 60cm/ 24 inches

2 Shale, blocky, fossiliferous – gastropods, pelecypods, ammonoids, limonite nodules, medium gray N5, olive gray 5Y4/1 fresh, weathers yellowish gray 5Y7/2 – 30cm/12 inches

3 Shale, clayey, very slightly calcareous, limonite nodules, light gray N8, yellowish gray 5Y8/1, pale yellowish orange 10YR8/6 – 0.625cm/.25 inches

4 Limestone, laminated, contains a 2mm rine of very fine grained sandstone, hard, light olive gray 5Y6/1 fresh, weathers brownish gray 5YR4/1, dark yellowish orange 10YR6/6 – 1.25cm/.5 inches

5 Shale, blocky, fossiliferous – gastropods, pelecypods, ammonoids, limonite nodules, medium gray N5 fresh, weathers light olive gray 5Y6/1 – 30cm/12 inches

6 Shale, blocky, limonite nodules, fossiliferous – gastropods, pelecypods, medium gray N5, greenish gray 5GY6/1 fresh, weathers light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 60cm/24 inches

7 Shale, blocky, large limonite nodules, fossiliferous – gastropods, pelecypods, medium gray N5 fresh, weathers light olive gray 5Y6/1, yellowish gray 5Y7/2, dark yellowish orange10YR6/6 – 30cm/12 inches

8 Shale, blocky, fossiliferous – gastropods, pelecypods, limonite nodules, medium light gray N6, olive gray 5Y4/1 fresh, weathers light olive gray 5Y6/1, dark yellowish orange 10YR6/6 – 30cm/12 inches

9 Covered section – 120cm/48 inches

10 Shale, limonite nodules, olive gray 5Y4/1, medium dark gray N4 fresh, weathers light olive gray 5Y6/1 – 30cm/12 inches

11 Shale, medium gray N5, olive gray 5Y4/1 fresh, weathers light olive gray 5Y6/1 – 30cm/12 inches

12 Shale, medium dark gray N4 fresh, weathers light olive gray 5Y6/1, dark yellowish orange 10YR6/6 – 30cm/12 inches

13 Shale, blocky, limonite fossils – gastropods, ammonoids, olive gray 5Y4/1 fresh, weathers dark yellowish orange 10YR6/6, light olive gray 5Y6/1 – 30cm/12 inches

14 Shale, clayey-blocky, slightly calcareous, silty, limonite fossils, abundant chir., medium gray N5 fresh, weathers light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 60cm/24 inches

15 Shale, thinly bedded, slightly calcareous, limonite fossils, medium light gray N6 fresh, weathers yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 – 30cm/12 inches

16 Shale, clayey-blocky, calcareous, limonite fossils, medium gray N5 fresh, weathers light olive gray 5Y6/1, pale yellowish orange 10YR8/6 – 30cm/12 inches

17 Shale, thinly bedded, slightly calcareous, limonite fossils, medium light gray N6 fresh, weathers yellowish gray 5Y7/2, dark yellowish orange 10YR6/6 – 60cm/24 inches

18 Shale, thinly bedded, calcareous, silty, very small limonite fossils, medium gray N5, light olive gray 5Y6/1 fresh, weathers yellowish gray 5Y7/2, yellowish gray 5Y8/1, pale yellowish orange 10YR8/6 – 90cm/36 inches

19 Shale, clayey-thinly bedded, silty, pale yellowish brown 10YR6/2, light olive gray 5Y6/1 – 1050cm/35 feet

20 Sandstone, medium grained, tanish yellow fresh, weathers brown, cross bedded – 300cm/120 inches

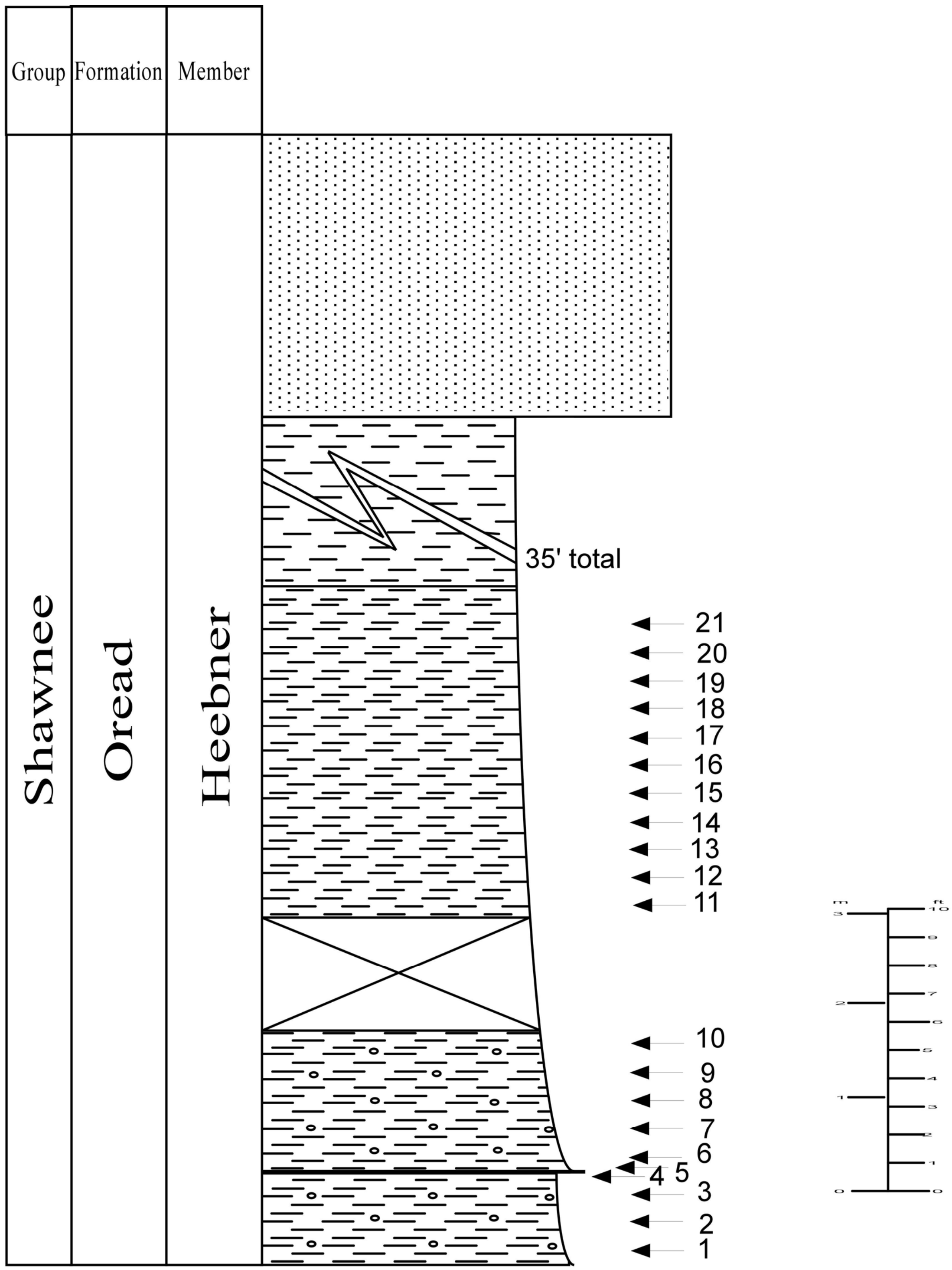


Figure 101. Stratigraphic section of locality 20.

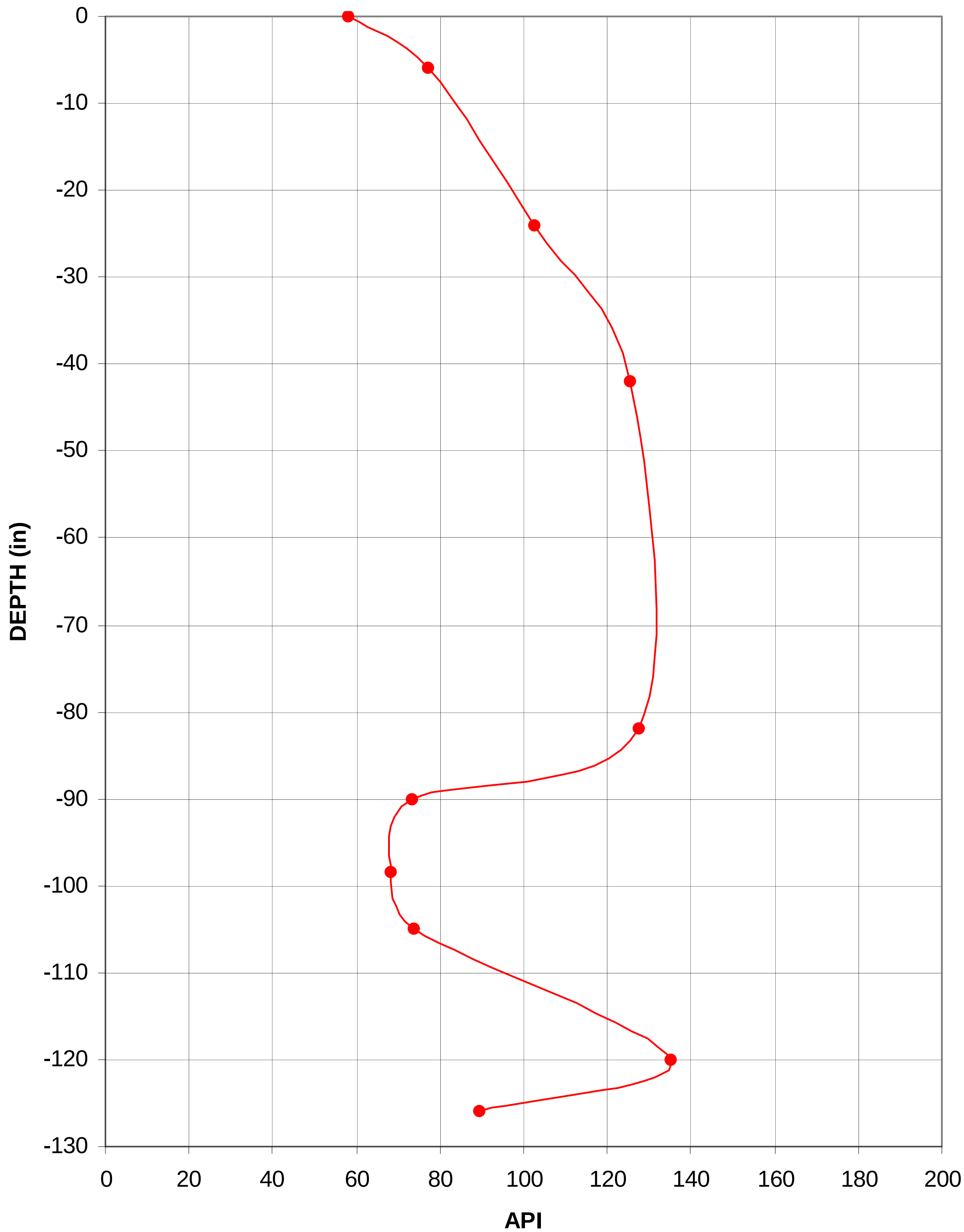
Figure 102. Photograph of locality 20.

APPENDIX B
Gamma-ray Observations

U (ppm)	TH (ppm)	K (%)	TOTAL (ppm)	API	API (+)	API(-)	DEPTH (in)	DEPTH (ft)	DESCRIPTION
1	8.9	0.9	11.7	58	70.7	45.3	0	0.00	Big Springs Limestone
1.2	12.1	1.2	14.2	77.2	94.1	60.3	-6	-0.50	Doniphan Shale
2.5	12.6	2	19.5	102.4	124	80.8	-24	-2.00	Doniphan Shale
1.8	17.4	2.6	23.3	125.6	151.8	99.4	-42	-3.50	Doniphan Paleosol
3.5	15.3	2.4	23.9	127.6	154.7	100.5	-82	-6.83	Doniphan Shale
2.8	8.7	1	13.4	73.2	89.5	56.9	-90	-7.50	Spring Branch Limestone
3.3	6.9	0.9	13	68.4	83.7	53.1	-98.5	-8.21	Spring Branch Limestone
3.4	7.2	1.1	13.3	73.6	89.8	57.4	-105	-8.75	Spring Branch Limestone
4.8	15.8	2.1	22.2	135.2	164.8	105.6	-120	-10.00	Stull Shale
2.3	14.2	0.9	15.4	89.6	110.2	69	-126	-10.50	Stull Sandstone

Table 1. Gamma-ray readings for locality 8.

Figure 103. Gamma-ray curve for locality 8.



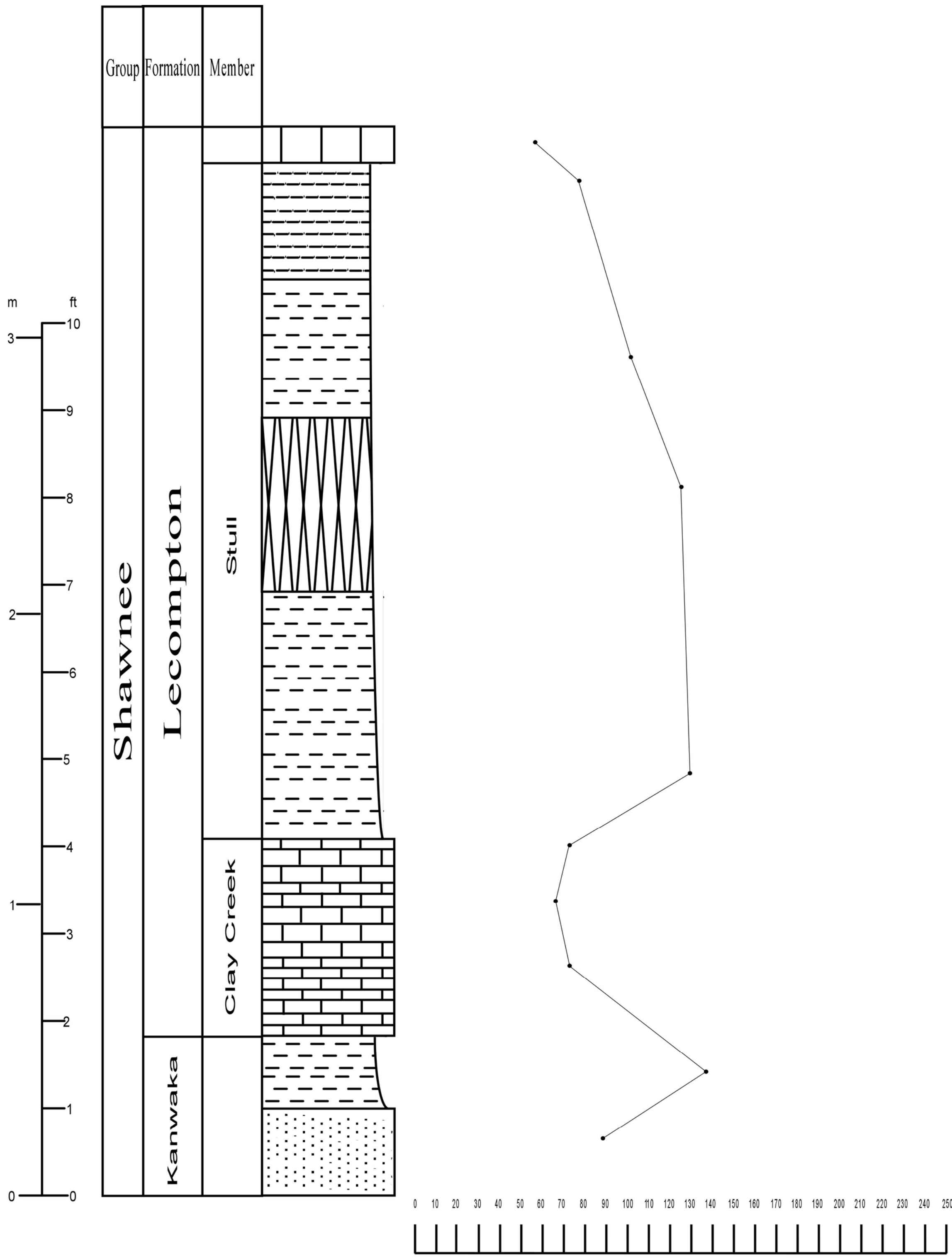
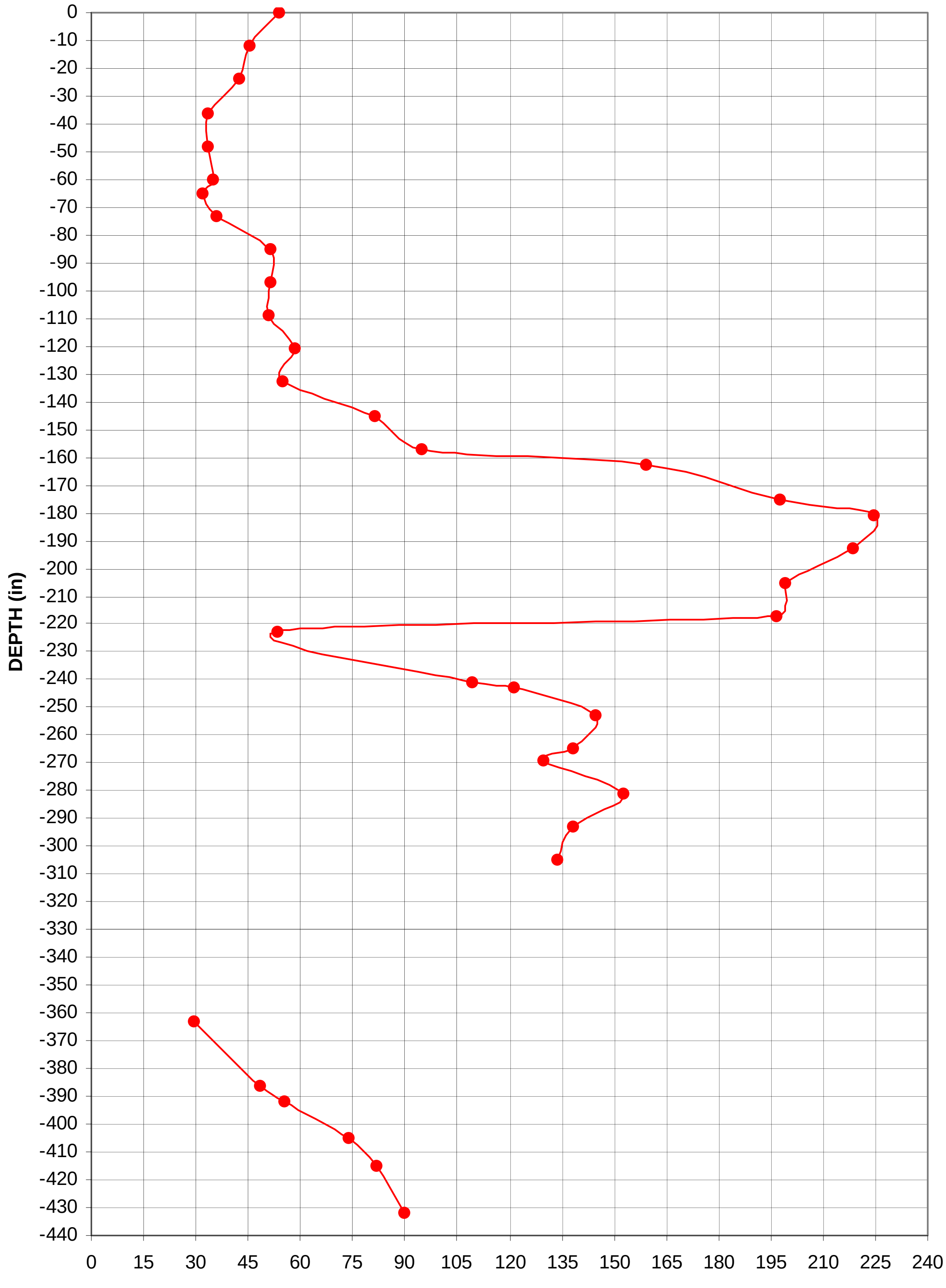


Figure 104. Sea-level curve for locality 7

U (ppm)	TH(ppm)	K (%)	API	API (+)	API(-)	DEPTH (in)	DEPTH (ft)	DESCRIPTION
5.6	1.3	0.2	53.92	66.92	40.91	0	0	upper Plattsmouth
4.5	1.9	0.1	45.64	56.79	34.50	-12	-1	upper Plattsmouth
4.1	2.3	0.1	42.46	52.98	31.95	-24	-2	upper Plattsmouth
3.4	0.3	0.3	33.49	41.21	25.77	-36	-3	upper Plattsmouth
3.0	1.6	0.2	33.34	41.32	25.37	-48	-4	upper Plattsmouth
3.3	1.2	0.2	34.94	43.20	26.69	-60	-5	upper Plattsmouth
3.1	0.8	0.3	32.10	39.60	24.60	-65	-5.42	upper Plattsmouth
3.7	0.3	0.3	35.72	44.01	27.43	-73	-6.08	lower Plattsmouth
4.7	2.7	0.2	51.51	63.99	39.03	-85	-7.08	lower Plattsmouth
4.8	2.4	0.2	51.20	63.58	38.83	-97	-8.08	lower Plattsmouth
4.7	1.5	0.5	50.97	62.76	39.17	-109	-9.08	lower Plattsmouth
5.6	1.3	0.5	58.28	71.83	44.73	-121	-10.08	lower Plattsmouth
5.6	1.5	0.3	55.06	68.24	41.87	-133	-11.08	lower Plattsmouth
4.5	5.1	1.6	81.54	98.72	64.35	-145	-12.08	lower Plattsmouth
4.6	6.7	1.9	94.79	114.60	74.97	-157	-13.08	lower Plattsmouth
4.5	15.6	3.8	159.13	191.33	126.92	-163	-13.58	Heebner
6.7	19.3	4.2	197.68	238.79	156.57	-175	-14.58	Heebner
9.2	18.4	4.8	224.46	270.96	177.96	-181	-15.08	Heebner
10.8	16.5	4.1	218.55	264.92	172.18	-193	-16.08	Heebner
9.8	14.7	3.8	198.93	240.98	156.89	-205	-17.08	Heebner
9.8	14.4	3.8	196.73	238.28	155.18	-217	-18.08	Heebner
3.8	3.3	0.6	53.34	65.46	41.23	-223	-18.58	Leavenworth
5.0	10.1	1.8	109.20	132.90	85.50	-241	-20.08	Leavenworth
4.7	13.3	1.9	121.20	147.70	94.70	-243	-20.25	Snyderville
5.8	14.6	2.5	144.80	176.00	113.60	-253	-21.08	Snyderville
7.7	10.3	2.2	138.00	168.10	107.90	-265	-22.08	Snyderville
5.5	12.2	2.3	129.60	157.40	101.80	-269	-22.42	Snyderville
5.5	14.4	3.2	152.80	184.60	121.00	-281	-23.42	Snyderville
3.2	14.5	3.4	138.00	165.70	110.30	-293	-24.42	Snyderville
4.6	12.2	3.0	133.60	161.00	106.20	-305	-25.42	Snyderville
						-362.96	-30.25	covered
0.9	4.3	0.3	29.20	35.90	22.50	-362.96	-30.25	Toronto
0.3	7.9	0.9	48.40	58.70	38.10	-385.96	-32.16	Toronto
0.7	8.8	0.9	55.20	67.20	43.20	-391.96	-32.66	Toronto
1.2	10.0	1.5	73.60	89.00	58.20	-404.96	-33.75	Toronto
0.9	11.4	1.8	81.60	98.40	64.80	-414.96	-34.58	Lawrence
1.8	11.3	1.9	90.00	108.70	71.30	-431.96	-36.00	Lawrence

Table 2. Gamma-ray readings for locality 14.

Figure 105. Gamma-ray curve for locality 14.



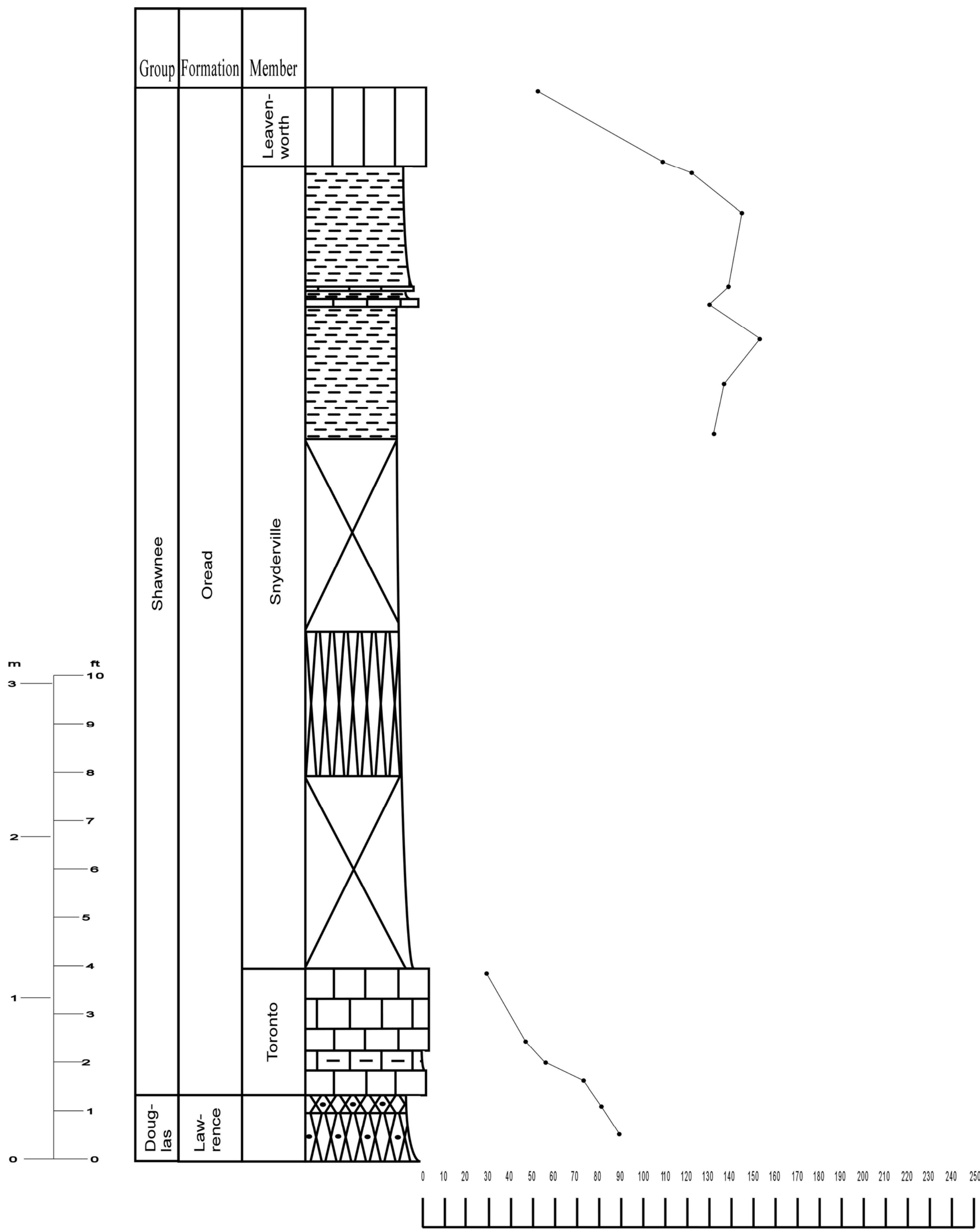


Figure 106.. Sea-level curve of the base of locality 14.

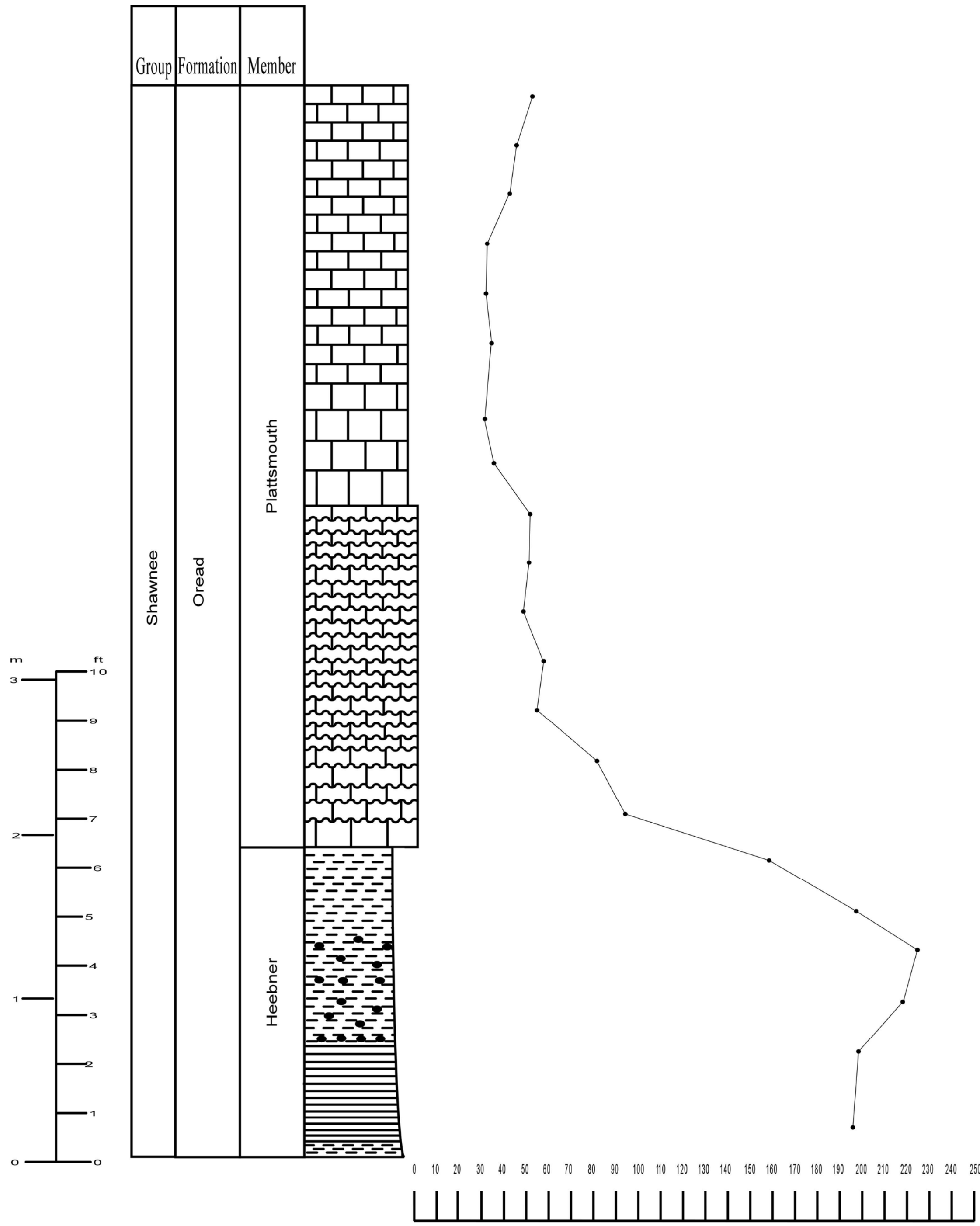
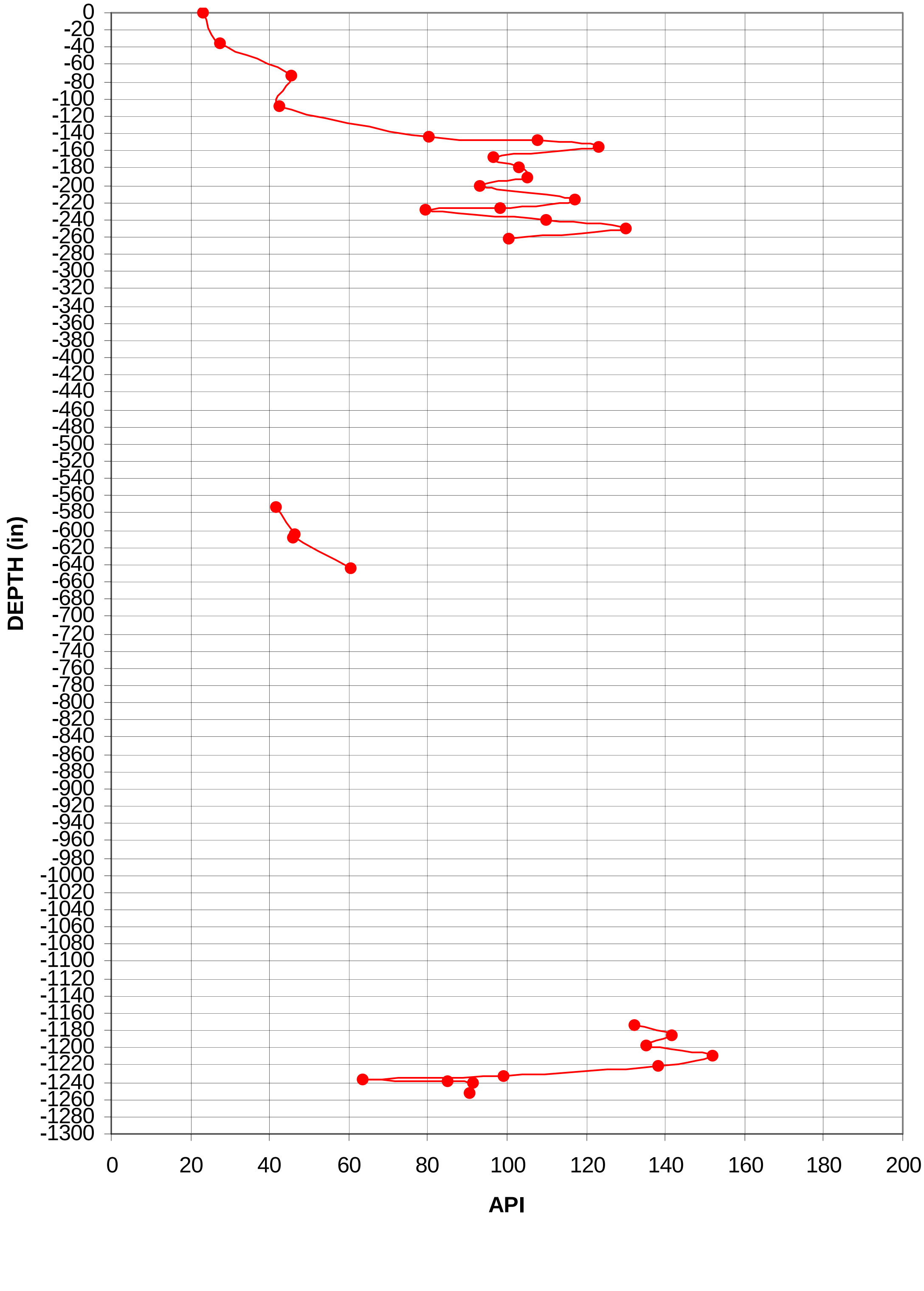


Figure 107. Sea-level curve of the top of locality 14.

U (ppm)	TH (ppm)	K (%)	TOTAL (ppm)	API	API (+)	API(-)	DEPTH (in)	DEPTH (ft)	DESCRIPTION
1.3	2.8	0.1	5.3	23.2	28.8	17.6	0	0.00	sandstone
1.3	3.5	0.2	5.9	27.6	34.1	21.1	-36	-3.00	sandstone
1.1	6.4	0.7	9.4	45.6	55.6	35.6	-72	-6.00	sandstone
2	5.4	0.3	7.7	42.4	52.4	32.4	-108	-9.00	sandstone
2.3	9.5	1.5	15	80.4	97.5	63.3	-144	-12.00	sandstone
1.7	14.3	2.3	21.6	107.6	129.9	85.3	-148	-12.33	green paleosol
3.4	14.4	2.4	21.7	123.2	149.2	97.2	-156	-13.00	maroon paleosol
2.3	11.5	2	19.3	96.4	116.5	76.3	-168	-14.00	grn & mrn paleosol
2.5	12.3	2.1	19.2	102.8	124.3	81.3	-180	-15.00	grn & mrn paleosol
3.5	10.9	2.1	19.5	105.2	127.3	83.1	-192	-16.00	maroon paleosol
1.7	10.7	2.3	19.1	93.2	111.9	74.5	-201	-16.75	green paleosol
1.2	15.7	2.8	21.5	117.2	140.9	93.5	-217	-18.08	maroon paleosol
1.9	12.4	2.1	19.2	98.4	118.8	78	-226	-18.83	green paleosol
1.9	9.6	1.6	16.4	79.2	95.8	62.6	-228	-19.00	siltstone
2.3	12.1	2.7	22.6	110	132.1	87.9	-240	-20.00	siltstone
2.9	15.1	2.9	25.3	130	156.7	103.3	-250	-20.83	green paleosol
1.8	12.3	2.3	20	100.4	120.9	79.9	-262	-21.83	maroon paleosol
							-286	-23.83	sandstone
							-346	-28.83	sandstone
							-406	-33.83	sandstone
							-466	-38.83	sandstone
							-526	-43.83	covered shale
1.5	5	0.6	8.1	41.6	50.8	32.4	-574	-47.83	limestone
1.7	6.6	0.4	8.5	46.4	57.2	35.6	-604	-50.33	sandstone
1.8	6.3	0.4	8	46	56.7	35.3	-609	-50.75	sandstone
1.7	9.7	0.5	10.9	60.4	74.5	46.3	-644	-53.67	sandstone
							-646	-53.83	covered shale
2.9	17.7	2.4	24.1	132.4	160.7	104.1	-1174	-97.83	Heebner
3.6	16.2	3	25.6	141.6	171	112.2	-1186	-98.83	Heebner
3.1	15.6	3	26.7	135.2	163	107.4	-1198	-99.83	Heebner
3.7	17.8	3.2	28.4	152	183.6	120.4	-1210	-100.83	Heebner
1.7	16.4	3.7	28.1	138.4	165.6	111.2	-1222	-101.83	Heebner
2.7	9.8	2.4	19.6	99.2	119.2	79.2	-1234	-102.83	Leavenworth
0.7	9.3	1.3	13.1	63.6	76.9	50.3	-1236	-103.00	Leavenworth
3.1	9	1.5	15.9	84.8	103	66.6	-1239	-103.25	Leavenworth
3.4	10.1	1.5	17.4	91.6	111.5	71.7	-1241	1.25	Snyderville
2.8	10.2	1.7	17	90.4	109.6	71.2	-1252	-104.33	Snyderville

Table 3. Gamma-ray readings for locality 15.

Figure 108. Gamma-ray curve for locality 15.



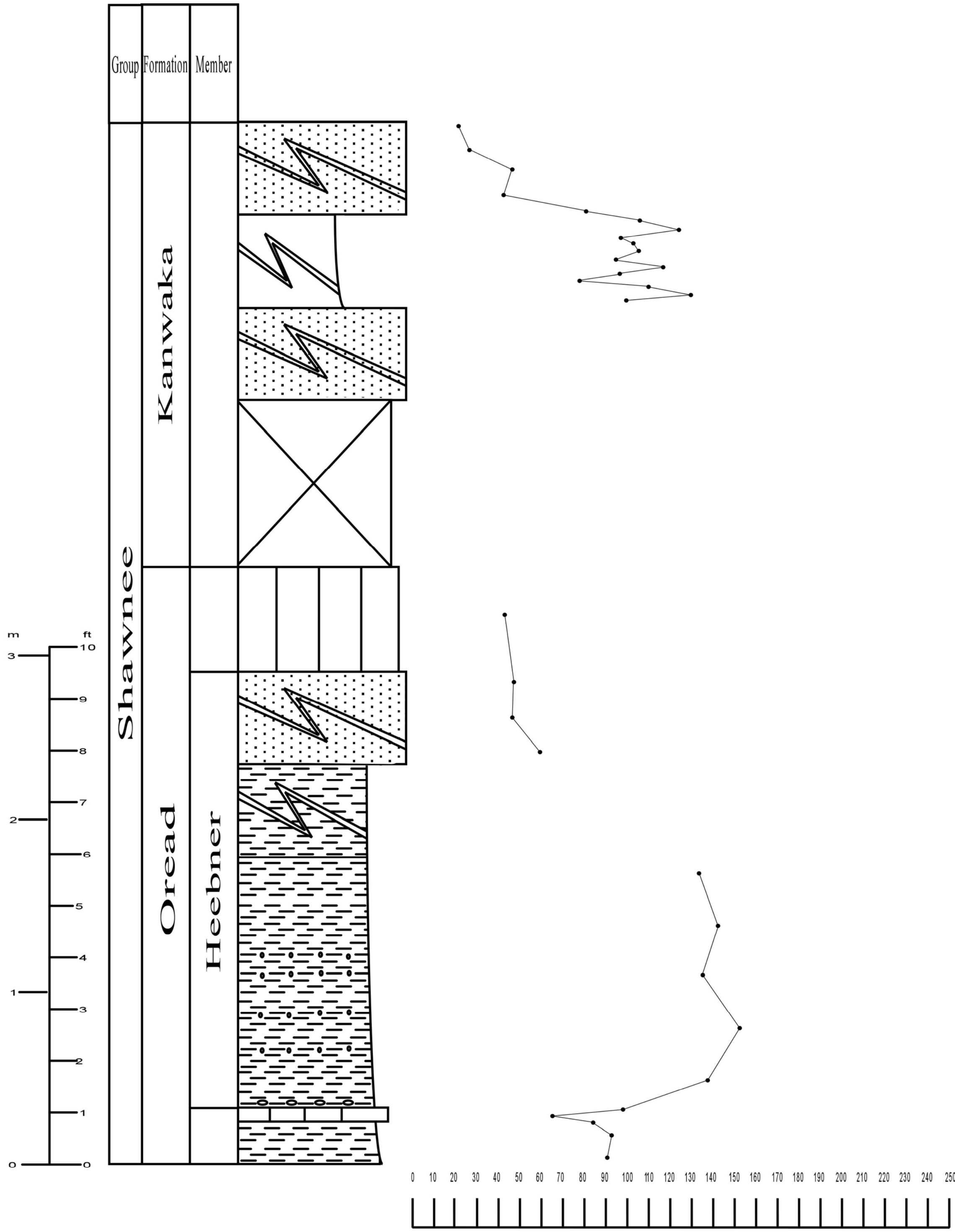
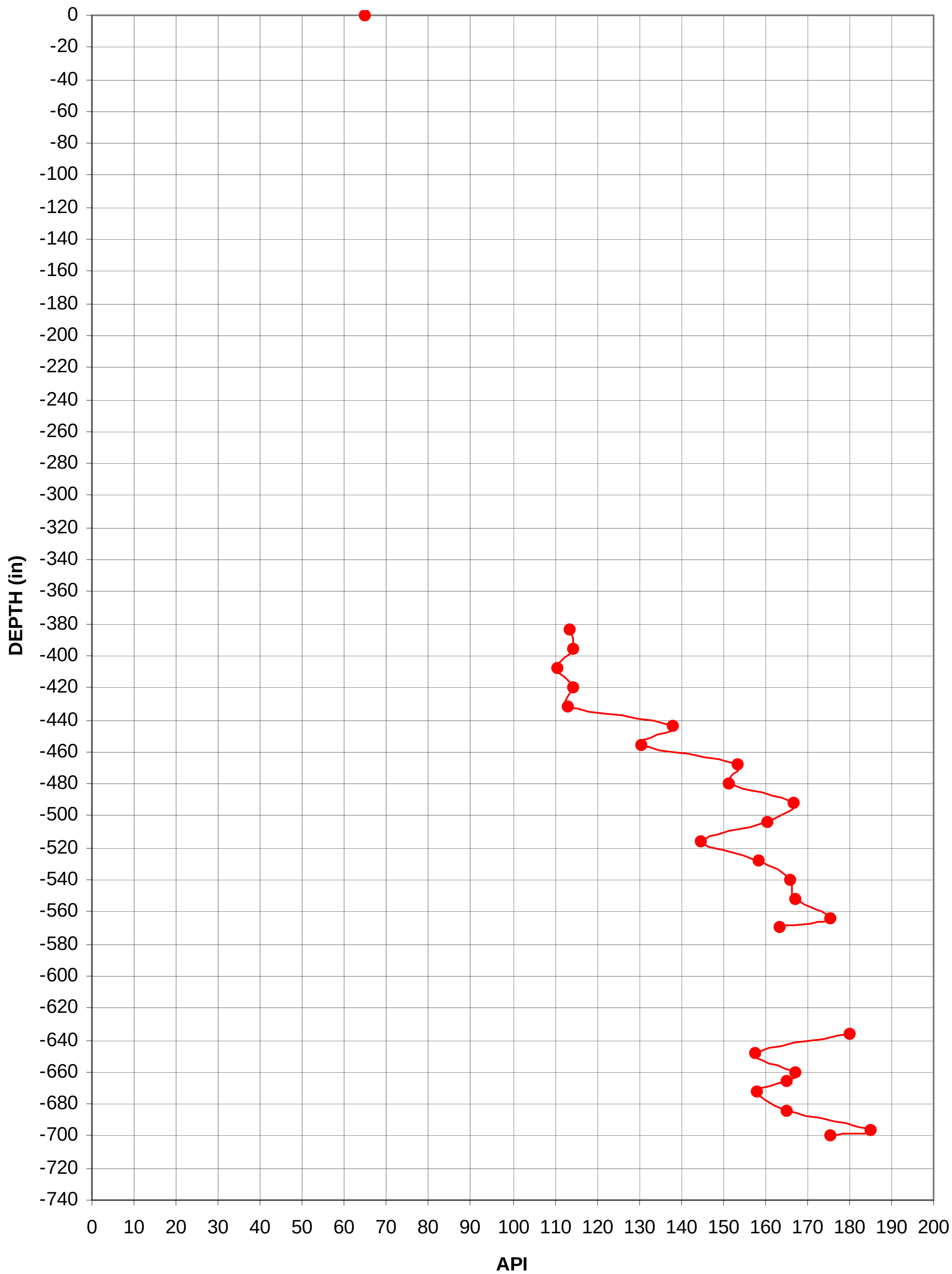


Figure 109. Sea-level curve for locality 15.

U (ppm)	TH (ppm)	K (%)	TOTAL (ppm)	API	API (+)	API(-)	DEPTH (in)	DEPTH (ft)	DESCRIPTION
1.9	7.6	1.2	13.5	64.8	78.6	51	0	0.00	base of sandstone
							-372	-31.00	covered
2.9	13.4	2.3	21.5	113.6	137.4	89.8	-384	-32.00	shale
2.7	12.8	2.6	22.2	114.4	137.8	91	-396	-33.00	shale
2.3	13.8	2.3	21.7	110.4	133.4	87.4	-408	-34.00	shale
1.7	15.6	2.4	21.6	114.4	138.2	90.6	-420	-35.00	shale
2.5	12.5	2.7	23.3	113.2	136.1	90.3	-432	-36.00	shale
4.1	14.7	2.9	25.9	138	166.7	109.3	-444	-37.00	shale
3.7	12.4	3.2	27.1	130.4	156.6	104.2	-456	-38.00	shale
4.3	15	3.7	28.1	153.6	184.6	122.6	-468	-39.00	shale
3	17.4	3.6	30	151.2	181.8	120.6	-480	-40.00	shale
4.3	19.5	3.4	30.4	166.8	201.7	131.9	-492	-41.00	shale
3.1	19.5	3.6	29.4	160.4	193.3	127.5	-504	-42.00	shale
3.9	15.2	3.3	28.8	144.8	174.4	115.2	-516	-43.00	shale
3.3	19.4	3.4	30.6	158.4	191.2	125.6	-528	-44.00	shale
3.3	19.3	3.9	32.6	166	199.7	132.3	-540	-45.00	shale
4.6	17.4	3.8	31.6	167.2	201.4	133	-552	-46.00	shale
5.8	17.9	3.6	31.9	175.6	212.3	138.9	-564	-47.00	shale
5	16.1	3.7	31.8	163.6	197.1	130.1	-570	-47.50	shale
							-618	-51.50	covered
3	22.2	4.2	33.4	180	216.6	143.4	-636	-53.00	shale
2.2	19	4	30.3	157.6	189	126.2	-648	-54.00	shale
2.3	21.2	4	32.1	167.2	201	133.4	-660	-55.00	shale
5	16.5	3.7	31.7	165.2	199.1	131.3	-666	-55.50	limestone
2.8	19.1	3.7	30.7	158	190.1	125.9	-672	-56.00	shale
3.9	16.3	4.3	33.3	165.2	197.9	132.5	-684	-57.00	shale
5.6	17.5	4.4	34.2	185.2	222.7	147.7	-696	-58.00	shale
5	18.3	3.9	32.7	175.6	211.7	139.5	-700	-58.33	shale

Table 4. Gamma-ray curve for locality 20.

Figure 110. Gamma-ray curve for locality 20.



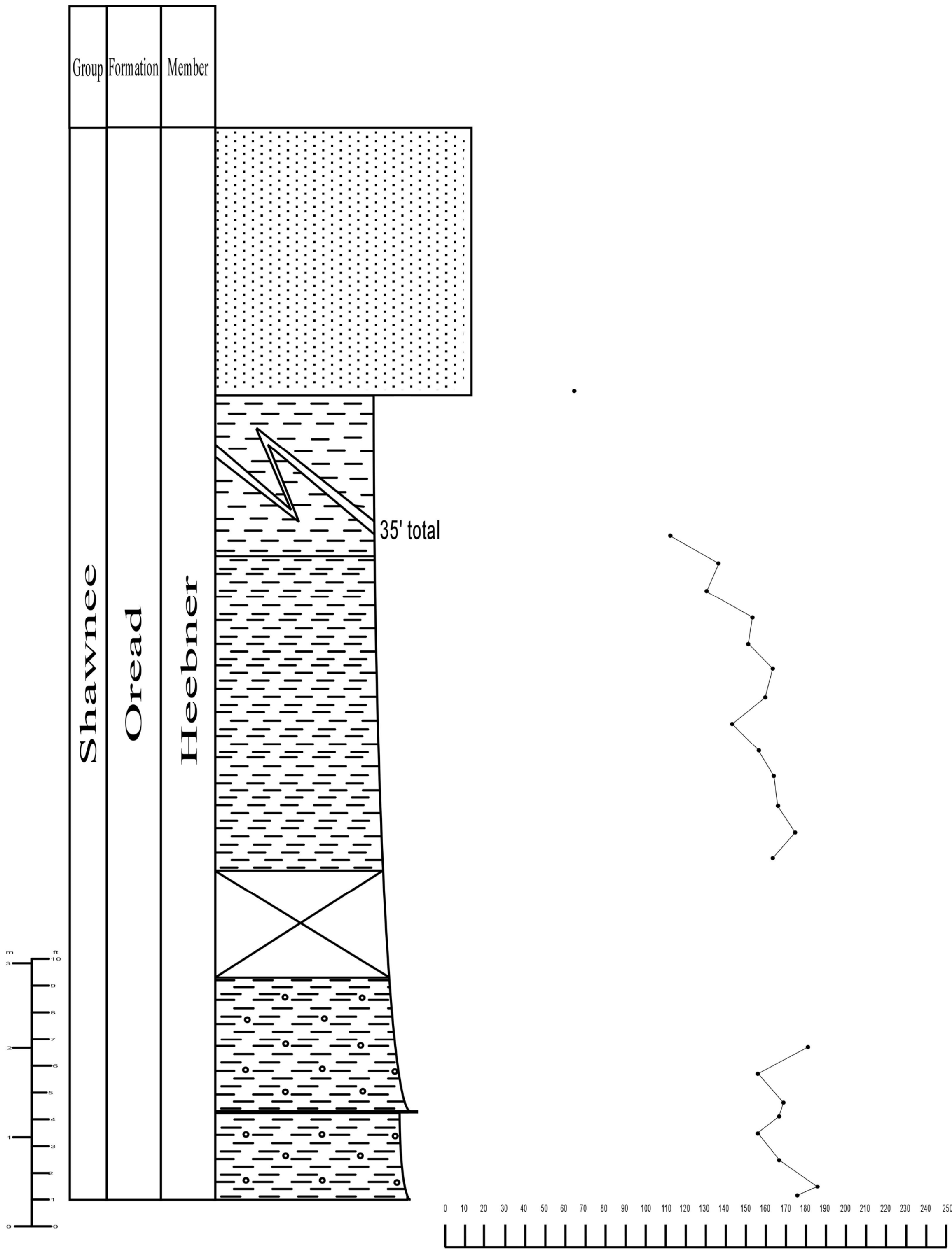


Figure 111. Sea-level curve for locality 20.

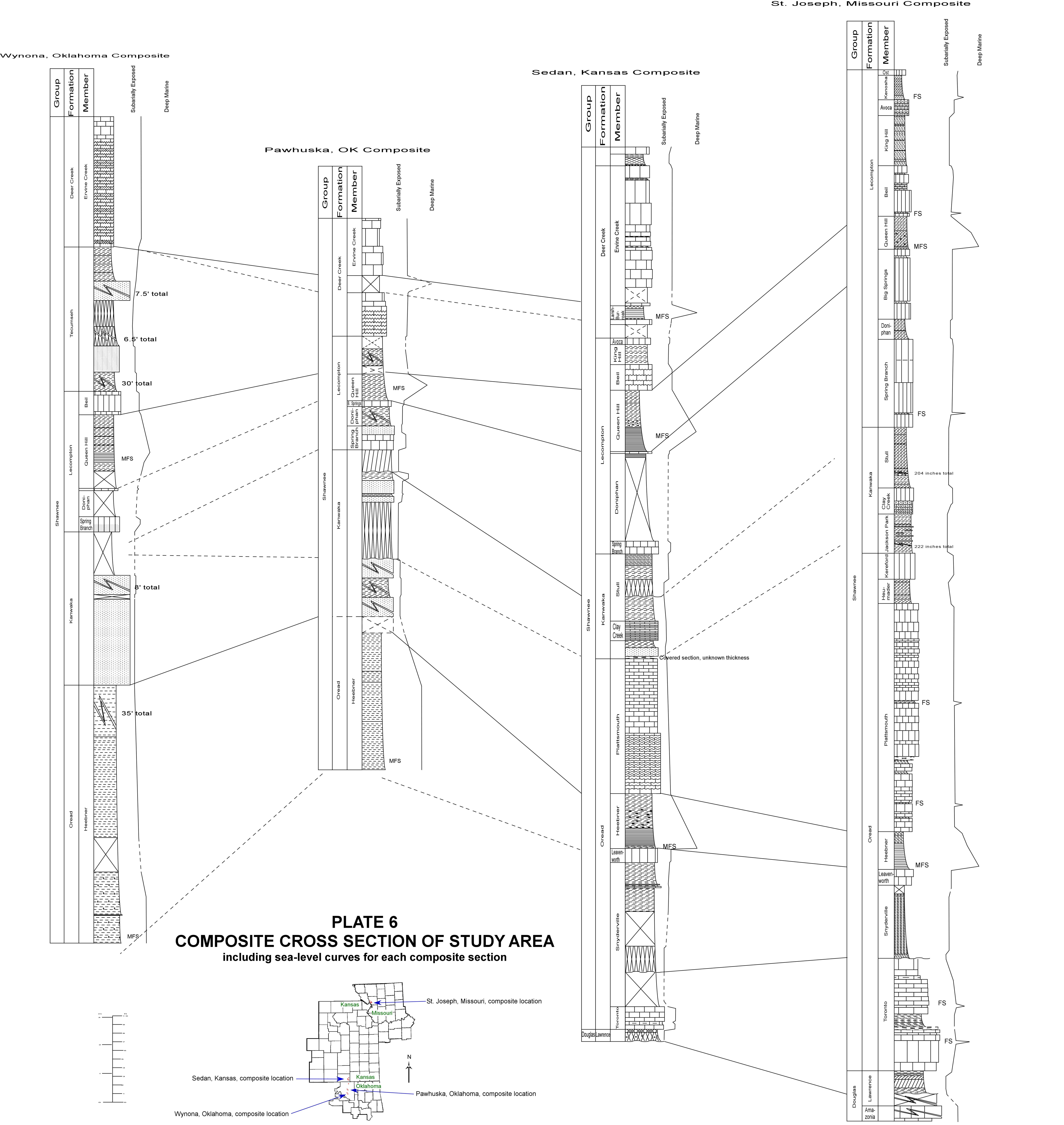


PLATE 6
COMPOSITE CROSS SECTION OF STUDY AREA
including sea-level curves for each composite section

VITA

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Master of Science

Thesis: HIGH RESOLUTION CORRELATION OF THE SHAWNEE GROUP (VIRGILIAN, PENNSYLVANIAN) CYCLOTHEMS FROM NORTHWESTERN MISSOURI TO EXPOSURES IN SOUTHERN KANSAS AND NORTHERN OKLAHOMA

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