Chapter 2: Coal Deposits of the Cherokee Basin

Previous work by Harris (1984) and Stanton (1987) divided the Cherokee Group into ten stratigraphic intervals using laterally persistent dark-gray to black "core" shales as stratigraphic markers (Figure 2.01). These highly radioactive black shales (150-300+ API units) are readily identifiable on gamma-ray well logs and are correlatable throughout eastern Kansas and into adjacent states. These "hot" gamma-ray shales serve as marker beds for the major coals within the study area. A composite section illustrates the stratigraphic relationship between marker beds and other units used in the study (Harris, 1984; Figure 2.02). In this study, an additional interval (Little Osage interval) was added above the Cherokee Group. The Little Osage interval contains the Summit coal of the Fort Scott Limestone a significant coal and important exploration target in southeast Kansas (Figure 2.01). Depositional environments in the Cherokee Group range from relatively deep, low energy marine environments to shallow, marginal marine and nonmarine environments. Due to significant hiatus before and after peat development, depositional environments of coals may not be directly related to the environments of the overlying or underlying sediments (McCabe, 1984). Depositional environments of coals may be better reflected by their geometry, average thickness, areal extent, orientation, ash content, and sulfur content (Flores, 1993, McCabe and Shanley, 1992).

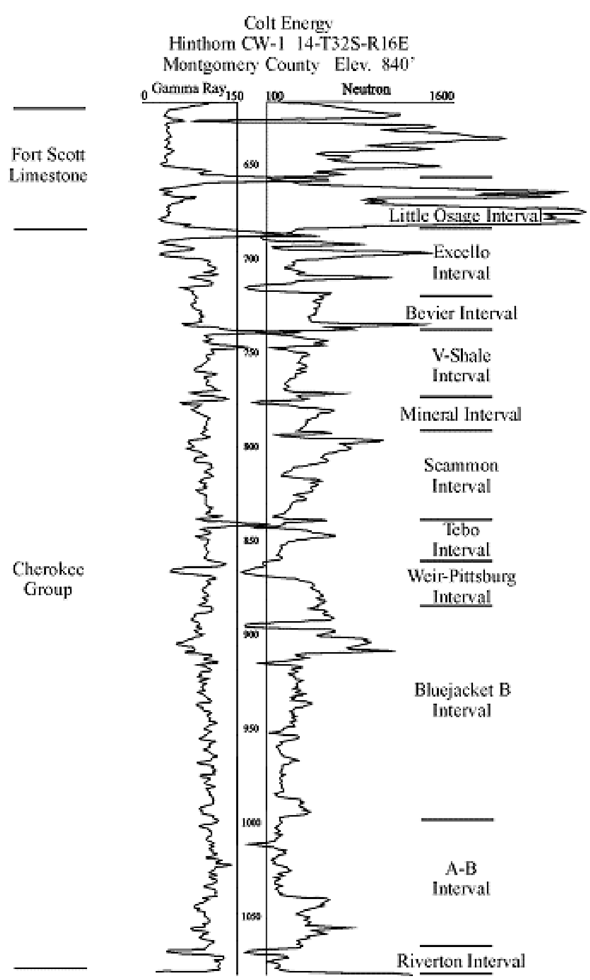


Figure 2.01 - Type log of the Cherokee Group and lower Fort Scott Limestone in the Cherokee Basin with designated intervals defined by marker beds, which are primarily dark gray to black shales (after Staton, 1987).

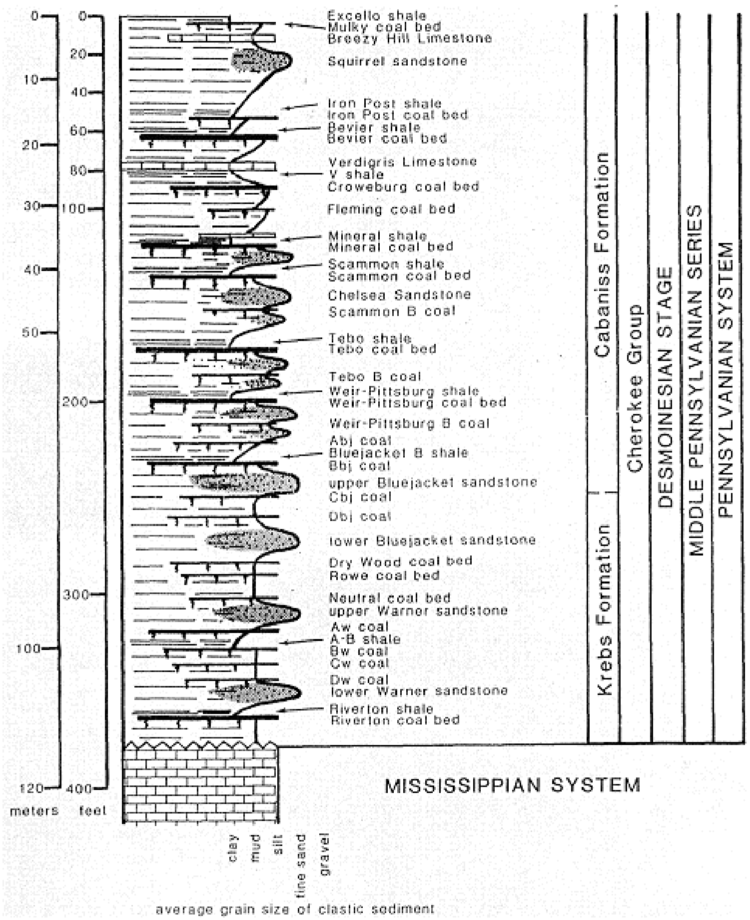


Figure 2.02 - Composite section of the Cherokee Group in southeastern Kansas showing relationship of marker beds, which are primarily dark gray to black radioactive shales and major named coals (modified from Harris, 1984)

2.1 Lithofacies and Depositional Environments of the Cherokee Group

Ten lithofacies were recognized in the Cherokee Group of southeast Kansas (Table 2.1). The depositional environment of each lithofacies was interpreted based on mineralogy, sedimentary structures, ichnology, log response and stratigraphic position of described cores (Table 2.1; Appendix 1). Individual lithofacies are listed below, along with an interpretation of the depositional process and sedimentary environment.

Table 2.1 - Facies scheme for the Cherokee Group in the Cherokee basin.

Lithofacies	Depositional Process	Sedimentary Environment
Coal to carbonaceous shale	Peat growth	Mire
Blocky mudstone	Pedogenesis	Paleosol
Pyritic shale	Sediment fallout	Coastal marsh-swamp
Interlaminated sandstone and siltstone	Tidal currents and slack-water sediment fallout	Marginal marine
Sideritic gray shale	Sediment fallout and low-energy tidal currents	Marginal marine
Laminated muddy sandstone	Tidal currents and slack-water sediment fallout	Muddy tidal flat
Bioclastic packstone to grainstone	Reworking by waves or tides and bioturbation	Marine, above fair-weather wave base
Bioclastic mudstone to wackestone	Bioturbation	Open marine, below fair-weather wave base
Dark gray shale	Storm action and sediment fallout	Offshore transition
Phosphatic black shale	Sediment fallout	Low oxygen shelf

2.1.1 Coal Facies

Description
The coal facies vary from low ash coal to high ash coal to carbonaceous shale. Diagnostic features of the coal are black color, moderately bright luster, laminations (3-10 mm), and moderate to well developed cleats (Figure 2.03). Diagnostic features of the carbonaceous shale are black color, moderately bright luster, and laminations (3-10 mm). Cleat spacing can vary widely (0.25 to 2 inches; 0.6 to 5 cm). Cleats are typically mineralized with calcite, pyrite and sulfur. Plant fragments are found throughout the facies. No trace or body fossils were observed in the coal facies. The coals facies ranges in thickness up to 6 feet (1.8 m). Lower and upper contacts are consistently sharp.

Paleoenvironmental Interpretation
The close association with marine detritus or marine carbonate sediments can explain the high-ash and carbonaceous nature of a coal. Peat growth exposed to the marine or fluvial environment is interpreted to be the cause of the carbonaceous shale or high-ash coals, while low-ash coal develops in mires protected from marine and fluvial influence. Coal splits are an indication of the margin of a coal seam and the margin of the mire. High sulfur contents are an indicator of increased marine influence during the coalification process. Historically, the coal facies would be interpreted as part of the “outside shale” in the cyclothem model (Heckel, 1977).

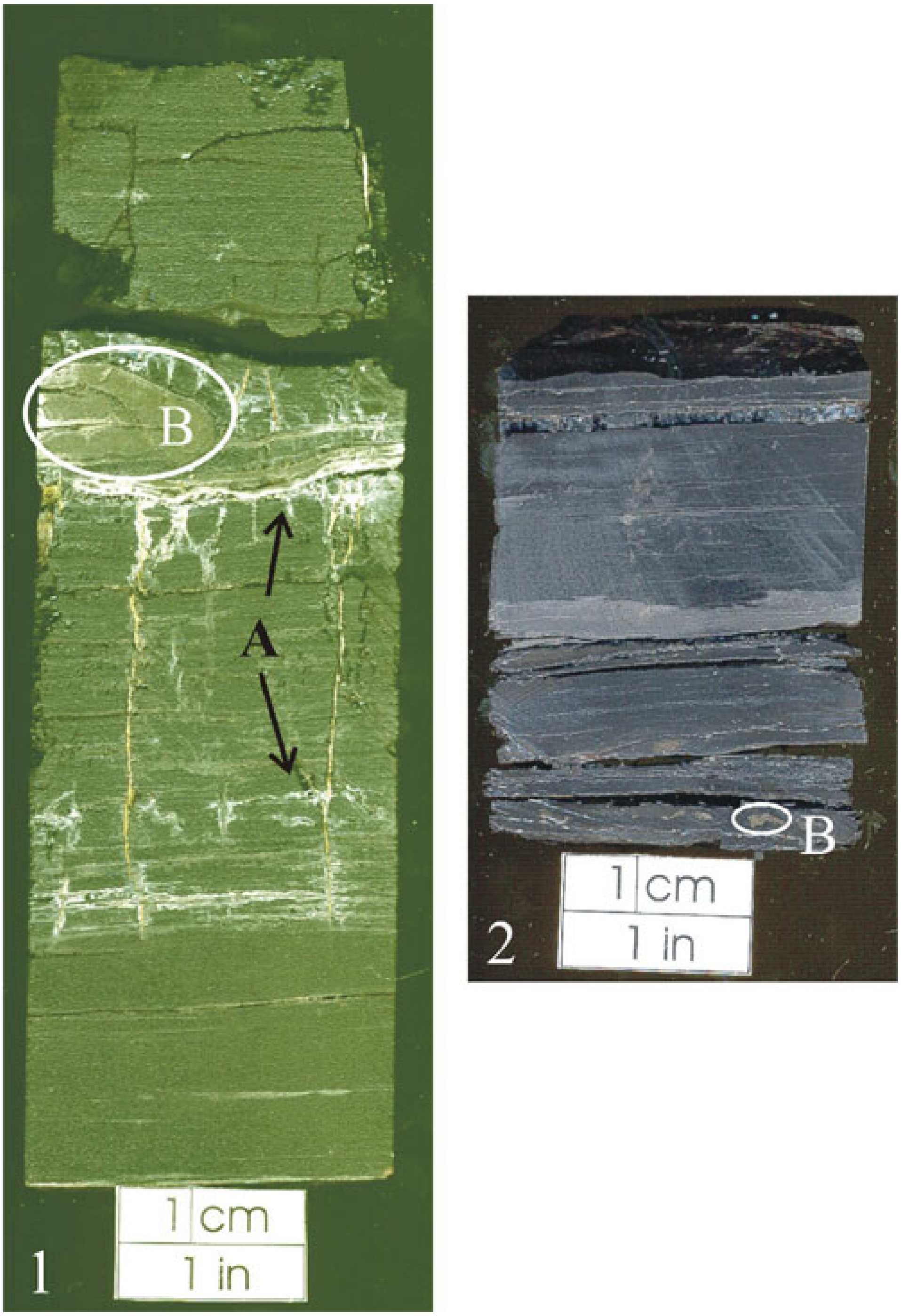


Figure 2.03 - Polished core section showing the coal facies of the Riverton coal. Coal is laminated with variations in lithotypes and macerals. Note mineralization of calcite (A) and pyrite (B) along cleats and laminations. Sample 1 from 850' in the Cooper CW#1 well, 11-T35S-R18E, Labette County, Kansas. Sample 2 from 895' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.2 Blocky Mudstone Facies

Description

The blocky mudstone facies consists of micaceous shale that is light gray to medium gray. Other features that characterize the blocky mudstone facies include slickensides, blocky and mottled texture, and plant fragments (Figure 2.04). Clay ironstone nodules (siderite) are usually present in the lower portion and decrease in abundance upwards. When the blocky mudstone facies is associated with an underlying limestone, caliche nodules may be present that are 0.25 inches in diameter (8 mm). Plant fragments and rhizoliths increase in abundance upwards toward the top of the blocky mudstone facies. No trace or body fossils were observed in the blocky mudstone facies. Thickness of the blocky mudstone ranges from 0.25 to 10 feet (.1 to 3 m). The lower contact is typically gradational with the underlying facies, while the upper contact is sharp.

Paleoenvironmental Interpretation

Blocky or mottled texture with soil slickensides, and plant fragments are evidence that the blocky mudstone lithofacies is a paleosol. Marine fossils were not observed. Development of slickensides indicates frequent shrink-swell cycles. These cycles are directly tied to paleoclimate. A higher frequency of cycles is expected in a subhumid temperate climate (Gustavson, 1991). Factors such as parent rock mineralogy, paleoclimate, duration of exposure, and rainfall played a major roll in soil development (Gustavson, 1991). The facies was probably formed in either an overbank area within an interfluve setting, or in swampy conditions of a mire, with the sediment of the facies being derived from pedogenic process acting on the underlying sediment, and wind derived sediment. The gradational contact with the underlying facies is interpreted as a C zone of a paleosol (Retallack, 1990). Historically, the blocky mudstone facies would be interpreted as part of the “outside shale” in the cyclothem model (Heckel, 1977).

Figure 2.04 - Polished core section showing blocky mudstone facies. Note pedogenic nature and weathered appearance of the mudstone. Soil slickensides are also observed within the blocky mudstone. Sample 1 from 780' and sample 2 from 870' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.3 Pyritic Shale Facies

Description

The pyritic black shale facies consists of micaceous dark gray to black shale. Diagnostic features include poorly developed irregular laminations (3 mm), and abundant pyritized wood and plant fragments (Figure 2.05). Angular pyrite concretions are approximately 0.25 inches in diameter (8 mm). Trace or body fossils were not observed in the pyritic black shale facies. Thickness of the pyritic shale facies ranges from 5 to 20 feet (1.5 to 6 m). Contacts with the overlying and underlying facies are gradational.

Paleoenvironmental Interpretation

The abundance of pyrite concretions, pyritized plant material and poorly developed laminations suggest deposition from sediment fallout in a brackish water marginal marine environment. An abundance of pyrite nodules and associated plant fragments appears related to swamp or marsh environments (Ho and Coleman, 1969). No marine fossils were observed. The pyritic black shale facies is interpreted as being deposited in a brackish water, coastal marsh or swamp environment. Historically, the pyritic shale facies would be interpreted as part of the "outside shale" in the cyclothem model (Heckel, 1977).

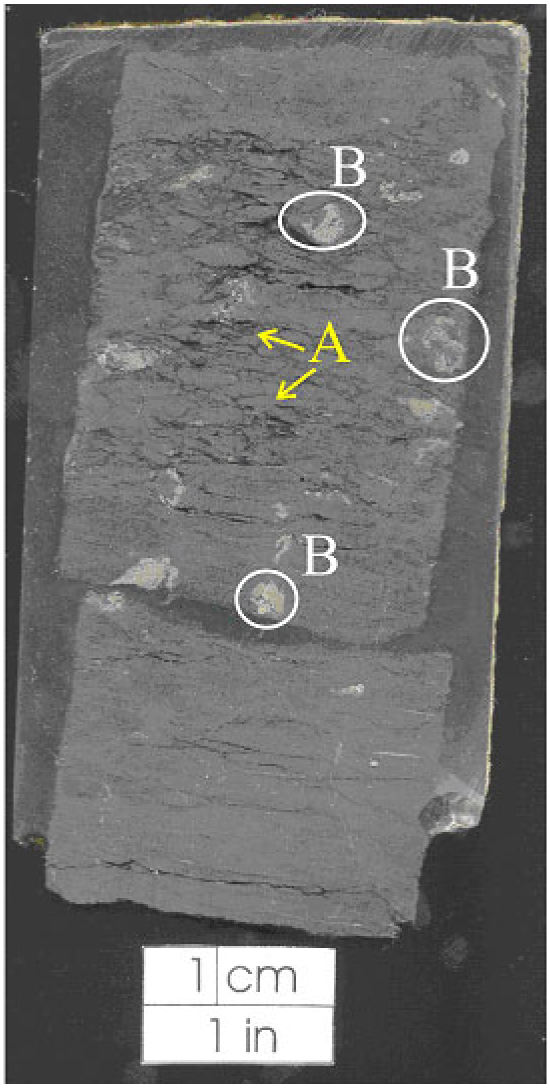


Figure 2.05 - Polished core section of the pyritic black shale facies. Note the development of irregular laminations (A) and angular pyrite concretions (B) of apporximately 0.25 inches in diameter (90 mm). The black appearance is due to a high organic content (i.e. carbonized wood fragments). Sample from 1,076' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.4 Interlaminated Sandstone and Siltstone Facies

Description

The interlaminated sandstone and siltstone lithofacies consists of light gray to brown medium- to fine-grained sand laminae intercalated with medium gray silt to mud laminae (3-10 mm; Figure 2.06). Diagnostic features include soft sediment deformation, clay ironstone nodules that are 0.5 inches in diameter (12 mm), mud laminations (3-10 mm) and scattered rip-up clasts that are 0.25 inches in diameter (6 mm), and wave ripples. The facies displays numerous fining upward packages (1-5 cm;

approx. 24 packages) over approximately 3 feet (1 m). The upper portion of the facies is commonly massive, fine-grained sandstone with minor mud drapes, while the lower portion is medium- to fine-grained sandstone with abundant intercalated mud and silt laminae. Individual sand laminae have unidirectional ripples, while mud drapes have a bimodal orientation. Wavy, flaser and lenticular bedding are also common. A low diversity trace fossil assemblage is dominated by actively filled horizontal (cf. Paleophycus), and passively filled vertical burrows (cf. Skolithos). No body fossils were observed. The interlaminated sandstone and siltstone facies ranges in thickness from 10 to 30 feet (3 to 9 m). The lower contact with underlying facies is typically erosional, while the upper contact with overlying facies is gradational.

Paleoenvironmental Interpretation
The presence of mud drapes dipping in opposite directions and numerous fining upward packages indicates sediment fallout during slack-water intervals from tidal influence (Buatois et al., 1999). The low trace fossil diversity indicates a stressed brackish-water marginal marine or deltaic environment. Erosional basal contacts, unidirectional flow alternating with bimodal flow, and upward fining packages suggest channel-fill deposition that may be tidally influenced. This facies is interpreted as a marginal marine environment. Historically, in the cyclothem model, the interlaminated sandstone and siltstone facies would be interpreted as part of the "outside shale" (Heckel, 1977).

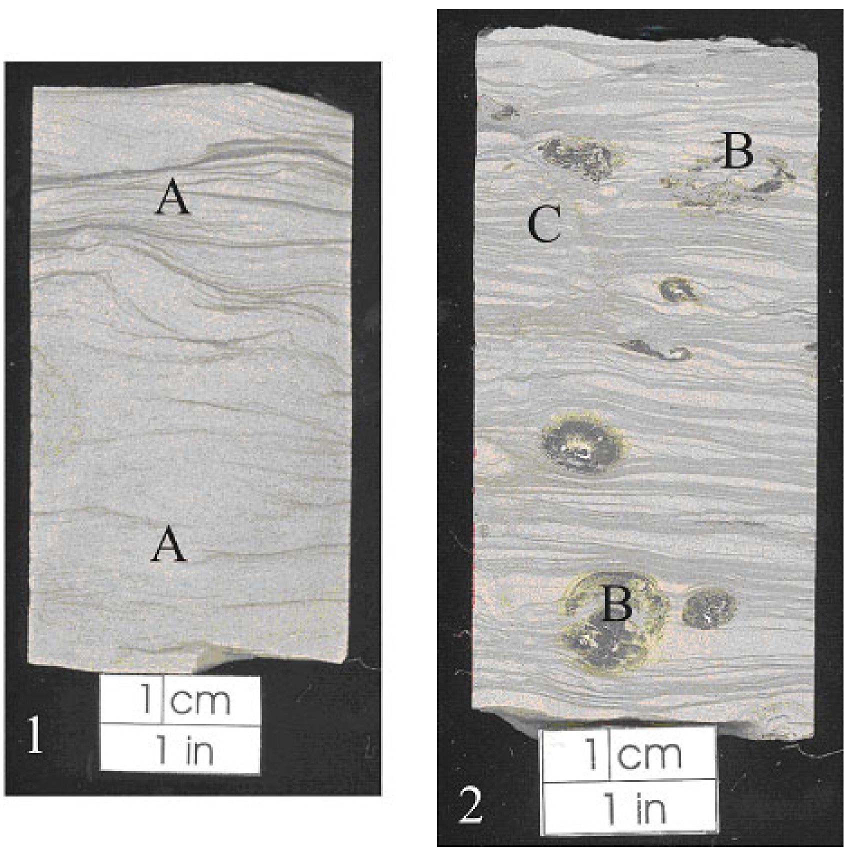


Figure 2.06 - Polished core section showing of the interlaminated sandstone and siltstone facies . 1) Rippled fine-grained sandstone laminae with minor mud drapes. Individual sandstone laminae are characterized by unidirectional cross-stratification (A). Cross-stratification orientations among sandstone laminae are bi-directional. 2) Medium- to fine-grained sandstone and interclated mudstone to siltstone laminae with soft sediment deformation, clay ironstone (B), vertical burrows (C). Sample 1 from 904' and sample 2 from 899' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

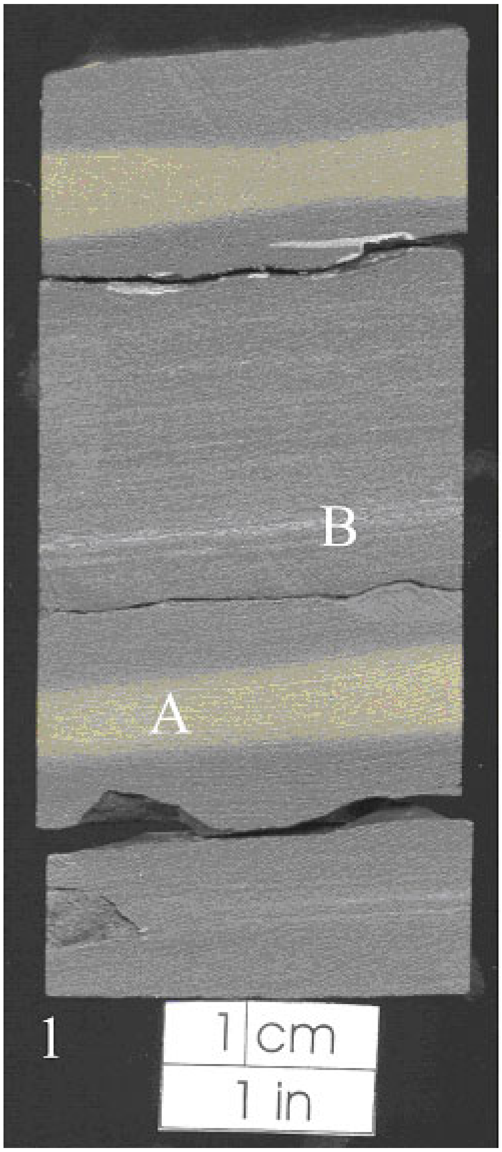
2.1.5 Sideritic Shale Facies

Description

Diagnostic features of the sideritic shale facies include quartz silt, parallel fissile laminae (less than 3 mm), dark gray to black color, and abundant clay ironstone bands (cf. siderite) that are approximately 1 inch in height (2.5 cm; Figure 2.07). Carbonaceous plant material are found throughout the facies. Body fossils were not observed, but actively filled horizontal burrows (cf. Planolities) are present. Overall, the intensity of bioturbation is relatively low. Thickness of the sideritic shale facies ranges from 6 to 12 feet (1.8 to 3.6 m). Contacts with overlying and underlying facies are gradational.

Paleoenvironmental Interpretation

Consistency of parallel laminated shale indicates sediment fallout in a low energy environment possibly due to upwelling or pseudo-estuarine circulation (Heckel, 1977). Fissility, plant material, and the dark gray to black appearance suggest a relatively high organic content. The low trace fossil diversity may indicate a stressed brackish-water, hypersaline, or anoxic environment (Buatois et al., 1999; Reineck and Singh, 1980). Presence of abundant siderite bands supports the presence of a marginal marine environment receiving fresh water input (Postma, 1982). This facies is interpreted as having been deposited in a marginal marine environment. Historically, the sideritic shale facies would be interpreted as part of the “outside shale” in the cyclothem model (Heckel, 1977).



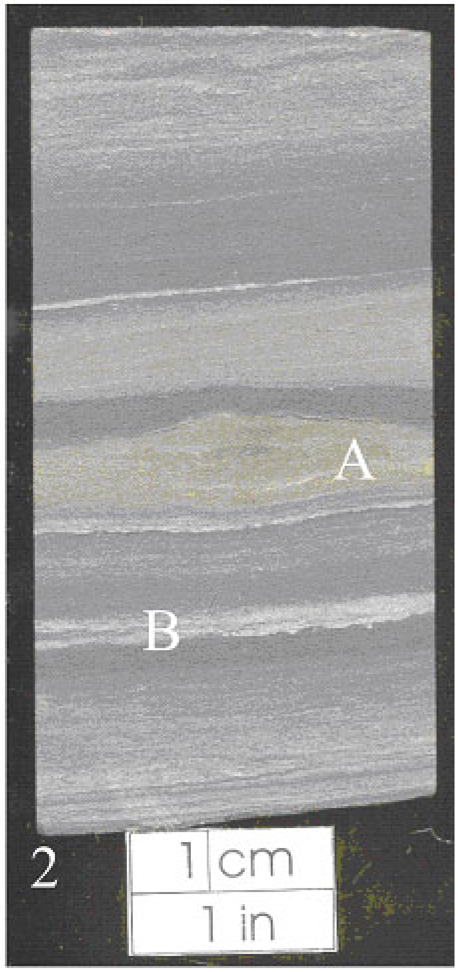


Figure 2.07 - Polished core section showing the sideritic shale facies. Note the abundance of siderite bands (A), minor amount of quartz silt (B), and absence of trace of body fossils. Sample 1 from 417' in the Cooper CW#1 well, 11-T35S-R18E, Labette County, Kansas. Sample 2 from 893' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.6 Laminated Muddy Sandstone Facies

Description

The laminated muddy sandstone facies is composed of dark-gray silt and mud and light-gray fine-grained sand (Figure 2.08). Diagnostic features of the facies are intervals (0.5-1 cm) of thin laminae (3 mm) of siltstone and sandstone that are separated by intervals (0.5-1 cm) dominated by bioturbated to laminated mudstone (1-3 mm). Many of the laminated intervals are cross-stratified, and have bimodal orientations. Contacts between the top of the mudstone and the bottom of the sandstone may be reactivation surfaces. Minor amounts of plant fragments are scattered through the facies (Figure 2.08). Body fossils were not observed, although bioturbation is prevalent along with sparse actively filled vertical and horizontal burrows. Thickness of the facies ranges from 5 to 12 feet (1.5 to 3.7 m). Contacts with the overlying and underlying facies are gradational.

Paleoenvironmental Interpretation

The laminated muddy sandstone facies is interpreted as having been deposited in a tidal-flat environment. Alternating fine-grained sand cross laminations and thicker mudstone laminations indicate bedload transport during variable tidal flow and sediment fallout during slack-water (Reineck and Singh, 1980). Presence of reactivation surfaces and cross lamination dipping in opposite directions indicates changes in flow direction and suggests tidal influence. Open-marine tidal flats often have an abundant and diverse trace fossil assemblage (Buatois et al., 1999). The paucity of trace and body fossils preserved in this setting may be due to the muddy system or freshwater influence from tidal channels. Historically, the cross-laminated muddy sandstone facies would be interpreted as part of the “outside shale” in the cyclothem model (Heckel, 1977).

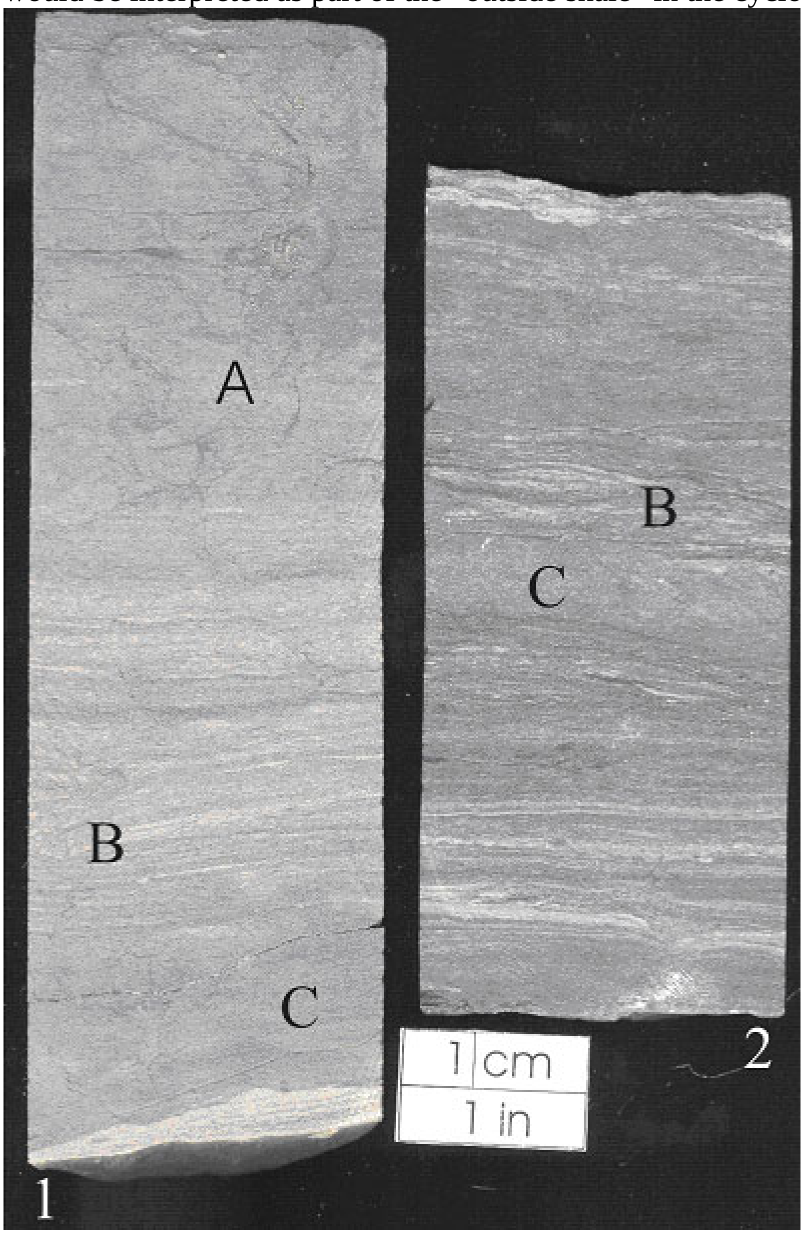


Figure 2.08 - Polished core section of laminated muddy sandstone facies. 1) Intercalated intervals of cross-stratified muddy sandstone (B) and laminated to bioturbated and burrowed mudstone (C). At top of core section abundant rooting has disrupted primary sedimentary structures (A). 2) Inercalated intervals of cross-stratified sandstone and mudstone (B) separated by intervals of laminated to bioturbated mudstone. Sample 1 from 881' and sample 2 from 851' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.7 Bioclastic-Packstone-to-Grainstone Facies

Description

The bioclastic-packstone-to-grainstone limestone lithofacies is light to medium gray. Diagnostic features of the lithofacies include medium bedding (10-30 cm), and well-preserved sparse marine bioclastic fragments (Figure 2.09). Stylolites are distributed throughout the facies, while caliche and rhizoliths are observed approaching the top of the facies. The dominant texture is packstone, although a peloidal, non-fossiliferous grainstone may also present in the facies. Identified fossils include disarticulated bryozoans, brachiopods, crinoids and fusulinids. Trace fossils are sparse, however the facies appears to be heavily bioturbated. Thickness of the bioclastic-packstone-to-grainstone facies ranges from 5 to 30 feet thick (1.5 to 9 m). Contacts with the overlying and underlying facies are gradational.

Paleoenvironmental Interpretation

Peloidal grains, the lack of abundant trace fossils, and disarticulation of body fossils are evidence that the bioclastic-packstone-to-grainstone facies was deposited in a high to moderate energy environment, probably above fair weather wave base. Fragmentation of bioclasts is due to reworking by wave or tidal processes in a relatively shallow-water environment and from extensive bioturbation. Bryozoans, brachiopods, and crinoids indicate a normal salinity marine environment (Heckel, 1972). Presence of caliche and rhizoliths in the upper portion of the facies suggests post depositional alteration by pedogenic processes. The combination of texture, peloidal grains, and fauna present suggests that the bioclastic-packstone-to-grainstone was deposited in a relatively normal marine, higher energy, and shallow environment. Historically, the bioclastic-packstone-to-grainstone facies would be interpreted as part of the “upper limestone” in the cyclothem model (Heckel, 1977).

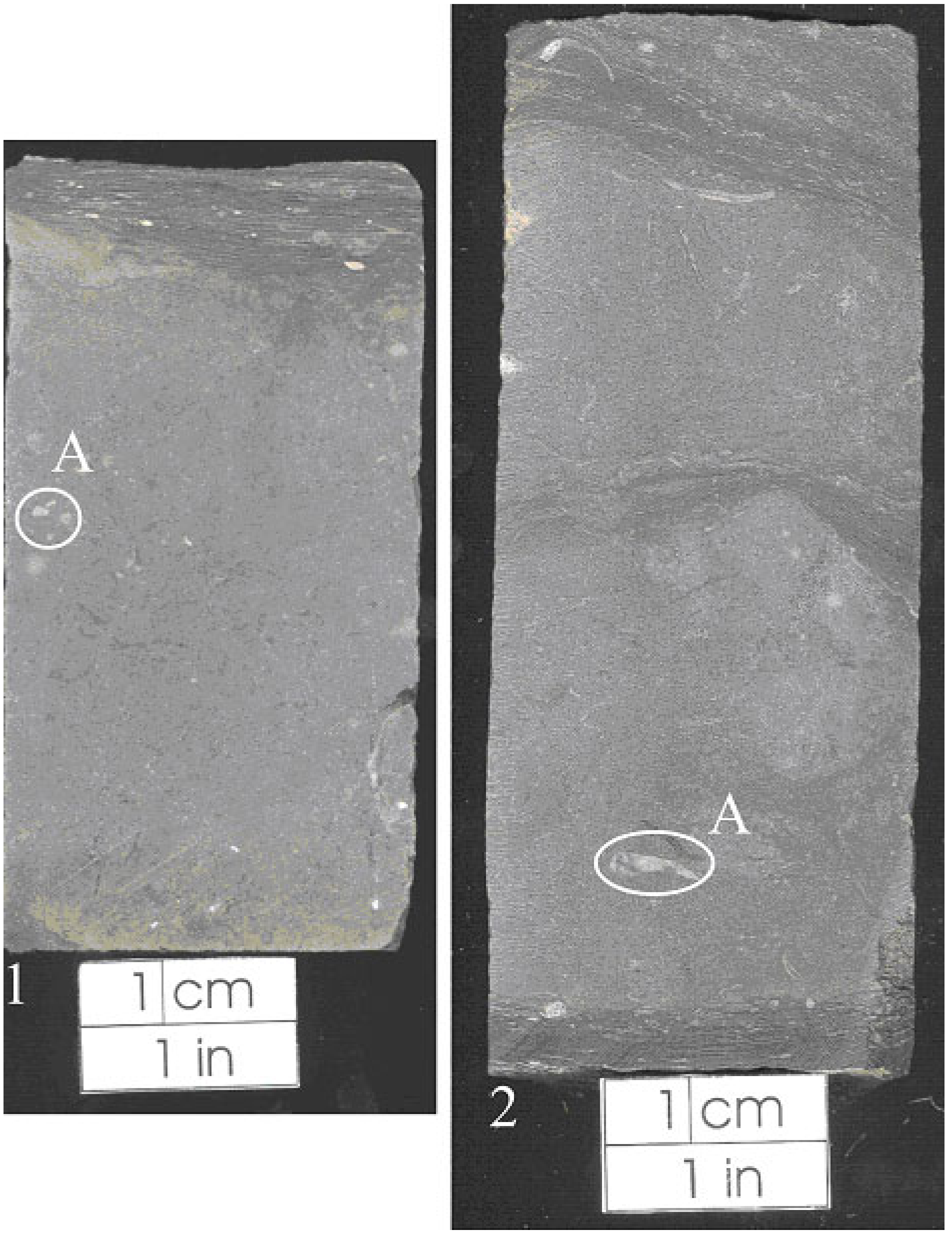


Figure 2.09 - Polished core section of bioclastic packstone to grainstone facies comprised of marine fossil fragments (A). Sample 1 from 623' and sample 2 from 625' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.8 Bioclastic Mudstone to Wackestone Facies

Description

The bioclastic mudstone to wackestone facies is typically medium to dark gray in appearance with a micritic matrix. Diagnostic features include medium bedding (10-30 cm), abundant well-preserved whole-fossil marine bioclasts, and high-degree of bioturbation (Figure 2.10). Stylolites are commonly observed in the upper portion of the facies. Identified fossils include bryozoans, crinoids, brachiopods, mollusks, foraminifera, phyloid algae, and chaetetids. Thickness of the bioclastic-mudstone-to-wackestone facies ranges from 1 to 20 feet with an average of 12 feet (0.3 to 6 m; average of 4 m). Upper and lower contacts of the bioclastic-mudstone-to-wackestone facies with adjacent facies are gradational.

Paleoenvironmental Interpretation

Bryozoans, brachiopods, phyloid algae, formainfera, chaetetids and crinoids indicate a normal salinity marine environment (Heckel, 1972). The presence of a micrite matrix is evidence of a low energy environment. Presence of well-preserved whole body fossils suggests a low-energy environment, probably below fair weather wave base. Disarticulation of bioclasts is due to bioturbation or storm activity. The combination of abundant and fragmented marine fauna, a micritic matrix, and texture suggests that the bioclastic-mudstone-to-wackestone facies was deposited in an open marine environment, probably below wave base. Historically, the bioclastic mudstone to wackestone facies would be interpreted as part of the "upper limestone" in the cyclothem model (Heckel, 1977).

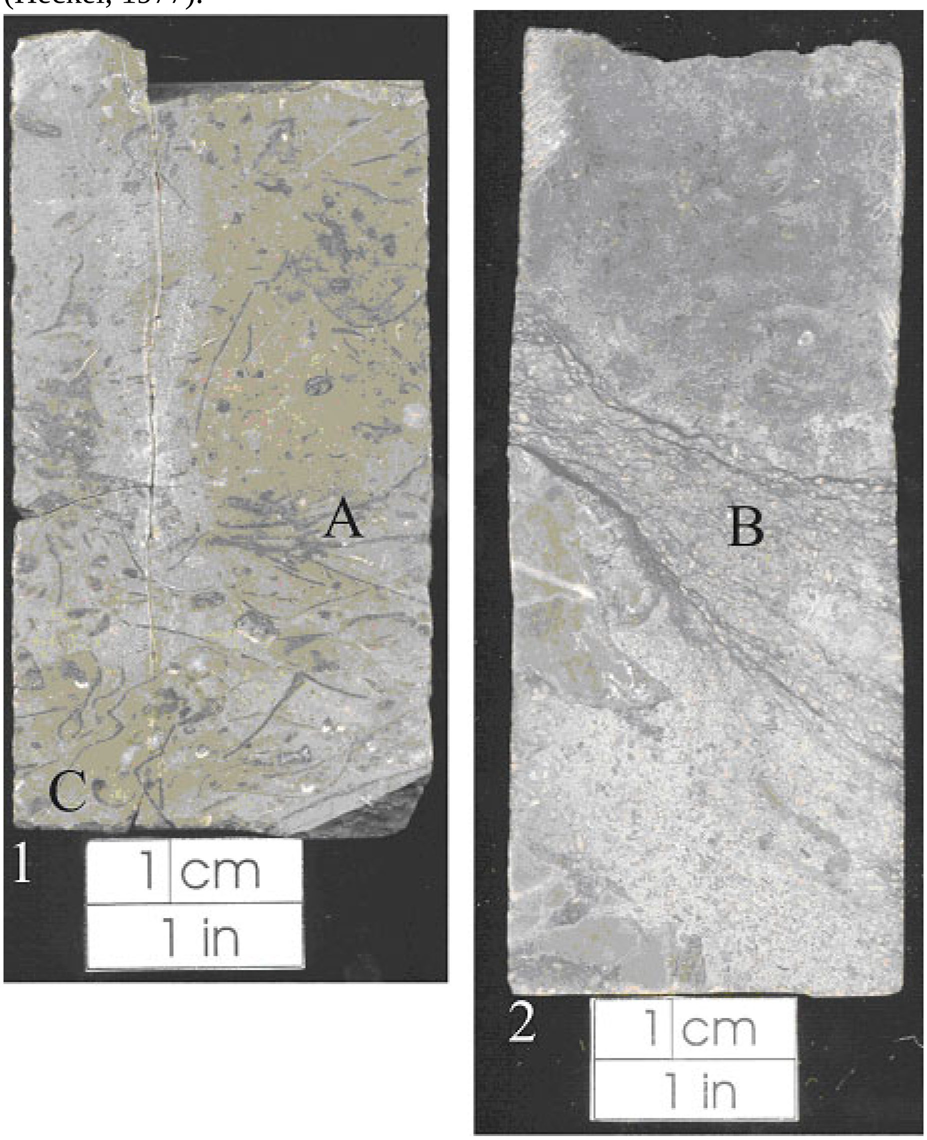


Figure 2.10 - Polished core section of bioclastic mudstone to wackestone facies with abundant whole fossil bioclasts. Note well persevation of bryozoans (A), chaetetes (B) and brachiopods (C). Sample 1 from 650' and sample 2 from 645' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.9 Dark Gray Shale Facies

Description

Diagnostic features of the dark gray shale facies include thin laminations (3 mm), fissility, parallel bedding, and minor amounts of quartz silt. The facies is dark gray to black changing gradually upwards to medium gray (Figure 2.11). Minor amounts of clay ironstone (cf. siderite) or pyrite nodules are observed in the middle to upper portion of the facies. Identified fossils, when present, include small fragments of brachiopods, fusilinids and crinoids. Fossil shells are commonly concave down and fossil material is concentrated in thin layers that are normally graded. The dark gray shale facies ranges in thickness from 10 to 15 feet (3 to 4.5 m). Upper and lower contacts of the dark gray shale facies are gradational.

Paleoenvironmental Interpretation

The parallel laminated shale indicates sediment fallout in a low energy environment possibly deep marine with little bioturbation. A gradual change from dark gray upward to light gray color indicates a change from anaerobic to more aerobic conditions. Thin intervals of normally graded and concave downward bioclastic fragments (5-10 cm) may represent higher energy storm deposits that are periodically introduced into offshore deeper water environments. The presence of minor amounts of pyrite and siderite in the upper portion of the facies also suggests the influence of freshwater and shift to aerobic conditions. This lithofacies is interpreted as a offshore transitional environment. Historically, the dark gray shale facies would be interpreted as part of the “core shale” in the cyclothem model.

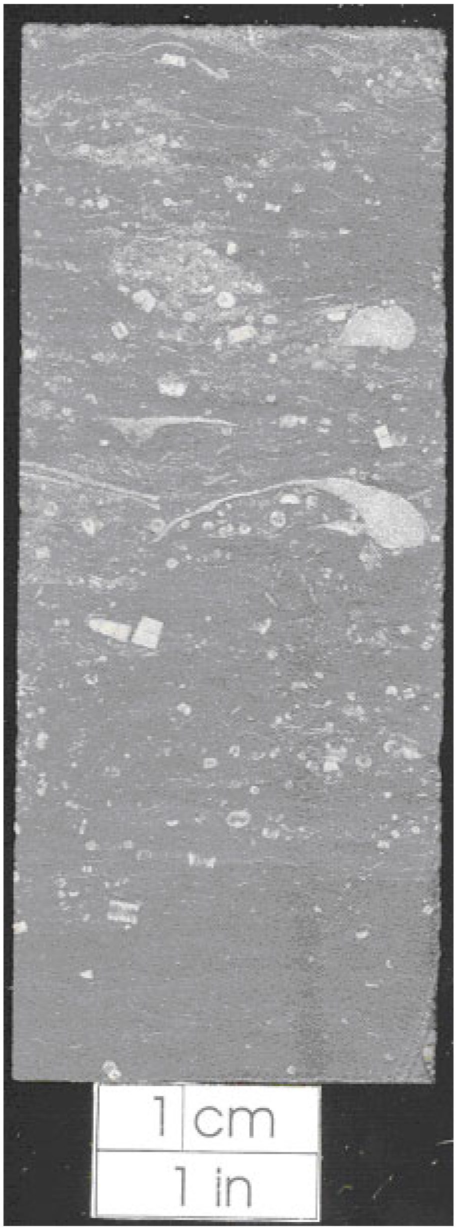


Figure 2.11 - Polished core section showing dark gray shale facies. Note small scattered fossil fragments and absence of bioturbation. Sample from 713' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

2.1.10 Phosphatic Black Shale Facies

Description
Very thin laminations (less than 3 mm), fissility, black color, and phosphatic nodules, characterize this facies (Figure 2.12). Phosphatic nodules are abundant and also vary in size (0.1 to 1 inch; 0.2 to 2.54 cm). Sparse pyrite and calcite concretions are also present. Planktonic organisms (such as conodonts) and disarticulated brachiopods are the only fauna observed in the black shale facies. No trace fossils or bioturbation were observed. The phosphatic black shale facies ranges in thickness from 1 to 10 feet with and average of 5 feet (0.3 to 3 m; average of 1.5 m). Upper and lower contacts are usually sharp, but the upper contact can be gradational.

Paleoenvironmental Interpretation

The black shale facies was deposited by sediment fallout in either low energy shallow marginal marine or deep marine environments. The dark black color, fissility, absence of bioturbation and presence of phosphatic nodules are indicative of anoxic conditions. Heckel (1977) proposed that upwelling or pseudo-estuarine circulation would support anoxic conditions in relatively shallow water. The widespread occurrence of the black shale facies across the Cherokee basin and into adjacent states suggests a relatively deep marine environment. The presence of normal marine planktic fauna (i.e. conodonts) supports an anoxic deep-water environment. This facies is interpreted as deposited in a shelf environment under anoxic conditions and far removed from sources of sediment supply. Historically, the phosphatic black shale facies would be interpreted as part of the "core shale" in the cyclothem model (Heckel, 1977).

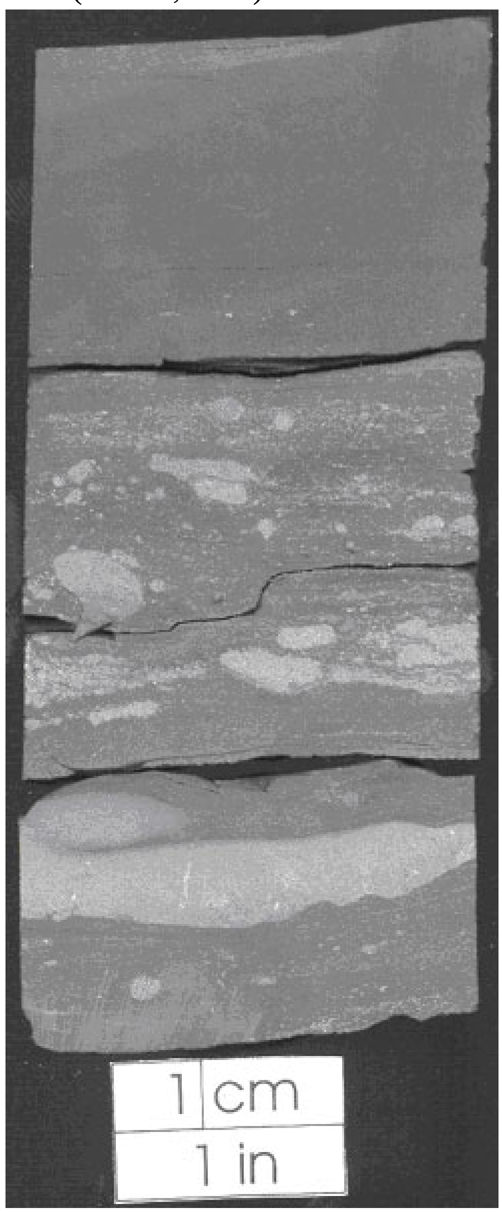


Figure 2.12 - Polished core section showing the phosphatic black shale facies. Note the abundance of authigenic phosphate nodules (light gray) that widely vary in size. Sample from 414' in the Cooper CW#1 well, 11-T35S-R18E, Labette County, Kansas

2.2 Distribution and Vertical Relationships of Facies

The Cherokee Group is composed of numerous repetitive successions of interbedded gray to dark gray shale, rippled sandstone and siltstone, underclay, thin coal, and thin argillaceous limestone. The following table lists a typical succession starting with marine facies progressively transitioning to marginal marine to non-marine facies (Table 2.2).

Table 2.2 – Distribution and vertical relationships of facies

		Vertical Relationships	
Lithofacies	**Distribution**	**Underlying facies**	**Overlying facies**
Phosphatic black shale	Entire basin & into adjacent states	Coal or blocky mudstone	Dark gray shale
Dark Gray shale	Across basin & throughout Cherokee Group	Phosphatic black shale	Interlam. Ss & Xs, lam. muddy shale, bio wackestone or pyrite sh
Bioclastic-mudstone to -wackestone	Observed in upper Higginsville, Black Jack Creek & Breezy Hill limestones	Phosphatic black shale	Bioclastic-packstone-to-grainstone
Bioclastic-packstone-to-grainstone	Observed in upper Higginsville, Black Jack Creek & Breezy Hill limestones	Bioclastic-mudstone-to-wackestone	Blocky mudstone or phosphatic black shale
Interlam. Ss and Xs	Observed as fill above incision surfaces and discontinuous	Phosphatic black shale or dark gray shale	Coal, sideritic gray sh or poorly developed blocky mudstone
Sideritic gray shale	Observed as fill above incision surfaces and discontinuous	Interlaminated Ss & Xs	Blocky mudstone or laminated muddy sandstone
Laminated Muddy Ss	Observed in middle and upper Cherokee Group	Dark gray shale	Poorly developed blocky mudstone or coal
Pyritic black shale	Observed in Krebs Fm and in upper Cherokee Group	Dark gray shale or sideritic shale	Blocky mudstone or coal
Blocky mudstone	Throughout basin and Cherokee Group	Pyritic black shale, cross-lam. muddy Ss, interlam. Ss & Xs, or bio-packstone-to-wackestone	Coal of phospatic black shale
Coal	Highly variable across basin & throughout Cherokee Group	Blocky mudstone	Dark gray shale or phospatic black shale

2.3 Coal Bearing Intervals of the Cherokee Group

Division of the Cherokee Group into ten intervals is based on regionally extensive marker beds, which serve to define mappable units. These marker beds are the black phosphatic shale lithofacies. Typically, the base of marker beds will be interpreted as flooding surfaces. The intervals also serve as a basis for identifying and mapping individual coals in the Cherokee Group. Coal thickness and distribution of individual coals can be related to the paleostructure reflected in the underlying units.

2.3.1 Mississippian Basement

In southeastern Kansas, Cherokee Group clastic rocks unconformably overly Mississippian limestones (Meremecian Stage; Merriam, 1963; Figure 2.13). The top of the Mississippian is characterized by a chert residue (Watney et al., 2001). Depth to the karstic Mississippian basement in the Cherokee basin ranges from 0 feet at outcrops in the extreme southeastern corner of Kansas, to more than 2500 feet (762 m) in Elk and Chautauqua counties, as the Mississippian and Cherokee Group rocks gradually dip to the west and southwest (Figure 2.14).

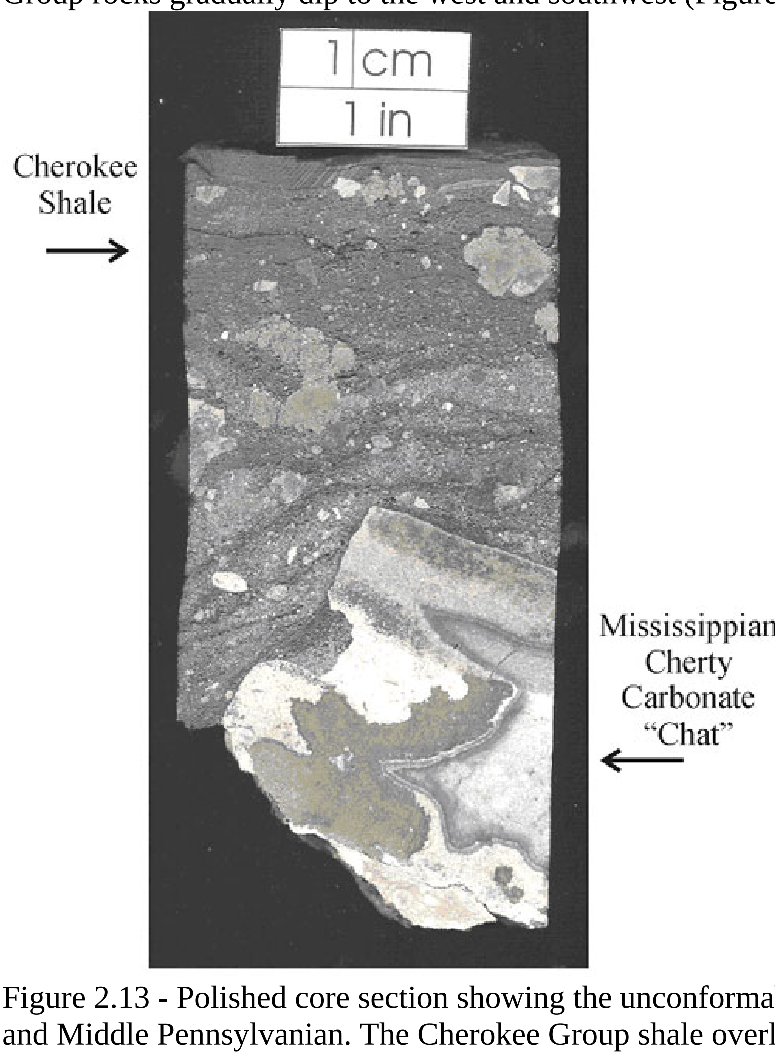


Figure 2.13 - Polished core section showing the unconformable contact between the Mississippian and Middle Pennsylvanian. The Cherokee Group shale overlies the karstic Mississippian Warsaw Limestone (Meremecian) and chert residium ("chat"). Sample from 1,081' in the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas

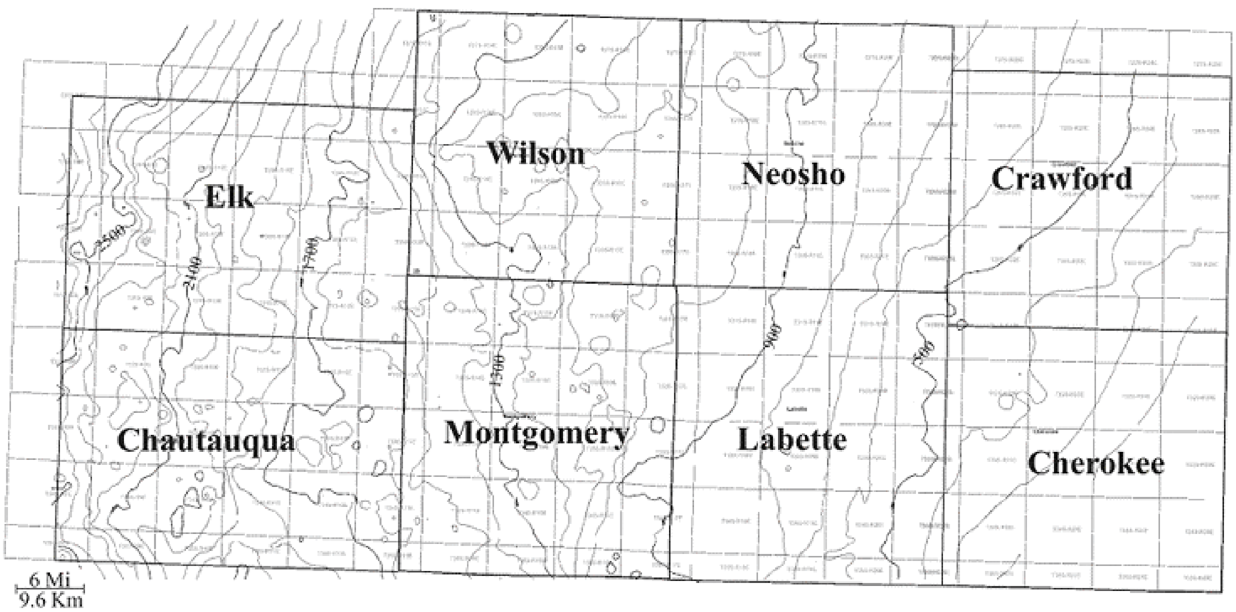


Figure 2.14 - Structure map on top of the Mississippian limestone showing regional dip to the west (CI:100 ft). The surface is characterized by extensive karst features resulting in a highly irregular topography for deposition of the overlying Cherokee Group coal bearing intervals.

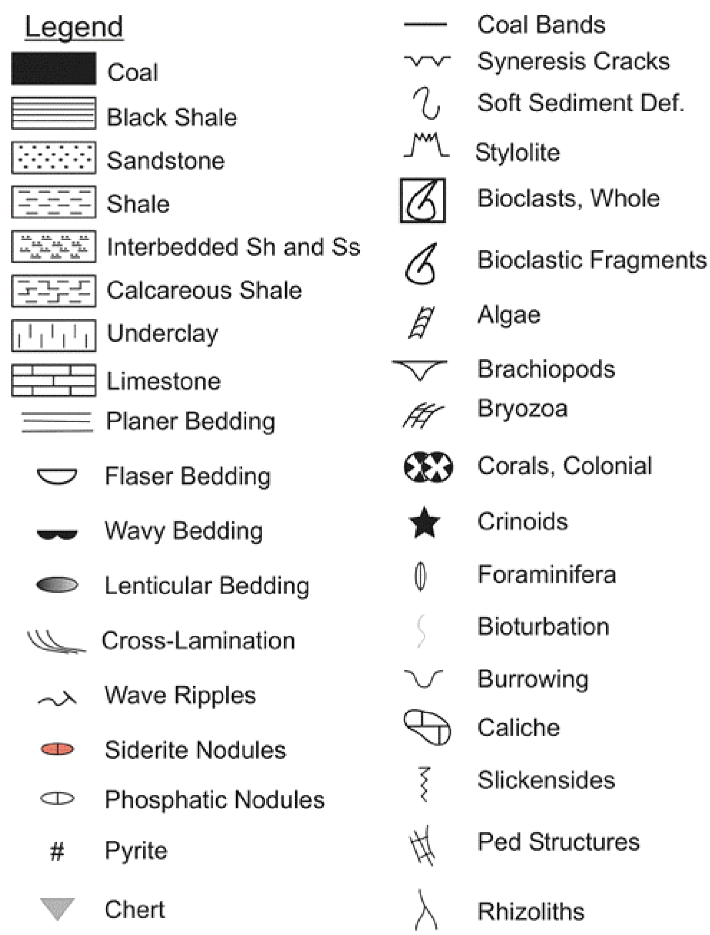


Figure 2.15a - Symbols for depositional sequences in figures 2.15, 2.17, 2.20, 2.22, 2.24, 2.28 and 2.30

2.3.2 Riverton Interval

Description

The interval from the top of the Mississippian to the top of the Riverton shale ranges in thickness from 4 to 40 feet with an average of 15 feet (1.2 to 12 m, 4.5 m; Figures 2.02 and 2.15). Variability in thickness is due to deposition of sediments on top of the high relief karstic Mississippian limestone. In ascending order, the Riverton interval consists of a pyritic shale facies and a blocky mudstone facies, which is overlain by the Riverton coal (Figure 2.15). The Riverton coal is capped by a phosphatic black shale facies (Figure 2.15). Locally, siltstone lenses, and additional coal beds are present below the Riverton coal. An additional blocky mudstone facies ranging in thickness from 1 to 3 feet (0.3 to 1 m) is locally found in the middle of the interval beneath the Riverton coal.

Riverton and Lower A-B Interval

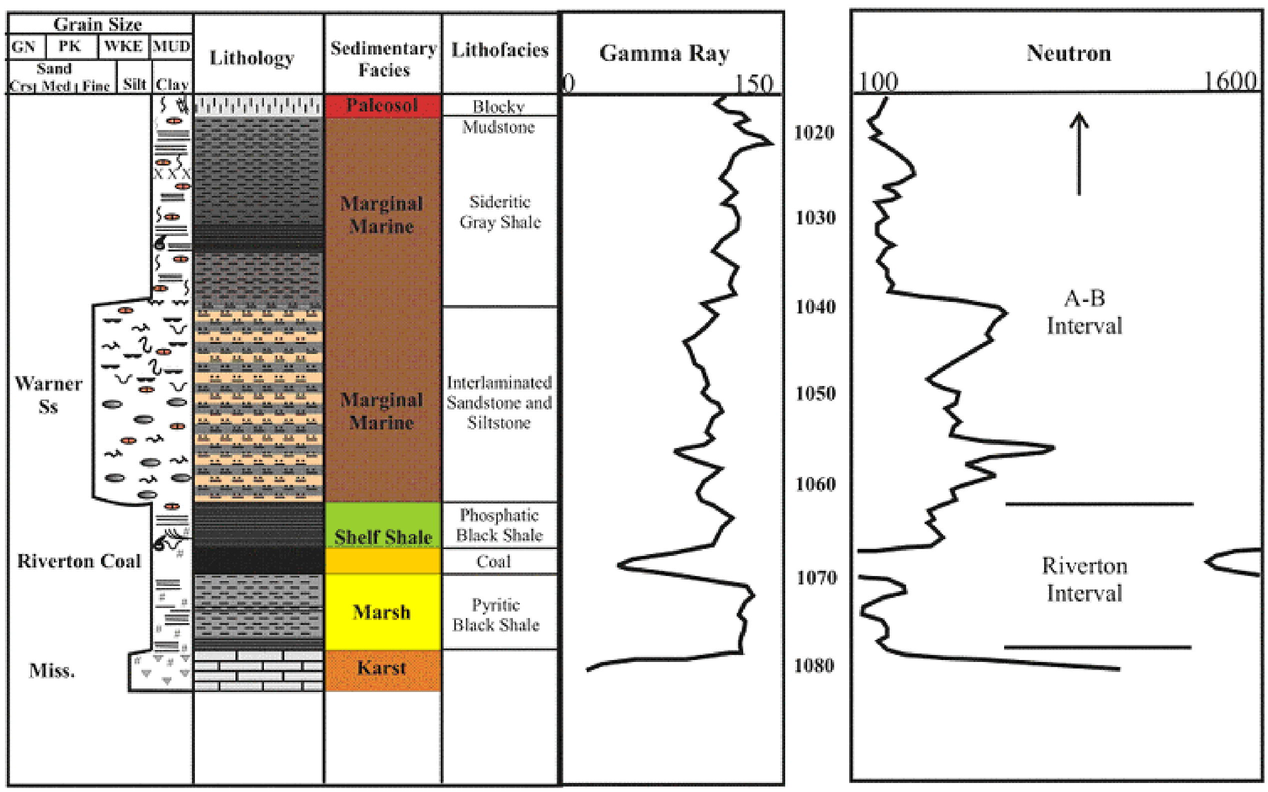


Figure 2.15 - Depositional sequence and log characteristics of the Riverton and lower A-B interval, based on core and well log from the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas (scale in feet). See Figure 2.15a for legend

Riverton Isopach Map

The Riverton shale is recognizable on logs due to a relatively high gamma ray response (approx. 110 API units) and low neutron response (< 400 neutron counts) followed down hole by a lower gamma-ray response (< 105 API units) associated with the underlying Riverton coal (Figure 2.15). The Riverton coal is the first thick and laterally extensive coal bed encountered in the Cherokee Group in southeastern Kansas (Figure 2.16). Thickness of the Riverton coal can be up to 4.5 feet with an average of 1.8 feet and a normal distribution (1.4 m, average of 0.5 m; Appendix 2).

Detailed isopach mapping of the Riverton coal reveals a coal that stays fairly consistent in thickness over an average distance of 5 square miles (8 km2). The Riverton coal locally appears to thicken into the Mississippian lows and thin onto the highs (Figure 2.16). The Riverton coal is consistently thicker in Montgomery, Labette, and Neosho counties, while its thins to the west and east in the study area.

Riverton Coal

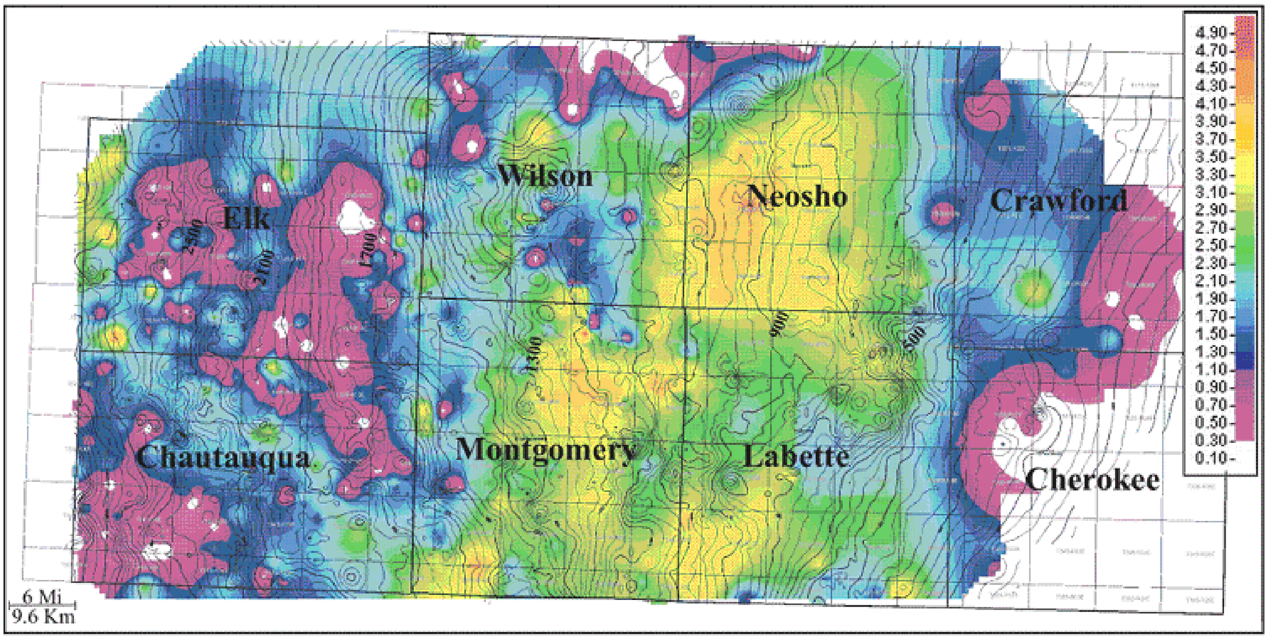


Figure 2.16 - Isopach of Riverton coal (color) overlain with contours of top of Mississippian limestone structure (isopach CI: 0.10 ft; structure CI:25 ft).

2.3.3 A-B Interval

Description

The interval from the top of the Riverton shale to the top of the A-B shale ranges in thickness from 22 to 112 feet with an average of 57 feet (6.7 to 34.1m, average of 17.4 m, Figure 2.01 and 2.15). Variability in interval thickness may be due to thick sandstone accumulations within the interval (up to 80 ft; 24 m). In ascending order, the A-B interval consists mainly of a dark gray shale facies, laterally discontinuous interlaminated sandstone and siltstone facies known as the Warner Sandstone, sideritic gray shale facies, and numerous discontinuous coal facies known informally as the Dw, Cw, and Bw (after Harris, 1984; Figure 2.15). The base of the Warner Sandstone is an unconformity. Due to the sporadic nature of coals distributed within the A-B interval, they were not mapped as part of this study. The A-B shale is recognizable on most well logs as the shale between the first split coal known as the Aw and Bw coals. When the coals are absent the A-B shale is approximately 25 feet (7.6 m) above the Warner Sandstone.

2.3.4 Bluejacket B Interval

Description

The Bluejacket B interval extends from the top of the A-B shale to the top of the Bluejacket B shale and ranges in thickness from 20 to 200 feet (6.1 to 59 m; Figures 2.01 and 2.17; Staton, 1987). Variability in interval thickness is the result of thick sandstone accumulations (up to 60 ft, 18 m). In ascending order, the Bluejacket B interval consists of a widely distributed dark gray shale facies, pyritic shale facies, coal facies, and erratically distributed sideritic shale facies. Continuing upward is an interlaminated sandstone and siltstone facies known as the Warner (upper), Bluejacket or Bartlesville sandstones. The sandstone is overlain by the Weir - Pittsburg B coal (lower Weir-Pitt coal; Figure 2.17). The base of the Warner Sandstone (upper) and Bluejacket/Bartlesville Sandstone is an unconformity.

Weir-Pittsburg and Upper Bluejacket B Interval

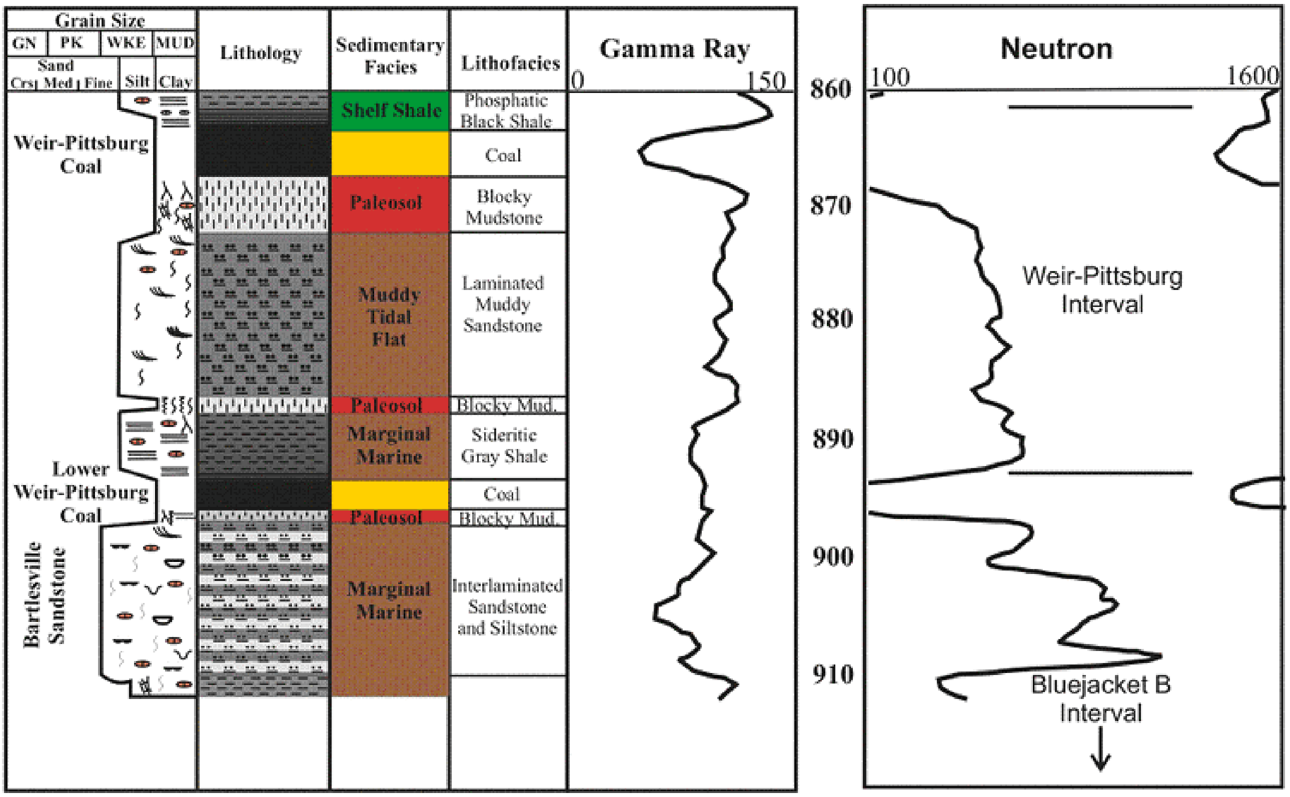


Figure 2.17 - Depositional sequence and log characteristics of the Weir-Pittsburg and upper Bluejacket B interval, based on core and well log from the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas (scale in feet). See Figure 2.15a for legend.

Laterally continuous coal beds known as the Aw, Neutral, Rowe and Dry Wood are sporadically distributed throughout the Cherokee basin. The informally named Bbj, Cbj, and Dbj coal beds are also distributed throughout the Cherokee basin, but are very difficult to correlate over any distance.

Aw Isopach Map

The Aw coal is recognizable on most logs due to its close stratigraphic relationship with the underlying thin Bw coal. Approximately 4 feet of shale separate the coals (1.2 m). Thickness of the Aw coal can be up to 4 feet with an average of 1.7 feet and a slightly skewed distribution to the maximum (1.2 m, average of 0.5 m; Appendix 2). The Aw coal is recognizable on most logs in the central part of the Cherokee basin as the next thick coal above the Warner Sandstone (Figure 2.18). Due to the lack of Aw coal in any of the described cores, this study does not include a depositional sequence for the Aw coal.

Detailed isopach mapping of the Aw coal reveals a coal that stays fairly consistent in thickness over an average of 3 square miles (4.8 km2; Figure 2.18). When bottom contours of Aw coal structure are overlain on the isopach map, the coal appears to thicken onto local highs and thin into lows. The Aw coal exhibits an elongate geometry that is oriented parallel to depositional dip (SW), and is consistently thicker within a north-south trend through Montgomery, Wilson, and Neosho counties. Locally thin areas and linear trends in the Aw coal thickness may be due to removal by erosion (ie. channel erosion).

Aw Coal

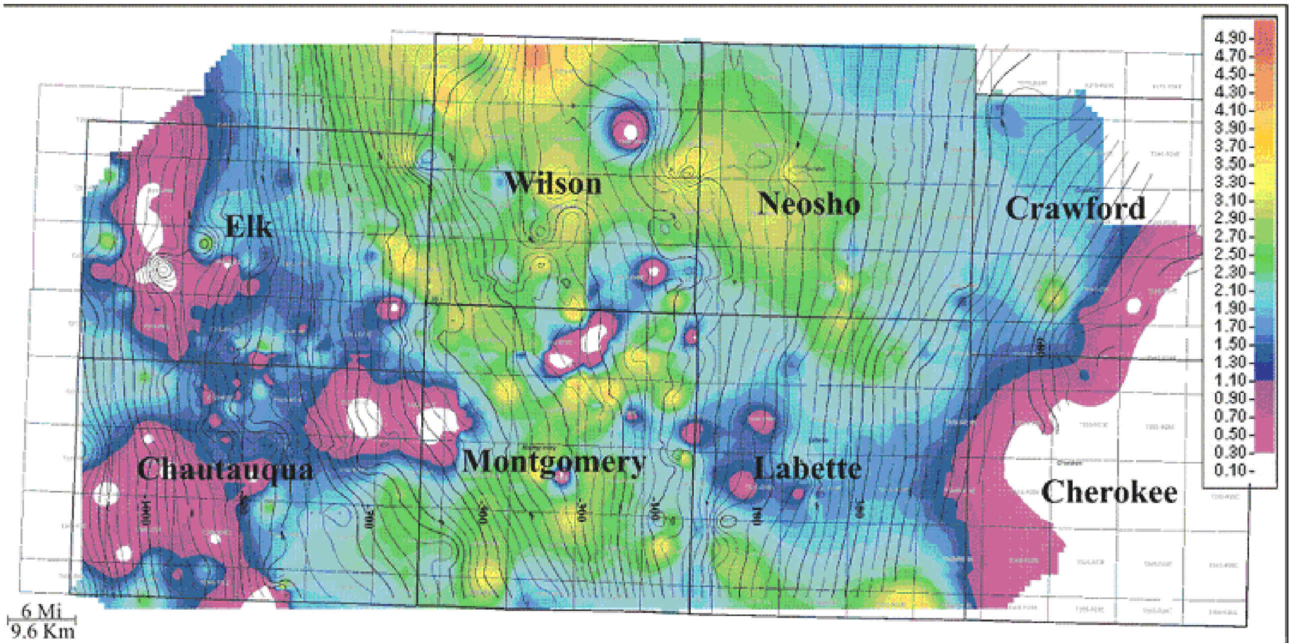


Figure 2.18 - Isopach of Aw coal (color) overlain with countours of bottom Aw coal structure (isopach CI: 0.10ft; structure CI: 25ft).

2.3.5 Weir-Pittsburg Interval

Description

The interval from the top of the Bluejacket B Shale to the top of the Weir-Pittsburg shale ranges in thickness from 5 to 60 feet with an average of 20 feet (1.5 to 18.2 m, average of 6.1 m; Figures 2.01 and 2.17). In ascending order, the Weir-Pittsburg interval consists mainly of a sideritic shale facies that passes upward into a laminated muddy sandstone facies or interlaminated sandstone and shale facies. These facies are overlain by a blocky mudstone facies followed up section by the Weir-Pittsburg coal, and capped by a dark gray shale facies (Figure 2.17). Poorly developed blocky mudstone facies can occur locally through the Weir-Pittsburg interval.

Weir-Pittsburg Coal Isopach Map

The Weir-Pittsburg coal is recognizable on logs due to a relatively high gamma ray response (> 120 API units) and low neutron response (< 200 neutron counts) from the Weir-Pittsburg shale followed down hole by a lower gamma ray response (< 75 API units) associated with the underlying Weir-Pittsburg coal (Figure 2.17). Thickness of the Weir-Pittsburg coal can be up to 6 feet with an average of 1.5 feet and distribution skewed to the minimum (1.8 m, average of 0.5 m; Appendix 2). The Weir-Pittsburg coal is recognizable on logs in the central part of the Cherokee basin as the thickest coal in the Cherokee Group (Figure 2.19). Of the many coals mined in the outcrop belt, the Weir-Pittsburg coal is known to be the thickest and best developed coal (Brady, 1997).

Weir-Pittsburg Coal

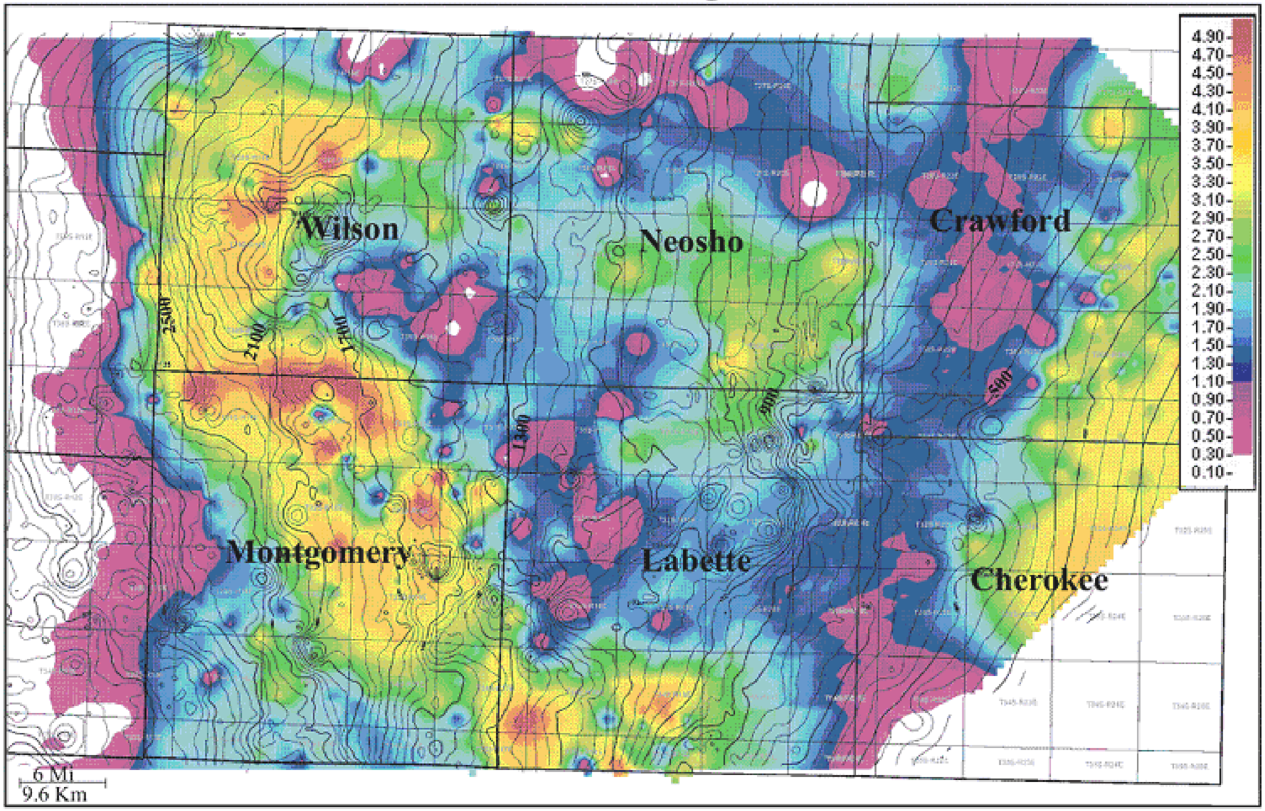


Figure 2.19 - Isopach of Weir-Pittsburg coal (color) overlain with contours of top Mississippian limestone structure (isopach CI:0.10ft; structure CI:25ft).

Detailed isopach mapping of the Weir-Pittsburg coal reveals a coal that stays fairly consistent in thickness over an average of 2.5 square miles (4 km2; Figure 2.19). When overlaying contours of top Mississippian structure on the isopach map, the coal appears to follow the structural strike. The Weir-Pittsburg coal exhibits a lenticular geometry that is oriented parallel to depositional strike (northwest), and is consistently thicker through an acute trend from southern Labette through Montgomery and Wilson counties. Localized circular areas of the Weir-Pittsburg coal may be due to removal by fire or crevasse splays (see Chapter 5).

2.3.6 Tebo Interval

Description

The interval from the top of the Weir-Pittsburg shale to the top of the Tebo shale ranges in thickness from 6 to 50 feet with an average of 25 feet (1.8 to 15.6m, average of 7.7 m; Figures 2.01 and 2.20). In ascending order, the Tebo interval consists of a dark gray shale facies passing upward into a laminated muddy sandstone facies. Overlying these facies is a regional coal facies (Tebo coal), capped by a phosphatic black shale facies (Figure 2.20). A poorly developed blocky mudstone facies locally underlies the Tebo coal.

Tebo Interval

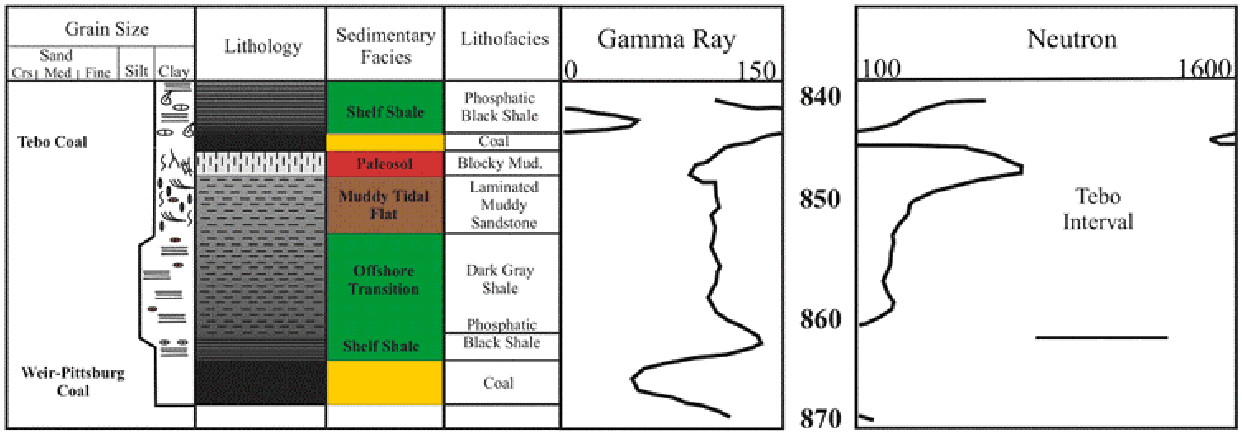


Figure 2.20 - Depositional sequence and log characteristics of the Tebo interval, based on core and well log from the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas (scale in feet). See Figure 2.15a for legend.

Tebo Coal Isopach Map

The Tebo coal is recognizable on logs due to a high gamma ray response (> 160 API units) and low neutron response (< 625 neutron counts) from the thick radioactive phosphatic black shale marker, which is followed down hole by a lower gamma ray response (< 105 API units) associated with the underlying Tebo coal (Figure 2.21). The Tebo shale marker extends across the Cherokee basin. Thickness of the Tebo coal can be up to 3 feet with an average of 0.9 feet and a distribution slightly skewed to the minimum (1 m, average of 0.3 m; Figure 2.21; Appendix 2).

Detailed isopach mapping of the Tebo coal reveals a coal that stays fairly consistent in thickness over an average of 5 square miles (8 km2; Figure 2.21). Structural contours of bottom of the Tebo coal are overlain on an isopach of the Tebo coal (Figure 2.21). The coal appears to thicken on highs and thin into lows. The Tebo coal exhibits an elongate geometry oriented obliquely to depositional dip (southwest) and strike (northwest) with an area of thicker accumulation through Montgomery and Wilson counties. Local thin areas and linear trends in the Tebo coal thickness may be the consequence of erosion (i.e. fluvial).

Tebo Coal

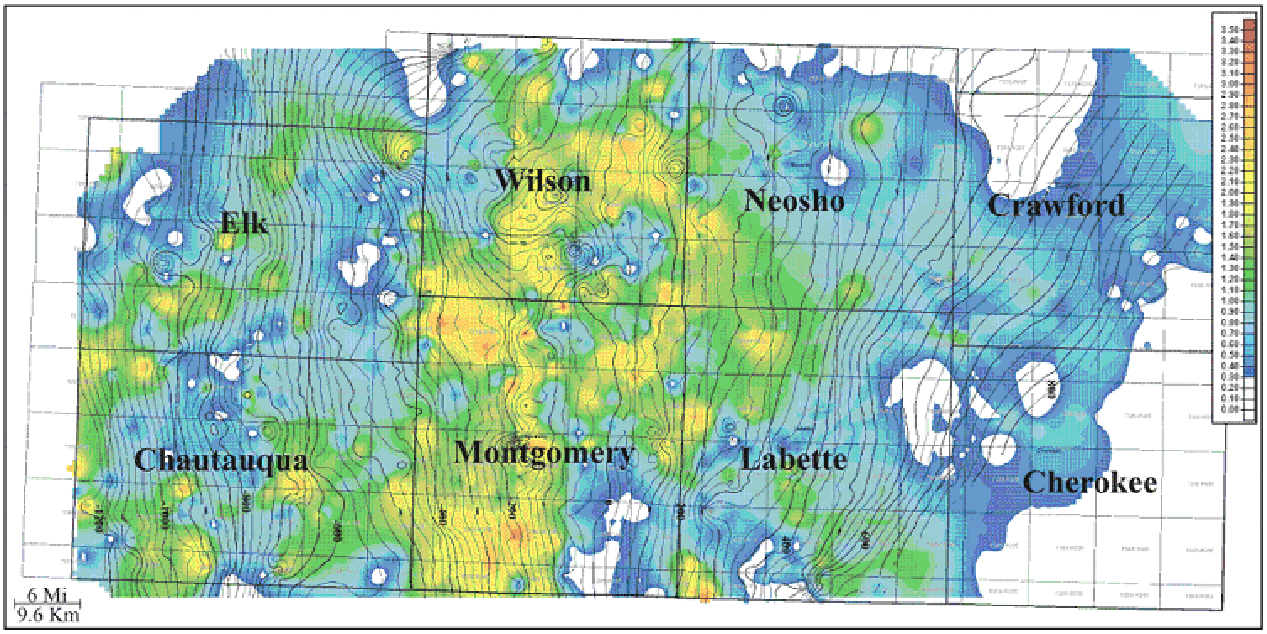


Figure 2.21 - Isopach of Tebo Coal (color) overlain with contours of bottom Tebo Coal structure (isopach CI:0.10ft; structure CI:25ft).

2.3.7 Scammon Interval

Description

The interval from the top of the Tebo shale to the top of the Scammon shale marker ranges in thickness from 8 to 80 feet with an average of 38 feet (2.4 to 24.4 m, average of 11.6 m; Figures 2.01 and 2.22). Variability in interval thickness may be due to thick sandstone accumulations within the interval (up to 40 ft, 12 m). In ascending order, the Scammon interval consists of a dark gray shale facies passing upward into interlaminated sandstone and siltstone facies known as the Skinner Sandstone or Chelsea Sandstone. A blocky mudstone facies, and the semi-continuous Scammon coal overlie the Skinner/Chelsea Sandstone. At the top of the Scammon interval is a dark gray shale facies (Figure 2.22). The bottom of the Skinner/Chelsea Sandstone is an unconformity that can erode deeply into the underlying interval (Tebo interval). Locally, a discontinuous coal facies (Scammon B coal) is present within the Skinner/Chelsea Sandstone.

Scammon Interval

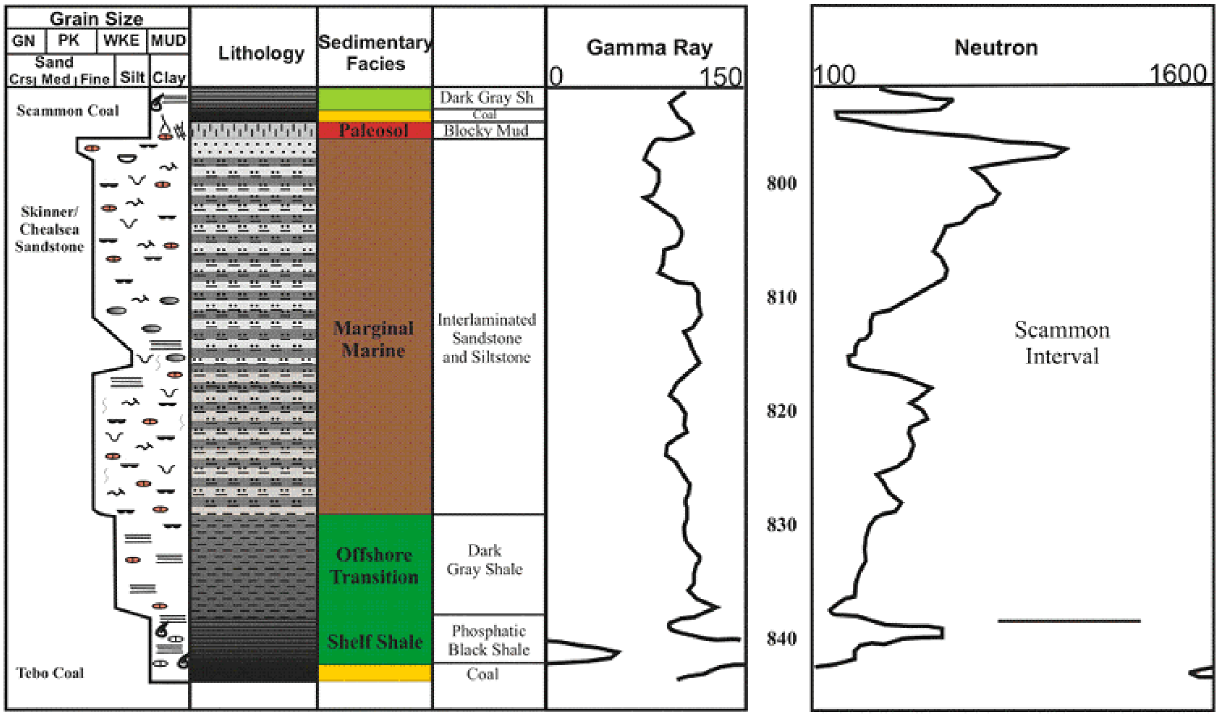


Figure 2.22 - Depositional sequence and log characteristics of the Scammon interval, based on core and well log from the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas (scale in feet). See Figure 2.15a for legend.

Scammon Coal Isopach Map

The Scammon coal is recognizable on logs due to a relatively high gamma ray response (> 105 API units) and low neutron response (< 475 neutron counts) from the thin black shale marker followed down hole by a lower gamma ray response (< 105 API units) associated with the underlying coal (Figure 2.22). The Scammon shale marker extends across most of the Cherokee basin. Thickness of the Scammon coal can be up to 3 feet with an average of 1 foot and distribution slightly skewed to the minimum (1 m, average of 0.3 m; Figure 2.23; Appendix 2).

Detailed isopach mapping of the Scammon coal reveals a coal that remains fairly constant in thickness over an average of 6 square miles (9.6 km2; Figure 2.23). When structural contours of top of the Skinner Sandstone are overlain onto an isopach of the Scammon coal thickness, the coal appears to thicken on highs and thin into lows. Highs associated with the Skinner Sandstone may be due to differential compaction, where thicker Skinner Sandstone units provide a relatively higher topographic area. Local thin trends within thicker Scammon coal may be due to removal by fluvial erosion. The Scammon coal exhibits an irregular geometry that is oriented parallel and oblique to depositional dip (southwest), and is consistently thicker in Labette, Montgomery and Wilson counties.

Scammon Coal

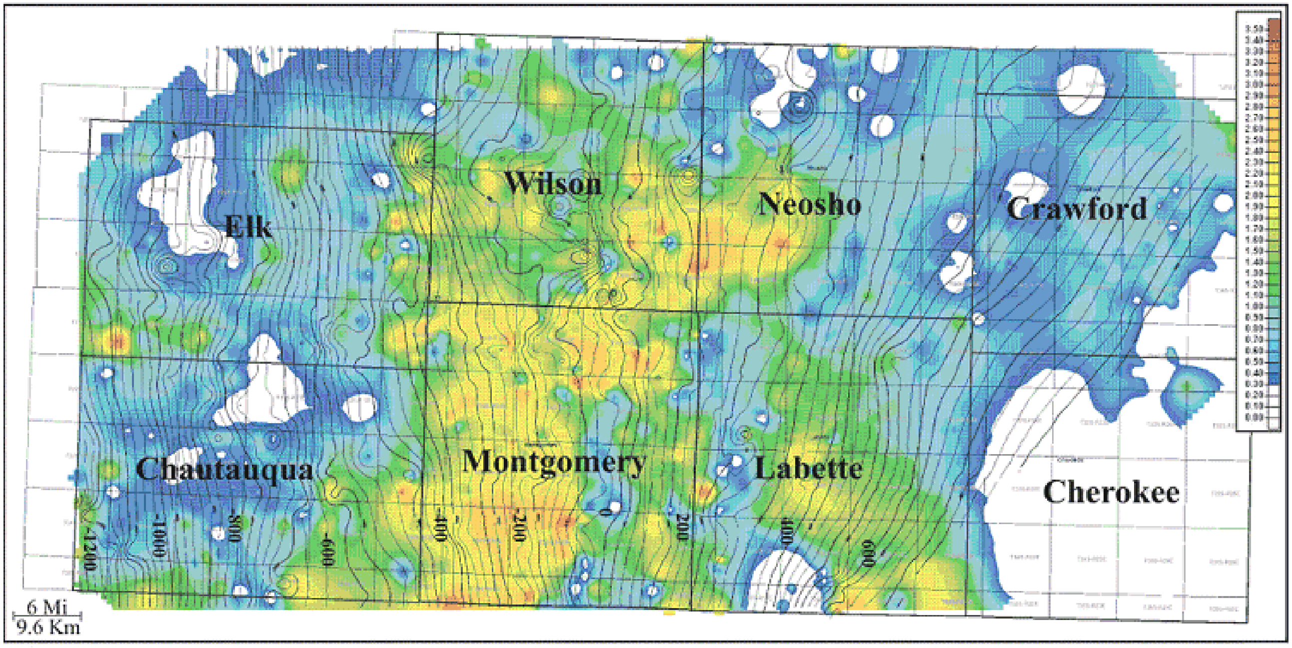


Figure 2.23 - Isopach of Scammon Coal (color) overlain with contours of bottom Skinner/Chelsea Sandstone structure (isopach CI:0.10ft; structure CI:25ft).

2.3.8 Mineral Interval

Description

The interval from the top of the Scammon shale to the top of the Mineral shale ranges in thickness from 10 to 40 feet with an average of 19 feet (3 to 12.2 m, average of 5.8 m; Figures 2.01 and 2.24). In ascending order, the Mineral interval consists mainly of a dark gray shale facies passing upward into a laminated muddy sandstone facies. A blocky mudstone facies, and the regional extensive Mineral coal overlies the sideritic shale facies. The regionally extensive Mineral coal is overlain by a phosphatic black shale facies (Figure 2.24). The blocky mudstone facies underlying the coal facies varies in thickness from 2 to 8 feet (0.6 to 2.4 m).

V-Shale and Mineral Interval

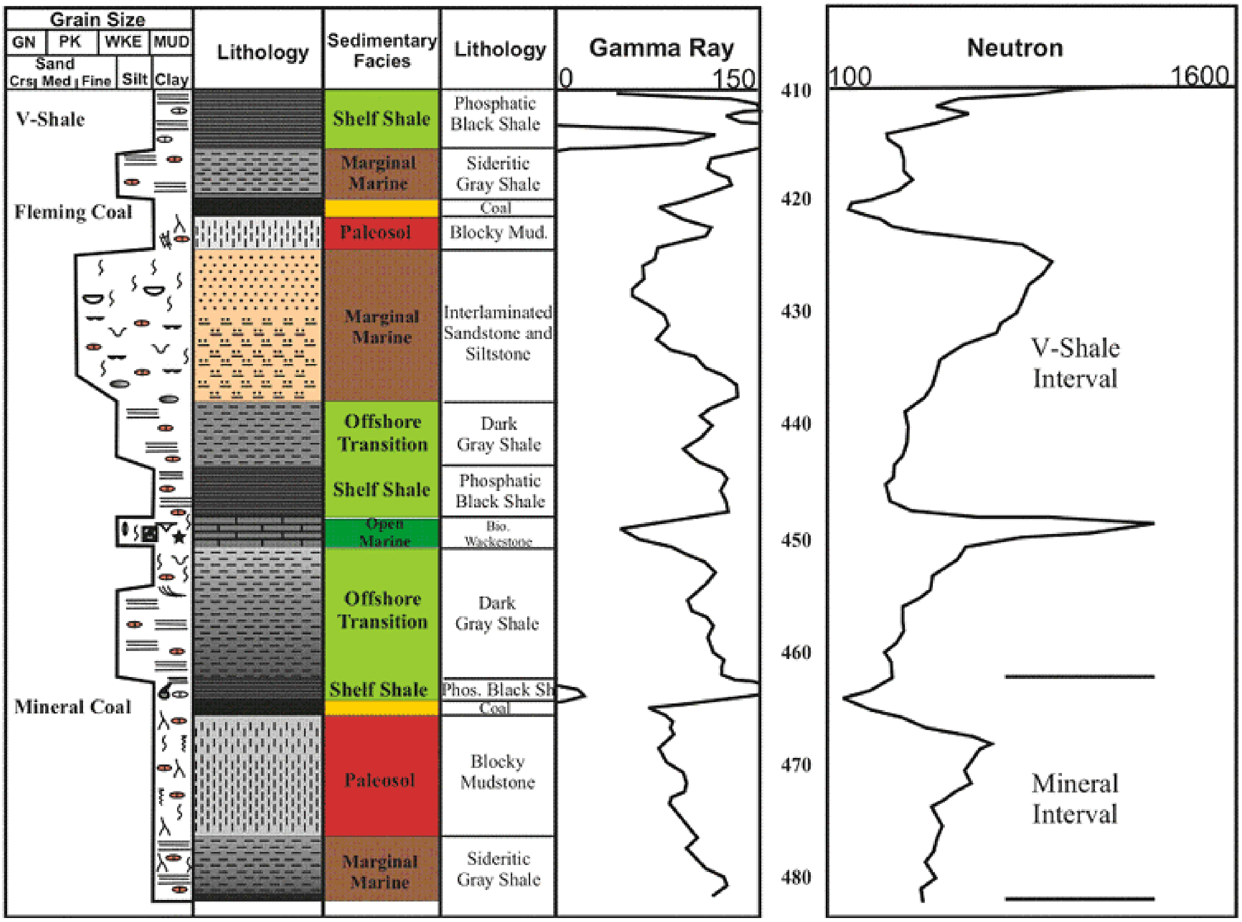


Figure 2.24 - Depositional sequence and log characteristics of theV-Shale and Mineral interval, based on core and well log from the Cooper CW#1 well 11-T35S-R18E, Labette County, Kansas (scale in feet). See Figure 2.15a for legend.

Mineral Coal Isopach Map

The Mineral coal is recognizable on most logs by the radioactive black shale marker (Mineral shale marker) present above the Mineral coal, which is due to a high gamma ray response (> 140 API units) and a lower neutron response (< 475 neutron counts). This black shale marker is followed down hole by a lower gamma ray response (< 100 API units) associated with the underlying coal (Figure 2.24). The Mineral coal marker extends throughout the Cherokee basin. Thickness of the Mineral coal ranges up to 4 feet with an average of 1.4 feet, and is normal in distribution (1 m, average of 0.4 m; Figure 2.25; Appendix 2).

Detailed isopach mapping of the Mineral coal reveals a coal that stays fairly constant in thickness over an average distance of 6 square miles (9.6 km2; Figure 2.25). The Mineral coal is the next laterally extensive and thick coal above the Weir-Pittsburg coal. Paleotopography reflected in structure appears to influence coal thickness. When structural contours of bottom of the Mineral coal are overlain onto an isopach of Mineral coal thickness, the coal appears to thicken on highs and thin into lows (Figure 2.25). The Mineral coal exhibits a lenticular geometry that is oriented parallel to depositional strike (northwest), and is consistently thicker in Labette, Neosho, Montgomery, Wilson, and Cherokee counties. Localized thin areas in the Mineral coal are usually circular in map view, and may be due to removal by erosion (see Chapter 5).

Mineral Coal

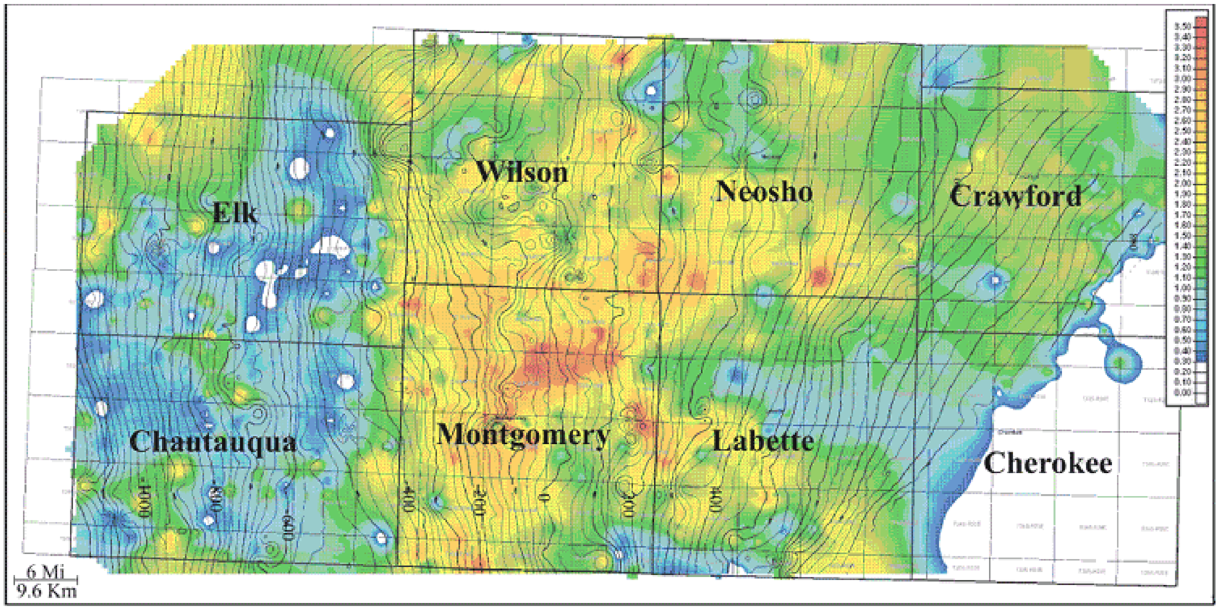


Figure 2.25 - Isopach of Mineral Coal (color) overlain with contours of bottom Mineral Coal structure (isopach CI:0.10ft; structure CI:25ft).

2.3.9 V-Shale Interval

Description

The interval from the top of the Mineral shale to the top of the V-Shale ranges in thickness from 20 to 70 feet with an average of 40 feet (6.1 to 21.9 m, average of 12.2 m; Figures 2.02 and 2.24). The V-Shale interval consists, in ascending order, of a dark gray shale facies that is locally overlain by approximately 10 feet (3 m) of an interlaminated sandstone and siltstone facies. The upper part of the V-Shale interval consists of thin bedded (3-10 cm), massive, clean sand, which is capped by a blocky mudstone facies and a thin (less than 3 ft; 0.9 m) discontinuous coal facies known as the Fleming coal. Overlying the Fleming coal is another dark gray shale facies or sideritic shale facies. Locally, an additional blocky mudstone facies and coal facies known as the Croweburg coal occurs on top of the sideritic shale facies. The top of the V-Shale interval is defined by a regionally extensive phosphatic black shale facies known as the V-Shale (Figure 2.24). The erosional basal contact of the interlaminated sandstone and siltstone facies below the Fleming coal is interpreted as an unconformity.

Fleming Coal Isopach Map

The V-Shale is the most recognizable radioactive black shale within the Cherokee Group, and is correlatable throughout southeastern Kansas and into adjacent states. The V-Shale is identifiable on logs due to a high gamma ray response (> 225 API units) moderate neutron response (~ 800 neutron counts; Figure 2.24). The high gamma ray response and stratigraphic position of the V-Shale is underlain by a much lower gamma ray response (< 150 API units) and lower neutron response (< 100 neutron counts) due to the underlying Croweburg coal. Approximately 10 feet (3 m) below the V-shale lies another thin radioactive shale (> 150 API units) that although not as laterally continuous is a useful marker for identifying the underlying Fleming coal.

Detailed isopach mapping of the Fleming coal reveals a coal that is laterally discontinuous but has a consistency in thickness over an average of 4 square miles (6.4 km2; Figure 2.26). Thickness of the Fleming coal can be up to 2.6 feet with an average of 1 foot and a distribution skewed to the minimum (0.8 m, average of 0.3 m; Appendix 2). The Fleming coal exhibits a dendritic geometry that is oriented parallel to depositional dip (southwest). In contrast with some of the other Cherokee Group coal deposits in the study area, structure does not appear to have as much control on coal thickness. The Fleming coal is consistently thicker in the southern half of the study area. Thin or zero coal trends of the Fleming coal appear to be the result of non-deposition.

Fleming Coal

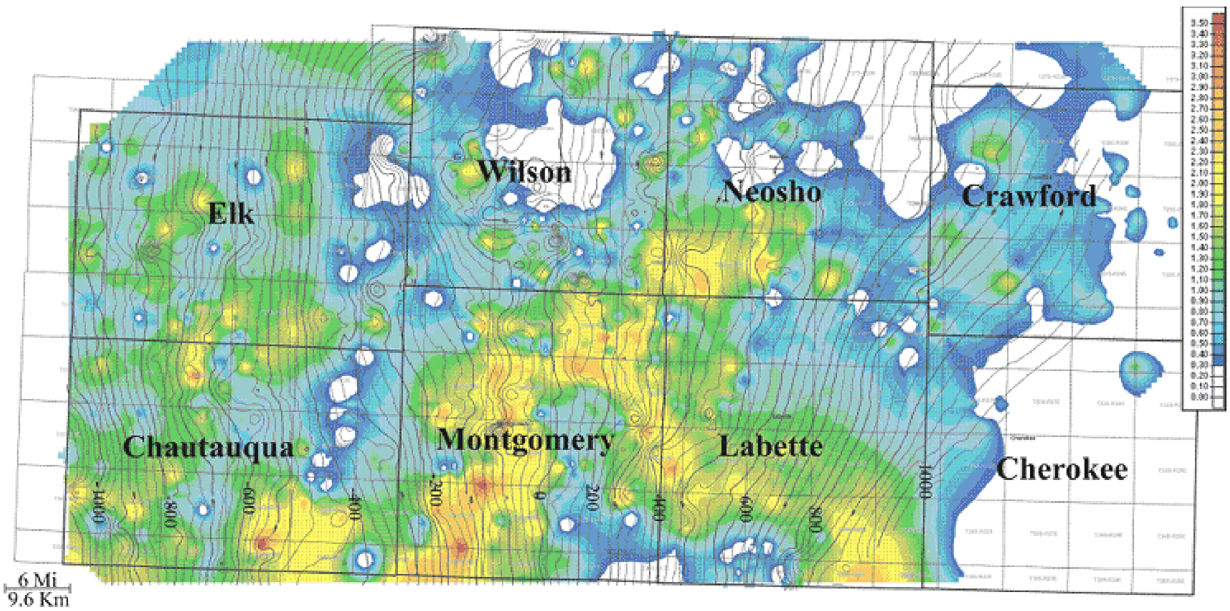


Figure 2.26 - Isopach of Fleming Coal (color) overlain with contours of bottom Fleming Coal structure (isopach CI:0.10ft; structure CI:25ft).

Croweburg Coal Isopach Map

Detailed isopach mapping of the Croweburg coal reveals a laterally continuous coal that has a consistency in thickness over an average of 6 square miles (9.6 km2; Figure 2.27). Thickness of the Croweburg coal can be up to 3 feet with an average of 1 foot and has a normal distribution (0.9 m, average of 0.3 m; Appendix 2). The Croweburg coal exhibits a lenticular geometry that is oriented parallel to both depositional dip (northwest) and strike (southeast). When overlaying structural contours of bottom of the Croweburg coal onto an isopach of Croweburg coal thickness, the coal appears to thicken on structural highs and thin into lows. The Croweburg coal is consistently thicker in Wilson, Montgomery, Neosho, and Labette counties. Localized thin areas and trends within the thicker Croweburg coal may be due to removal by erosion.

Croweburg Coal

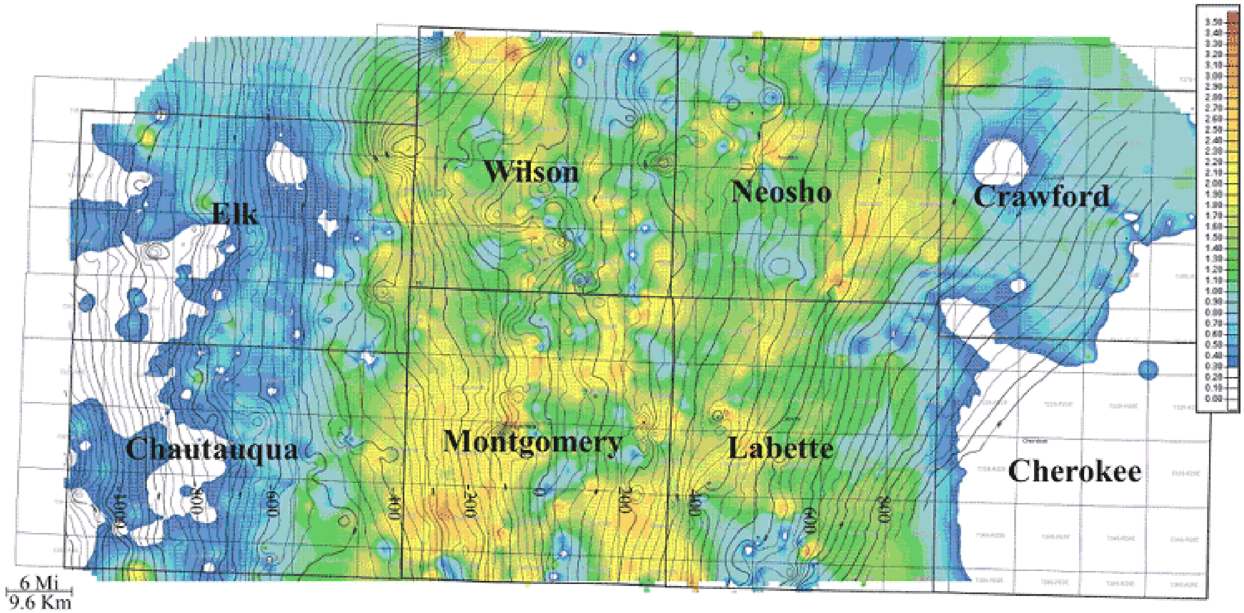


Figure 2.27 - Isopach of Croweburg Coal (color) overlain with contours of bottom Croweburg Coal structure (isopach CI:0.10ft; structure CI:25ft).

2.3.10 Bevier Interval

Description

The interval from the top of the V-Shale shale to the top of the Bevier shale ranges in thickness from 5 to 24 feet with an average of 14 feet (1.5 to 7.3 m, average of 4.3 m; Figures 2.01 and 2.28). In ascending order, the Bevier interval consists of a bioclastic mudstone to wackestone facies passing upward into a dark gray shale facies overlain by a 5 to 10 feet of thick (1.5 to 3 m) interlaminated sandstone and siltstone facies. The Bevier interval is capped by a blocky mudstone facies, coal facies (Bevier coal), and a dark shale facies (Bevier shale marker; Figure 2.28). An unconformity is located at the base of the interlaminated siltstone and sandstone facies below the Bevier coal.

Bevier and Lower Excello Interval

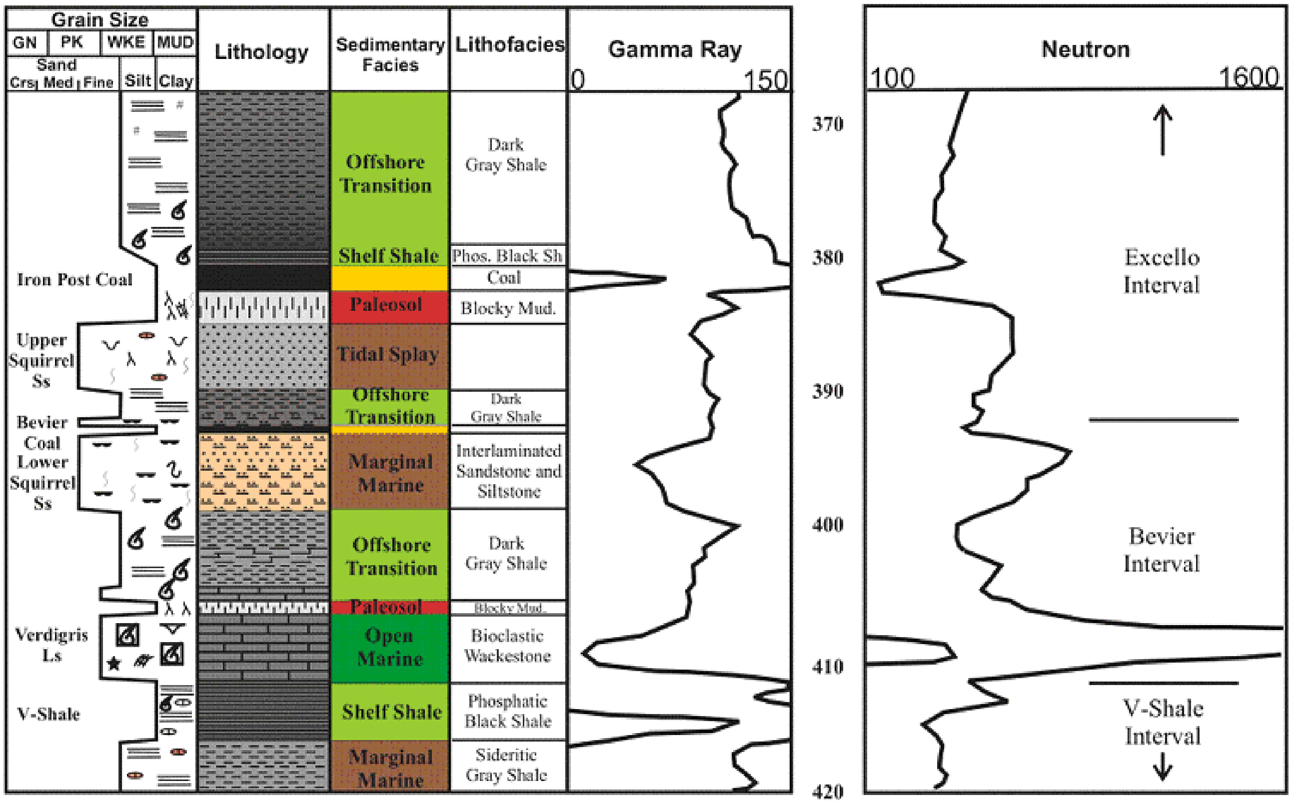


Figure 2.28 - Depositional sequence and log characteristics of the Bevier and Lower Excello interval, based on core and well log from the Cooper CW#1 well 11-T35S-R18E, Labette County, Kansas (scale in feet). See Figure 2.15a for legend.

Bevier Coal Isopach Map

A shale marker is present above the Bevier coal and is recognizable on logs due to a relatively high gamma ray response (> 105 API units) and low neutron response (~ 475 neutron counts) followed down hole by a lower response (< 90 API units) associated with the Bevier coal (Figure 2.28). The Bevier coal marker extends through most the Cherokee basin. If present, the Bevier coal is the next coal stratigraphically below the Iron Post coal.

Detailed isopach mapping of the Bevier coal reveals a coal that is discontinuous in the southern half of the study area and has a consistency in thickness over an average of 6 square miles (9.6 km2) in the northern half of the study area (Figure 2.29). Thickness of the Bevier coal ranges can be up to 4.5 feet with an average of 1.5 feet and has a normal distribution (1.4 m, average of 0.5 m). The Bevier coal exhibits a lenticular geometry that is oriented parallel to depositional dip (southwest). Structure appears to influence coal thickness. The Bevier coal appears to thicken on highs and thin into lows as defined by structure contours of the base of the Bevier coal overlain onto an isopach of Bevier coal thickness (Figure 2.29). The Bevier coal is consistently thicker in the northern half of the study area especially within Wilson, and Neosho counties. Localized thin trends in areas of thicker Bevier coal may be due to erosion.

Bevier Coal

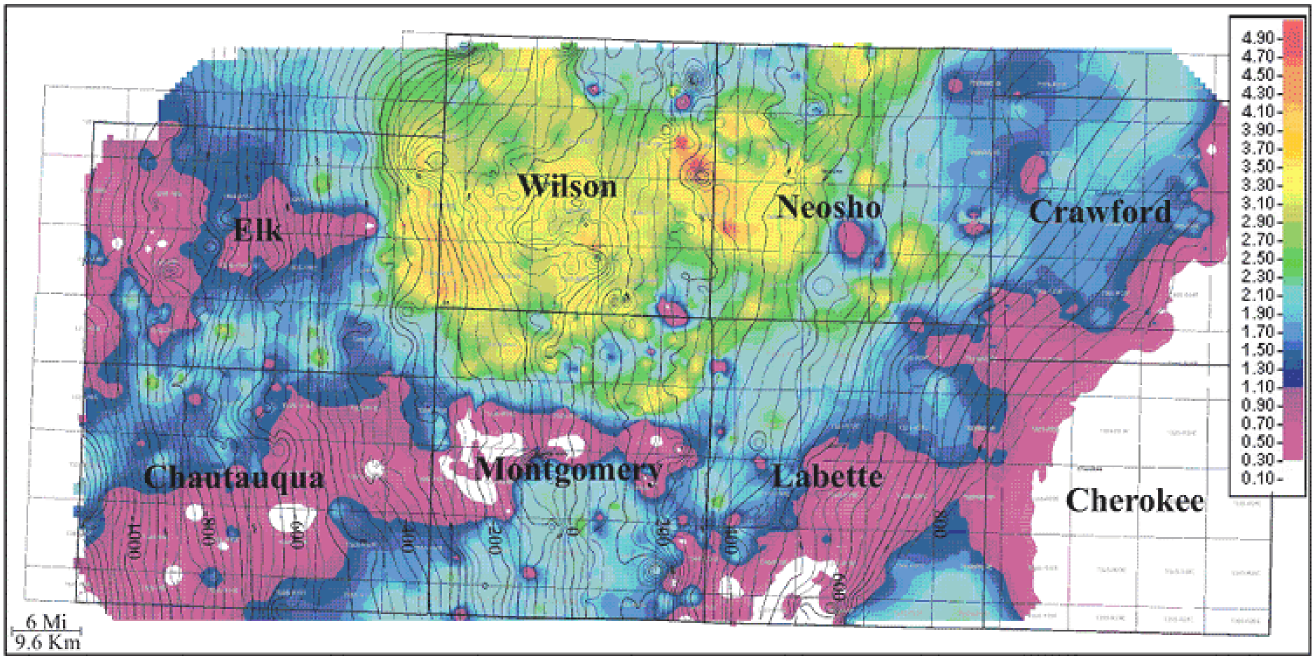


Figure 2.26 - Isopach of Bevier Coal (color) overlain with contours of bottom Bevier Coal structure (isopach CI:0.10ft; structure CI:25ft).

2.3.11 Excello Interval

Description

The interval from the top of the Bevier shale to the top of the Excello Shale ranges in thickness from 25 to 130 feet with an average of 63 feet (7.6 to 40 m, average of 19 m; Figures 2.01 and 2.30). Variability in interval thickness may be due to thick sandstone accumulations within the interval (up to 30 ft, 9m; Staton, 1987). The Excello interval consists of a dark gray shale facies passing upward into a blocky mudstone facies or locally discontinuous sandstone, which is known as the Squirrel Sandstone. The Squirrel Sandstone is overlain by a coal facies known as the Iron Post coal (Figure 2.30). Above the Iron Post coal is a dark gray shale facies that grades into a pyritic shale facies (Figure 2.30). Overlying the pyretic shale facies is a regionally continuous bioclastic wackestone facies that grades into a bioclastic packstone facies. This carbonate facies is known as the Breezy Hill Limestone. Locally, capping the interval is a coal to carbonaceous shale facies (Mulky coal), followed by a phosphatic black shale facies (Figure 2.30). The phosphatic black shale facies is a regionally extensive unit known as the Excello Shale.

The Excello Shale is a highly radioactive phosphatic black shale that extends throughout the Cherokee basin and mid-continent (Wanless et al., 1969). The Excello is the first highly radioactive shale in the Cherokee Group and is recognizable on logs by a high gamma ray response (> 225 API units) and low neutron response (< 325 neutron counts) followed down the hole by a lower gamma ray response (< 150 API units). The lower gamma-ray response is associated with the underlying Mulky coal or carbonaceous shale (Figure 2.30). The Iron Post coal is identifiable as either the next coal stratigraphically below the Breezy Hill Limestone or by the overlying Iron Post shale. The Iron Post shale exhibits a relatively high gamma ray response (> 105 API units) and high neutron response (~ 925 neutron counts) followed down hole by a lower gamma ray response (< 90 API units) and low neutron response (< 100 neutron counts) due to the underlying Iron Post coal. Due the close stratigraphic relationship between the Iron Post and Bevier coals, misidentification can be a problem when only one relatively thick and easily identifiable coal is present in the upper portion of the Cherokee Group. Through mapping and cross section construction, the Bevier coal is identified as the predominate of the two coals in the northern half of the study area, whereas the Iron Post coal tends to be the thicker coal in the southern half of the study area.

Iron Post Coal Isopach Map

Detailed isopach mapping of the Iron Post coal reveals a coal that is laterally continuous and has a consistency in thickness over an average of 6 square miles (9.6 km2; Figure 2.31). Thickness of the Iron Post coal ranges from 0 to 2.6 feet with an average of 1 foot and a distribution that is skewed to the minimum (0 to 0.8 m, average of 0.3 m; Appendix 2). The Iron Post coal exhibits an elongate geometry that is oriented parallel to depositional dip (southwest). Unlike some of the other coals local structure does not appear to influence the local thickness of coal. The Iron Post coal is consistently thicker in the southern half of the study area, especially within Chautauqua, Montgomery, and Labette counties.

Iron Post Coal

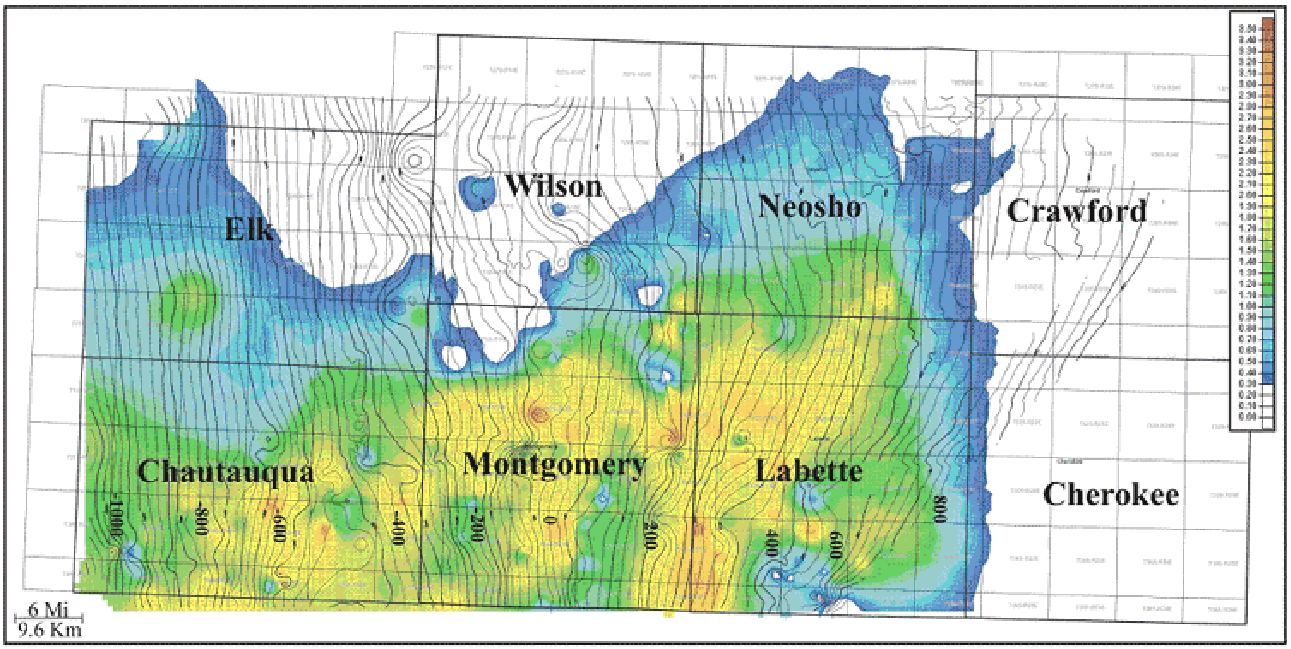


Figure 2.31 - Isopach of Iron Post Coal (color) overlain with contours of top Iron Post coal structure (isopach CI:0.10ft; structure CI:25ft).

Mulky Coal Isopach Map

Detailed isopach mapping of the Mulky coal reveals a coal that has a consistency in thickness over an average of 3 square miles (4.8 km2; Figure 2.32). Thickness of the Mulky coal can be up to 2.5 feet with an average of 0.75 feet and a distribution that is skewed to the minimum (0.8 m, average of 0.2 m, Appendix 2). The Mulky coal exhibits an irregular distribution. Local structure appears to have influenced coal thickness. When overlaying structural contours of top Brezzy Hill Structure onto an isopach of Mulky coal thickness, the coal appears to thicken on highs and thin into lows. The Mulky coal is consistently thicker in areas of Montgomery, Labette, and Neosho counties. Areas and trends of thin Mulky coal thickness may be due to non-deposition or deposition of carbonaceous shale instead of coal.

Mulky Coal

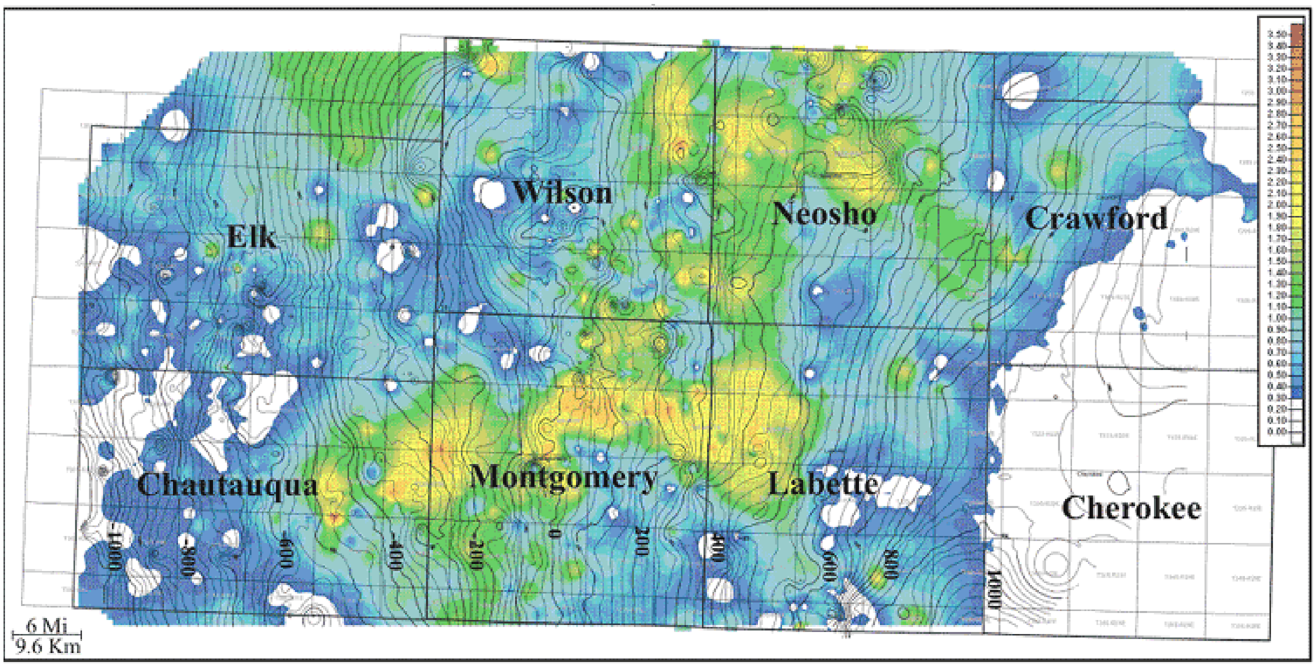


Figure 2.32 - Isopach of Mulky Coal (color) overlain with contours of top Brezzy Hill Limestone structure (isopach CI:0.10ft; structure CI:25ft).

2.3.12 Little Osage Interval

Description

The Little Osage interval extends from the top of the Excello Shale to the top of the Little Osage Shale and ranges in thickness from 10 to 45 feet with a mode of 20 feet (3 to 13.7 m, average of 6 m; Figures 2.01 and 2.30). The Little Osage interval consists of a regionally extensive bioclastic wackestone facies that grades into a bioclastic packstone/grainstone facies known as the Blackjack Creek Limestone. Above the Blackjack Creek Limestone is a coal to carbonaceous shale facies known as the Summit coal that is overlain by regionally extensive phosphatic black shale known as the Little Osage Shale (Figure 2.30).

The Little Osage Shale is a highly radioactive phosphatic black shale in the Fort Scott Limestone Formation that extends throughout the Cherokee basin and into adjacent states. It separates the Higginsville Limestone from the Blackjack Creek Limestone and is recognizable on logs due to a high gamma ray response (> 225 API units) and low neutron response (< 200 neutron counts) followed down the hole by a lower gamma ray response (< 150 API units) and low neutron response (< 100 neutron counts) associated with the underlying coal or carbonaceous shale known as the Summit coal (Figure 2.30).

Little Osage and Upper Excello Interval

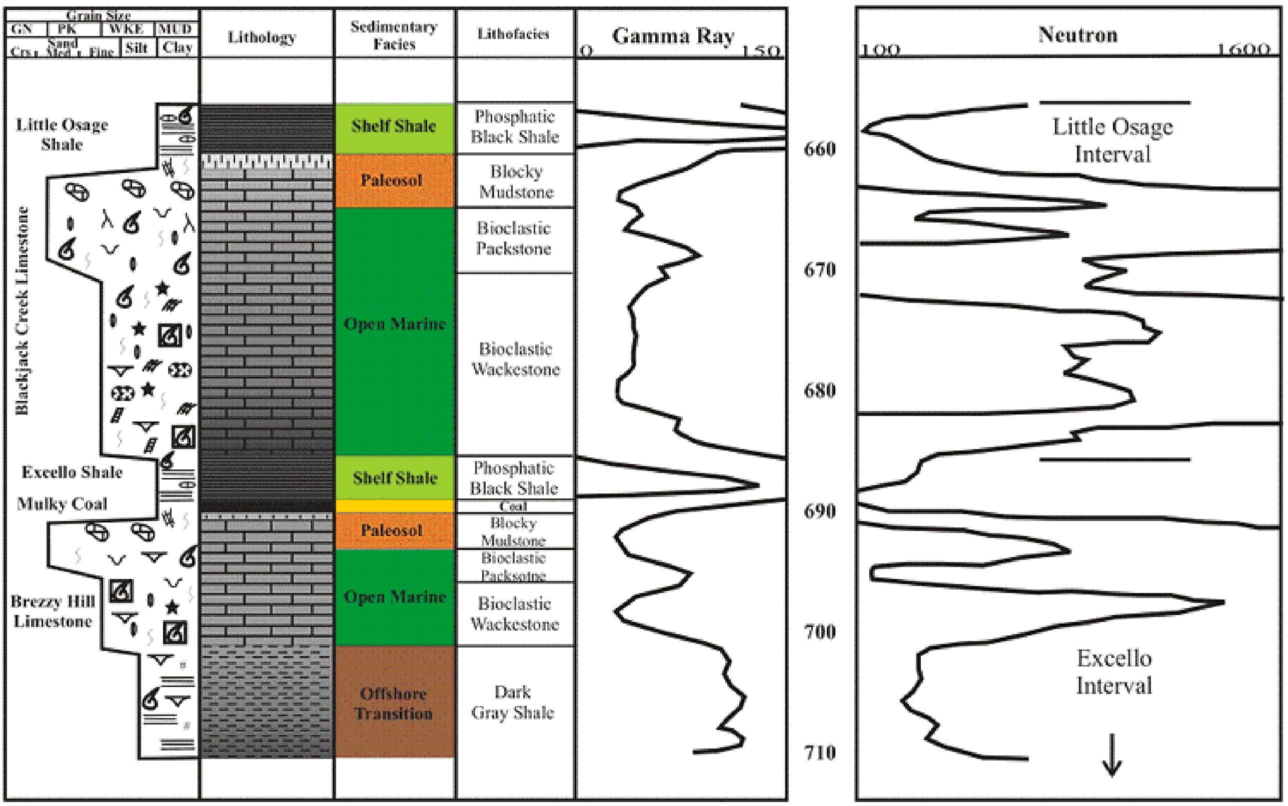


Figure 2.30 - Depositional sequence and log characteristics of the Little Osage and Upper Excello interval, based on core and well log from the Hinthorn CW#1 well, 14-T32S-R16E, Montgomery County, Kansas (scale in feet). See Figure 2.15a for legend.

Summit Coal Isopach Map

Detailed isopach mapping of the Summit coal reveals a coal that has a consistency in thickness over an average of 6 square miles (9.6 km2; Figure 2.33). Thickness of the Summit coal can be up to 2.8 feet with an average of 1 foot and a distribution that is slightly skewed to the minimum (0.9 m, average of 0.3 m; Appendix 2)). The Summit coal exhibits an irregular circular to polygonal geometry. Structure appears to have an influence on coal thickness. When overlying contours of top Blackjack Creek Limestone structure onto an isopach of Summit coal thickness, the coal usually to thickens on the highs and thin into lows. The Summit coal is consistently thicker in Neosho County. Areas and trends of thin Summit coal thickness may be due to non-deposition or deposition of carbonaceous shale instead of coal.

Summit Coal

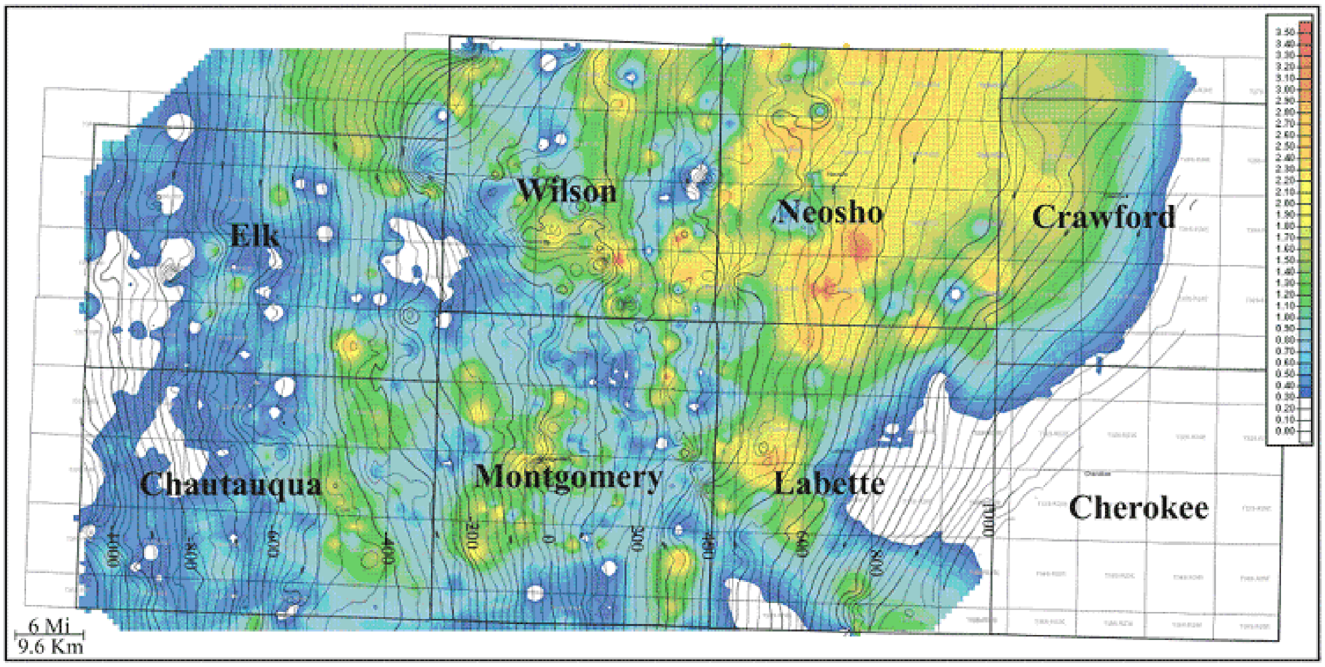


Figure 2.33 - Isopach of Summit Coal (color) overlain with contours of top Blackjack Creek Limestone structure (isopach CI:0.10ft; structure CI:25ft).