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Regional Stratigraphic Analysis of the Blackjacket Creek Limestone (Desmoinesian, Middle Pennsylvanian) in Southeast Kansas and Northeast Oklahoma

by

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REGIONAL STRATIGRAPHIC ANALYSIS OF THE BLACKJACK CREEK LIMESTONE (DESMOINESIAN, MIDDLE PENNSYLVANIAN) IN SOUTHEAST KANSAS AND NORTHEAST OKLAHOMA

by

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INTRODUCTION

GENERAL STATEMENT

Cyclic alternations of limestone and shale units that dominate Pennsylvanian stratigraphy along the Midcontinent outcrop belt (Figure 1) and have intrigued geologists since the 1930's (Weller, 1930; Moore, 1931; Wanless and Weller, 1932). Pennsylvanian units have been described, interpreted, and correlated based on recognition of specific lithofacies occurring in cyclic alternations (or "cyclothems" as defined by the North American Commission on Stratigraphic Nomenclature, 1983) proposed by Wanless and Weller (1932). Recently, throughout the Midcontinent, specifically southeast Kansas and northeast Oklahoma, Pennsylvanian rocks have been interpreted and described relative to "Kansas Cyclothems" (Heckel, 1977) (Figure 2). However, as discussed by Suchy and West (in press), Heckel's (1977) model is based primarily on studies of Missourian rocks of Kansas and may not be adequate to explain cyclicity in the Desmoinesian.

Although cyclothem recognition is useful for stratigraphic reconnaissance at the scale of the lithostratigraphic unit (i.e. formation), recent work has shown that smaller-scale, regionally correlatable stratigraphic units can be recognized within these cyclothems (Busch and Rollins, 1984; Suchy, 1987).

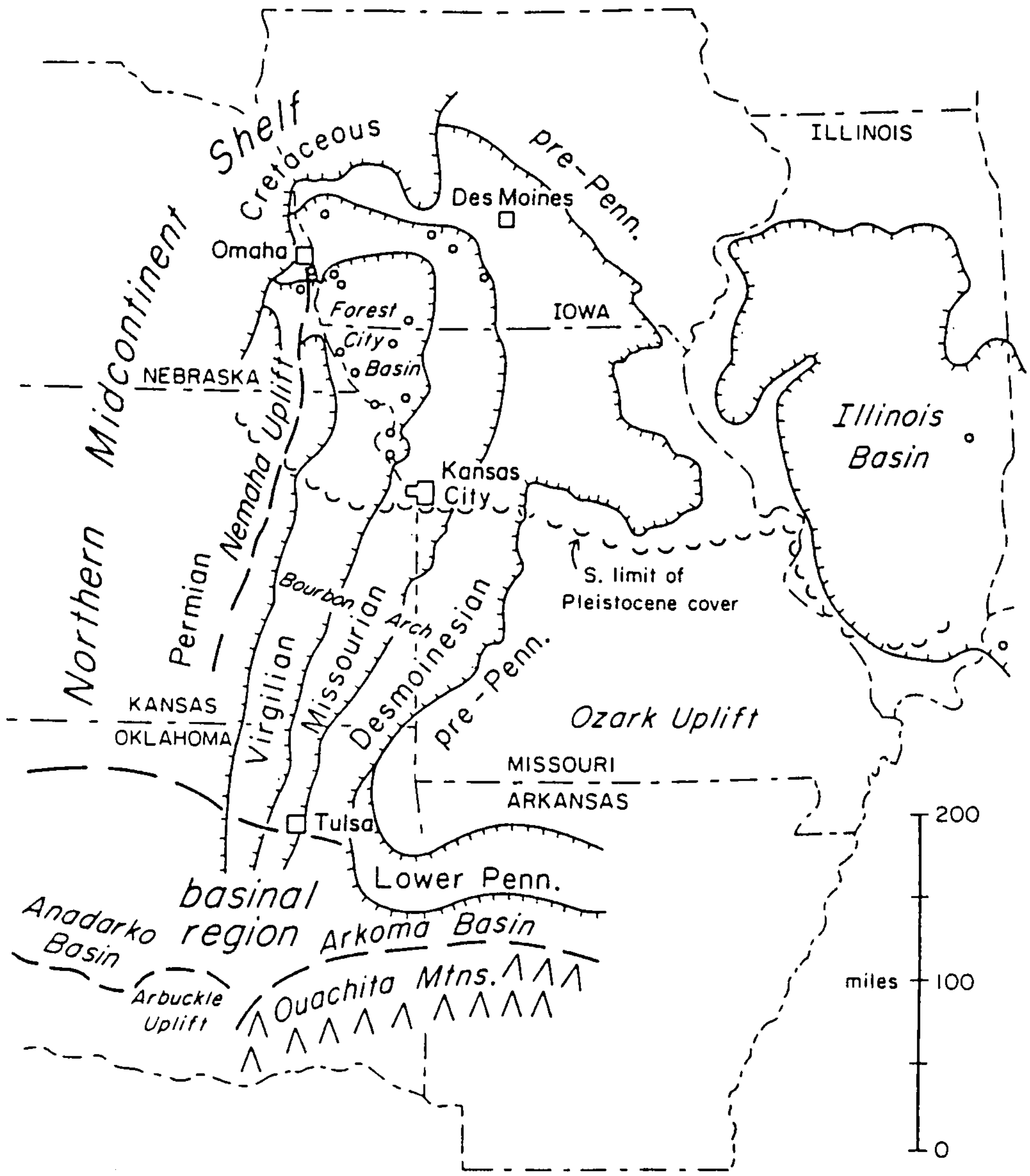

Figure 1. Map of Pennsylvanian (Desmoinesian) outcrop in the Midcontinent. From Heckel (1985).

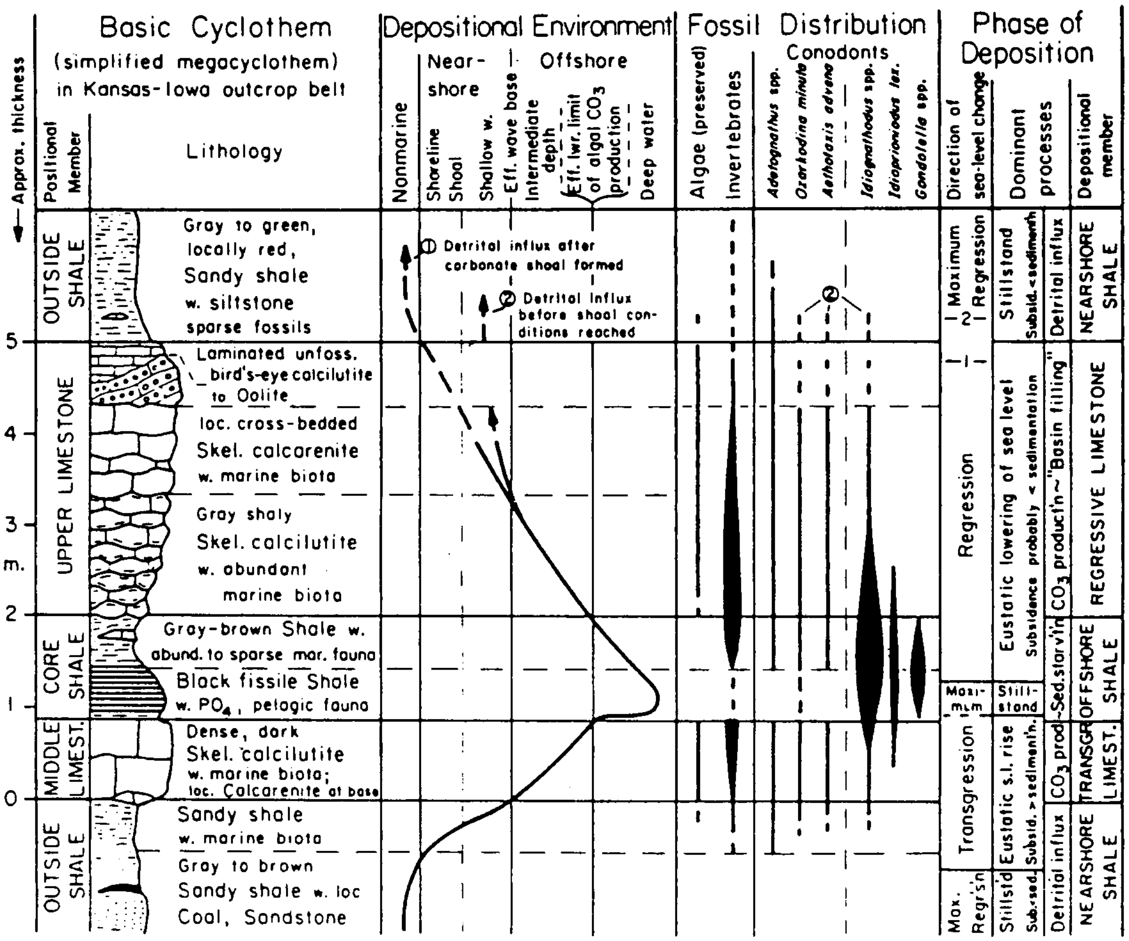

Figure 2. Basic Kansas Cyclothem Characterizing Marine Cycles of Deposition across the Midcontinent. From Heckel (1977).

Anderson and Goodwin (1980) introduced the Punctuated Aggradational Cycle (PAC) hypothesis, a genetic approach, that provides: 1) a chronostratigraphic framework for interpreting the strata, and 2) a more realistic sea level curve than does the cyclothem model. PACs are typically regarded as shallowing-upward units, which can be formed by small-scale sea level fluctuations. However, as Suchy and West (in press) suggest for the Houx-Higginsville limestone, these cycles could also be the result of changes in climate.

Recently, workers have been able to describe and interpret Pennsylvanian rocks by utilizing Hierarchal Genetic Stratigraphy (HGS) (Busch and Rollins, 1984; Busch and West, 1987), which traces small-scale genetic events (i.e. deepening-shallowing) across a depositional basin (autogenic) and sometimes, between two or more basins (allogenic).

As defined by Busch et al. (1989), autogenic units are not widely correlative and are presumed to be the net depositional result of an event that affected only a small geographic area or single environment of deposition (i.e. delta switching, basin subsidence). Allogenic units are widely correlative and are presumed to be the net depositional result of an event that affected a very large geographic area (i.e. sea level, climate).

The Blackjack Creek Limestone Member of the Fort Scott Formation is the lowest unit within the Marmaton Group, Middle Pennsylvanian. Using Heckel's (1977) model, the Blackjack Creek limestone is considered a "regressive limestone" within Knight's (1985) "lower Fort Scott cyclothem". However, as stated by Suchy and West (in press), the more appropriate model for this study interval would be the typical Illinois cyclothem model of Wanless and Weller (1932). Here, the Blackjack Creek limestone would be equivalent to their upper limestone member; "...limestone with marine fossils." (Wanless and Weller, 1932, p. 1004).

PURPOSE OF STUDY

The purpose of this study is first, to determine the general stratigraphy, lithology, and lateral continuity of the Blackjack Creek Limestone Member (Figure 3) and associated units which comprise Knight's (1985) "Breezy Hill cyclothem" and "lower Fort Scott cyclothem" (i.e. the interval from the top of the Breezy Hill limestone [Cherokee Formation], to the base of the Little Osage Shale Member [Fort Scott Formation]) (Figure 4).

The second purpose is to recognize and correlate, regionally, small-scale, genetic cycles (PACs) and associated surfaces within the Blackjack Creek limestone. Delineation of these genetic stratigraphic units (sixth-order T-R units, Busch and Rollins, 1984; PACs, Anderson and Goodwin, 1980) will help refine correlations, sedimentologic interpretations, paleoenvironmental reconstructions, and

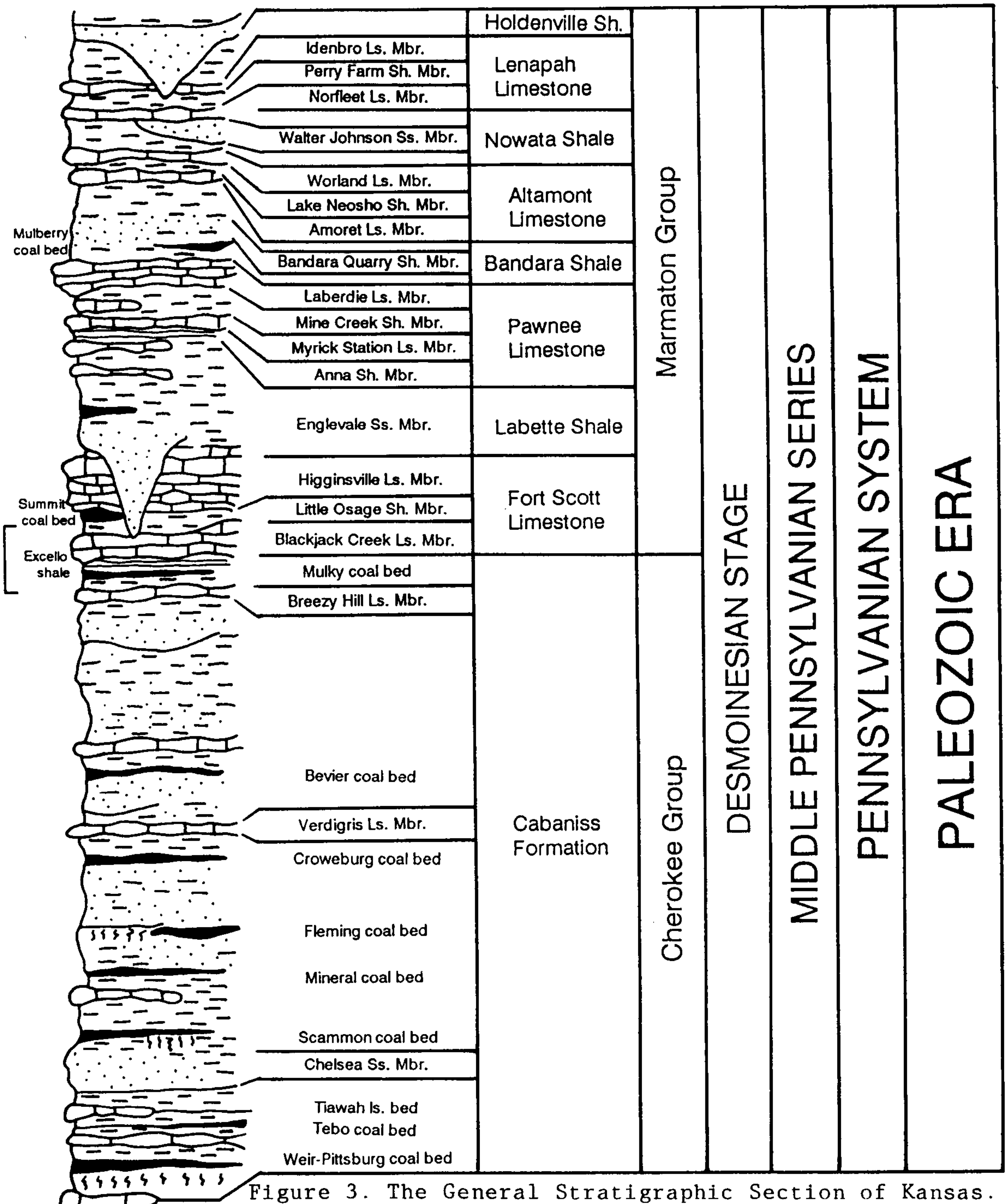

Figure 3. The General Stratigraphic Section of Kansas. Brackets indicate interval studied. Revised from Zeller (1968).

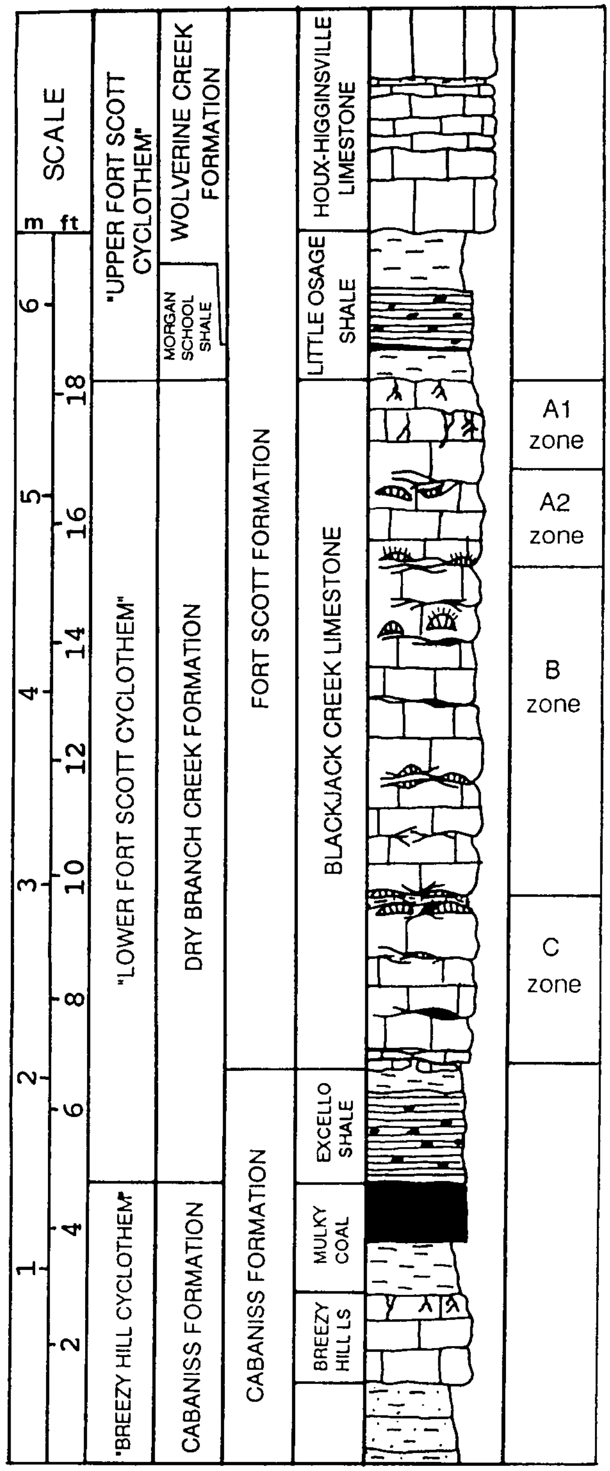

Figure 4. Composite Section of the Interval Studied. Nomenclature in the first two columns is from Knight (1985), the next two from Cline (1941). The last column on the right designates the zones identified in the Blackjack Creek Limestone.

relative sea level interpretations at a scale (PAC) that is an order of magnitude smaller than the cyclothem. Hopefully, this PAC approach will suggest an influence, if any, of climate as a controlling factor on Pennsylvanian cyclic sedimentation. Cecil (1990), based on work done in the Appalachian region, stated that stratigraphic models based entirely on physical processes cannot completely explain the distributions of siliciclastic (shales) and chemical (coals and carbonates) rocks.

The third purpose is to document the paleoecological aspects of <u>Chaetetes</u> relative to small-scale genetic units using sedimentologic and stratigraphic information. Recent studies, using detailed genetic stratigraphy (e.g. West et al., 1989), indicate that chaetetids occur in predictable stratigraphic and paleoecologic sequences. From an economic perspective, chaetetids exposed in outcrops of the Amoret Limestone Member, Altamont Formation (Marmaton Group), in southeast Kansas contain hydrocarbons. Thus, any predictability of chaetetid occurrences has a potential for significant economic importance because the occurrence of porous chaetetid skeletons in mounds can have value as subsurface exploration targets. Randolph (1974) suggested that chaetetid buildups are associated with the flanks of Pennsylvanian highs in Texas. He also demonstrated that the 60 to 150 feet-thick (18m to 46m) Lower Strawn Formation (Pennsylvanian) in Gaines County, Texas, produces oil and that the hydrocarbon accumulation is usually dependent on both the presence of chaetetids and paleotopographic highs. Further work, based on correlations described herein, could determine if similar relations occur in my study area.

The fourth purpose is to determine the sedimentologic response of the Blackjack Creek limestone (Desmoinesian) to Middle Pennsylvanian structural elements throughout the study area.

AREA AND METHODS OF STUDY

The Blackjack Creek limestone is exposed across a four state area, from Appanoose County, Iowa to southern Rogers County, Oklahoma (see Figure 1). Field work for this study was concentrated in eight counties in southeast Kansas and northeast Oklahoma (Figure 5). Surface data consisted of twelve measured sections along roadcrops, and in stream cuts and quarries. Measurements were made with a hand-held tape and Brunton compass. Surface information was supplemented with subsurface borehole data: three cores and thirty-one well logs. Field observations included color of both fresh and weathered samples, bedding characteristics, texture, composition, fossils, sedimentary structures, and lithologic contacts. Laboratory work included: alizarin red staining of hand samples, thin sections, and cores; petrographic analyses of hand samples, thin sections, and acetate peels. Carbonate rock types were categorized using Dunham's (1962)

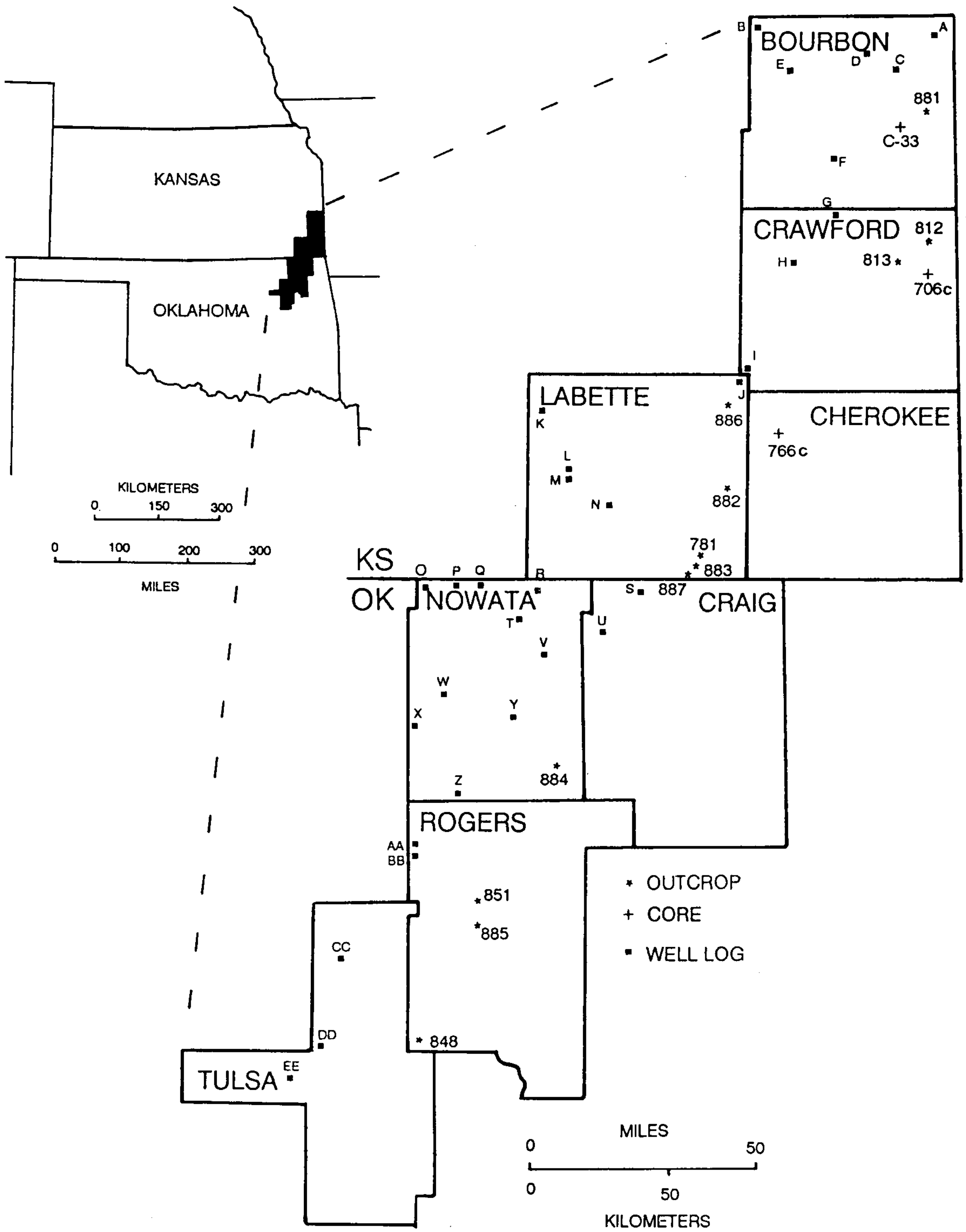

Figure 5. Locality Map of Data Points in Kansas and Oklahoma.

classification.

Fossils were identified as accurately as possible. Every attempt was made to identify specimens to genus. In cases where this was not possible, a higher taxonomic category was designated. Discussions of biotic diversity refer to relative differences between the numbers of these taxonomic categories in each unit.

PREVIOUS INVESTIGATIONS

GENERAL STRATIGRAPHY

This study concentrated on the small-scale genetic stratigraphy of the Blackjack Creek Limestone Member of the Fort Scott Formation, Marmaton Group, (Desmoinesian, Middle Pennsylvanian) (see Figure 3). However, to better understand the regional aspect of this interval, the entire "lower Fort Scott cyclothem" and upper part of the "Breezy Hill cyclothem" (Knight, 1985) were examined in detail, from the top of the Breezy Hill Limestone Member (Cabaniss Formation) to the base of the Little Osage Shale Member (Fort Scott Formation).

The Desmoinesian Stage, the lowest division of Pennsylvanian rocks that appear at the surface in the study area, consists of the Cherokee and Marmaton Groups in Kansas (Zeller, 1968) and the Krebs, Cabaniss, and Marmaton Groups in Oklahoma (Krumme, 1981) (Figure 6). In Kansas, Missouri, Nebraska, and Iowa, the term Cherokee Group is still formally accepted and the Krebs Group and Cabaniss Group of Oklahoma have been designated formations in Kansas and subgroups in Missouri (Krumme, 1981).

Cherokee Group

The Cherokee Group, as it will be called throughout this study, includes both marine and nonmarine rocks that occur between the base of the Fort Scott Formation (Marmaton

	KANSAS	NORTHEAST OKLAHOMA PLATFORM	MC ALESTER BASIN	NORTHEAST OKLAHOMA PLATFORM (KRUMME, 1981)	MC ALESTER BASIN (KRUMME, 1981)
DESMOINESIAN	Marmaton Group: Holdenville Sh. Lenapah Ls. Nowata Sh. Altamont Ls. Bandara Sh. Pawnee Ls. Labette Sh. Fort Scott Ls.	Marmaton Group: Holdenville Sh. Lenapah Ls. Nowata Sh. Altamont Ls. (Oolagah Fm.) Bandara Sh. (Oolagah Fm.) Pawnee Ls. (Oolagah Fm.) Labette Sh. Fort Scott Ls.	Holdenville Sh. Wewoka Fm. Wetumka Sh. Calvin Fm.	Marmaton Group: Altamont Ls. (Oolagah Fm.) Bandara Sh. (Oolagah Fm.) Pawnee Ls. (Oolagah Fm.) Labette Sh. Fort Scott Ls.	Wewoka Fm. Wetumka Sh.
	Cherokee Group: Cabaniss Fm. Krebs Fm.	Cabaniss Group: Senora Fm. Krebs Group: Boggy Fm. Savanna Fm. McAlester Fm. Hartshorne Ss.	Cabaniss Group: Senora Fm. Stuart Sh. Thurman Ss. Krebs Group: Boggy Fm. Savanna Fm. McAlester Fm. Hartshorne Ss.	Cherokee Group: Calvin Fm. Senora Fm. NOT STUDIED	Cabaniss Group: Calvin Fm. Senora Fm. NOT STUDIED

Figure 6. Correlation Chart of Kansas and Oklahoma (Desmoinesian).

Group) and the Mississippian System with an outcrop thickness ranging from 350 ft (91m) to 500 ft (152m) (Zeller, 1968). Initially, Howe (1956) subdivided the Cherokee Group into the Krebs Subgroup and the Cabaniss Subgroup. Jewett (1959), based on mapping practicality in Kansas, redefined the Krebs and Cabaniss subgroups as formations.

The Krebs Formation (Krebs Subgroup in Oklahoma), although not considered in this study, consists of shale, sandstone, limestone, underclay, and coal. In Kansas, it is defined to include all rocks from the top of the Atokan Stage to the top of the Seville Limestone Member (Howe, 1956; Zeller, 1968).

The Cabaniss Formation (Cabaniss Subgroup in Oklahoma) in Kansas, is approximately 220 feet (67m) of predominately shale along with sandstone, limestone, and coal. It occurs below the Fort Scott Formation (Marmaton Group) and above the Seville Limestone Member (Zeller, 1968).

Breezy Hill Limestone Member - The uppermost member of the Cabaniss Formation, and the only limestone of the Cherokee Group considered in this study is the Breezy Hill Limestone Member. Pierce and Courtier (1938) applied the name "Breezy Hill" to the uppermost limestone of the Cherokee Group for exposures near Mulberry, Kansas (eastern Crawford County). The Breezy Hill limestone occurs below the underclay of the Mulky Coal (where present) and above the Lagonda (Squirrel) sandstone in southeastern Kansas or above the Kinnison shale in northeastern Oklahoma. In extreme southeast Kansas, where the Mulky Coal is missing, the Excello shale directly overlies the Breezy Hill.

In eastern Kansas, Howe (1956) described the Breezy Hill Limestone Member as a fossiliferous, nodular, irregularly bedded, silty to sandy, conglomeratic limestone. Along the Kansas-Oklahoma border, Howe (1956), described the Breezy Hill as thin bedded to massive, dense to medium-grained, brown to gray limestone that weathered tan to brown.

The Oswego Limestone, although not recognized as a formal unit, is still used in subsurface (petroleum) terminology and consists of: in ascending order, Breezy Hill limestone, Excello shale, Blackjack Creek limestone, Little Osage shale, and Higginsville limestone (Cole, 1967; 1968). In a report on the "Oswego Limestone" in the subsurface of west-central Oklahoma, Michlik (1984) described the Breezy Hill as a thin, argillaceous, black phylloid algal calcilutite with silicified algal blades and pyrite.

<u>Mulky coal</u> - The Mulky coal was named by Broadhead (1874) for a thin, discontinuous coal unit exposed along Mulky Creek, Lafayette County, Missouri.

Searight et al. (1953) defined the "Mulky Formation" as all strata occurring above the Iron Post coal (found only in Oklahoma), and below the top of the Mulky coal (which is absent in Oklahoma). Where it is exposed in southeastern Kansas and western Missouri, the Mulky coal lies between the top of the Breezy Hill limestone and below the base of the Excello shale.

As presently defined in Kansas (Zeller, 1968), the Mulky coal is a bed within the Cabaniss Formation (Cherokee Group) and does not include the underclay.

Knight (1985, p.118) reported that he could trace the "Mulky coal zone", a lateral variation of the Mulky coal defined as "...a thin limonitic, poorly cemented, sandy zone with thin stringers of coal-like (plant) material, as far south as northern Craig County, Oklahoma." Knight (1985) also recognized this zone in a core from Labette County, Kansas, where it is represented by a dolomitic, laminated sandstone (0.75m thick).

Excello Shale - The Excello shale (Formation of Searight et al., 1953) is defined to include all strata between the top of the Mulky coal, or where the coal is absent, the top of the Breezy Hill limestone, up to the base of the Blackjack Creek limestone. The type section was designated by Searight (1955) as the highwall of an abandoned strip pit located in the NW 1/4, Section 30, T.56N., R.14W., about 2 miles west of Excello, Macon County, Missouri.

In Kansas, the Excello shale is recognized, informally, as a member of the Cabaniss Formation of the Cherokee Group

(Searight et al., 1953). It is recognized as a formation in the Cherokee Group of Missouri (Searight and Howe, 1961) and as a member of the Senora Formation of the Cabaniss Group in Oklahoma (Krumme, 1981). Knight (1985) included the Excello as the lowest member of the "Dry Branch Creek Formation" at the base of the Marmaton Group. Presently, the Kansas Geological Survey is organizing a stratigraphic lexicon that will recognize the Excello shale as a formal member of either the Fort Scott Formation or the Cabaniss Formation (pers. comm., Brady, 1990).

Lithologically, the Excello, as defined by Searight et al. (1953) and Howe (1956), consists of black, fissile shale with phosphatic concretions or nodules. The thickness of the unit ranges from 2 ft (.6m) to 5 ft (1.5m) (Howe, 1956). Michlik (1984) described the Excello, in cores and well logs, as a black, radioactive, carbonaceous, fissile shale containing brachiopods, conodonts, fish remains, pyrite and phosphate nodules.

Marmaton Group

The Marmaton Group, approximately 250 feet-thick (76m), is defined to include all beds between the base of the Fort Scott Limestone Formation and the upper limit of the Desmoinesian Stage (Jewett, 1941). The type locality of the Marmaton Group is exposures along the Marmaton River in Bourbon County, Kansas (Haworth, 1898). In Kansas, the Marmaton consists of eight formations of alternating limestones and shales: 1) Fort Scott Limestone (oldest), 2) Labette Shale, 3) Pawnee Limestone, 4) Nowata Shale, 5) Altamont Limestone, 6) Bandara Shale, 7) Lenapah Limestone, and 8) Holdenville Shale (youngest) (Zeller, 1968; see Figure 3).

In Oklahoma, the Desmoinesian Stage consists of the Krebs, Cabaniss, and Marmaton Groups. For the Northeast Oklahoma Platform Region, Krumme (1981) defined the Marmaton to include three formations, the Fort Scott Limestone, the Labette Shale, and the Oologah Limestone (Pawnee, Bandara, and Altamont). In the western Arkoma Basin (McAlester Basin of Krumme, 1981), the Marmaton is divided into the Wetumka Shale and the Wewoka Formation (Krumme, 1981).

Swallow (1866) first applied the name Fort Scott Limestone to the upper limestone member (Higginsville limestone) of what is now called the Fort Scott Limestone Formation. Redefined by Bennett (1896), the Fort Scott included two limestones and an intervening shale: the lower "Cement rock" (Blackjack Creek limestone) and the upper "Lexington bottom rock" (Higginsville limestone). Cline (1941) renamed the lower limestone member the Blackjack Creek, the upper limestone the Higginsville, and a thin limestone that occurs within the shale between them the Houx limestone. Based on an exposure in Bourbon County, Kansas, Jewett (1941) proposed the name Little Osage shale for all beds between the Blackjack Creek and the Higginsville limestones. He regarded the Houx limestone as a bed within the Little Osage shale.

Knight (1985) recognized that what was known as the Higginsville limestone, a single limestone unit in Kansas and Oklahoma, is split by a siliciclastic wedge in Missouri and Iowa forming two separate limestone units: the lower Houx limestone and the upper Higginsville limestone. Consequently, he proposed the name Houx-Higginsville Limestone to replace Higginsville limestone in Kansas and Oklahoma.

Knight (1985) also introduced a revised nomenclature for the lower Marmaton and upper Cherokee Groups (Figure 7), which included five units in ascending order: 1) Breezy Hill Limestone Member (Cabaniss Formation, Cherokee Group), 2) Mulky coal (Cabaniss Formation, Cherokee Group), 3) Dry Branch Creek Formation, 4) Morgan School Shale, and 5) Wolverine Creek Formation. Units within the Fort Scott Limestone have been incorporated into the Dry Branch Creek Formation, Morgan School Shale, and the Wolverine Creek Formation.

Initially, the type locality of the Fort Scott Formation was an exposure just east of the Missouri Pacific Railway station in Fort Scott, Kansas (Bennett, 1896). Jewett (1941) explained that it was later moved to a cement quarry northeast of Fort Scott, Kansas; NE 1/4, Section 19, T.25S., R.25E. Since then, due to road construction and

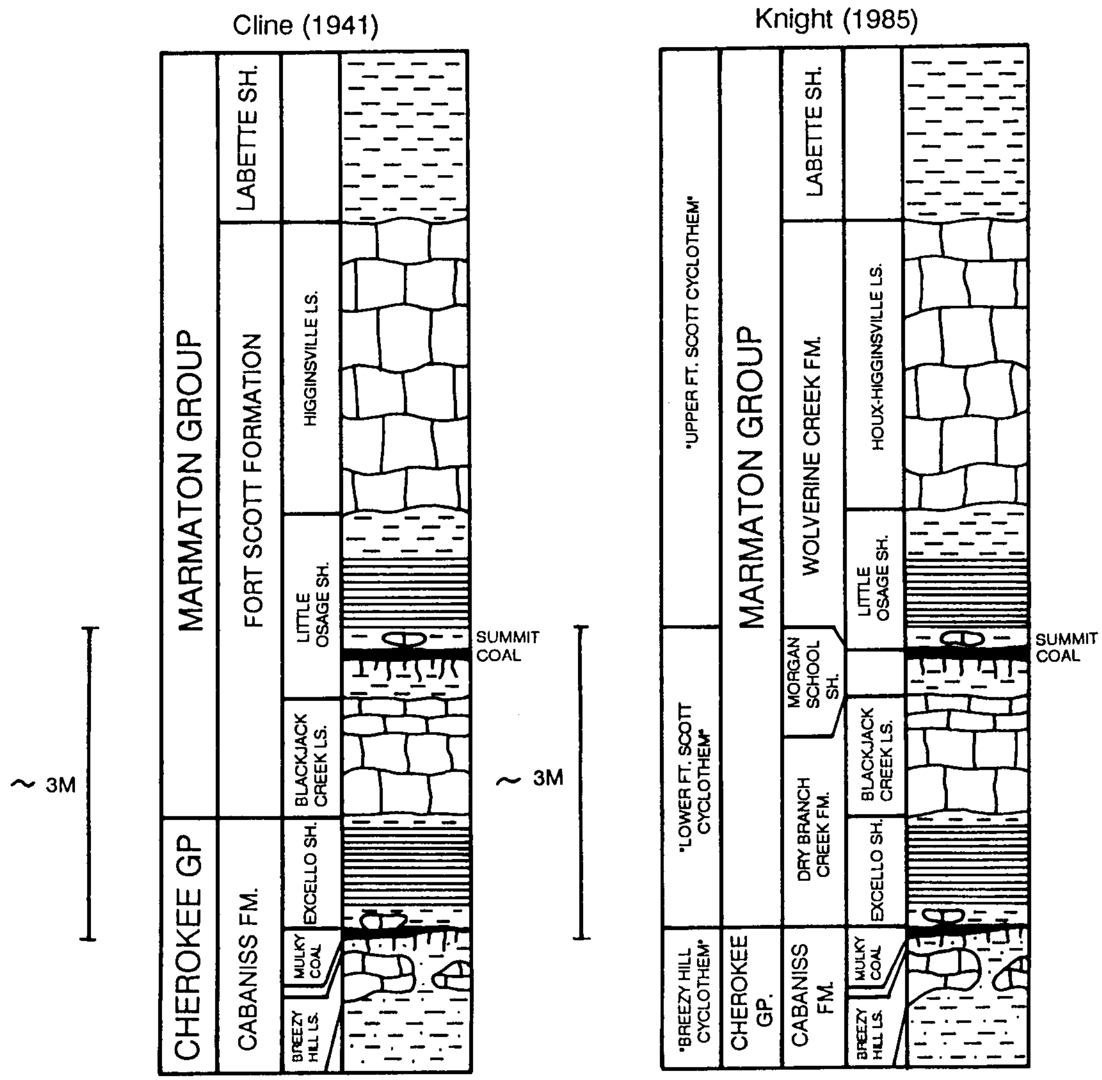

Figure 7. Comparison of the Stratigraphic Nomenclature of Cline (1941) with that of Knight (1985). This study uses Cline's (1941) original nomenclature, but recognizes the Houx-Higginsville Limestone as used by Knight (1985). Modified from Knight (1985).

erosion of the quarry walls, the type locality is now considered to be a railway cut under the Highway 69 bridge, just north of old Fort Scott, Fort Scott, Kansas (see Appendix A, measured section 881).

<u>Blackjack Creek Limestone Member</u> - Cline (1941) applied the name Blackjack Creek limestone to exposures along Blackjack Creek, four miles southeast of Fayetteville, Missouri. This replaced "lower Fort Scott" of Swallow (1866) and "Cement rock" of Bennett (1896). At the type section of the Blackjack Creek limestone, Cline (1941) reported: 1) a basal bed of massive, gray limestone [2.5 ft-thick (0.75m)], 2) an unnamed calcareous, gray shale [7.4 ft-thick (2.25m)], and 3) a gray, nodular limestone [.99 ft-thick (0.3m)].

Schell (1955) recognized three distinct lithologies in the Blackjack Creek, which, along with their corresponding depositional environment, were: 1) algal calcilutite (nearshore, shallow marine, deposited on a firm bottom by strong current action), 2) microfragmental calcilutite (seaward of the algal facies), and 3) lithographic limestone with pellets, fusulinids, and discontinuous shale breaks (farthest from shore in deep water). Furthermore, Schell (1955) suggested that these facies occur in a definite cyclic arrangement. Thus, a complete sequence of limestones would be, from bottom to top: algal, microfragmental, lithographic, microfragmental, and algal. Schell (1955) reported that in central Rogers County, Oklahoma, only the algal lithology was present.

Jeffries (1958) defined the Blackjack Creek as including all calcareous strata from the top of the Excello shale to the base of the underclay of the Summit coal. He designated a new type section exposed in the north ditch of a gravel road along the south line of SW 1/4, SE 1/4, SW 1/4, Section 14, T.47N., R.25W., Lafayette County, Missouri.

Neal (1969) recognized seven facies within the Blackjack Creek limestone throughout Missouri, from bottom to top: 1) Fulton Lime-Mudstone, 2) Burrowed Dolomite-Mudstone, 3) Platy-Algal Facies, 4) Burrowed Fragmental Facies, 5) Oncolitic Calcarenite, 6) Burrowed Wilkingia Dolomite, and 7) Fusulinid-Crinoidal Packstone.

O'Brien (1977), based on exposures in Iowa, subdivided the Blackjack Creek limestone into two subunits: 1) a burrowed, skeletal wackestone [3.0 ft-thick (0.9m)], which locally, grades into a skeletal packstone, and 2) a barren, brecciated mudstone [0.99 ft-thick (0.3m)] which is capped by a clay-rich conglomerate [1.2 inches (less than 3cm)].

After studying cores of the "Oswego limestone" from the Anadarko basin of western Oklahoma, Drexler (1984) grouped the Blackjack Creek limestone within the "Middle Oswego" cycle. He reported the Blackjack Creek to consist of a basal skeletal wackestone, an intraclastic packstone, and a mudstone.

Michlik (1984), discovered facies similar to those recognized by Shell (1955) in cores from the northern Anadarko basin. The lower part of the Blackjack Creek consists of dark gray to black calcilutite with normal marine fossils. The middle part was described as a gray calcilutite with normal marine fossils and pellets, all of which have undergone varying degrees of recrystallization and dolomitization. The upper part of the Blackjack Creek, like the lower part, is a thin, dark gray to black calcilutite with a normal marine biota.

Knight (1985) described the Blackjack Creek limestone as a marine skeletal calcilutite and a mixed calcarenite (intraclastic, skeletal, peloidal packstone).

<u>Little Osage Shale Member</u> - Jewett (1941) assigned the name Little Osage shale to all beds between the top of the Blackjack Creek limestone and the base of the Higginsville limestone of the Fort Scott Formation. The type section was designated for exposures in the NE 1/4, SE 1/4, Section 2, T.24S., R.25E. on the south wall of the Little Osage River, Bourbon County, Kansas.

In Kansas, the Little Osage shale varies from 5 (1.5m) to 11 feet (3.4m), and was originally defined to contain the Houx limestone in the upper part and the Summit coal in the lower part (Zeller, 1968).

Ravn et al. (1984) proposed the name "Morgan School Shale" for the nonmarine to marginal marine clastic unit overlying the Blackjack Creek and underlying the marine strata of the Little Osage shale.

Knight (1985) included the Little Osage shale as the lowest member of his "Wolverine Creek Formation", i.e. the lowest unit within his "upper Fort Scott cyclothem".

In Oklahoma, the Houx limestone and the Summit coal are missing, so Schell (1955) defined the Little Osage shale as only a black fissile shale facies bounded below by the Blackjack Creek limestone and above by the Higginsville limestone. Near Tulsa County, the Higginsville is absent and the Little Osage shale is overlain by the Labette Shale Formation.

Michlik (1984) reported that the Little Osage shale is nearly identical to the Excello shale; a black, radioactive, carbonaceous, fissile shale with brachiopods and pyrite nodules.

Knight (1985) defined the Little Osage shale to include, in ascending order: 1) a thin, persistent unit of light and dark gray, fossiliferous marine shale containing interbedded, less persistent, thin, nodular to bedded, fossiliferous calcilutite with a gradational upper contact, 2) a thicker, black, fissile shale containing phosphate nodules, and 3) an overlying dark to light gray, fossiliferous, marine shale to gray-blue to yellow marine claystone. Knight (1985) recognized that the Summit coal is absent south of Bourbon County, Kansas, but that a claystone, which he believed equivalent to the underclay of the Summit coal, remains.

The Summit coal was originally named by McGee (1892) for a coal bed within a shale at an outcrop in Macon County, Missouri. Jewett (1945) considered the Summit coal bed to be a distinct unit within the Little Osage Shale Member. Zeller (1968) reported that the coal, which occurs in the upper middle part of the Little Osage, can be traced from northern Crawford County, Kansas northeastward into Missouri and ranges from 4 (1.2m) to 12 (3.7m) feet-thick.

DEPOSITIONAL MODELS

General

Most of the Middle Pennsylvanian Series in southeast Kansas and northeast Oklahoma is characterized by an alternating sequence of persistent marine limestones with thin shale members and nearshore to terrestrial deposits - shales, sandstones, and coals.

Udden (1912, p.49-50) was the first to recognize rhythmic or cyclic alternations of lithologies of the Pennsylvanian rocks of Illinois. He described depositional cycles, each including in ascending order: coal, shale, limestone, and sandstone. Udden (1912) explained that the succession began with a coal swamp that became submerged by the sea eventually forming the limestones in open water. The cycle was completed with currents sweeping in sand and subsequent subaerial erosion.

Moore (1929) noticed the occurrence of marine fossils in the black fissile shales and that the shales occur between two marine limestones. However, he felt that the high organic and sulfide content indicated an environment related to stagnate, extremely shallow water (too shallow for circulation or agitation).

Weller (1930) recognized that cyclic Pennsylvanian strata existed on a regional scale and that these "rhythmic alternations", which he called formations, provided a new criterion for correlation. He proposed (p.99) the term formation for a cycle defined as "...a recurrence, repetition, or return to the starting point..." Weller (1930) described the typical Pennsylvanian formation as composed of 8 members (lower 4 nonmarine and upper 4 marine), in ascending order: sandstone, sandy and micaceous shale, underclay, coal, black shale, calcareous shale, limestone, and shale which becomes less marine upward. Unlike Udden (1912), Weller (1930) regarded the unconformity at the base of the sandstone, which he believed to be the result of fluvial processes, as the base of the cycle. However, both agreed that the black shale was the first to be deposited by the transgressing sea. Weller (1930) stated that each cycle was initiated by regional uplift, allowing for subaerial erosion and the development of unconformities, followed by a long period of stability. Subsidence then terminated these conditions and the area was inundated by a shallow sea in which marine sediments were deposited over nonmarine (or less marine) sediments (Wanless and Weller, 1932).

Wanless and Weller (1932, p.1003) proposed the term cyclothem (commonly referred to as the Illinois cyclothem), equivalent to Weller's (1930) formation, for "...a series of beds deposited during a single sedimentary cycle that prevailed during the Pennsylvanian period." Each cyclothem is composed of 8 successive members deposited on an unconformity (from bottom to top): sandstone; sandy shale; nonmarine limestone; underclay; coal; phosphatic, black shale; marine limestone; shale (marine at base grading upward into nonmarine). Wanless and Weller (1932, p.1016) stated that the seas, which periodically transgressed over the eastern half of North America throughout the Pennsylvanian, were "...very extensive and connected the various basins..." and that the cyclic occurrence of strata in the different basins was "...controlled by the same series of diastrophic movements..." (uplift and subsidence).

Wanless and Shepard (1936) proposed an alternative process, glacial eustasy, which they argued could have produced the cyclic Pennsylvanian strata. Based on their ability to correlate these cycles regionally, they proposed that world-wide, glacially controlled sea level fluctuations occurred and that a rise and fall of sea level could produce the different lithic members of Wanless and Weller's (1932) cyclothem.

Using some of his data published in 1931, where he was the first to describe a Pennsylvanian cyclic sequence in Kansas, Moore (1936) designated the term megacyclothem for cyclic rock units of the Wabaunsee, Shawnee, and Douglas Groups (Lower Virgilian). He modified the cyclothem concept, as applied in the Illinois basin, for smaller limestone-shale couplets within the megacyclothems of Kansas.

Jewett (1945, p.50) stated that "...depositional cycles of two or more magnitudes can be recognized in some rock sections." Specifically, he recognized that Moore's (1936) Midcontinent Pennsylvanian megacyclothem consisted of several smaller-scale cyclic events and that some cyclothems (Wanless and Weller, 1932) are equivalent to previously identified megacyclothems. Jewett (1945) proposed restriction of the term megacyclothem such that it be used to indicate a unit, cyclic in itself, which is composed of two or more cyclothems and that the term cyclothem be restricted to the smallest recognizable cyclic event, except varves.

Beerbower (1964) stated that Pennsylvanian stratigraphy cannot simply be explained by only one controlling mechanism. Local origins, eustatic fluctuations, climate changes, or diastrophism, acting alone, were not adequate for cyclothem development. He went on to say that interrelated allocyclic (regional) and autocyclic (local) processes may reinforce, diminish, or obscure previously formed cycles. Furthermore, autocyclic mechanisms may obscure or remove evidence of any allocyclic mechanism, whereas two or more allocyclic mechanisms, occurring simultaneously, will make interpretations of cyclic sequences difficult (Beerbower, 1964).

Harbaugh (1964, p.203) suggested that some transitions from marine to nonmarine facies (or vice versa) are not solely dependent upon sea-level fluctuations, but are in part due to: 1) "ecologic succession of organism communities" and 2) "differences in types and volumes of sedimentary materials supplied to the sites of deposition." The example used by Harbaugh (1964, p.203) was the occurrence of a coal bed which "...may record the lateral expansion of a coal swamp due to progressive colonization of shallow-water marine areas by coal-forming plants capable of living in salt water."

Laporte and Imbrie (1964) proposed that local hydrographically controlled facies genesis is as important as sea level fluctuations in the formation of stratigraphic cycles. Moreover, both processes may be interrelated (Laporte and Imbrie, 1964).

Similar cyclothems occur in Permian-aged strata of the Midcontinent. Estimates of sea level fluctuations needed to produce such Permian cyclothems may some bearing on interpretations of Pennsylvanian strata. For example, McCrone (1964), based on stratigraphic repetitions in Kansas "Wolfcampian cyclothems", reported that water depths were less than 60 feet (18m) and that these cyclic changes were caused by sea level fluctuations. Additionally, McCrone (1963) suggested that strata from the Red Eagle Cyclothem may have been deposited in water less than 12 ft (3.7m) to 18 ft (5.5m) deep.

Not all parts of cyclic sequences are completely controlled by eustatic oscillations. For example, Wanless (1967), who was one of the first to propose glacially controlled, cyclic sequences (Wanless and Shepard, 1936), suggested that the enigmatic clastic wedges (or outside shales of Heckel, 1977) could best be explained by local delta shifting occurring penecontemporaneously with worldwide glacial eustasy.

Heckel (1977) abandoned the term megacyclothem and defined the Kansas Cyclothem as having five specific lithologic members (see Figure 2). Redefining a larger-scale sequence (the megacyclothem) as a smaller-scale sequence (a cyclothem) has subsequently caused a great deal of confusion in the literature. Thus, the term cyclothem as defined by Heckel (1977) and as used in the midcontinent, is a larger-scale stratigraphic entity as compared to the cyclothems of the Illinois basin. He stated that the cyclothem sequence from lower outside shale up through the lower limestone, black (core) shale, upper limestone, to upper outside shale is "reasonably" explained by a single transgression and regression of the sea, with the maximum transgression (deepest water) represented by the black shale (Heckel, 1977). Heckel (1977; 1979) stated that a large scale glacial-eustatic rise and fall of sea level accompanied by smaller scale events in nearshore areas controlled the cyclothem's distribution and formation. Later, Heckel (1985) stated that eustatic events were the driving force controlling the Upper Pennsylvanian cyclic deposits based on the: 1) lateral continuity of cyclothems, 2) paucity of deltaic deposits, and 3) widespread paleosols and subaerial exposure surfaces on regressive carbonates that alternate with core (black) shales. Although tenuous, Heckel (1977; 1986; 1989) explained that the duration of one Pennsylvanian cyclothem is approximately 235,000 to 400,000 years (comparable to the Milankovitch eccentricity orbital parameters of 100,000-410,000 yrs), the same order of magnitude as that of the Pleistocene glacial episodes. Furthermore, Heckel (1980) pointed out that this differs dramatically from the frequency of plate-tectonically controlled worldwide eustatic sea level changes, which is closer to one every tens of millions of years.

Boardman et al. (1984; 1989) supported glacial eustasy as the primary control of sea level fluctuations with tectonics (regional and local) and delta switching as important secondary mechanisms.

Heckel (1985; 1989), realizing that there were different types of cyclothems, proposed the term cycle for any marine inundation and subsequent withdrawal and recognized three types of cycles based on their extent of transgression onto the shelf. **Major cycles** (235,000 to 400,000 yrs) record inundations that transgressed far enough on to the shelf to produce a conodont-rich shale along the northern limit of the outcrop belt (Iowa and Nebraska) and to develop enough of the "other facies" to be recognized as a cyclothem. **Intermediate cycles** (120,000 to 220,000 yrs) extend as marine horizons into Iowa and Nebraska and contain conodont-rich zones on the lower shelf but generally are not considered as complete cyclothems. **Minor cycles** (44,000 to 120,000 yrs) extend as marine horizons across only the lower shelf and typically lack conodont-rich zones, or represent a minor reversal within a more major cycle; minor cycles are not considered as cyclothems nor are they named as separate lithologic units (Heckel, 1985; 1989).

Klein and Willard (1989) proposed that there were three Pennsylvanian cyclothem "types" caused by both eustatic and tectonic processes; Kansas-type, Illinois-type, and Appalachian-type. Associated facies variations between cyclothem "types" are controlled by the local distribution of sedimentary basins across the eastern half of the United

States. Klein and Willard (1989) suggested that differences, between Kansas-type cyclothems of the Midcontinent, characterized by extensive marine deposits and subordinate coals, and Appalachian-type cyclothems of eastern United States, dominantly nonmarine sequences with well developed coals, are the result of flexural deformation and continental accretion coupled with glacial-eustatic sea level fluctuations.

Klein and Willard (1989) suggested that Illinois-type cyclothems are an intermediate development between two end-members; the Kansas-type and the Appalachian-type.

Since cyclic sequences were first described and interpreted, geologists have proposed different causal mechanisms for their occurrence (i.e. glacial-eustasy, tectonics, etc...). Although the idea is not new (Swann, 1963), recent work has suggested that climate change be considered a primary mechanism of Pennsylvanian cyclic sedimentation rather than as only a modifying or obscuring, secondary effect.

Phillips et al. (1985) pointed out that large scale cycles of climate change appear to not only affect vegetation and coal formation, but also influence lithologic change, regionally, if not globally. Their relative wetness curve, based on bituminous coal resources in the eastern half of the United States, depicted two extremely dry periods displaced by an extremely wet period. The drier intervals are referred to as first drier and second drier, respectively (Figure 8). The second drier interval, which occurs at the Desmoinesian-Missourian boundary, marked a major decline in the number of coal beds and an increase in the proportion of limestones (see Zeller, 1968). Schutter and Heckel (1985, p.111) based on the: 1) decrease in coal resources, 2) progression of evaporites from western Colorado (Desmoinesian) to Kansas (Permian), and 3) greater proportion of limestone deposited at intermediate water depths, agreed that the Missourian climate became "at least seasonally drier....as North America moved north from the equator." However, Phillips et al. (1985) proposed that the actual cause for the severe vegetational change, and in turn, the change from coal-dominated environments to carbonate-dominated environments, is probably due to numerous interrelated factors (i.e. sea level fluctuations, decreased rainfall and runoff, and changes in tectonic activity), not just a drier climate.

Schutter and Heckel (1985) suggested that a combination of a marine regression extending farther basinward than normal, and an increasingly drier climate could also account for the minor floral and faunal extinctions, primarily lycopods, conodonts, and brachiopods. Additionally, they stated that an increasingly drier climate decreased the amount of available detritus and increased sea water salinity. Clastics, which commonly cap Marmaton

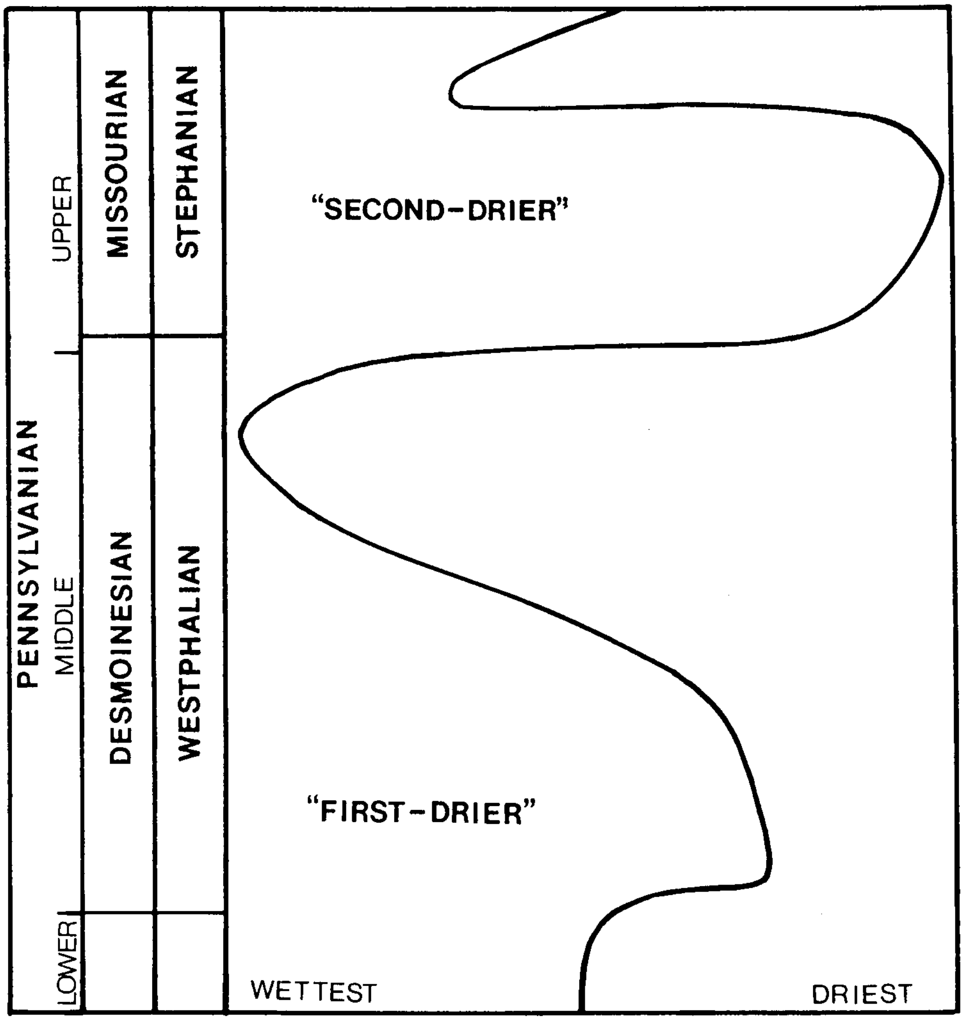

Figure 8. Relative Wetness Curve Based on Pennsylvanian Coal Resources in the Eastern United States. From Phillips et al. (1985).

(Desmoinesian) regressive limestones, are replaced by cross-bedded calcarenites, oolites, and fenestral laminated calcilutites in the Missourian.

Cecil et al. (1985) and Cecil (1990) also suggested that small-scale, cyclic alternations in Pennsylvanian rocks of the eastern United States, with changes from carbonate dominated cycles to coal dominated cycles, can be explained by climatic changes. For example, nonmarine rocks with a chemical origin, such as laterally extensive coal beds and leached paleosols, signify wet periods whereas limestones, dolomites, evaporites, and calcretes represent relatively dry periods (Figure 9) (Cecil, 1990). Distinct differences in lithologies exist in the Pennsylvanian Midcontinent, and these differences, along with major changes in the stratigraphic distribution and quality of coal beds (Cecil et al., 1985), correlate in relative terms with the climatic wetness of the Pennsylvanian (Phillips and Peppers, 1984). Phillips and Peppers (1984) divided the Pennsylvanian into five intervals, based on the degree of wetness: early Pennsylvanian (moderately wet); early Middle Pennsylvanian (dry, probably seasonally dry-wet); late Middle Pennsylvanian (very wet); early Late Pennsylvanian (very dry, the driest); very Late Pennsylvanian (very wet).

Cecil (1990) developed a climate-change classification (Figure 10) that takes into account a range of climate cycles and their periodicities which can affect

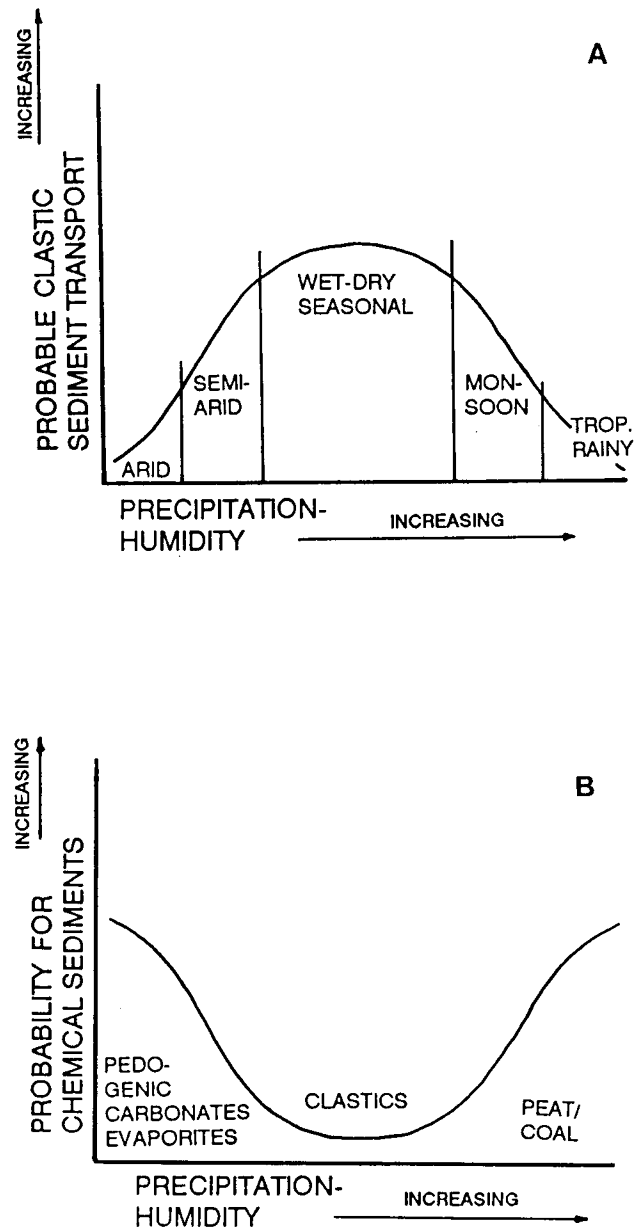

Figure 9. Sedimentologic Response to Climate Change.
A) Probability for clastic input in response to climate wetness.
B) Conditions for formation of chemical sediments in response to climate wetness. From Cecil (1990).

RELATIVE DURATION	CAUSE	TIME (years)
Long-term	Movement of continents through latitudes;	10^6-10^8
	Orogenesis	10^5-10^7
Intermediate-term	100 and 400 ka cycles of of orbital eccentricity	10^5
Short-term	cycles in axial tilt and precession	10^4
Very-short-term	not qualified	10^3
Instantaneous	Catastrophic storms	10^{-2} (weeks, days, hours)

Figure 10. Tropical and Subtropical Climate Change Classification. From Cecil (1990)

sedimentation locally or globally. Cecil (1990, p.534) demonstrated that for climate sensitive rocks in the eastern United States, "...climate changes were not confined to high latitude glacial cycles. Major shifts in low latitude climate belts accompanied high latitude glacial cycles." These low latitude, 100,000 - 400,000 year eccentricity cycles correspond to the periodicity of Heckel's (1977) Kansas cyclothem. Therefore, the stratigraphic repetition of siliciclastics, carbonates, and coals of the Midcontinent appears to be dependent on changes in paleoclimate, global tectonics, and glacial-eustatic transgressive-regressive events (Cecil et al., 1985; Cecil, 1990).

Events at different scales are also suggested by the punctuated aggradational cycle (PAC) approach of Goodwin and Anderson (1980). Using the PAC approach, Busch and Rollins (1984) suggested that Carboniferous stratigraphic sequences are best described, interpreted, and correlated utilizing a hierarchy of six scales (i.e. first through sixth) of genetic transgressive-regressive (i.e. deepening-shallowing) units referred to as Hierarchal Genetic Stratigraphy. Important to this study are the fifth- and sixth-order T-R units with fifth-order T-R units equivalent to Heckel's (1977) Kansas Cyclothem and Goodwin and Anderson's (1980) Cyclothemic PAC Sequence. Sixth-order T-R units are equivalent to PACs (Anderson and Goodwin, 1980).

Using Hierarchal Genetic Stratigraphy (HGS), Suchy

(1987) demonstrated that the Houx-Higginsville limestone, the regressive limestone in Knight's (1985) "upper Fort Scott cyclothem" contains two PACs. The entire "upper Fort Scott cyclothem" contains 5 PACs (Suchy, 1987; Suchy and West, in press).

Study Interval

Jewett (1945) recognized four megacyclothems within the Marmaton Group: 1) Fort Scott, 2) Pawnee, 3) Altamont, 4) Lenapah. He further recognized that each of these megacyclothems contained three or more distinct cyclothems as defined by Wanless and Weller (1932).

The Fort Scott megacyclothem was defined to include the basal Labette Shale Formation, Fort Scott Limestone Formation, Excello shale, Mulky coal and underclay.

Jewett (1945) recognized three cyclothems within the Fort Scott megacyclothem. They are, in ascending order: 1) Blackjack Creek cyclothem, 2) Houx cyclothem, 3) Higginsville cyclothem.

The lowest cyclothem, the Blackjack Creek cyclothem, as defined by Jewett (1945), contained the Mulky coal and underclay, the overlying Excello shale, and the Blackjack Creek limestone. Capping the cyclothem is a calcareous, fossiliferous, gray shale overlain by a coal (Summit coal and underclay).

Wanless (1950) reported that the "Marmaton cycle" in Missouri and Kansas is simpler than Moore's (1936) megacyclothem and apparently is somewhat intermediate between it and Wanless and Weller's (1932) Illinois cyclothem.

Heckel (1984), abandoned the terminology used by Jewett (1945) and divided the Fort Scott Formation into two separate cycles: the "lower Fort Scott cycle" and the "upper Fort Scott cycle". The cycles had no transgressive limestone, but Heckel (1984) reasoned that the black, fissile shale, which in places, overlies coal, along with fossiliferous clay-shales, represents "most of the transgression". The lack of a transgressive limestone, according to Heckel (1984), resulted from a very rapid transgression, too rapid for the limestone to form. Earlier, Heckel (1977) proposed that a subsiding peat swamp was not conducive to carbonate production, therefore, the transgressive limestone is missing. Boardman et al. (1984) proposed that the pH conditions of the inundated coal swamp, where flooding supposedly began, may have inhibited the development of the transgressive limestone as (p.153) "...such limestones are usually present in other areas where coals are not developed."

Heckel (1989) stated that, in order for complete development of a Kansas cyclothem, a marine transgression and regression must: 1) inundate the shelf slow enough to establish conditions conducive to limestone formation, and be extensive enough to produce black shale conditions, i.e.

thermocline development; 2) withdraw slow enough and remain free of any terrigenous material to, again, establish conditions necessary for limestone development over most of the shelf, and must have retreated far enough basinward to allow for either soil development or for land derived (nonmarine) sediments to cover much of the shelf.

Heckel's (1984) "lower Fort Scott cycle" consisted of the Excello shale and the overlying Blackjack Creek limestone. The Breezy Hill limestone, which underlies the Excello shale in Oklahoma and parts of Kansas (where the Mulky coal bed is absent) was considered by Heckel (1984) to be a minor transgressive-regressive unit with no associated black, fissile shale. The "upper Fort Scott cycle" comprises the Little Osage shale and the Houx and Higginsville limestones (Houx-Higginsville limestone, of this study, in Oklahoma and Kansas) (Heckel, 1984).

Michlik (1984) compared information from cores of the Oswego Limestone in the Anadarko basin to previous work of equivalent units in northern Oklahoma and southern Kansas. Using the Heckel's (1977) Kansas Cyclothem model, Michlik (1984) suggested that the Oswego limestone was produced by several sea level fluctuations (deepening-shallowing).

He reported that the black, fissile, phosphatic shales (Excello and Little Osage) are very similar and represent maximum transgression with deposition in a deep euxinic marine sea. Based on its stratigraphic position, below a core shale, coupled with its lateral traceability, Michlik (1984) regarded the Breezy Hill as a middle limestone deposited during the flooding event prior to the formation of the anoxic bottom conditions. Michlik (1984) suggested that the Blackjack Creek limestone is slightly more complex with both a regressive part and a transgressive part. The basal and middle parts of the Blackjack Creek were interpreted as regressive deposits because of their stratigraphic position above the regressive parts of the Excello shale and because they exhibit the shoaling-upward sequence described by Heckel (1977). The upper part of the Blackjack Creek, based on its open marine facies, its widespread character, and its position below a black core shale, is also described as a middle limestone deposited during a marine transgression (Michlik, 1984).

Drexler (1984) divided the Oswego limestone into three shallowing upward cycles: Lower Oswego, (unnamed shale to the Breezy Hill limestone); Middle Oswego, (Excello shale to the Blackjack Creek limestone); Upper Oswego, (Little Osage shale to the Higginsville limestone). Each cycle begins with a black shale that represents rapid deposition in a sediment starved, anoxic, subtidal environment at maximum transgression. As the seas regressed, a shoaling-upward cycle began with a shallow subtidal, open marine facies grading into tidal and supratidal facies, and finally into a terrestrial facies (Drexler, 1984). The Blackjack Creek limestone is reported to contain a lagoonal facies between the tidal and supratidal facies (Drexler, 1984).

Knight (1985) proposed new nomenclature for the boundary between the Marmaton and Cherokee Groups (see Figures 4 and 6). He defined three cyclothems: the "Breezy Hill cyclothem" as the Breezy Hill limestone and Mulky coal, the "lower Fort Scott cyclothem" as all beds from the base of the Excello shale to the top of the Morgan School Shale (base of the Little Osage Shale), and the "upper Fort Scott cyclothem" as beds from the top of the Morgan School Shale to the top of the Labette Shale.

"BLACK" SHALE CONTROVERSY

Shallow Water

Since geologists began describing and interpreting Pennsylvanian cyclic stratigraphy, problems have existed concerning depositional environments (i.e. water depth), causes of the cyclic sequences (i.e. sea level fluctuations), and the interpretation of the sequence itself. Over the years, and throughout the United States, particular attention has been given to the enigmatic origins of the black shales. Much of the following discussion is based on studies in the Illinois basin where the obvious association of the bituminous shale and coal is clearly developed. This shale/coal association is less obvious in my field area (i.e. Kansas and Oklahoma) because the coals become less continuous and often absent.

Udden (1912) proposed a shallow water origin for the black shales. He stated that initial transgression of a coal swamp formed a shallow water, coastal lagoon environment.

Weller (1930) was one of the first to invoke a layer of algae floating on the water surface in a lagoonal environment which prevented (p.127) "...the development of waves, and when they died they left no other trace than the carbonaceous content of the shales."

Although Wanless and Shepard (1936) disagreed with Weller (1930) as to how the cycles formed, both agreed that the black shale, which normally lies between coal and limestone, was the earliest marine deposit.

Later, Wanless (1950), based on the limited biota of the black shales, still proposed that during deposition, sea water was shallower and more restricted than during limestone deposition.

Zangerl and Richardson (1963) proposed a very shallow water archipelago-bayou environment for two Pennsylvanian black shales of western Indiana. They suggested that the black shales represented the initial phase of deposition in a shallow, rapidly transgressing sea, deposited immediately over coal beds or underclays, with anaerobic conditions present at the bottom. Furthermore, to explain the "near-perfect sheety" shales in a shallow body of water, Zangerl and Richardson (1963) invoked an algal flotant or floating cover of vegetation that prevented virtually all bottom disturbances of any kind.

Paleoenvironmental interpretations have also been based on geochemical analyses of the bituminous shale (i.e. organic content, and sulfur isotope ratios).

Wenger and Baker (1986), based on organic geochemical studies, reported that the organic content of the Little Osage and Excello shales correlates with their inferred transgressive-regressive sea level cycle; abruptly increasing at the base of the black shale facies with a gradual decline into the overlying gray clay-shale.

They also discussed the origin of these Pennsylvanian black shales which began with the inundation of extensive peat swamps. A short summary of Wenger and Baker's (1986) idea is included below.

As widespread coal-forming peat swamps were flooded during a marine transgression, a large supply of nutrients and humic detritus were provided which stimulated algal growth. This lead to the deposition of organic-rich muds containing a mixture of organics (marine) and terrestrial detritus which combined to promote highly anoxic bottom waters. The anoxic conditions enhanced organic matter preservation. However, as flooding of coastal peat swamps continued, the influx of nutrients and humic detritus gradually declined. This decreased the intensity of anoxia and in turn, the preservation which lead to the deposition of the lower organic-rich facies (e.g. clay-shales) of the Excello and Little Osage shales (Wenger and Baker, 1986).

Recent geochemical studies (e.g. Coveney and Shaffer, 1988) reported that the Pennsylvanian bituminous shale are not restricted to one specific environment. However, sulfur isotope variations suggested three possible depositional conditions. Coveney and Shaffer (1988) are referenced in this section (i.e. Shallow Water) because of their interpretation of the Desmoinesian shales in Kansas.

Coveney and Shaffer (1988), after analyzing Pennsylvanian shales throughout Indiana, Illinois, Missouri, and Kansas, suggested that a systematic relation exists between sulfur-isotope (delta 34 S) variations and paleogeography. They have shown that some Desmoinesian shales in Indiana typically contained sulfur with an erratic delta 34 S distribution (mean = -10o/oo; standard deviation = 9), which they suggested was common in nearshore brackish water environments. Slightly lighter delta 34 S values with less variation (mean = -14.5o/oo; standard deviation = 5) were said to be typical of offshore, shallow marine waters as in the Desmoinesian of Kansas. On the other hand, Coveney and Shaffer (1988) suggested that still lighter, more uniform delta 34 S values (mean = -27o/oo; standard deviation = 3.1) as in the Missourian shales of Kansas were typical of deep water, anoxic environments. This would suggest that maximum water depth for Missourian black shale deposition was greater than that for the preceding Desmoinesian shales (Coveney and Shaffer, 1988).

Deep Water

Pennsylvanian midcontinent bituminous shales are not normally associated with coal beds as is most often the case in the Illinois basin (Heckel, 1979). Therefore, studies based on bituminous shale units (i.e. in the Virgilian), where no significant coal beds occur, are often explained by a deep water model.

Evans (1967) and Schenk (1967) agreed that two Pennsylvanian black shales (without associated coal beds), the Heebner (Virgilian) and the Lake Neosho (Desmoinesian) respectively, represented the most offshore facies within a Midcontinent cyclic sequence, deposited at maximum transgression. Schenk (1967) suggested that changing sea floor topography had a minor effect on deposition of the Lake Neosho shale, whereas, in the overlying and underlying limestones, lateral facies changes were directly related to small topographic irregularities. However, Neal (1969) stated that the bituminous shale facies of the Excello shale disappears over the crest of the Schell City-Rich Hill Anticline while the Mulky coal and Blackjack Creek limestone thin considerably.

James (1970) and James and Baker (1971) proposed that accumulation and preservation of the Excello shale occurred in a deep water, anoxic environment during maximum transgression. They suggested that:

1) The epicontinental sea gradually flooded the Midcontinent and Illinois basin during a marine transgression.

2) A density gradient formed due to temperature variations (thermocline) preventing normal sea water circulation. This resulted in anoxic bottom conditions and the preservation of organic matter.

3) Organic sediments accumulated as the lack of available oxygen inhibited decomposition and, as bottom dwelling fauna were removed from the environment. Sedimentation was controlled by submarine topography.

4) A slow sediment influx consisted of clay minerals, organics (plant and animal remains), and minor amounts of fine-grain detrital quartz.

5) The Excello sea shallowed during the regressive phase; normal marine conditions replaced anoxic conditions along the bottom as the thermocline was destroyed.

Heckel and Baesemann (1975) stated that, within the Midcontinent cyclic sequence, the black shale facies was deposited farthest from shore. Furthermore, based on conodont studies, Heckel and Baesemann (1975) reported that the middle and upper limestones are mirror images of one another in conodont distribution, and thus might be transgressive and regressive members in a cycle symmetrical about the black (core) shale.

Heckel (1977) summarized the cyclothem sequence from outside shale to outside shale as a single transgression and regression of the sea, with the core shale marking the deepest water attained during maximum transgression. However, Heckel (1977) recognized the possibility for two different types of black shales: 1) a widespread (deep water), nonsandy shale with nonskeletal phosphorite, and 2) a shallow water, sandier shale deposited in shoreline lagoons.

Schultz (1989), using geochemical studies, particularly the degree of pyritization (DOP), also suggested that there were two contrasting black shale classes for the Virgilian black shales of eastern Kansas: 1) a deeper water Heebner-type, and 2) a shallower water Shanghai-type. Schultz stated that the degree of pyritization was used to infer bottom-water oxygenation conditions present during deposition: aerobic bottom water conditions (DOP = 0.45 or less), and restricted bottom water conditions (DOP = 0.45-0.75).

Phosphate Occurrence

Typically, phosphate nodules have been, and are, used as paleodepth indicators for Pennsylvanian Midcontinent seas. Particularly when found in black, fissile shales, high concentrations of phosphate (phosphate nodules) represent maximum transgression of ancient seas (Heckel, 1977). In his paper on the origin of phosphate-rich, black shales in Pennsylvanian cyclothems of the Midcontinent, Heckel (1977) proposed a model to explain the large amount of organic matter and phosphate deposited in an anoxic environment (Figure 11), i.e. his deep water black shale.

Bennison (1979, p.292) stated that the phosphate-rich black shale "...probably represents stagnant anoxic water below a thermocline over a decaying biota and, in the opinion of the author, has little depth significance."

Bentor (1980) reported that modern phosphorites are forming in relatively shallow water; most along the continental shelf or upper continental slope. The maximum water depth for the Peru-Chile phosphorites is 400m, but most are shallower (Bentor, 1980).

Leeder (1982, p.233) stated that the most favorable conditions for phosphate precipitation occur on shallow continental shelves and oceanic plateaus. Continuing, he said that the high organic content in black shales is not the result of decreased organic decomposition, but is "...a consequence of the enhanced organic productivity which produced the conditions in the first place." Furthermore, citing a paper by Rayner (1963), Leeder (1982) reported that phosphates are present in Middle Devonian lake deposits.

Boardman et al. (1984) suggested that if black, phosphatic shales were deposited in a shallow water environment, then they should also be present below the

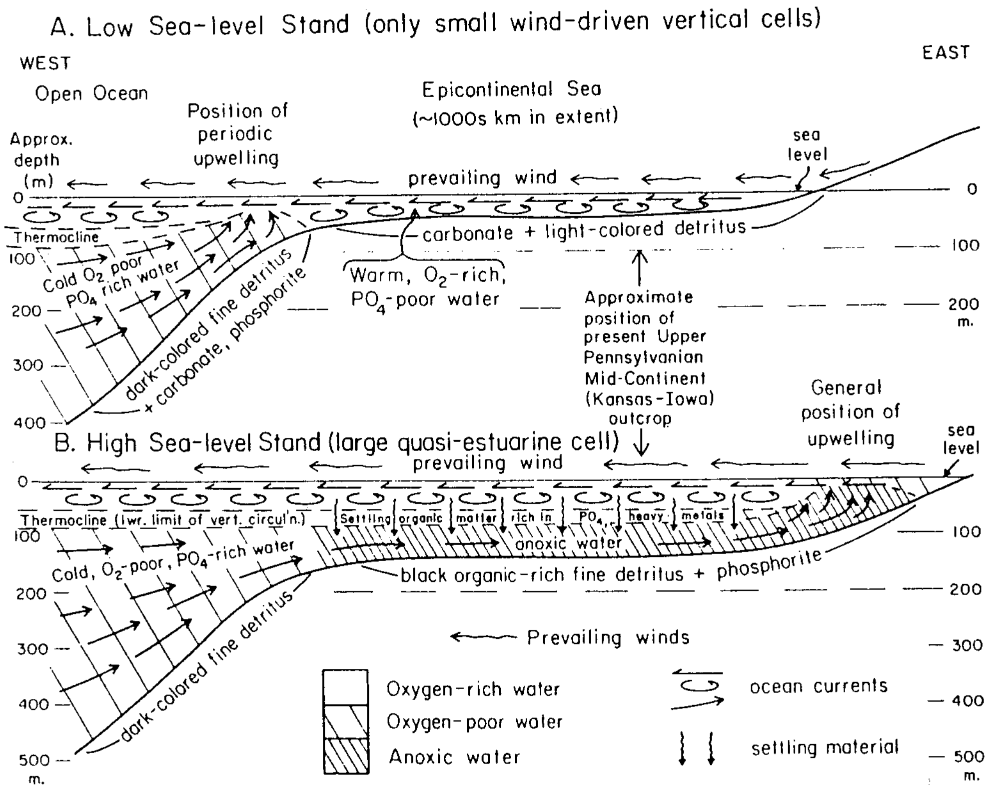

Figure 11. Cross-section of Expected Patterns of Vertical Circulation Relative to the Origin of Organic Matter and Phosphate. A) Low stand of sea level where photosynthesis helps maintain bottom oxygenations. B) Highstand of sea level, high enough to develop a permanent thermocline. From Heckel (1977).

transgressive limestone, at the top of the regressive limestone, as well as between the two limestones. Additionally, they reported that the phosphate nodules are commonly found at boundaries between the black, fissile, phosphatic shale and the gray to dark gray clay-shales and represent offshore, open marine phosphate deposition in 100 to 200m of water.

Kidder (1985) explained that phosphate nodules were best developed at the top (and rarely at the bottom) of black shale units, which he interpreted as enhanced conditions near the boundary between anoxic and disoxic environments. The lack of phosphate nodules at the base of black shales may reflect rapid transgression as suggested by Heckel (1980) which prevented the development of proper phosphate-generating conditions at the lower boundary.

Ganz et al. (1990), in their study of Cretaceous black shales from southeast Egypt, stated that phosphorites and black shales are not necessarily the product of upwelling. They suggested (p.226) that a coastal environment with a tropical climate, mangrove swamps, and "...intense humid weathering, would have produced sufficient quantities of terrestrially derived organic matter and phosphorous to initialize blooming of microorganisms in a shallow shelf embayment."

Leckie et al. (1990) suggested that an organic-rich, radioactive shale facies of the Cretaceous Shaftesbury

Formation does not represent the deepest water sediments of a transgression. However, the unit could be a condensed section deposited in a brackish-water estuarine environment.

It is obvious that many questions pertaining to the origin of bituminous shales exist and at this time remain unresolved. Although most published theories on Pennsylvanian (midcontinent) shales are well documented in the literature, all are not necessarily accepted. As research continues on the Pennsylvanian as well as on other rock units (i.e. the Cretaceous), the depositional history of bituminous shales will be refined.

CHAETETIDS

Chaetetids have previously been recognized as members of many different phyla (see West and Clark, 1984; Connolly et al., 1989, for the history of chaetetid classification). Recently, based on their small-scale internal structure, Paleozoic chaetetids were considered to be sclerosponges (West and Clark, 1984). However, Reitner (1986) and Connolly et al. (1989) suggested that chaetetids should be classified as demosponges.

Stratigraphically, Chaetetes range from Silurian to the Triassic (West, in press), and are reported to occur throughout the United States (see Suchy, 1987, for list of the geographic distribution). In southeast Kansas and northeast Oklahoma, chaetetids occur most commonly in limestone strata of the Lower and Middle Pennsylvanian (West and Clark, 1984) particularly within the Marmaton Group (Schenk, 1963, 1967; Knight, 1985; Suchy, 1987).

Chaetetids exhibit three different growth forms based on height-width relationships: 1) laminar; 2) ragged, low domical; 3) columnar (Figure 12). Many authors have demonstrated that different growth forms are related to general environmental conditions (Bottjer, 1976; Spaw, 1977; West and Clark, 1984; Connolly et al., 1989). West and Clark (1984, p.339) suggested that growth forms can be directly related to substrate and sedimentation rate: laminar forms in mudstones and wackestones with higher sedimentation rate, low-domical to columnar forms in packstones to grainstones with a low sedimentation rate.

Connolly et al. (1989) suggested that _Chaetetes_ are indicative of a wide range of very shallow subtidal conditions, approaching intertidal depths. Based on their observations in the Lower and Middle Pennsylvanian, _Chaetetes_ favored environments of moderate water energy.

Recently, workers have suggested that chaetetid occurrences are related, stratigraphically, to genetic sequences (West et al., 1989). Suchy (1987) demonstrated that chaetetid-rich intervals in the Houx-Higginsville limestone (Fort Scott Formation) represent the regressive part of a PAC (Figure 13). Furthermore, West et al. (1989) suggested that chaetetids may occur in predictable

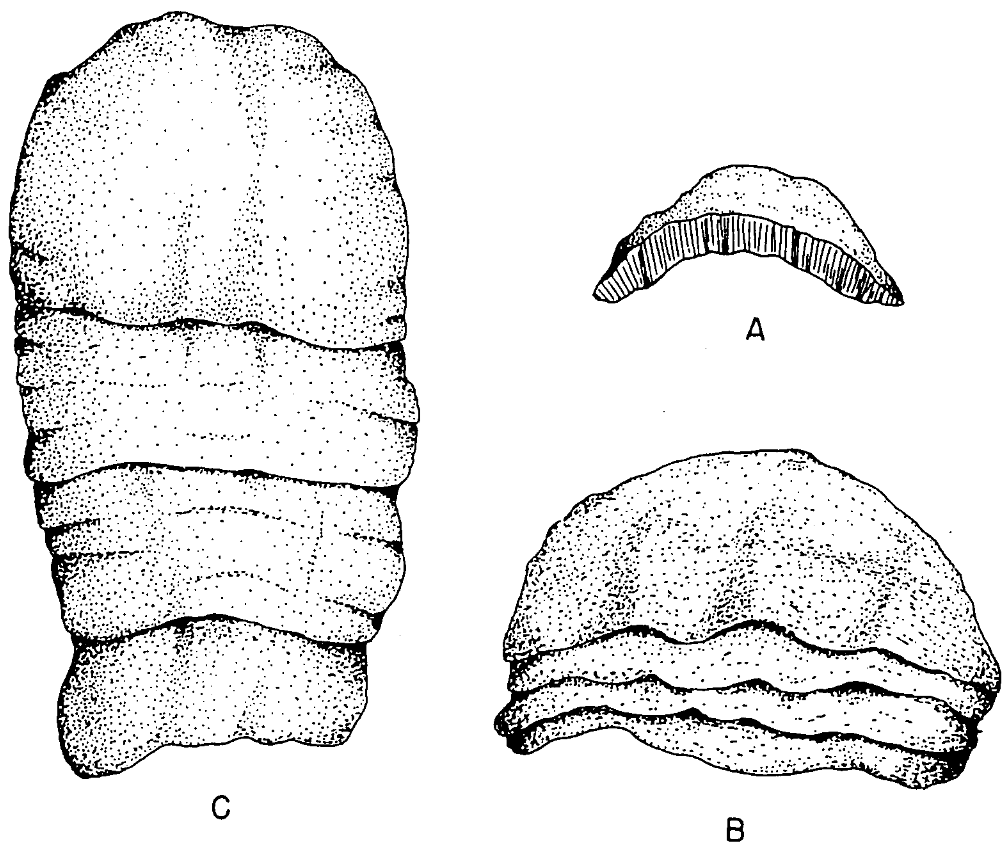

Figure 12. Three Dominant Growth Forms of Chaetetes; A) laminar, B) low-domical, C) columnar. From West and Clark (1984).

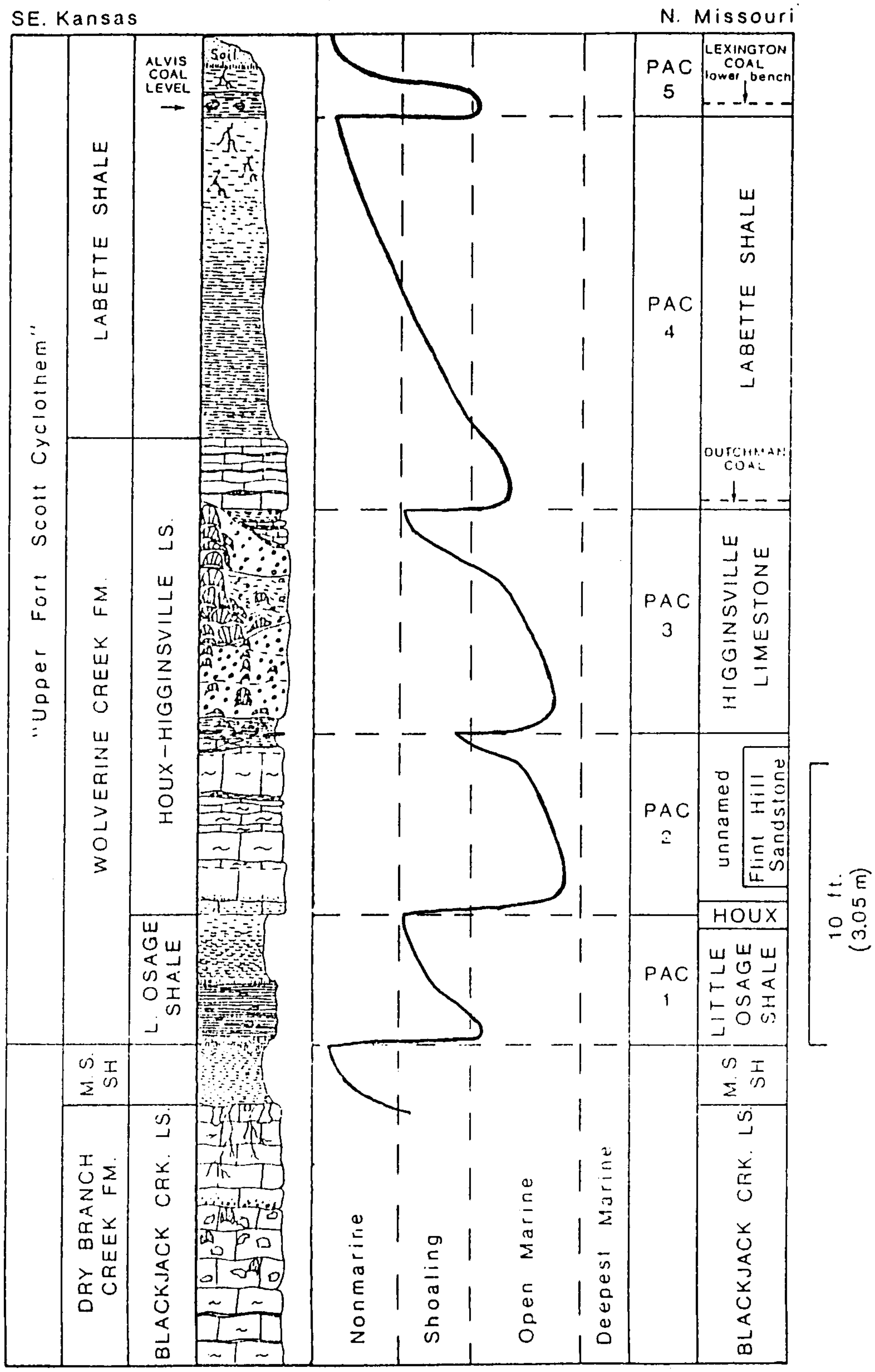

Figure 13 . Schematic Illustrating Chaetetid Occurrences in the Regressive Phase of the Houx-Higginsville Limestone. From Suchy and West (in press).

stratigraphic, and paleoecologic sequences that are discernable using detailed genetic stratigraphy.

GEOLOGIC STRUCTURE
OF THE
STUDY AREA

The study area extends from Bourbon County, Kansas to Tulsa County, Oklahoma. Outcrops of the Blackjack Creek limestone are exposed along the Pennsylvanian (Desmoinesian) outcrop (see Figure 1). Stratigraphic sequences were studied from the eastern edge of the Bourbon Arch, across the Cherokee and Northeast Oklahoma Platforms, and onto the Shelf Edge Rise (Figure 14).

Throughout the generally flat region of the Midcontinent, mild flexures and fractures of the craton developed into topographically high and low areas with different amounts of relief (Knight, 1985). Numerous workers have identified major structural features that influenced sedimentation during Middle Pennsylvanian time (see Knight, 1985, for history of Pennsylvanian Midcontinent structures).

Some of these structural elements inherit attributes from earlier tectonic activity, but for the most part, they apparently originated in crustal disturbances that occurred during the Middle Pennsylvanian (Merriam, 1963). Sources of Midcontinent Pennsylvanian sediments were from the north (stable craton; Wisconsin and Iowa), the east (Ozark Dome), the south-southeast (Ouachita Mountains), the south-southwest (Arbuckle and Wichita Mountains), and the west (Ancestral Rocky Mountains) (Boardman et al., 1984).

The Ladue-Freeman Anticline, located in western

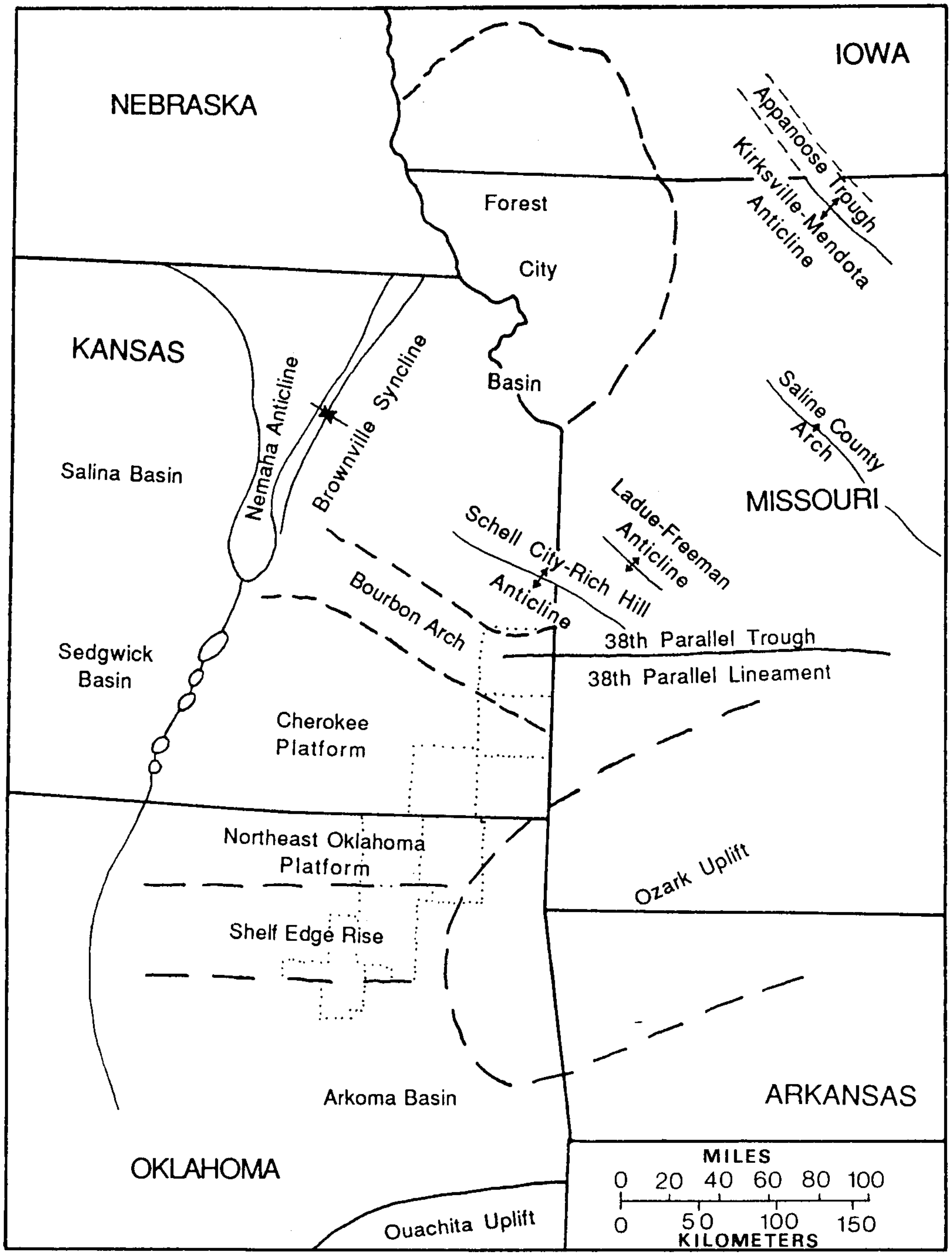

Figure 14 . Pennsylvanian Midcontinent Structures (suspected of having affected sedimentation). From Knight (1985).

Missouri (see Figure 14), is reported to be one of the northernmost highlands present during Blackjack Creek deposition (Neal, 1969). Neal (1969) identified a lagoonal facies within the Blackjack Creek limestone over the crest of this anticline.

Neal (1969) also documented the effects of the Schell City-Rich Hill Anticline in west-central Missouri (see Figure 14), just south of the Ladue-Freeman Anticline. Over the crest of this anticline, the black, phosphatic shale facies of the Excello shale is absent while the Mulky coal has thinned considerably (Knight, 1985). In addition, Neal (1969) recognized that the Blackjack Creek limestone developed an oncolitic calcarenite facies on the flanks of the Schell City-Rich Hill Anticline.

Continuing south along the outcrop belt, Price (1981) identified a depression, the 38th Parallel Trough, based on a thickening of a clastic wedge and the presence of a coal in western Missouri (see Figure 14). The trough parallels the south side of the 38th Parallel Lineament noted by Heyl (1972).

The Bourbon Arch, named by Moore and Jewett (1942), trends northwest - southeast and separates the Forest City Basin from the Cherokee Platform (see Figure 14). It was suggested that this pre-Desmoinesian, post-Mississippian structure is a remnant of the pre-Mississippian Chautauqau Arch which was an extension of the Ozark Uplift into southeastern Kansas (Merriam, 1963).

McMillan (1956) claimed that the Bourbon Arch continued to influence sedimentation as late as the Upper Pennsylvanian.

Schenk (1967) cited evidence for the influence of the Bourbon Arch on carbonate deposition of the upper Desmoinesian Altamont Limestone Formation. He stated that the transgressive limestone member of the Altamont pinches out over the arch and the regressive limestone member contains brecciated fabrics and Osagia-grain calcarenites along the flanks of the arch and a phylloid algal build-up over the crest.

Conversely, Gentile (1968) suggested that this area was inactive or did not affect Upper Cherokee or Lower Marmaton sedimentation.

Price (1981) recognized numerous effects by the Bourbon Arch on Marmaton rocks. He reported that there were: 1) algal buildups in the Pawnee limestone on the flanks of the arch, 2) that black shales thinned over the arch, and 3) that clastic deposits were blocked from the east by the arch. He also noted that an algal mound, identified by Heckel and Cocke (1969) in Missourian rocks, coincides with the geographic position of the Bourbon Arch.

The Cherokee Platform, defined by Moore (1979), was originally designated the Cherokee Basin by Jewett (1951). He suggested that a mild downwarp of the ancient Chautauqau

Arch created the basin during pre-Desmoinesian time. This depositional platform, along with its contiguous, equivalent in Oklahoma, the Northeast Oklahoma Platform (Krumme, 1981) is an extension of the Arkoma Basin into northeast Oklahoma and southeast Kansas where Lower Pennsylvanian beds overlie Cambrian through Ordovician beds (Merriam, 1963).

Price (1981; 1984) identified the Shelf Edge Rise as a slight topographic high along the northern edge of the Arkoma Basin (see Figure 14). He inferred it to be remnants of an algal (phylloid) buildup, and based this on a local thickening of the Laberdie limestone (Pawnee Formation) south of the Kansas-Oklahoma border.

According to Krumme (1981), the Arkoma Basin, which he called the McAlester Basin, acted as a depositional sink into which Pennsylvanian sediments accumulated. Middle Desmoinesian sediments entered the area from the south as well as from the north as the Ouachita Mountains became a dominant source (Krumme, 1981). Price (1981) and Krumme (1981) believed that by late Missourian time, the Arkoma Basin had been filled by deltaic deposits that had prograded from a southern source.

HIERARCHAL GENETIC STRATIGRAPHY

INTRODUCTION

Hierarchal Genetic Stratigraphy (HGS) delineates a hierarchy of genetic chronostratigraphic units that does not change at different locations within a basin (Busch and West, 1987). HGS recognizes six scales of genetic transgressive-regressive (T-R) units, and is essentially based on physical relationships of T-R units themselves (Busch and Rollins, 1984; Busch et al., 1989).

Periodicities, inferred for these T-R units, are 225-300 m.y. (first-order), 20-90 m.y. (second-order), 7-13 m.y. (third-order), 0.6-3.6 m.y. (fourth-order), 300,000-500,000 years (fifth-order = a Cyclothemic PAC Sequence), and 50,000-130,000 years or less (sixth-order = a PAC) (Figure 15).

Boundaries between T-R units are defined as conformable or unconformable "genetic surfaces" of two types: transgressive surfaces and "climate-change surfaces" (Busch and West, 1987). Transgressive surfaces are defined to be contacts where: 1) marine facies directly overlie nonmarine facies, 2) relatively deeper water facies "abruptly" overlie relatively shallower water facies, or 3) relatively more open marine facies "abruptly" overlie relatively less open marine facies (Busch and West, 1987; Busch et al., 1989). Climate-change surfaces are represented by: 1)

BUSCH & ROLLINS, 1984	VAIL et al., 1977	CHANG, 1975 AND RAMSBOTTOM, 1979	MOORE, 1936	GOODWIN AND ANDERSON, 1985	HECKEL, 1977 AND HECKEL, 1986	WANLESS AND WELLER, 1932
FIRST-ORDER 225-300Ma	FIRST ORDER DEPOSITIONAL SEQUENCES					
SECOND-ORDER 20-90Ma	SECOND-ORDER DEPOSITIONAL SEQUENCES	SYNTHEMS				
THIRD-ORDER 7-13Ma	THIRD ORDER DEPOSITIONAL SEQUENCES					
FOURTH-ORDER 0.6-3.6Ma		MESOTHEMS				
FIFTH-ORDER 300-500ka		CYCLOTHEMS	MEGACYCLOTHEMS	SHALLOWING PAC SEQUENCE	KANSAS CYCLOTHEMS; MAJOR CYCLES	CYCLOTHEMS
SIXTH-ORDER 50-130ka			CYCLOTHEMS	PUNCTUATED AGGRADATIONAL CYCLES (PACS)	MINOR CYCLES	

Figure 15. Hierarchy of Permo-Carboniferous Transgressive-Regressive Units. From Busch and West (1987).

nonmarine facies, commonly formed under subaerial conditions, overlain by subaqueous nonmarine facies, 2) relatively more open subaqueous nonmarine facies "abruptly" overlying a relatively less open subaqueous nonmarine facies, 3) relatively deeper subaqueous nonmarine facies "abruptly" overlying relatively shallower subaqueous nonmarine facies, or 4) relatively more humid subaerial nonmarine facies "abruptly" overlying relatively less humid subaerial nonmarine facies (Busch and West, 1987; Busch et al., 1989). To avoid ascribing the sequences recognized in this study to specific causes, I have used the term PAC (Punctuated Aggradational Cycle) for these small-scale genetic packages.

OBSERVATIONS

Descriptions of each unit are summarized below, and the results of the field work are contained in the measured sections found in Appendix A.

Breezy Hill Limestone

In a northeast to southwest traverse, the Breezy Hill limestone changes from a poorly preserved, bioturbated, clay- to silt-rich, dolomitic mudstone (52cm thick; 20in) to a slightly dolomitic, fossiliferous wackestone to packstone (122cm thick; 48in). In the northern sections, the unit is dominated by rhizocretions, root traces, burrows(?), mudcracks(?), micrite clasts, smooth-shelled ostracodes, brachiopod fragments, and crinoid fragments. Near the southeast corner of Kansas (Labette County) and continuing south into Oklahoma, the Breezy Hill contains articulated Composita, Crurithyris, and other brachiopod shell fragments, crinoid and bryozoan fragments, fusulinids, phylloid algal blades(?), and peloids. Although rhizocretions are best developed and preserved in the northern sections, some occur at section 885 (see Figure 5).

Mulky Coal

The Mulky coal (and underclay) is present only in the northern most sections and subsurface cores (see Appendix A and B). The southern extent of the coal bed reaches Englevale, Kansas (locality 706c, a core), and is a black, blocky (slightly fissile, in places) coal commonly with few plant fragments. On the outcrop, contacts are extremely sharp. In cores, the upper contact is similar to a 'transgressive lag' deposit represented by coal fragments contained within the overlying Excello shale. The coal bed ranges from 22cm (8.7in) to 46cm (18in) thick.

Below the Mulky coal, the blocky to laminated underclay is light to medium gray to light olive gray and commonly contains plant and brachiopod fragments. The underclay is typically mottled with root traces, carbonized plant debris, and shale clasts (found only in the southern part of the field area). The underclay ranges from 18cm (7in) (partially exposed) to 78cm (31in).

Excello Shale

The Excello, regarded as one of the most widely correlative units of the Midcontinent (Wanless, 1967), consists, when complete, of four siliciclastic-rich facies. These are, in ascending order: 1) lower clay-shale (sometimes silty), 2) bituminous shale, 3) upper clay-shale (silt-rich), and 4) claystone. The only facies common to all sections, cores, and well logs is the bituminous shale; a radioactive black, fissile, phosphatic, conodont-rich shale. Contrary to Kidder (1985), my study demonstrates that the nodules are not concentrated in specific intervals (i.e. the upper contact or lower contact), but appear randomly distributed and most commonly found to decrease in abundance toward the contacts.

The light olive gray to dark gray lower clay-shale facies is platy to flaky with poor fissility. Root(?) traces, burrows, limestone and shale clasts, and silt (less than 5 percent) accompany isolated brachiopod shell fragments, <u>Orbiculoidea</u>, and plant fragments. Thickness of the interval varies from 6cm (2.4in) at locality C-33 to 19cm (7.5in) at locality 886.

The bituminous shale facies, Heckel's (1977) "core" shale, is common to all measured sections and cores that include the Excello shale, and is a prominent marker bed on subsurface well logs (Gamma Ray and Neutron logs). This facies is black to grayish black and greenish black, fissile, and phosphatic (fluorapatite nodules) with some nodules pyritized. The shale contains conodonts, Chondrites, Dunbarella, Orbiculoidea, plant fragments, brachiopod shell fragments, and fish fragments(?). The clay content increases toward the contacts as the phosphate nodules decrease. Across the outcrop belt, the thickness varies from 58cm (22.8in) at locality 812 to 144.8cm (57in) at locality 885. At locality 882, the Excello is only 28cm (11in) thick, but the lower contact is covered.

The very light gray and olive gray to black upper clay-shale facies is very similar to the lower clay-shale facies, but with burrows and, locally, silt-size quartz grains along with conodonts and fish scales(?). The average thickness of the interval is slightly greater than the lower interval; the upper clay-shale facies ranges from 9.2cm (3.6in) at locality 706c to 18cm (7in) at locality 766c.

The uppermost facies of the Excello shale is described as a medium light gray and dark gray to greenish gray, blocky to platy, bioturbated (roots? and burrows) claystone to siltstone facies (in places, silt content nearly equals clay content) with micritic clasts and isolated laminar, phosphate nodules. Fossils are mainly fragmented debris, but Linoproductus and Punctospirifer (shell fragments), articulated ostracodes, productid spines, bivalve fragments, and crinoid fragments were identified. The thickness of the interval varies from 14cm (5.5in) at locality 812 to 48.1cm

(19in) at locality 706c.

Blackjack Creek Limestone

The Blackjack Creek limestone is here defined as all carbonate beds (i.e. limestones) between the lowest siliciclastic-dominated interval of the Little Osage shale, above, and the uppermost siliciclastic-dominated interval of the Excello shale, below. In many measured sections, claystones and clay-shales, above and below, are slightly calcareous, but will not be included in the Blackjack Creek limestone. Furthermore, in Kansas, the Summit coal and underclay are present only in the northernmost sections (see Appendix A and B).

The Blackjack Creek limestone exhibits a gradual thickening across Kansas from Bourbon County, locality 881 (148cm; 58.3in), to the Kansas-Oklahoma border, locality 883 (808.2cm; 318.2in), where an abrupt thickness change occurs. Across the Oklahoma outcrop belt, the Blackjack Creek limestone maintains this thickness until the southernmost section, locality 848, where it is only 360cm (141.7in) thick. However, the well logs indicate that as the unit is traced into the subsurface (near Tulsa, Oklahoma) it retains a thickness between 750-1000cm (see Appendices A, B, C).

I have divided the Blackjack Creek limestone into four zones designated C, B, A2, and A1 (Figure 16). All four zones are recognized south of locality 882.

<u>C zone</u> - The lowest part of the **C zone** is a light gray

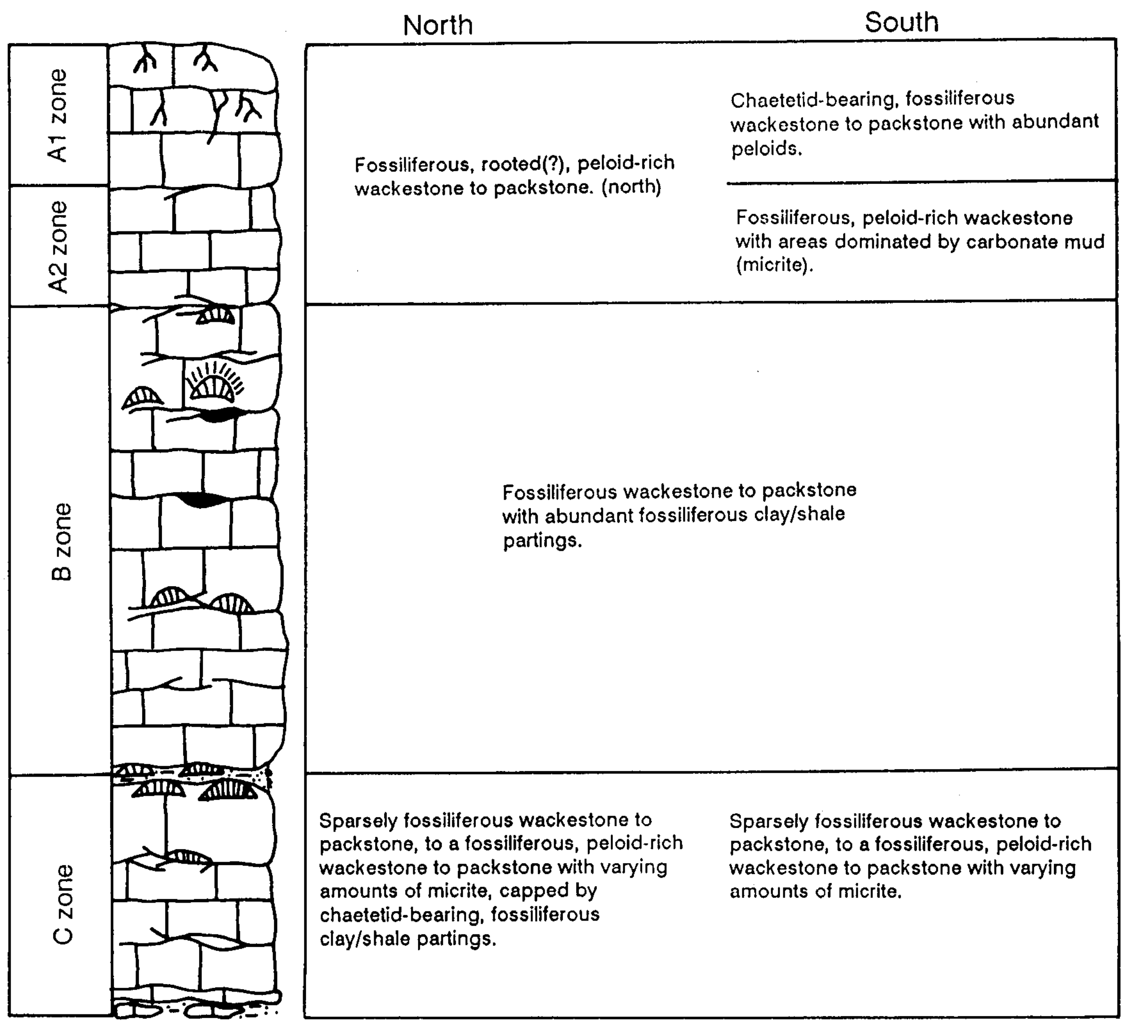

Figure 16. Four Subdivisions (Zones) of the Blackjack Creek Limestone.

to dark gray, sparsely fossiliferous wackestone to packstone. Within the basal part of the C zone fossil diversity is limited, yet, in places, unidentifiable fossil debris persists. The fossils present are fragmented and abraded with the exception of a few articulated brachiopods. The dominant fossil constituents are crinoid fragments, phylloid algal blades, and ramose bryozoan fragments. Also present are echinoid spines, Composita and Crurithyris fragments.

Clay/shale partings occur frequently throughout this interval, and typically contain abraded fossil fragments along with silt-size quartz grains. Geopetals, most commonly Composita, exhibit up-directions that are not consistent with the stratigraphic up-direction nor are they consistent with each other.

The rest of the C zone can be described, in general, as a light gray, peloid-rich fossiliferous wackestone facies with varying amounts of micrite (peloids) and fossil debris. Fossiliferous, chert-bearing clay/shale partings, with overturned chaetetid fragments, and microstyolitic clay seams are prominent and typically break up the massive unit into thick and thin beds.

Fossil diversity and density appears to increase from the base of the C zone. At the same time, quality of fossil preservation has also improved (i.e. more articulated valves and less abrasion). Fossils within the middle to upper C zone are Composita, ramose and fenestrate bryozoan fragments, Tetrataxis, Crurithyris, phylloid algal blades, crinoid fragments, fusulinids, and productid spines. Other fossils are isolated Chaetetes fragments (sometimes overturned), bivalve shell fragments, echinoid spines, gastropod fragments, and Cleiothyridina. In places, fossil fragments, particularly phylloid algal blades, have micritic coatings.

Capping this interval, in places, are laminar to low-domical Chaetetes in life position, which in the northern region (except localities 881 and C-33) form a distinct, laterally traceable (100km; 62mi) interval with interbedded fossiliferous clay/shale partings (see plate 1).

Thickness of the interval ranges from a minimum of 8cm (3.1in) at locality C-33, Bourbon County, Kansas, to a maximum of 351cm (138.2in) at locality 887 near the Kansas-Oklahoma border, then thins again to 121cm (47.6in) at the southernmost section (locality 848) in Rogers County, Oklahoma.

B zone - The **B zone** is generally a light gray to light olive gray, mottled, fossiliferous wackestone to packstone with fossiliferous clay/shale partings throughout the entire interval. Partings commonly contain peloids, clay- to sand-size quartz grains, silt- to sand-size dolomite, chert concretions, and fossil debris (crinoids, foraminiferids, brachiopods, productid spines). The micrite content, commonly peloidal, decreases downward within the interval as well as decreases from north to south across the study area (to a fossiliferous packstone). The thickness of this zone, which commonly comprises the thickest part of the Blackjack Creek limestone, varies from 101cm (39.8in) (locality 881), Bourbon County, Kansas, to 384cm (151.2in) (locality 885) along "Claremore Mound", near Claremore, Oklahoma.

Although the fossil density decreases slightly from that of the C Zone, the B zone appears to demonstrate the greatest fossil diversity of the Blackjack Creek limestone. Quality of fossil preservation is better than in the C zone (articulated valves with only minor amounts of abrasion occur). Crinoid fragments, Composita, fusulinids, ramose and fenestrate bryozoan fragments, phylloid algal blades, productid spines, Crurithyris, Tetrataxis, echinoid spines, and Chaetetes, dominate. Other fossils common at many localities are palaeotextulariids, horn corals, ostracodes, Cleiothyridina, gastropods, and bivalves (pectins). Locally, burrows(?), mudstone clasts, micrite coated algal blades, chert nodules, and dolomite occur.

A2 zone - The **A2 zone**, a zone which does not occur north of locality 781, can generally be described as a light brownish gray to brownish gray, fossiliferous, peloid-rich wackestone with areas dominated by carbonate mud (micrite). At most localities, weathered, discontinuous, fossiliferous clay/shale partings occur, commonly with chert concretions, bounding thick lenticular limestone beds. Where partings are absent, the interval is most commonly massive and mottled. Locally, micritic clasts, root(?) traces, coated grains, and burrows occur.

Fossil diversity and, in places, density appear to decrease from that of the B zone and C zone. Articulated brachiopods, particularly Linoproductus and Composita occur, and in places, appear to be in life position. Also, locally, clay and/or micritic layers coat individual fossil fragments (coatings disappear upward). Biota common to most sections are Linoproductus, Composita, crinoid fragments, sponge spicules, bivalve (pectin) fragments, fusulinids, productid spines, bryozoan fragments, and phylloid algal blades. Minor fossil constituents include ostracode fragments, low-spire gastropod fragments, echinoid spines, Chaetetes (sometimes, up-side down), globivalvulinids, palaeotextulariids, Neosyringopora, trilobite fragments, and bellerophontid fragments.

Thickness of the A2 zone increases from 83cm (32.7in) at locality 781, in southern Labette County, Kansas, to 135.7cm (53.4in) at locality 885, near Claremore, Oklahoma.

A1 zone - The uppermost zone of the Blackjack Creek limestone, the **A1 zone**, varies from a light gray to grayish black, rooted(?) mudstone to a pale yellowish orange to grayish orange pink, fossiliferous, rooted(?) packstone in the northern two-thirds of the study area (from Nowata

County, Oklahoma, to Bourbon County, Kansas). It is recognized in the three southernmost sections of the study area as a chaetetid-bearing, light gray to pale yellowish orange, fossiliferous, peloid-rich wackestone to packstone. Throughout the entire study area, the A1 zone commonly contains peloids and, in the northern thirteen localities, is capped by a thin calcrete-like crust with densely packed rhizocretions (roots?). At the southern three localities, rhizocretions are scarce and poorly developed, and _Chaetetes_ appear within and on top of the zone.

Fossils are generally similar to those of the A2 zone with a slight decrease in diversity and density. Also, there appears to be an increase in diversity and density from north to south, but fossils in the northern area are better preserved and commonly covered with micritic or algal coatings. Fossils common to most sections are _Linoproductus_, fusulinids, productid spines, _Composita_, crinoid fragments, ramose bryozoans, low- and high-spire gastropods, ostracodes, _Tetrataxis_, echinoid spines, phylloid algal blades, and bivalve fragments. Other fossils present are palaeotextulariids, _Neospirifer_, globivalvulinids, bellerophontids, productid shell fragments, and _Neosyringopora_. Laminar _Chaetetes_, which occur at two of the three southernmost localities, are associated with clay/shale partings, and decrease in abundance from north to south (Note: _Chaetetes_ in section

885 occur in the B zone).

Although fossiliferous clay/shale partings occur in this zone, they are relatively rare when compared to the zones below.

Locality 883, just north of the Kansas-Oklahoma border, contains an anomalous light gray and olive gray to dark reddish brown, chert band along the upper surface of the A1 zone; it occurs only where an overlying claystone and limestone are present (see Appendix A).

Thickness of the A1 zone varies from 29cm (11.4in) at locality C-33, in Bourbon County, Kansas, to 97cm (38.2in) at locality 883, near the Kansas-Oklahoma border, and then to 111cm (43.7in) (locality 848), in southern Rogers County, Oklahoma.

Little Osage Shale

The Little Osage shale, as used herein, includes all beds between the base of the Houx-Higginsville limestone, above, and the top of the Blackjack Creek limestone (an interval that includes the Summit coal and underclay). In places where the overlying limestone is missing, mainly northeastern Oklahoma, the Little Osage shale is overlain by the Wewoka Shale (equivalent to the Labette Shale in Kansas) (Krumme, 1981).

The Little Osage shale, the lowest unit in Knight's (1985) "upper Fort Scott cyclothem", is typically composed of marine siliciclastics, a coal and an underclay. Across the study area, the Little Osage exhibits three general sequences from north to south (Figure 17), with coal only present at the northernmost locality (locality 881). The southern sequence not only lacks the coal bed, but also the claystone (underclay?).

The thickness of the Little Osage shale varies from 263cm (103.5in) (locality C-33), in Bourbon County, Kansas, to 172cm (67.7in) (locality 882), in Labette County, Kansas, and 174cm (68.5in) (locality 885), in Rogers County, Oklahoma. At locality C-33, the northernmost core, the Summit coal and underclay comprise 103cm (40.6in), whereas in the other two localities (882 and 885), the Summit coal is absent.

INTERPRETIVE (GENETIC) STRATIGRAPHY

PAC 1

Using a criterion suggested by Busch et al. (1989), the lower boundary of PAC 1 is defined as a relatively more open marine facies abruptly overlying a less open marine facies. The first genetic surface (PAC 1) occurs at the base of the black, fissile, phosphatic bituminous shale facies of the Excello shale (Figure 18). In the northern four localities (881, C-33, 812, and 813), the bituminous shale abruptly overlies a black, blocky coal bed (Mulky coal) with underclay; elsewhere, the shale overlies a marginal marine clay-shale, or claystone, dominated by plant fragments,

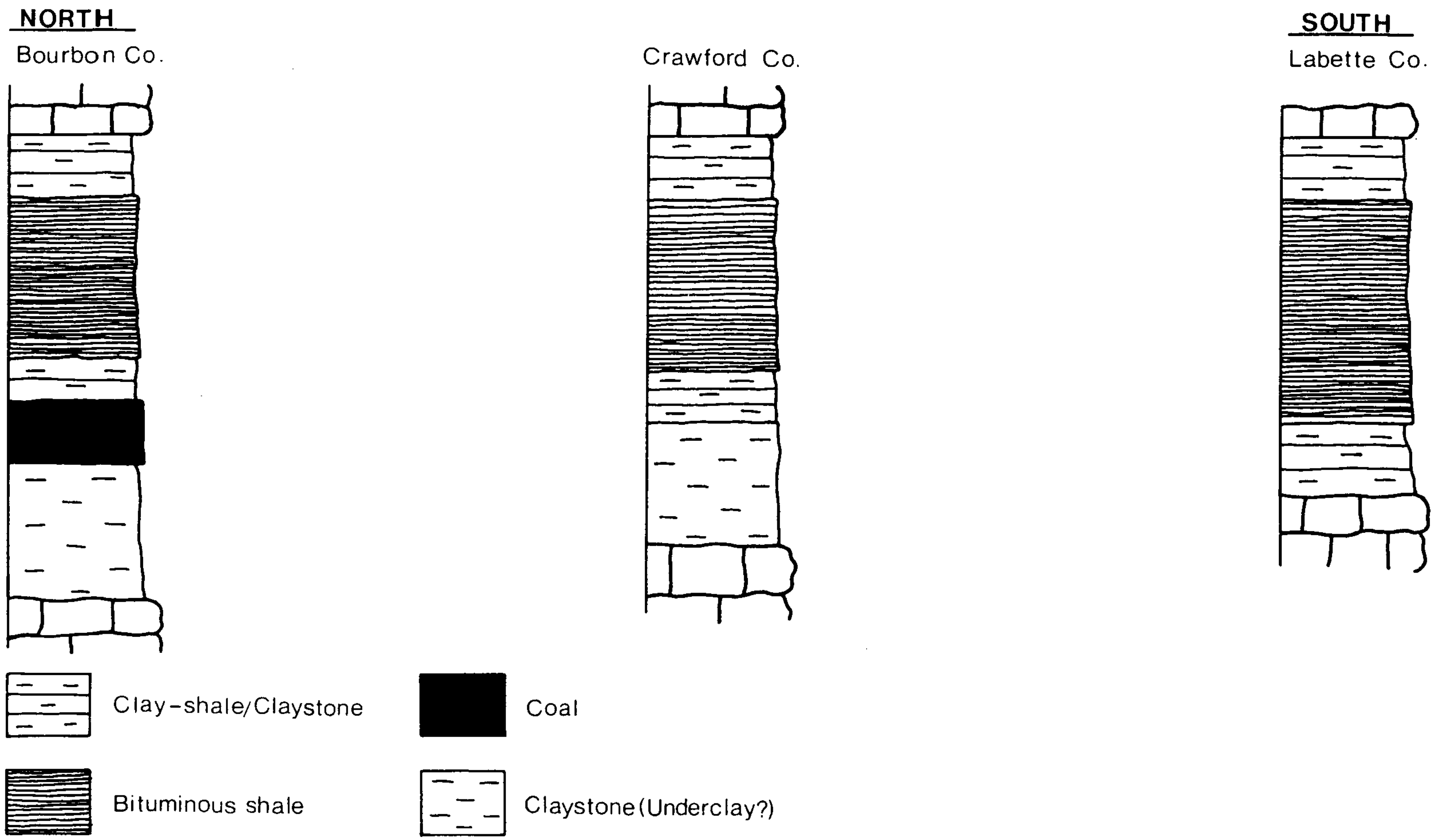

Figure 17 . Three General Sequences of the Little Osage Shale Member; from North to South.

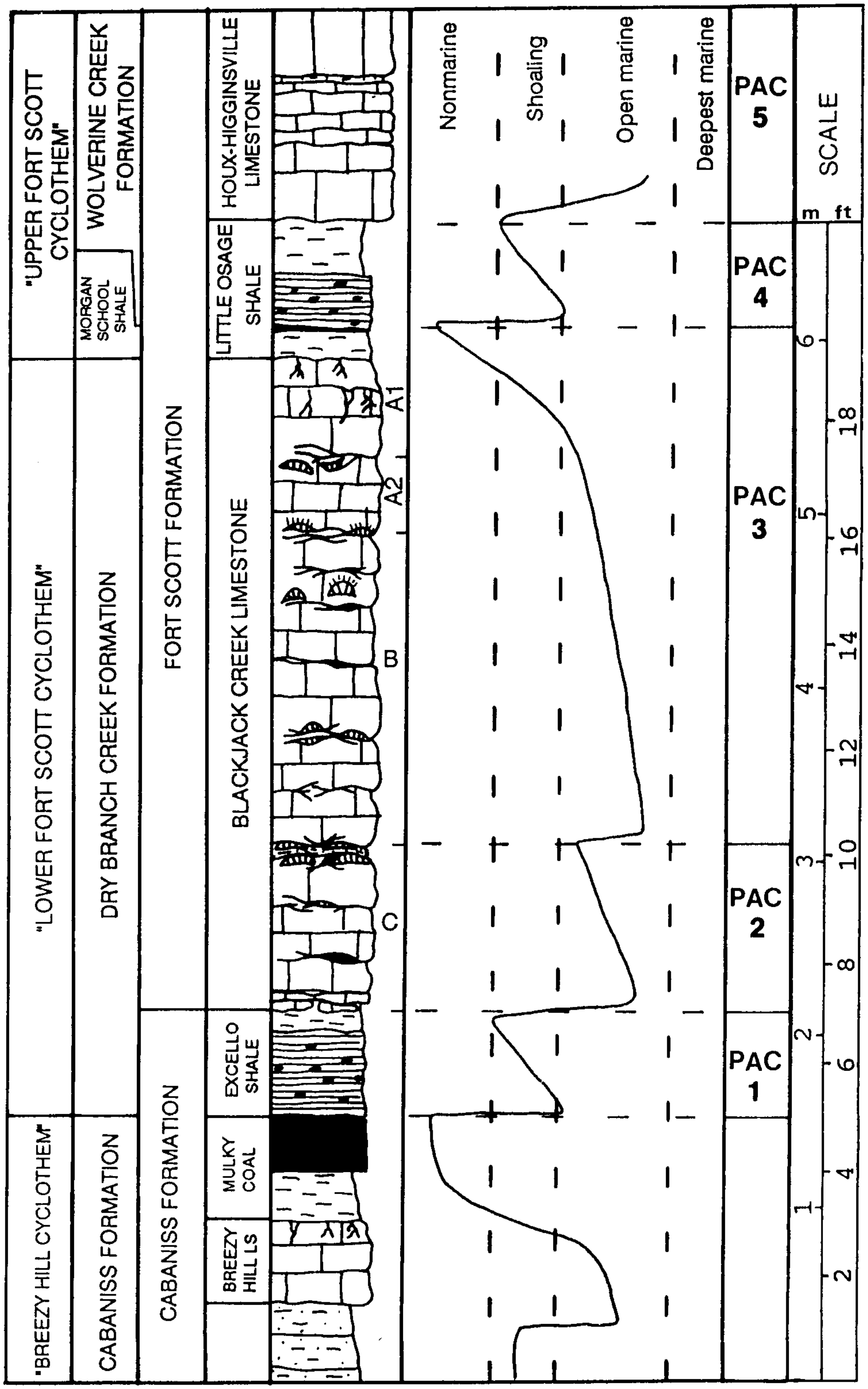

Figure 18. Composite Section with Relative-Water Depth Curve and PACs to the right.

root(?) traces, burrows, limestone and shale clasts, and some fossil fragments (mainly brachiopods). Where the coal is present, the genetic surface varies from a thin, sharp shale/coal contact with no evidence of reworking (i.e. no coal clasts) to a shale/coal contact where coal fragments occur in the overlying shale. Farther south, the genetic surface occurs as a sharp contact between the overlying fissile shale and the bioturbated claystone. At locality 883, the bituminous shale overlies interbedded claystone and wackestone rubble.

Thickness of the clay-shale ranges from 6cm (2.4in) to 15.5cm (6.1in). The thickness of the bituminous shale ranges from 57cm (22.4in) to 144.8cm (57in).

As sea level fell (or the climate changed?), the upper clay-shale and claystone of the Excello and, in places, a thin, discontinuous, sparsely fossiliferous wackestone to packstone (the top of PAC 1) was deposited. This thin sequence of beds is interpreted to have formed in a marginal marine or lagoonal environment.

PAC 2

The lower boundary of PAC 2 occurs at the base of the Blackjack Creek limestone which abruptly overlies the upper marginal marine claystone, or clay-shale of the Excello shale (see Figure 18). Recall that the claystone (Excello) contains root(?) traces, burrows, micrite clasts, and isolated phosphate nodules. The base of the Blackjack Creek (basal C zone) varies from a sparsely fossiliferous wackestone to packstone facies (along the base) to a fossiliferous, peloid-rich wackestone to packstone facies. As noted earlier, the lower C zone contains poorly preserved fossils (abraded and fragmented), with a very limited diversity. The rest of PAC 2 is a peloid-rich, fossiliferous wackestone to packstone facies with abundant chert-bearing clay/shale partings. Fossil diversity and density increase with brachiopods, foraminiferids, bryozoan fragments, crinoid fragments, phylloid algal blades, and productid spines conspicuous. At locality 881, PAC 2 consists of a sparsely fossiliferous wackestone bed (8cm; 3in) overlain by interbedded claystone and wackestone rubble (8cm; 3in). Just south of 881, at locality C-33, PAC 2 is a thin (8cm; 3in), laminated, clay-rich mudstone. Both of these localities are interpreted as nearshore, possibly restricted (lagoonal) environments, with deposition influenced by the topographically high Bourbon Arch. Again, as in the case of PAC 1, the transgressive surface is defined to be where a relatively more open marine facies abruptly overlies a less open marine facies (Busch et al., 1989).

Capping PAC 2 are well developed, fossiliferous clay/shale partings, which, in the northern sections (except localities 881 and C-33), are interbedded with laminar to low-domical chaetetids in a wackestone to packstone matrix.

To the south, the upper part of PAC 2 is represented by a bioturbated, peloid-rich, fossiliferous wackestone to packstone (Appendices A and B and Plate 1).

PAC 3

The lower boundary of PAC 3, occurs within the lower part of the Blackjack Creek limestone (at the base of the B zone) (see Figure 18). PAC 3, a highly fossiliferous wackestone to packstone facies, abruptly overlies the claystone at locality 881, the thin, laminated mudstone at locality C-33, and the chaetetid-rich clay/shale partings of the underlying limestone (PAC 2) at localities 812, 813, 706c, 886, 766c, and 882. At localities where the chaetetids are absent (781, 883, 887, 884, 851, 885, and 848), PAC 3 abruptly overlies a reworked (bioturbated) interval disrupted by clay/shale partings. The greatest biotic diversity in the Blackjack Creek limestone occurs at the base of PAC 3.

The diverse marine biota is well preserved with numerous articulated brachiopods and relatively few, if any, abraded fossils. This could suggest that the fossils were not transported (or not transported great distances).

Bretsky and Lorenz (1970) reported that fossil diversity increased as you moved away from unstable nearshore environments to less rigorous ("physically stable") offshore environments. Furthermore, Donahue and Rollins (1974) reported that highest diversities occur at the time of maximum stability (i.e. during maximum transgression). Therefore, PAC 3 is defined where a relatively deeper marine facies, the fossiliferous wackestone to packstone facies abruptly overlies a relatively shallower (marine) facies; the chaetetid-rich wackestone to packstone facies (to the north) and the bioturbated, peloid-rich, fossiliferous wackestone to packstone facies (to the south). PAC 3 is interpreted to be the deepest water interval of the Blackjack Creek limestone deposited at maximum transgression.

The regressive phase of PAC 3 consists of the upper Blackjack Creek limestone (upper B zone, A2 zone, and A1 zone) and the lowest Little Osage shale (i.e. to the base of the bituminous shale facies). This suggests a gradual shallowing upward sequence from shallow normal marine water (upper B zone of the Blackjack Creek) to restricted, possibly lagoonal water (A2 zone of the Blackjack Creek) up to extremely shallow water, intertidal to supratidal (subaerial?) conditions (A1 zone of the Blackjack Creek; north of locality 851). Shallowing continued and nonmarine conditions prevailed as coal (peat) and clay sediments accumulated.

PAC 4

PAC 4 occurs between the base of the black, fissile, phosphatic bituminous shale and the underlying clay-shale of the Little Osage (see Figure 18). It is very similar to PAC

1 of the Excello shale, and corresponds to PAC 1 of Suchy and West (in press).

The lateral relationships of the PACs recognized in outcrops within the study area are shown in Plate 1.

Subsurface Expression

PACs identified from outcrop studies are apparently recognizable in the subsurface as suggested by well log patterns. Small-scale events within logs can be distinguished at intervals similar to PACs observed in surface exposures (Figure 19). While these subdivisions of the well logs are not always unequivocal, I have attempted to identify them on all well logs used in this study (Appendix C). If PACs can be recognized from well logs, it will be possible to correlate from the outcrop to the subsurface at a scale smaller than has previously been done. It is important, however, to compare the results of a detailed core study to the wireline logs of the same bore holes to evaluate the validity of PAC identification using only the wireline logs.

INFERRED LITHOFACIES RELATIONSHIPS

Inferred lithofacies maps were constructed based on data acquired using small-scale genetic stratigraphic techniques. Hierarchal Genetic Stratigraphy (HGS) yielded considerable information with regard to depositional environments, and thus paleogeographic aspects, at each

P

LOCATION: C, NW1/4, SE1/4, SW1/4, section 29, T.29N., R.15E.
Nowata County

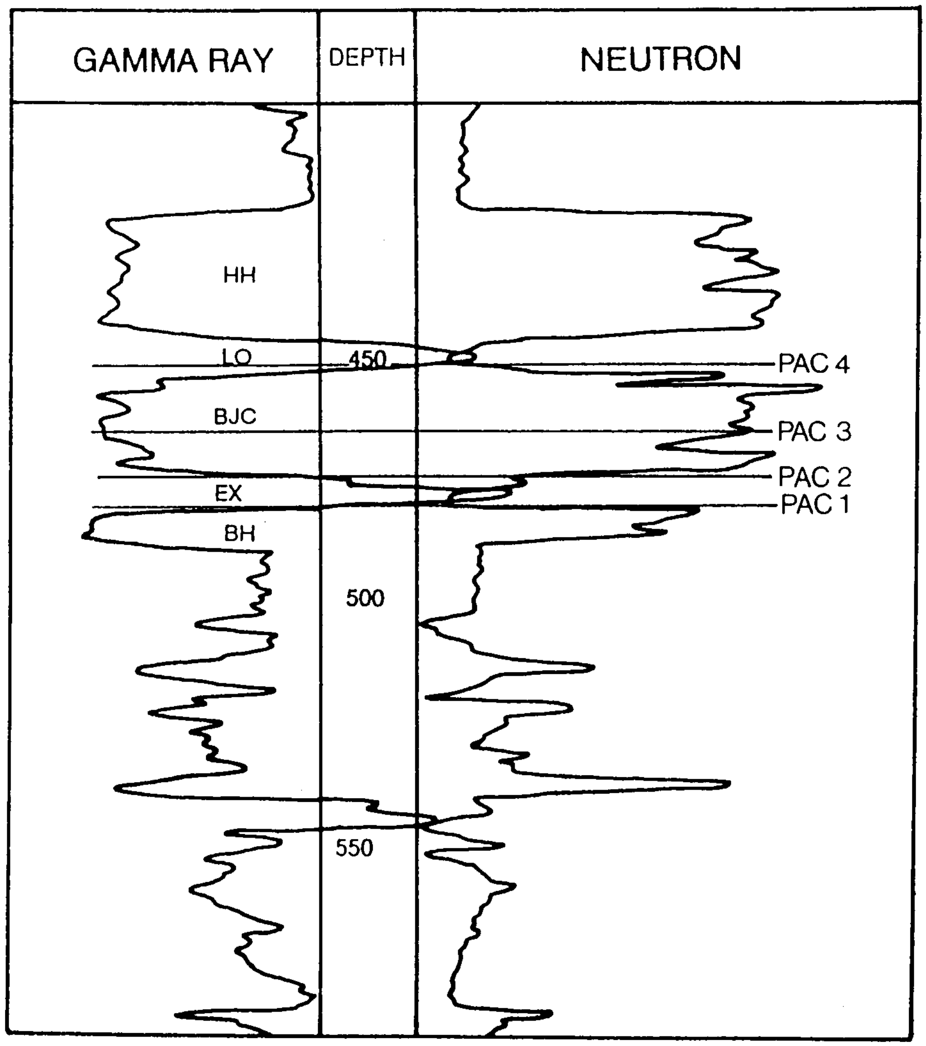

Figure 19. PACs Recognized on Gamma Ray and Neutron Logs. HH=Houx-Higginsville Limestone, LO=Little Osage Shale, BJC=Blackjack Creek Limestone, EX=Excello Shale, BH=Breezy Hill Limestone. The lower boundary of each PAC is identified.

locality in this study. Correlations of four PACs within the study interval (see Figure 17) provides a framework for constructing some generalized lithofacies maps. These maps depict the lithofacies mosaic at times of inferred maximum transgression and maximum regression (or wetness/dryness?), and: 1) illustrate the development of the interval studied (i.e. show the changes from one PAC to the overlying PAC), 2) help visualize two dimensional relationships between adjacent paleoenvironments, and 3) illustrate the role of relative sea level and/or climate changes in the geologic history of the interval studied.

Figures 20 and 21 represent sediment accumulation prior to the development of PAC 1, where the Breezy Hill limestone and Mulky coal depositional histories are summarized. The transgression at the base of the Breezy Hill is shown in Figure 20. Near the Kansas-Oklahoma border, the Breezy Hill changes laterally from a normal marine, sparsely fossiliferous wackestone to packstone (south) to a weathered, silt-rich, fossiliferous mudstone. In the north (localities 886 and 766c), the Breezy Hill contains roots(?), brachiopod and crinoid fragments, and smooth-shelled ostracodes, and is heavily bioturbated. Clay- to silt-size quartz grains are very abundant in the matrix and also fill root(?) cavities. This would suggest that the Bourbon Arch acted as a topographic (depositional) high at this time and that it might have influenced sedimentation as

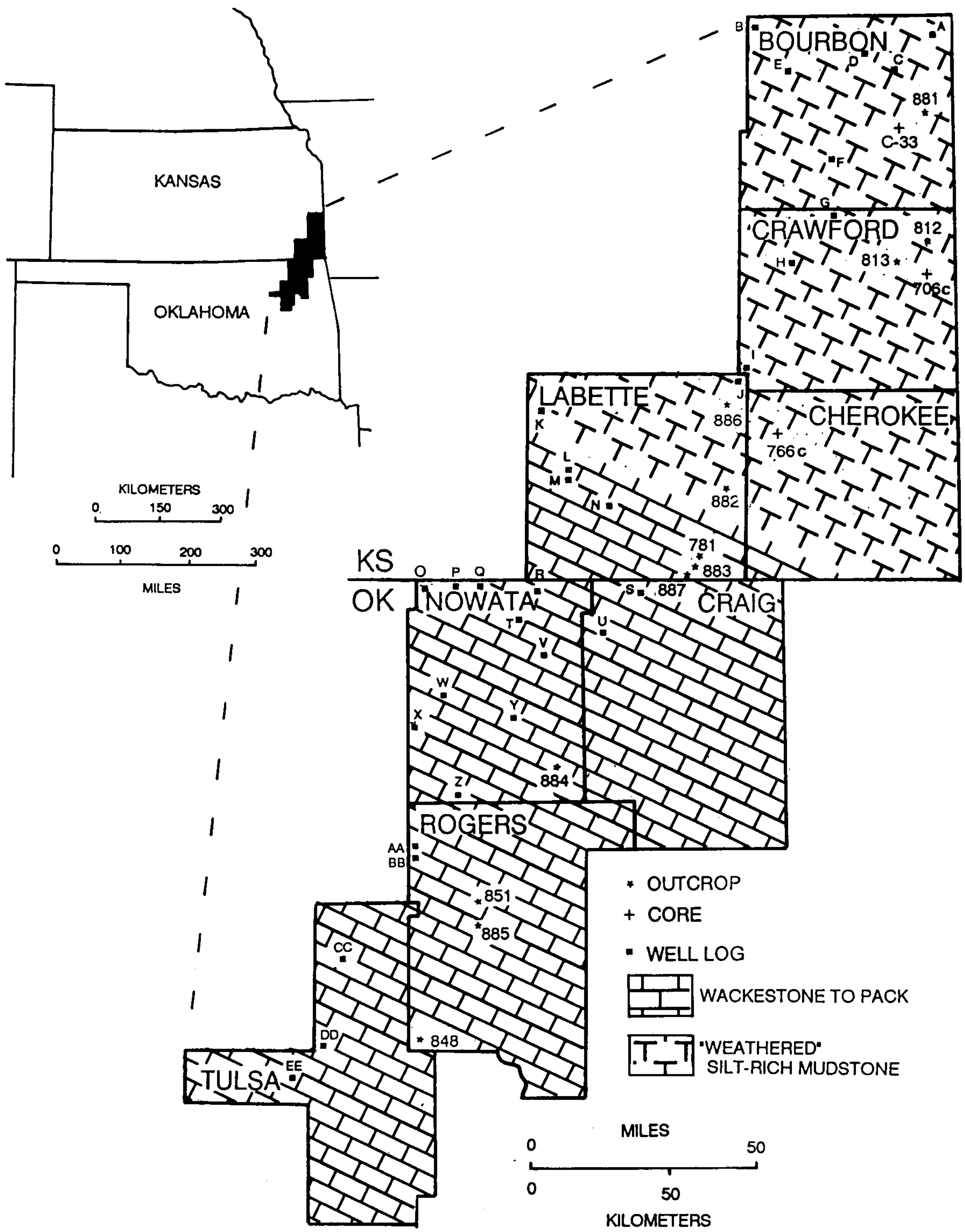

Figure 20. Inferred Lithofacies Map for 'Breezy Hill Limestone Time', Maximum Transgression.

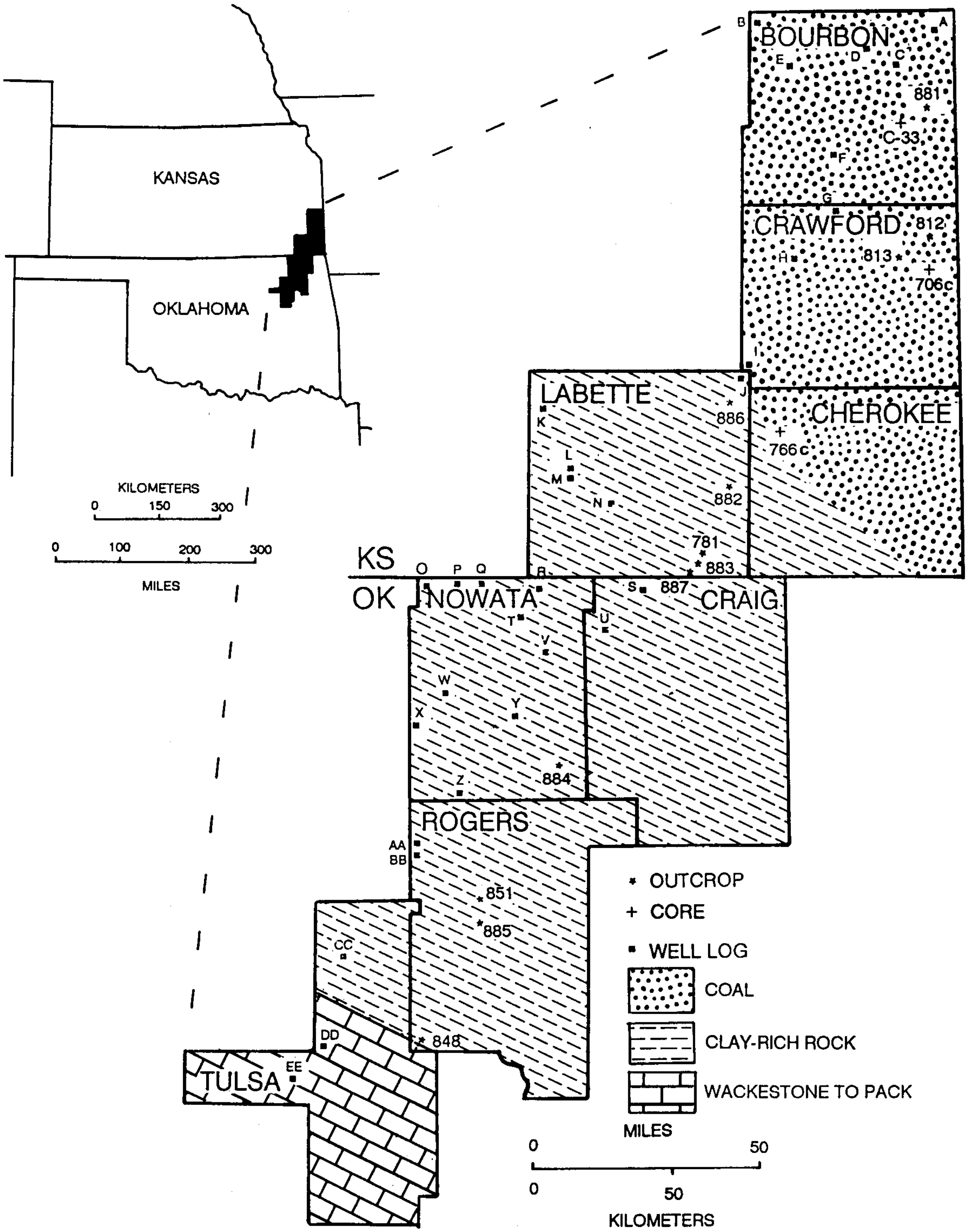

Figure 21. Inferred Lithofacies Map for 'Mulky Coal Time', Maximum Regression.

far south as northeastern Labette County, Kansas.

A regression, which formed the underclay and the Mulky coal, preceded the transgression that produced the bituminous shale facies and marked one of the last major coal forming periods in the Desmoinesian of the Midcontinent. Figure 21 represents a time of maximum regression where the Mulky coal covered the northern part of the field area (i.e. parts of Crawford, Cherokee, and Bourbon Counties). The rest of the study area was covered by predominately marginal marine claystones and/or clay-shales. The southernmost part (i.e. Tulsa County) of the area was still below sea level as indicated by normal marine fossiliferous wackestones and packstones.

Figure 22 illustrates the maximum transgression for PAC 1 as the Excello Sea covered the entire study area and deposited the bituminous, black Excello shale facies. Knight (1985) considered this to be the deepest water facies of the "lower Fort Scott cyclothem". Although this unit represents maximum transgression of PAC 1, its stratigraphic position (i.e. directly overlying a laterally persistent coal bed and where the coal is absent, a marginal marine claystone) would suggest a more marginal marine depositional environment. Also, criteria previously used in favor of deep water models, have been shown to occur in other environments as well (i.e. fresh water phosphate deposits or coastal marine phosphate deposits, Leeder, 1982).

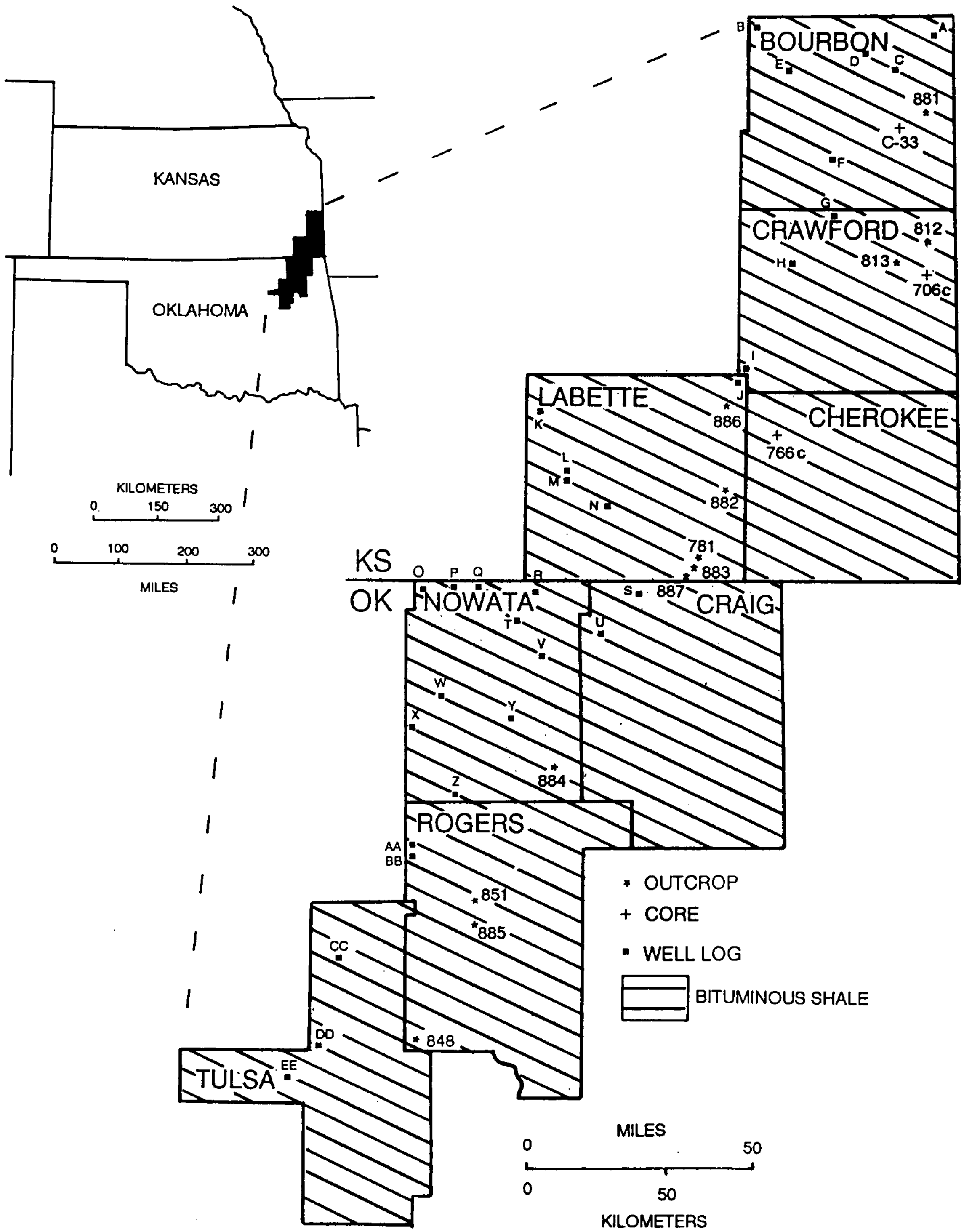

Figure 22. Inferred Lithofacies Map for the Maximum Transgression during PAC 1.

Wenger and Baker (1986) gave a more reasonable and appropriate depositional history for the Pennsylvanian bituminous shales with which I agree. Based on organic geochemical data from the Excello and Little Osage shales, they suggested (p. 85) that "Eustatic rise of sea level and rapid marine transgression over the continental craton, with consequent flooding of adjacent extensive brackish-marine (peat) swamps and the resultant influx of a large supply of nutrients and humic detritus, appear to be the key geologic control of black-shale deposition."

Maximum regression of PAC 1 (Figure 23) is characterized by relatively widespread shallow marine claystones and clay-shales. An isolated lagoonal or nearshore limestone occurs at one locality (882) in Kansas, and a bituminous shale reported to be the Excello by Bennison (pers. comm., 1990) occurs in southeastern Tulsa County. The limestone is a fossiliferous (mainly abraded and fragmented brachiopods, bryozoans, and crinoids) packstone (locality 882, western Labette County, Kansas).

During the maximum sea level stand of PAC 2 (Figure 24), normal open marine limestone was deposited everywhere throughout the study area except in Bourbon County, where nearshore or lagoonal limestones and claystones accumulated. Apparently, water depth remained relatively shallow in this area which would suggest that the Bourbon Arch was a topographic high during deposition of the Blackjack Creek

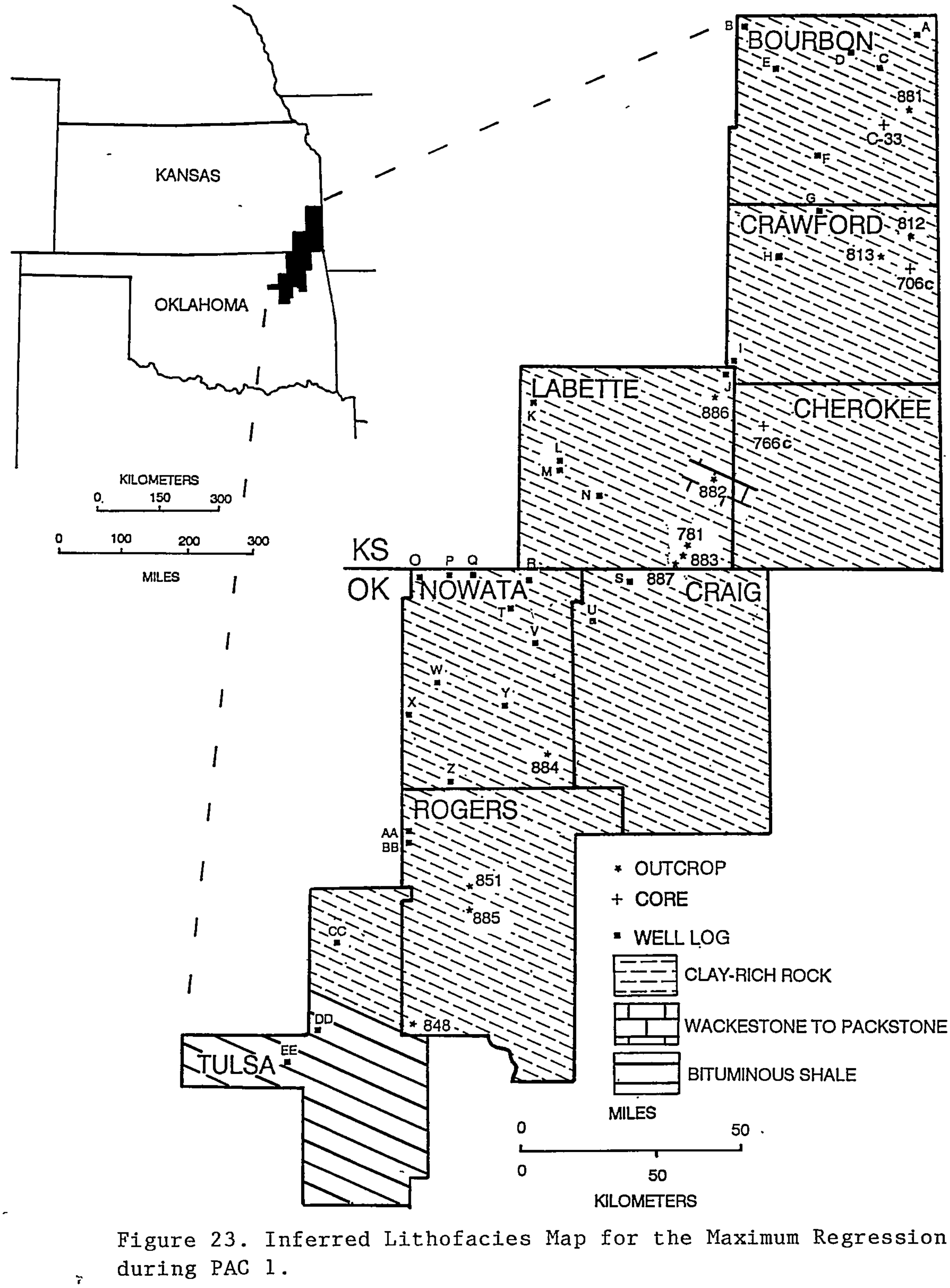

Figure 23. Inferred Lithofacies Map for the Maximum Regression during PAC 1.

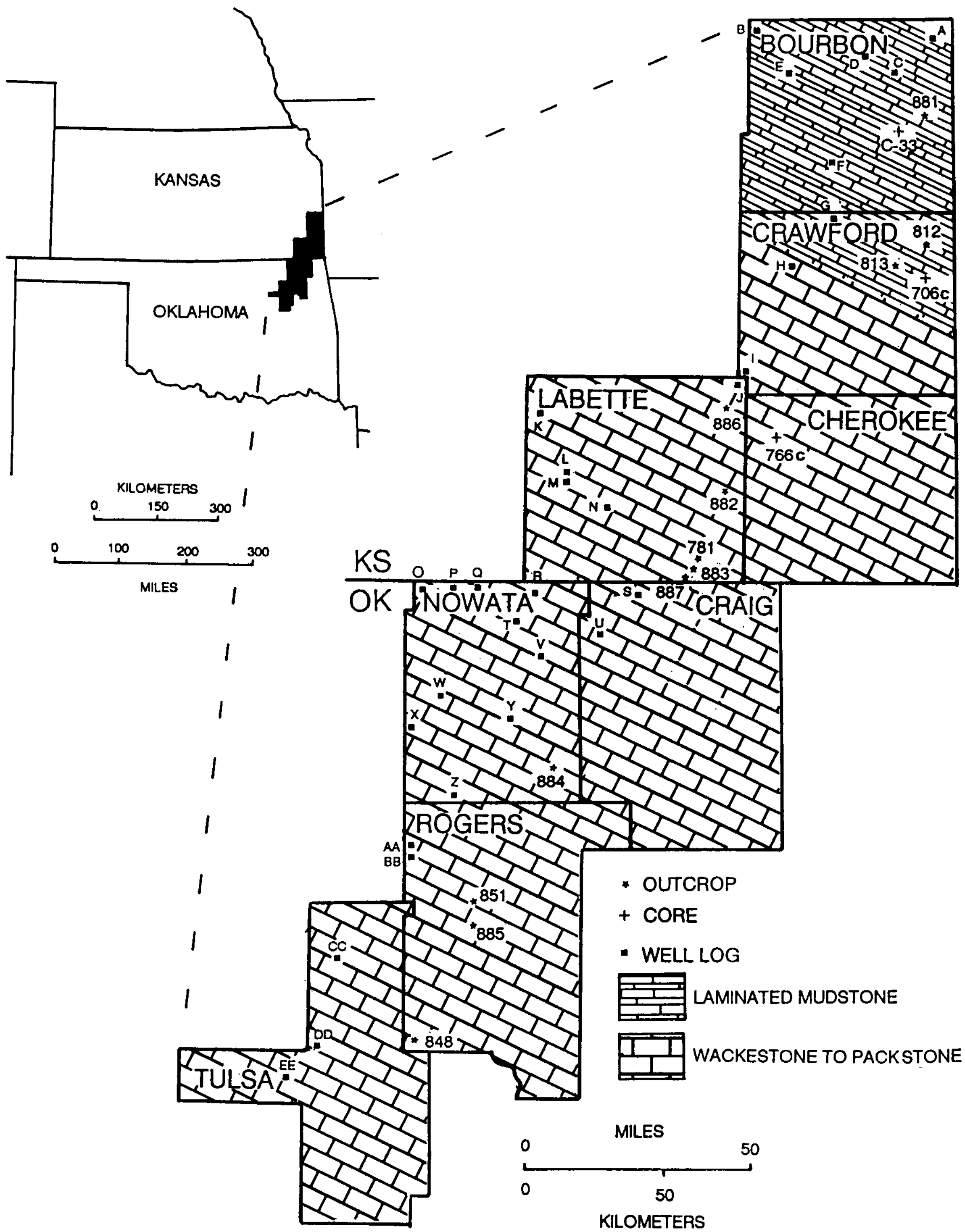

Figure 24. Inferred Lithofacies Map for the Maximum Transgression during PAC 2.

limestone. On the crest and flanks of the Bourbon Arch, the basal Blackjack Creek varies from a sparsely fossiliferous, peloid-rich wackestone (locality 881) and laminated, clay-rich mudstone (locality C-33) to a sparsely fossiliferous mudstone to wackestone (locality 812). Fossils are abraded fragments of brachiopods, bryozoans, and foraminiferids. South of locality 812, except for localities 886 and 766c, the laterally equivalent normal marine facies of PAC 2 varies from a sparsely fossiliferous, wackestone to packstone to a fossiliferous, peloid-rich wackestone to packstone. At localities 886 and 766c, the interval is represented by a sparsely fossiliferous, clay-rich mudstone. Fossils (mainly crinoids, phylloid algal blades, and bryozoans) are poorly preserved and diversity is low.

The maximum regression of PAC 2 (Figure 25) is dominated by normal marine limestone capped to the north by low-domical to laminar chaetetids interbedded with clay/shale partings and to the south by reworked limestones interbedded with clay/shale partings and chert concretions. The limestone is dominantly a peloid-rich, fossiliferous wackestone facies with normal marine fossils. However, the two northernmost localities (881 and C-33) near the crest of the Bourbon Arch appear to have been influenced by this feature. Claystone deposition occurred at locality 881, while deposition of a laminated, argillaceous, carbonate mudstone occurred at C-33.

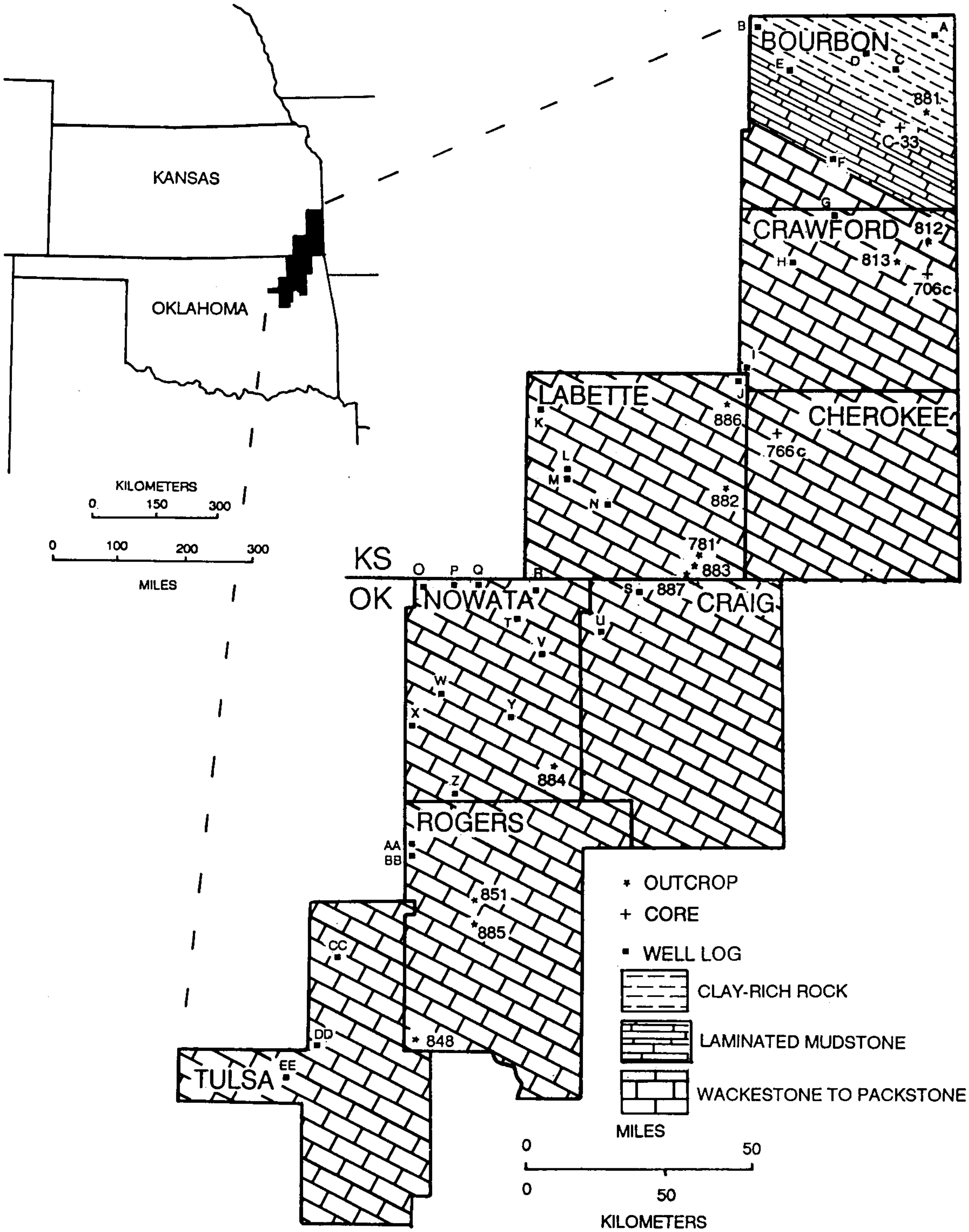

Figure 25. Inferred Lithofacies Map for the Maximum Regression during PAC 2.

Figure 26 illustrates the maximum transgression of sixth-order PAC 3. This interval is characterized as a highly fossiliferous wackestone to packstone facies with abundant fossiliferous clay/shale partings. PAC 3, which extends over the entire field area, records a rapid marine transgression, with a long period of limestone accumulation in open marine conditions.

The maximum regression for PAC 3 (Figure 27) is characterized by coal, marginal marine claystones (underclays) and a normal marine, chaetetid-bearing limestone. This is approximately equivalent to strata beneath Suchy and West's (in press) PAC 1. The limestone is best described as a peloid-rich, fossiliferous wackestone to packstone with isolated laminar chaetetids and, in places, poorly developed rhizocretions. An extremely shallow water nearshore or restricted environment is inferred from these data.

The last transgression discussed briefly in this study is PAC 4 which is the same as Suchy and West's (in press) PAC 1. Their interpretation of the Little Osage shale (and Summit coal) in PAC 1 is very similar to my interpretation of the Excello shale (and Mulky coal) in PAC 1. A rapid, shallow marine flooding (transgression) of the craton associated with a eustatic sea level rise and subsequent inundation of coastal peat swamps is a reasonable inference and has been suggested by Wenger and Baker (1986).

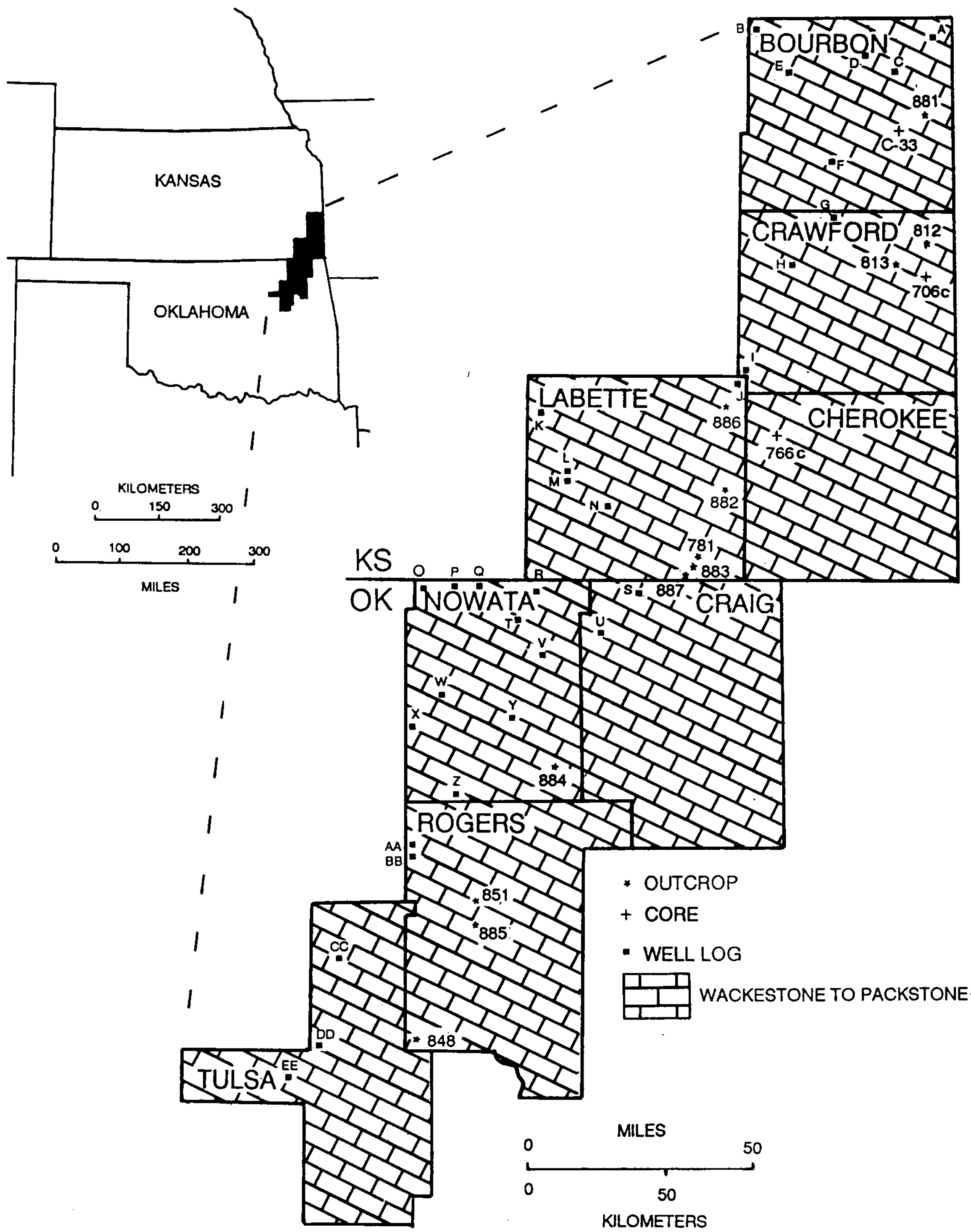

Figure 26. Inferred Lithofacies Map for the Maximum Transgression during PAC 3.

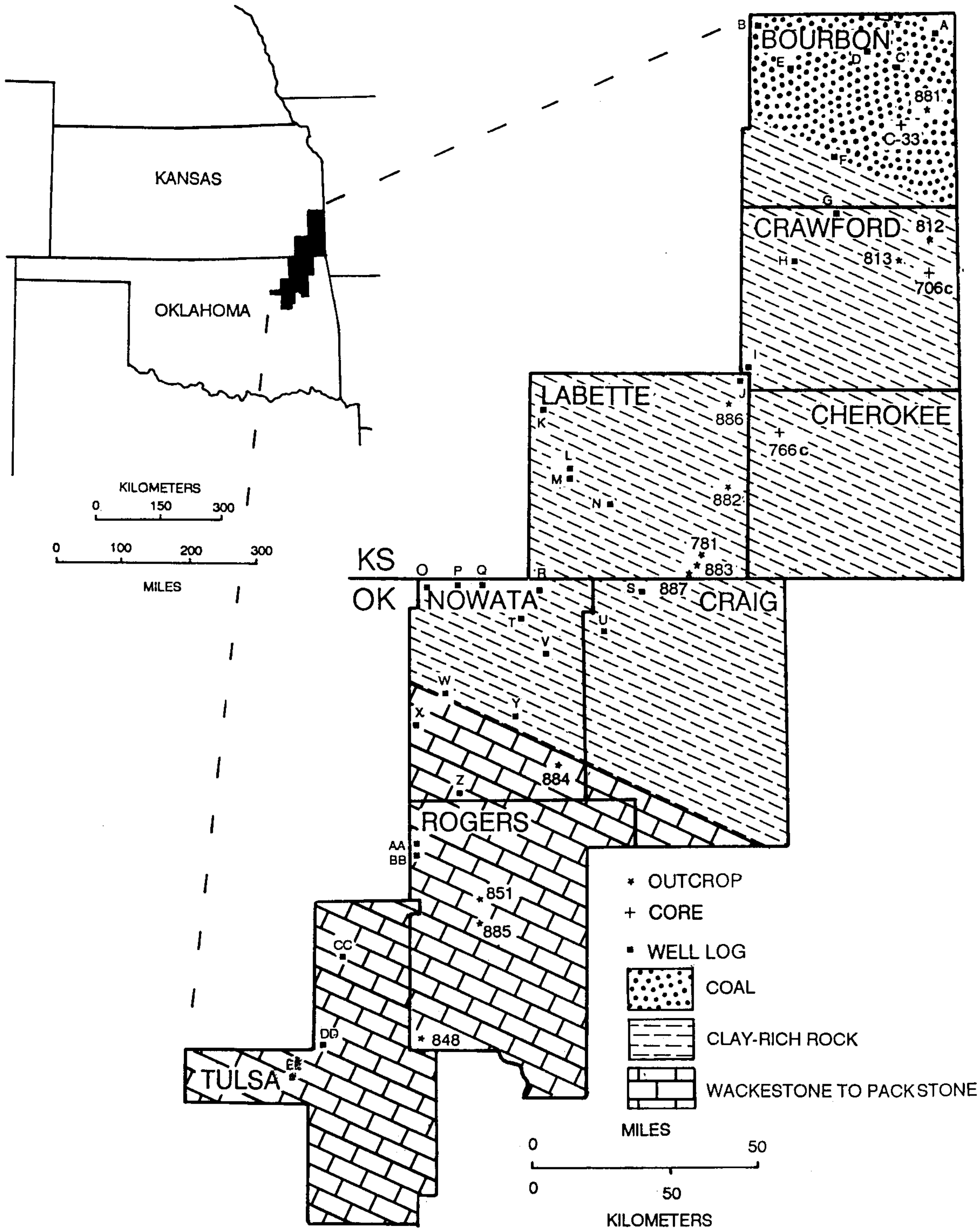

Figure 27. Inferred Lithofacies Map for the Maximum Regression during PAC 3.

CLIMATICALLY-CONTROLLED CYCLES EVIDENT IN MIDDLE PENNSYLVANIAN ROCKS OF KANSAS

In the previous section, the primary depositional control of the interval studied was assumed to be fluctuations in sea level. My interpretations in this section are based on fluctuations in climate with a static sea level.

Schutter and Heckel (1985) suggested that the abrupt decrease in laterally extensive coals (minable) from the lower Desmoinesian to the Missourian rocks of the Midcontinent were probably due to a subtle climate change. The Missourian climate "...became at least seasonally drier than the Desmoinesian climate." (Schutter and Heckel, 1985, p.111).

Phillips et al. (1985) proposed a general relative wetness curve for Pennsylvanian rocks of the United States based on stratigraphic patterns of identified bituminous coal resources and changes in coal-forming vegetation in the eastern United States (see Figure 8). Cecil (1990) developed a similar paleoclimate curve based on large scale (i.e. groups and formations) stratigraphic changes in "climate sensitive" rocks of the Appalachian basin. He suggested that Late Carboniferous rocks reflect the gradual progression (drift) of the United States through the

Pennsylvanian paleoequator. Early Pennsylvanian rocks formed in wet latitudes, and as drifting continued northward into dry latitudes, Late Pennsylvanian sediments were deposited.

As suggested by Schutter and Heckel (1985) and Scotese and McKerrow (1990), the North American continent moved north through the paleoequator in positions similar to those shown on Figure 28. Climatic regimes (zones) would affect different parts of the continent at different times. Given the paleolatitudinal reconstruction, the paleointertropical convergence zone (PICZ), a narrow band near the equator (see Figure 28) of trade wind convergence and persistently rising air (Gross, 1990), would have an impact on the Midcontinent prior to its influence on the Appalachian basin (Figure 29). Seasonally wet to always wet climates (i.e. coal forming conditions) would have affected the Midcontinent (Interior Coal Province) before reaching the Appalachian Coal Region. Consequently, the rock record should reflect these changing climates.

Based on the coal distributions in Kansas (Zeller, 1968) I have reinterpreted the relative wetness curve of Phillips et al. (1985) and have shown a slight offset of coal-dominated intervals in the Pennsylvanian (Figure 30). It is important to note that the curve of Phillips et al. (1985) is based on an average of the bituminous coal resources for the eastern half of the United States (Figure

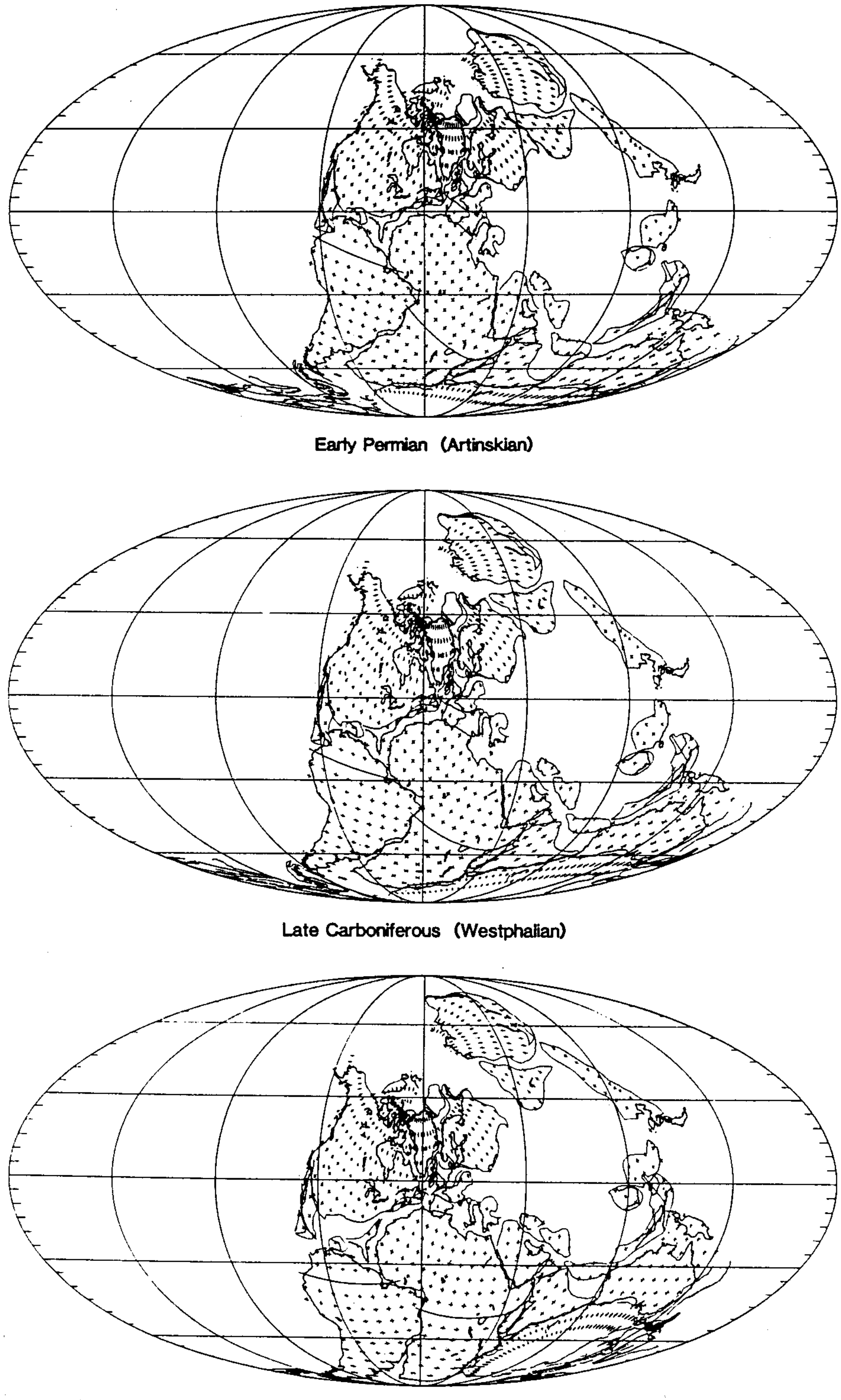

Figure 28. Schematic Diagram of Inferred Position of the North American Continent during the Carboniferous and Early Permian. Modified from Scotese and McKerrow (1990).

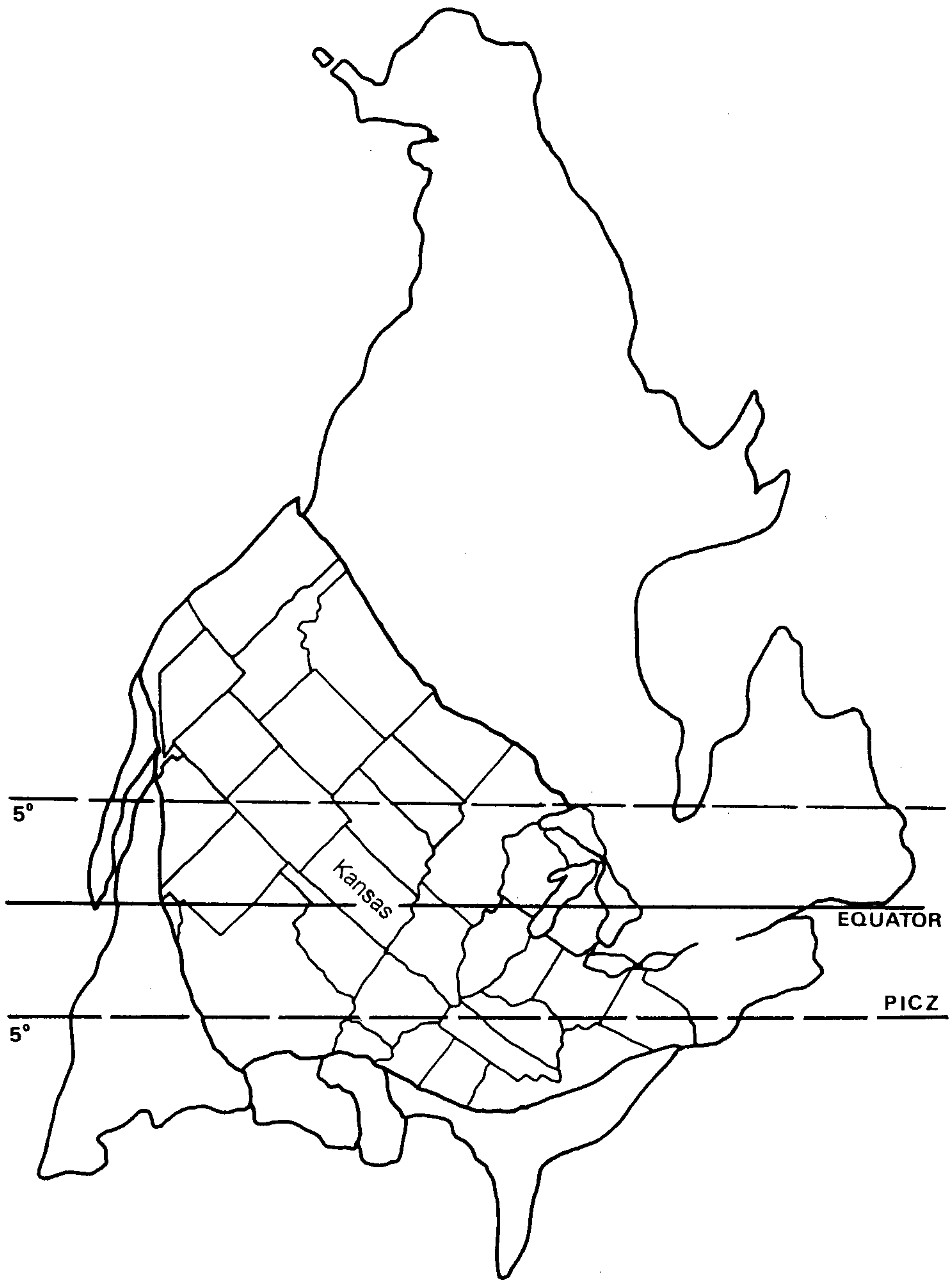

Figure 29. Location of the Equator and Paleointertropical Convergence Zone (PICZ) during the Middle Pennsylvanian. Modified from Scotese and McKerrow (1990).

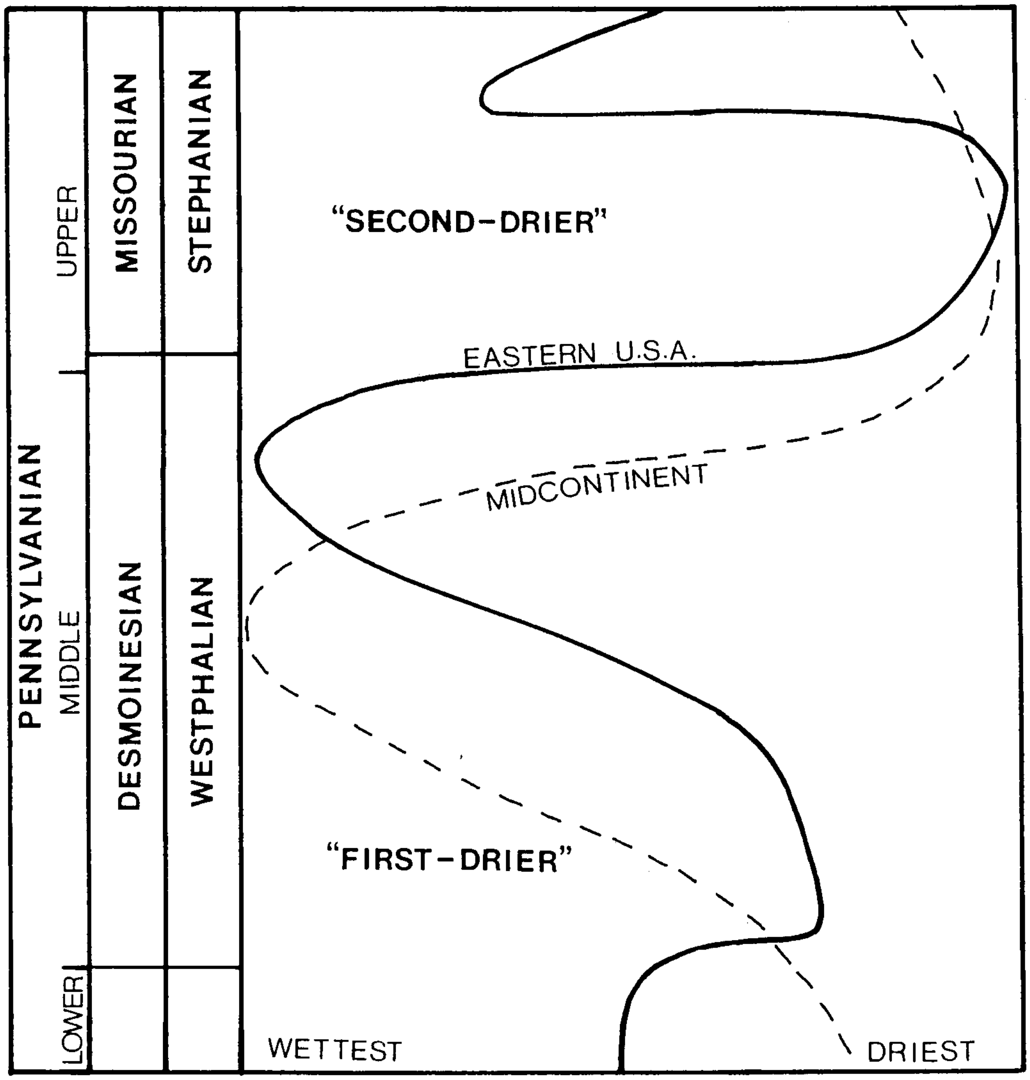

Figure 30. Relative Wetness Curve for the Midcontinent (this study) and Relative Wetness Curve for the Eastern United States. Modified from Phillips et al. (1985). The terms drier or driest are relative and are not meant to convey arid or semiarid conditions.

31). This includes coals from the Midcontinent, Illinois basin, and the Appalachian basin. The coal-dominated Cherokee Group (lower Desmoinesian) developed prior to the "equivalent" coal-dominated strata of the Illinois basin and Appalachian basin (Westphalian D). Also, using Cecil's (1990) climate-change model (see Figure 9), I constructed: 1) a generalized paleoclimate curve for the interval containing the Cherokee-Marmaton boundary (Figure 32), 2) a climate curve for my composite section (Figure 33), and 3) climate curves for each measured section and core (Plate 2).

These climate curves are based on subtle lithologic changes within my study interval. The wettest interval is represented by the coals and the driest represented by the limestones, particularly the rooted(?), calcrete-like horizon at the top of the Blackjack Creek limestone. The siliciclastics (i.e. the claystones, clay-shales, and bituminous shales) depict seasonally-wet climates.

Although climate changes appear more sensitive and document more subtle changes within some PACs (see Figure 33), the climate-change curves developed in this section, generally correspond to my suggested relative water depth curves of the previous section. The coals formed during wet periods and the limestones formed generally during the driest climate.

In some cases, the evidence suggests that eustatic sea level fluctuations (i.e. transgression-regression) are more

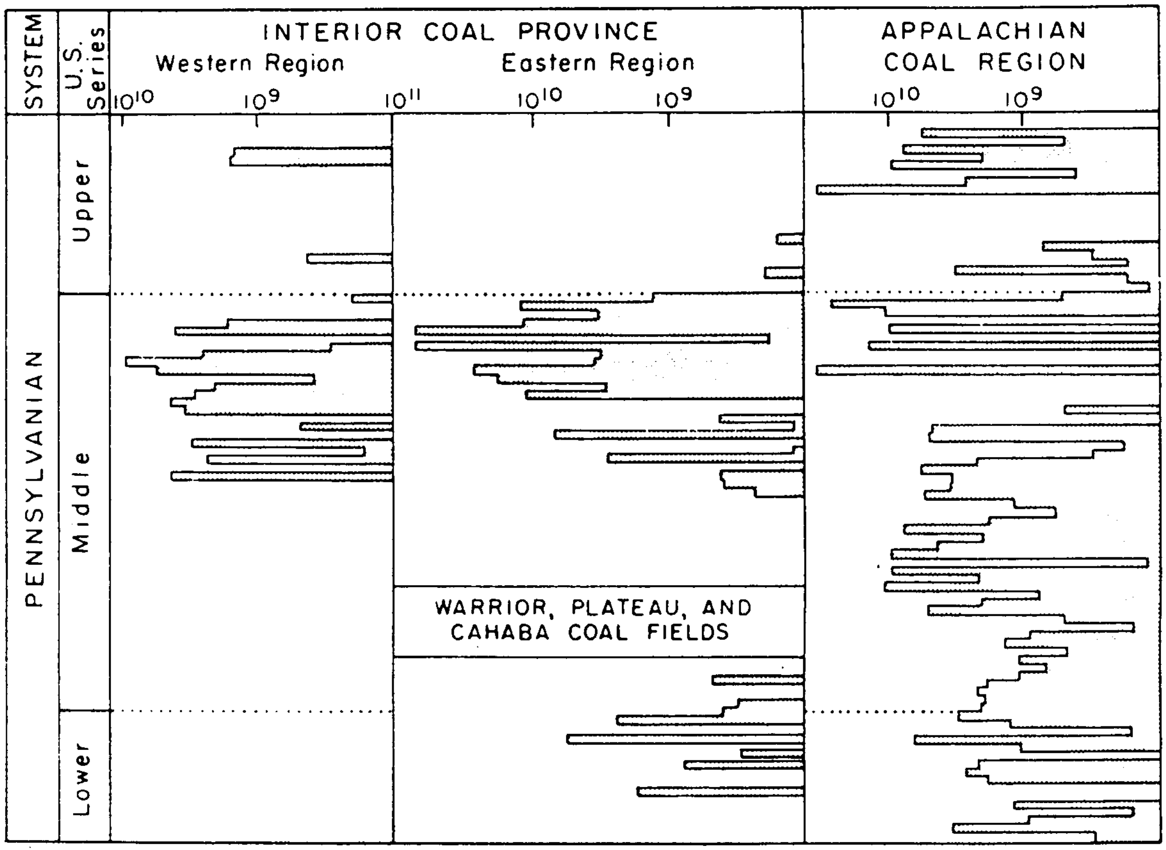

Figure 31. Bituminous Coal Resources for the Pennsylvanian across the Eastern Half of the United States. From Phillips et al. (1985).

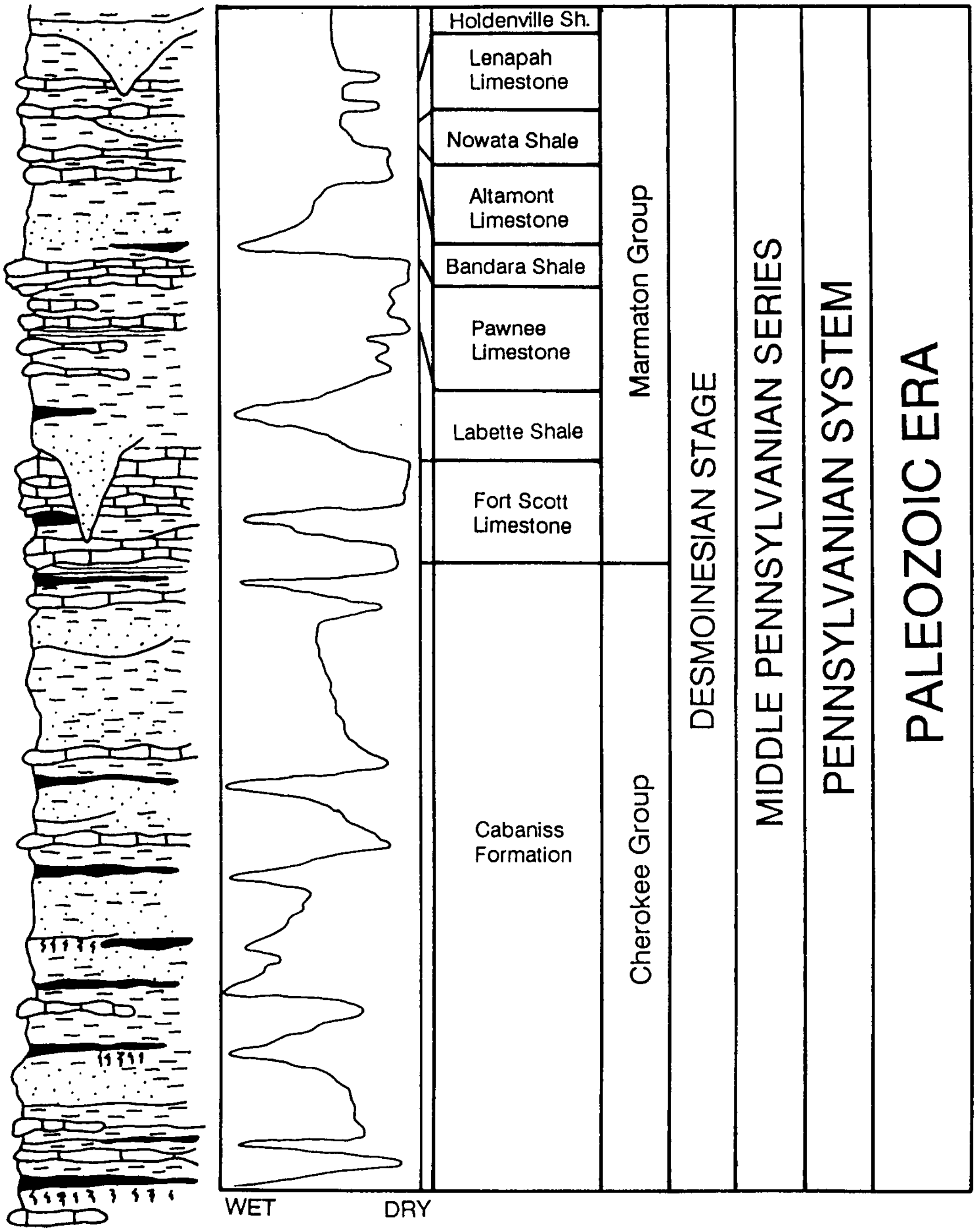

Figure 32. Climate Change Curve for the Cherokee-Marmaton Interval in Zeller (1968) based on Cecil's (1990) Climate-Change model.

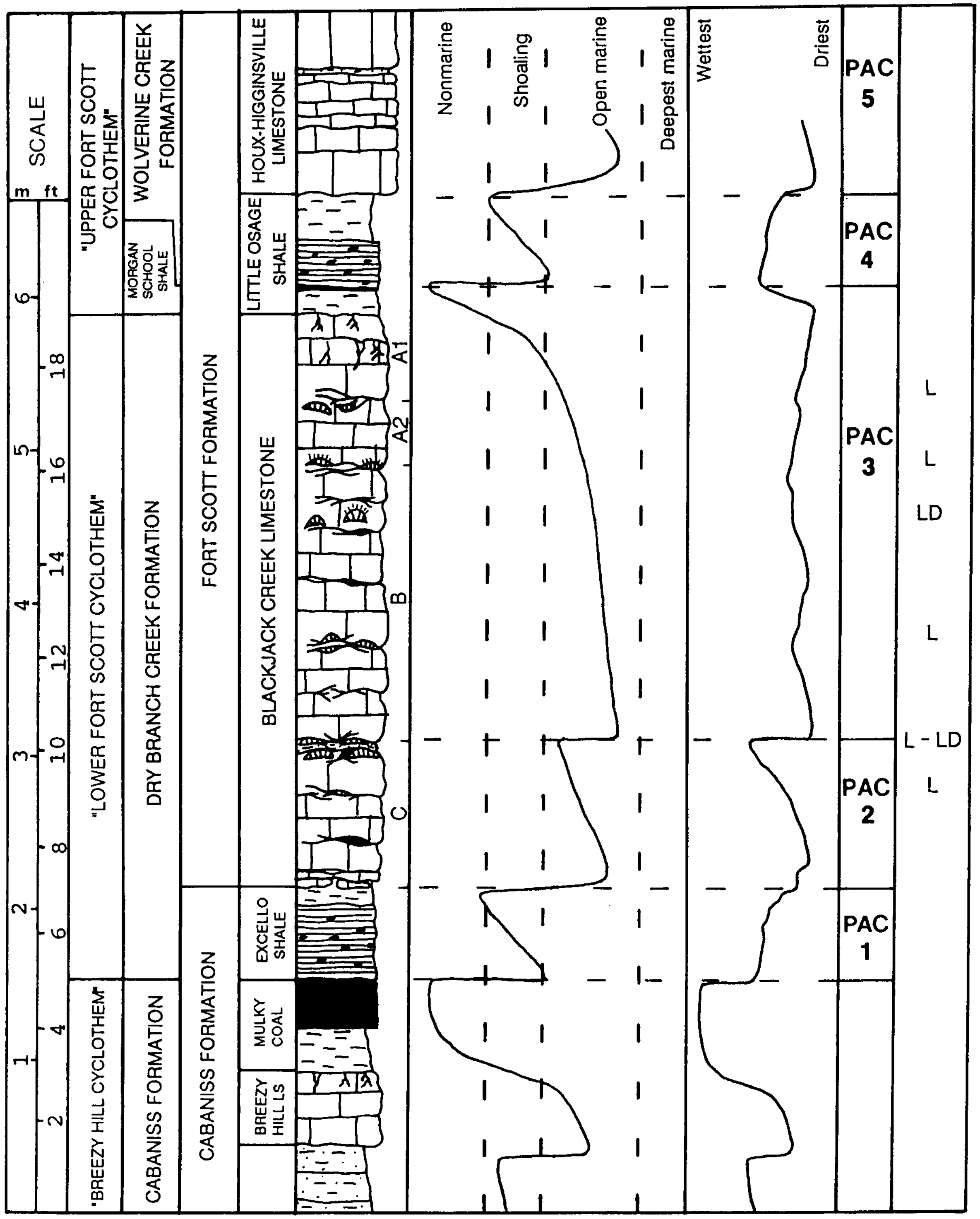

Figure 33. Composite Section with Relative Water Depth Curve and Climate Curve, based on Cecil's (1990) Climate-Change model. The last column on the right represents chaetetid growth form: L-laminar, LD-low-domical.

reasonable. For instance, a rooted calcrete in the upper Blackjack Creek limestone (A1 zone) suggests extremely shallow water and/or subaerial exposure caused by a regression (i.e. eustatic lowering of sea level). However, in places where bituminous shales overlie coals (Little Osage shale/Summit coal, Excello shale/Mulky coal), a climatic change appears to be a more reasonable explanation. As figure 33 shows, coals are the result of extremely wet climates, and the siliciclastics (i.e. shales) are the result of seasonally wet climates.

It is most reasonable to expect both climate and sea level changes (along with tectonics and sediment supply) to have played a role in the formation of the interval studied.

CHAETETIDS

PALEOECOLOGICAL ASPECTS

One objective of this project was to examine the relationship between chaetetid morphology and their occurrence and distribution in the Blackjack Creek limestone and to demonstrate their association, if any, to small scale genetic stratigraphy.

Chaetetids within the Blackjack Creek limestone are laminar to low-domical (with the height of the organism never exceeding the width, Figure 11), and often completely silicified with chert filling small fractures. From north to south, within the study area, chaetetids occur at all localities (Figure 34) except localities 881 and C-33. Although chaetetids do not occur in the Blackjack Creek limestone localities 881 and C-33, chaetetids have been found farther northeast (i.e. northwest Missouri) in the Blackjack Creek (Jeffries, 1958) and in the Houx-Higginsville limestone interval at locality C-33. Low-domical growth forms are restricted to the northern sections and cores of Kansas (see Figure 34). South of locality 886, all chaetetids are laminar.

Laminar chaetetids, sometimes overturned, are found throughout the Blackjack Creek limestone, but occur most commonly within clay/shale partings, associated with limestone clasts and rubble, chert concretions, and clay- to

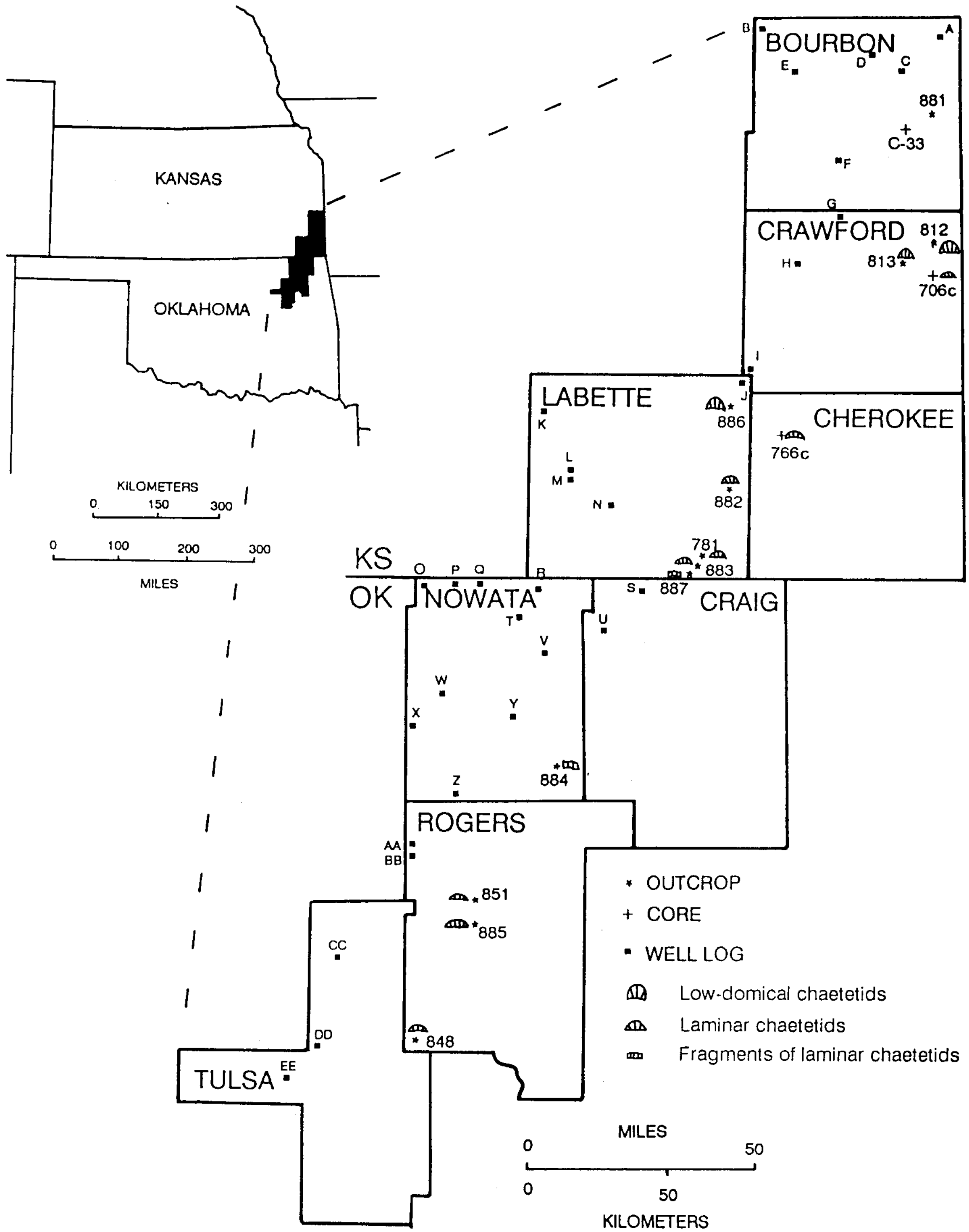

Figure 34. Chaetetid Occurrence and Distribution Relative to Growth Form.

sand-size quartz grains. These partings, which are sometimes fossiliferous and/or microstyolitic, either drape over the chaetetids, contain chaetetid fragments, or sometimes create the substrate for subsequent chaetetid growth. Also, laminar chaetetids occur with low-domical forms in the laterally traceable chaetetid mounds in the northern localities.

Low-domical chaetetids form either isolated mounds in the upper part of the Blackjack Creek limestone (B zone) or laterally traceable mounds (intergrown heads) in the lower-middle to lower part (C zone) of the Blackjack Creek. These mounds are confined to the northern region of the study area (localities 812, 813, 706c, 886, and 766c). The isolated chaetetids, although sometimes enclosed in clay/shale partings, are frequently encrusted by Neosyringopora colonies.

PALEOECOLOGICAL ASPECTS RELATIVE TO SMALL-SCALE GENETIC UNITS

Although chaetetids occur throughout the Blackjack Creek limestone, the distribution and morphology differ with respect to their positions within small-scale genetic units (i.e. PAC 2 and PAC 3; no chaetetids were found in PAC 1). Recall that Suchy (1987) reported that chaetetid-rich intervals of the Houx-Higginsville limestone represent the regressive part (i.e. shallowing) of a PAC (see Figure 12).

PAC 2

Laminar and low-domical chaetetids most commonly occur in the upper part or regressive (drying) phase of PAC 2. However, very sparse, overturned laminar chaetetid fragments occur near the lower boundary where the Blackjack Creek overlies a claystone. In the northern sections and core (except 881 and C-33), the regressive (drying) part of PAC 2 contains laterally traceable (100km; 62mi), laminar to low-domical chaetetids capping a peloid-rich, fossiliferous wackestone to packstone facies.

After the transgressive (or climate change) phase of PAC 2, shallowing (drying) began/continued. At this time, limestone deposition was influenced by the Bourbon Arch and the Cherokee Platform to the south. Directly over the crest of the arch (localities 881 and C-33), where very shallow, turbid water (too turbid for normal marine limestone deposition) prevailed, no chaetetids developed. Along the southern flank of the arch, laminar to low-domical chaetetids formed in shallow, slightly less turbid water. Still farther south (i.e. south of locality 882), deeper or cleaner water (relative to the north) produced algal-rich limestones free of detrital debris. It appears that where algal-rich environments dominated, chaetetids are absent.

PAC 3

The upper chaetetid-rich interval of PAC 2 was transgressed by PAC 3 destroying conditions necessary for continued chaetetid growth. Along the base of PAC 3, small, overturned laminar fragments occur, which could possibly be remnants of the underlying chaetetid horizon, ripped up by the transgression/flooding. During the regressive (drying) phase, "optimum" conditions for chaetetid growth were again present in the northern region. Abundant isolated, laminar to low-domical chaetetids occurred throughout the middle to upper Blackjack Creek limestone. Such optimum conditions are defined by Connolly et al. (1989, p.159), to be "...in the shallowest but subtidal water, ...adequate water energy."

I suggest that, overall, the relative water depth during PAC 3 was greater than that of PAC 2. Relatively deeper water existed over the Bourbon Arch as well as across the southern part of the field area. Recall that chaetetids were not identified at localities 881 and C-33 although normal marine limestones formed. On the southern flank of the arch, algal-rich environments dominated with chaetetids restricted to isolated laminar forms interbedded with clay/shale partings (i.e. when turbidity was greater).

Sea level continued to drop (or climate became drier) as a rooted(?), calcrete-like horizon developed at the top of the Blackjack Creek limestone (except at localities 851, 885, and 848). At these southernmost localities, shallow, turbid, marine water prevailed and thin encrusting chaetetids developed.

Laminar chaetetids are inferred to have flourished in a more turbid, shallow, marine environment with slightly higher water energy (i.e. higher than that for low-domical to columnar forms). The suspended (detrital) sediment inhibited the formation of both low-domical (and columnar) chaetetid forms and algal-rich limestones. Furthermore, low-domical chaetetids formed in slightly more turbid marine water relative to the algal-rich limestones, which are inferred to have formed in cleaner, deeper, normal marine water (e.g. in the southern part of the field area). This is reflected in the insoluble residues, which suggest that greater amounts of clastic debris are typically associated with thin, laminar chaetetids. Lower insoluble percentages occur with low-domical forms, and still lower values are associated with algal-rich limestones.

SECONDARY OIL TARGETS

Randolph (1974) reported that chaetetid build-ups in the Lower Strawn Formation (Desmoinesian) of Texas are associated with the flanks of paleotopographic highs and have, in the past, produced oil.

Two cores of the Blackjack Creek taken along the flanks of the Bourbon Arch contain chaetetids, and in one instance, hydrocarbon stains were observed (Appendix B, locality 706c, bed 3a).

Unlike other chaetetid-rich limestones of the Marmaton Group, where domical to columnar buildups are common (i.e. the Amoret Limestone Member and the Houx-Higginsville

Limestone Member), the Blackjack Creek limestone contains only laminar to low-domical chaetetids where they form, in most cases, small, isolated colonies rather than significant bioherms. However, if domical to columnar chaetetid buildups occur down dip to the west, I would expect them to be associated with the flanks of paleotopographic highs in the regressive parts of Punctuated Aggradational Cycles (PACs). Such occurrences would be distinguishable targets for hydrocarbon exploration.

STRUCTURAL CONTROLS
ON DEPOSITION

Lithologic changes depicted on the lithofacies maps and changes in unit thickness can be used to infer temporal changes in paleotopography.

There were two main structural elements or regions active during deposition of the interval studied; the Bourbon Arch, and the Cherokee Platform (Northeast Oklahoma Platform) (see Figure 13). Price (1984), based on studies of the Pawnee Limestone in northeast Oklahoma, suggested that the "Shelf Edge Rise" was also structurally active during the Desmoinesian. However, Krumme (1981), in a study of the Marmaton Group, reported that the Northeast Oklahoma Platform extended south, beyond my field area, into central Oklahoma (Okfuskee County) (Figure 35).

Based on isopach maps (Figures 36, 37, and 38) of the PACs identified (i.e. PAC 1, PAC 2, and PAC 3), it is apparent that both the Bourbon Arch and the Cherokee Platform influenced deposition during these intervals.

The Bourbon Arch, a structural high during the Desmoinesian Stage, trends northwest-southeast across the northern edge of the study area (see Figure 13). All three PACs thin dramatically as they onlap onto the Bourbon Arch; PAC 1 (75cm; 30in), PAC 2 (8cm; 3in), PAC 3 (227cm; 89in) (see Figures 36, 37, and 38). Other studies (Jeffries,

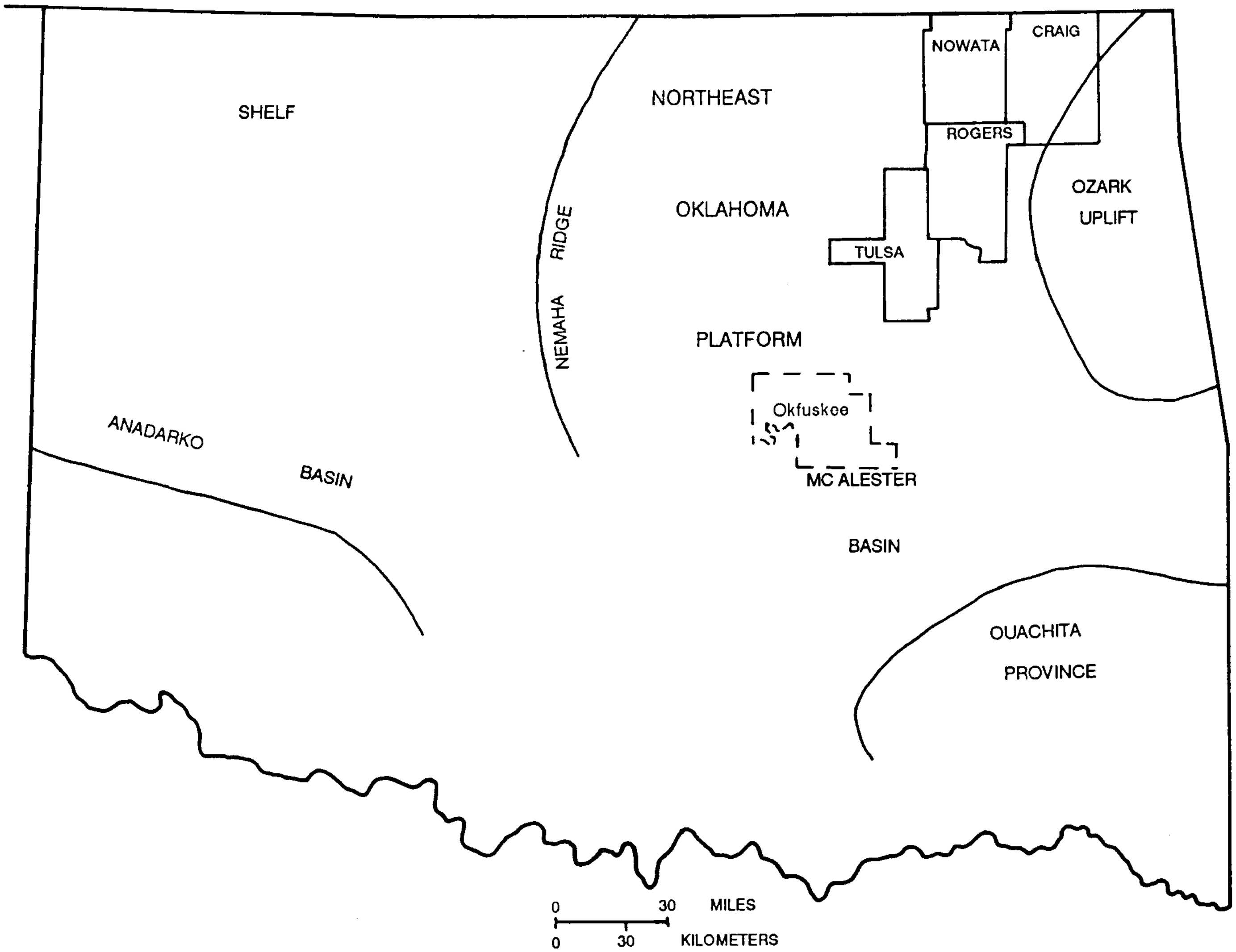

Figure 35. Location of the Northeast Oklahoma Platform as reported by Krumme (1981). Modified from Krumme (1981).

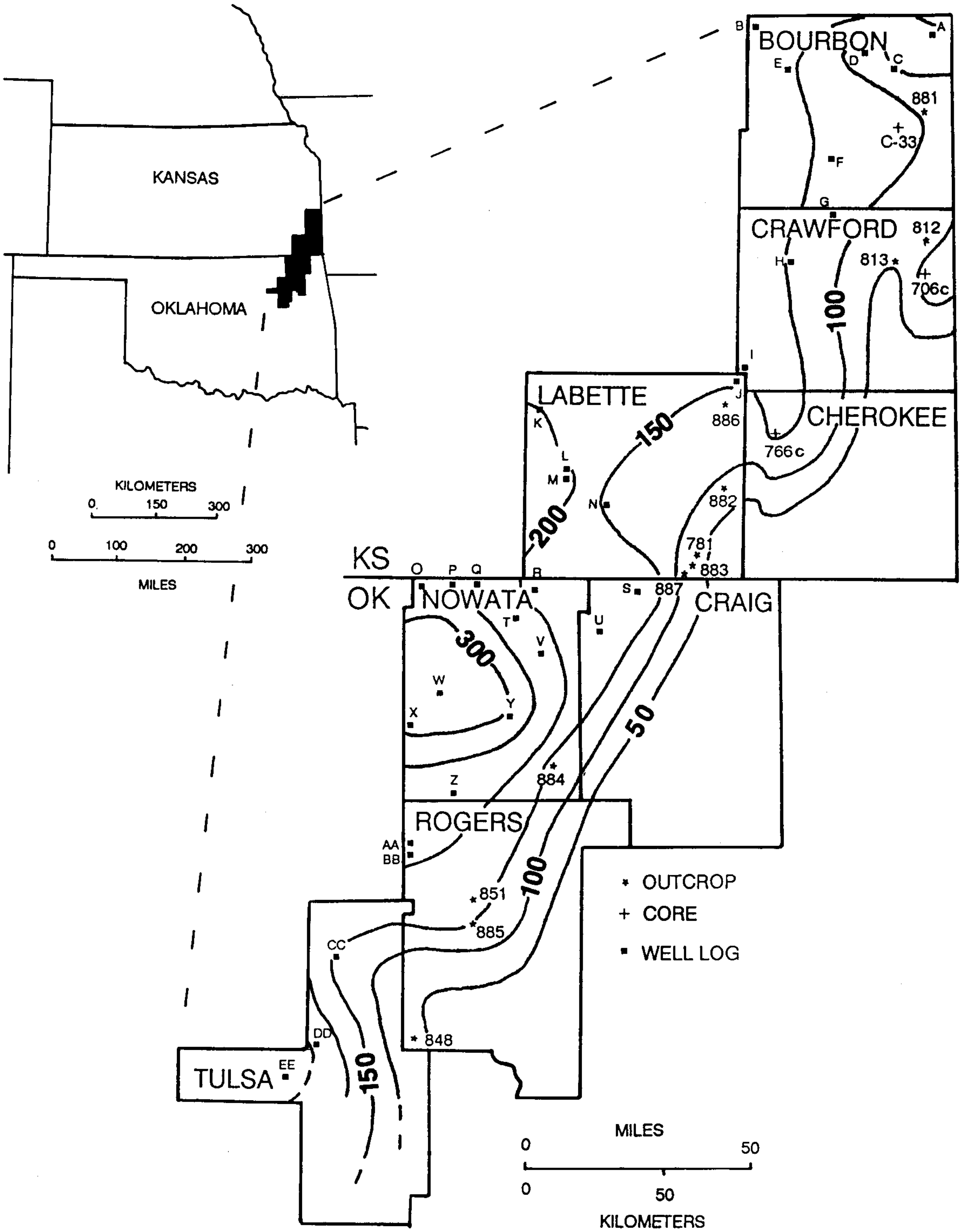

Figure 36. Isopach Map of PAC 1. Contour Interval=50cm.

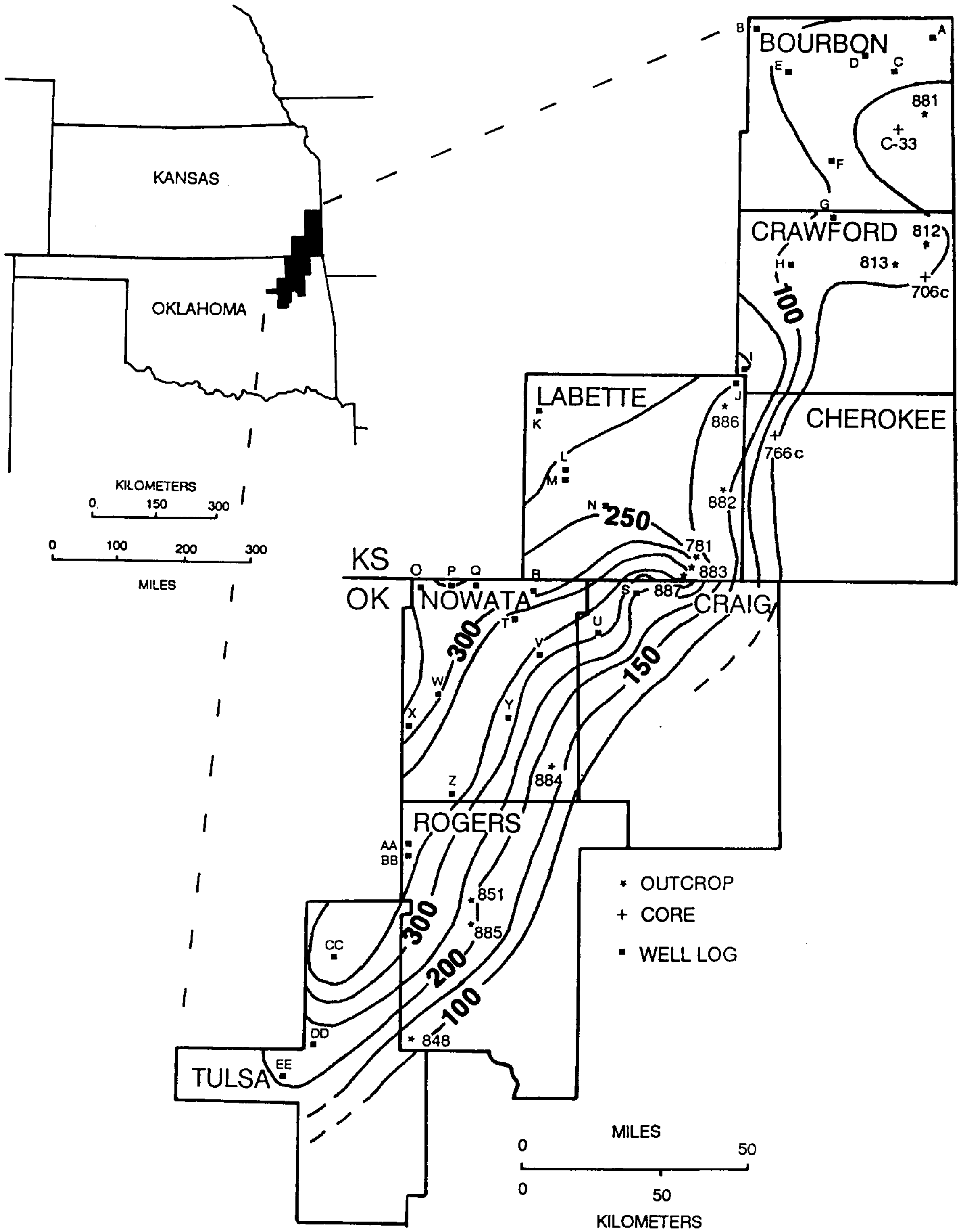

Figure 37. Isopach Map of PAC 2. Contour Interval=50cm.

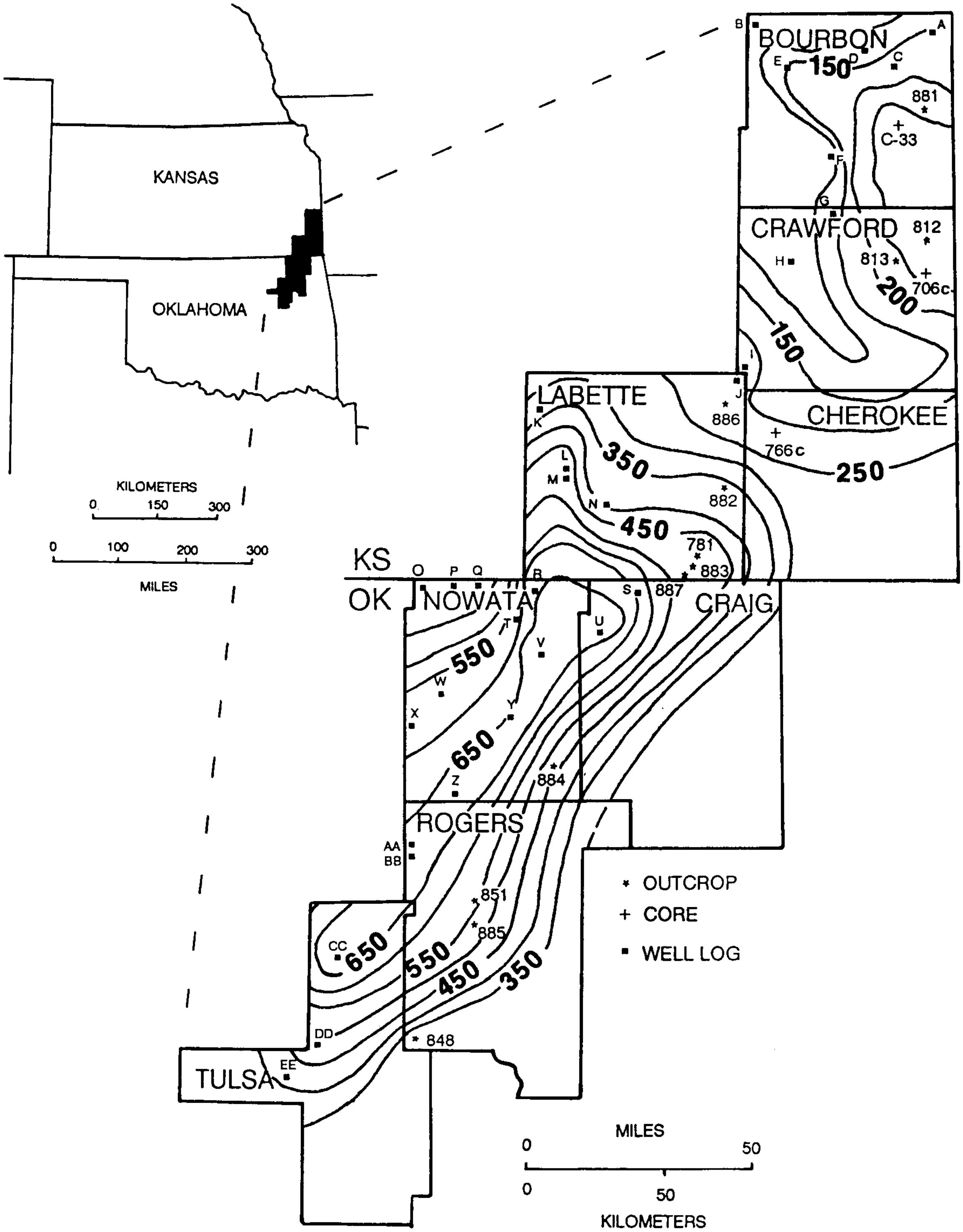

Figure 38. Isopach Map of PAC 3. Contour Interval=50cm.

1958; Neal, 1969; Knight, 1985) demonstrated that the Blackjack Creek increases in thickness again, north of the arch, in Missouri and Iowa.

The Cherokee and Northeast Oklahoma Platforms, considered structural lows (intermediate), are contiguous elements that developed as a result of a mild downwarp of the Chautauqua Arch prior to the deposition of Desmoinesian sediments. South of the Bourbon Arch, sediments accumulated on this broad, gentle-dipping "depositional platform". Across southern Crawford, Cherokee, and Labette Counties, the PACs exhibit a very gradual increase in thickness from north to south (see Figures 36, 37, 38).

Along the Kansas-Oklahoma border, slightly more abrupt increases occur with some units continuing to increase in thickness across Craig, Nowata, and Rogers counties. PAC 1 reaches a maximum thickness of 305cm (120in) (well log data point W) in central Nowata County (see Figure 36) with subsequent thinning south of Nowata County. PAC 2 (see Figure 37) increases from 155cm (61in) at locality 882 to 351cm (138in) at locality 887 along the Kansas-Oklahoma border. The thickness of PAC 2 increases into northern Tulsa County along a distinct northeast-southwest trend (see Figure 37). PAC 3, generally the thickest interval, increases from 353cm (139in) at locality 882 and 492cm (194in) at locality 883 to 610cm (240in) south of the border (well log data point S) (see Figure 38). PAC 3 also follows a northeast-southwest trend with a maximum thickness of 695cm (274in) in northern Tulsa County (well log data point CC) (see Figure 38).

All three PACs also exhibit a thickening from the southeast to the northwest across Craig and Nowata counties (see Figures 36, 37, 38). There is a six-fold increase in thickness, from approximately 50cm to 350cm, in PAC 1, which is essentially a siliciclastic unit (see Figure 36). PAC 3, a carbonate-rich unit exhibits the least relative change in thickness, from approximately 350cm to 650cm (see Figure 38). Since the majority of the data across Craig and Nowata counties is from wireline logs, further evaluation of these subsurface PACs and additional subsurface information (cores and wireline logs), west of the study area in Kansas and Oklahoma, will help evaluate this conspicuous trend.

CONCLUSIONS

1. The Blackjack Creek Limestone Member of the Fort Scott Formation is a laterally continuous marine unit, composed of four vertically differentiated zones, which extend across the Desmoinesian outcrop belt. Using Dunham's (1962) carbonate classification scheme, the Blackjack Creek limestone is best described as a fossiliferous wackestone to packstone.

2. The "lower Fort Scott cyclothem" (Knight, 1985), approximately equivalent to a fifth-order T-R unit of Busch and Rollins (1984) or a Cyclothemic PAC Sequence of Anderson and Goodwin (1980), is composed of three smaller-scale (sixth-order) PACs. PAC 3 represents the greatest marine transgression, or driest climate, within the study interval, followed by a period of stasis, shallowing, or wetter climate. Future work should be directed toward helping differentiate between climate and eustatic effects and aid in refining the genetic stratigraphy.

3. Laminar chaetetids are inferred to have flourished in a turbid, shallow, marine environment with moderately high water energy. Low-domical chaetetids formed in slightly less turbid, possibly deeper, marine water with slightly less energy (relative to laminar forms). Algal-

rich limestones are suggested to have formed in the cleanest marine water, and possibly deeper than that of the low-domical chaetetids. Comparison of insoluble residues within and between occurrences of different chaetetid growth forms will aid in evaluating this interpretation.

4. In the study area, laminar and low-domical chaetetids primarily occur within the regressive (drying) parts of PACs in the Blackjack Creek limestone. If these chaetetids were to occur as domical to columnar forms down dip (in the subsurface), and be associated with the flanks of paleotopographic highs, such occurrences could become distinguishable targets for hydrocarbon exploration. Examination of cores, cuttings, and wireline logs, west (down-dip) of the study area, should suggest such targets.

5. Large-scale climate changes (Cecil, 1990) can be recognized and should be considered a major factor in understanding and interpreting the Pennsylvanian stratigraphy of the Midcontinent. As Cecil (1990) demonstrated for the eastern United States, climate-change could have created the dominant lithologies of the Midcontinent. For example, a change from coal-dominated strata of the lower Desmoinesian Stage to limestone-dominated in the Missourian Stage could have resulted in a shift from a relatively wet climate to a drier climate.

6. Desmoinesian (Pennsylvanian) bituminous "black" shales should not be used as a deep water indicator. Conversely, in this study, the Excello and Little Osage shales are recognized as shallow, marginal marine deposits, probably deposited during the inundation of peat swamps.

7. Inferred lithofacies and isopach maps illustrate the development of the "lower Fort Scott cyclothem", and in turn, help visualize two dimensional relationships between adjacent paleoenvironments. During deposition of the Blackjack Creek limestone, the only apparent topographic high, across the study area, was the Bourbon Arch. All units studied thin or pinch out, from south to north. The rest of the field area was part of the Cherokee (Northeast Oklahoma) Platform where the interval studied thickens from north to south across the Kansas-Oklahoma border, and from southeast to northwest across Craig and Nowata counties.

8. While small-scale genetic units (PACs) are recognized, the causes of such units are still unclear. Some are best explained in terms of sea level changes while others seem better explained in terms of climate changes. For Midcontinent cycles, a single cause is unrealistic, rather a combination of relative water depth, climate-change, tectonics, and sediment supply all had an impact on their formation.

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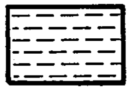
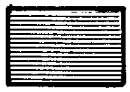
APPENDIX A

Stratigraphic Sections of Localities Used in Regional Study

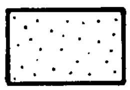
Lithologic Symbols

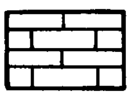
 Claystone, laminated in places

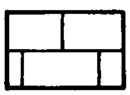
 Clay-shale

 Bituminous shale

 Coal

 Siltstone

 Mudstone, in places laminated

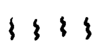
 Wackestone to packstone

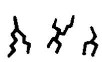
Contact

 Clay/shale partings, some microstyolized

 Root(?) traces and rhizocretions

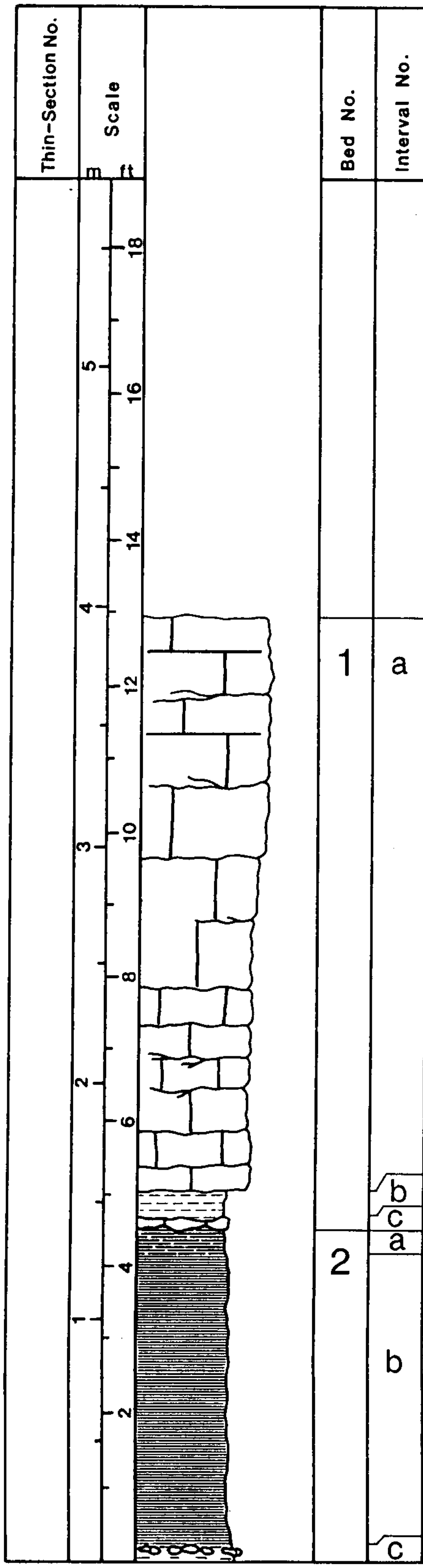
 Chert concretions and bands

 Burrows

 Fractures

 Limestone clasts (rubble), shale fragments

 *Chaetetes*, in places with *Neosyringopora*



Locality Description: Strat. Sec. 881,
S. side of railroad, at N. edge of old Ft. Scott property,
west of U.S. Hwy. 69 overpass.

Location: NE1/4, NW1/4, Sec. 30, T.25S., R.25E.,
Bourbon Co., Kansas.

Measured By: S. Roth 1989

Remarks: Same as Suchy's (1987) FST

Description

Bed No.

Fort Scott Formation

Houx-Higginsville Limestone Member

1 a Fossiliferous (algal) wackestone to packstone (243cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); thickly bedded; phylloid algal blades dominate and increase in abundance upward; Composita (articulated and shell fragments), crinoid debris, horn corals; beds have sharp, wavy contacts produced by numerous fossiliferous (brachiopod and crinoid fragments) clay/shale partings with abundant clay- to coarse sand-size grains; lower contact sharp.

b Claystone (10cm); medium gray (N5) to dark gray (N3); flaky to slightly fissile and laminated; slightly calcareous; sharp contacts.

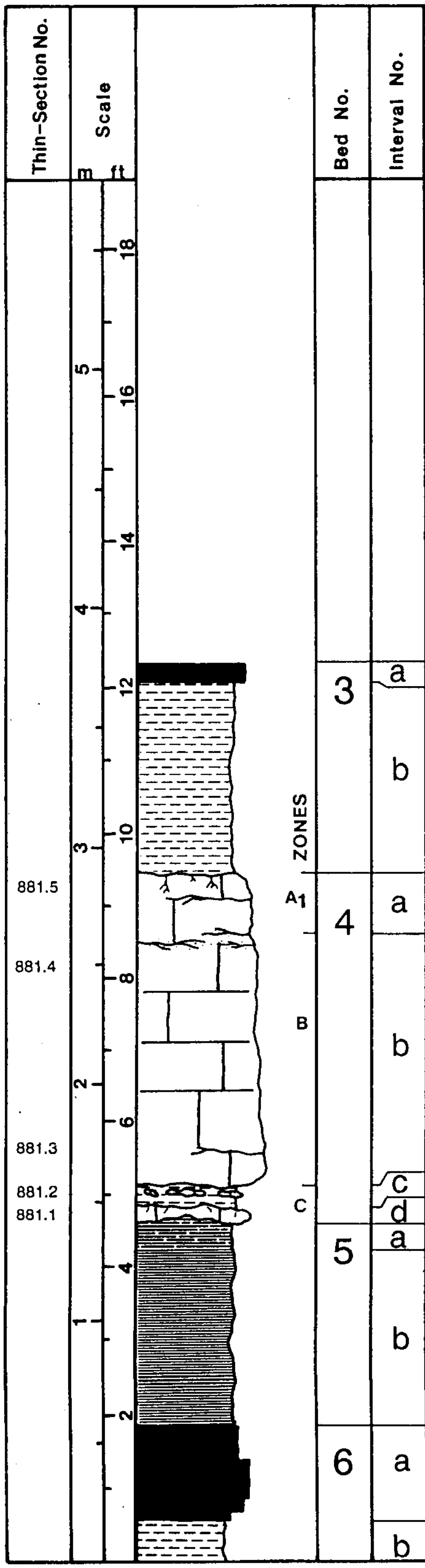
c Fossiliferous wackestone (6-12cm); pale yellowish orange (10YR 8/6); thin, lenticular bed; brachiopod shell fragments, crinoid fragments, phylloid algal blades; contacts undulatory, sharp.

Little Osage Shale Member

2 a Clay-shale (10cm); dark gray (N3) to grayish black (N2); calcareous; flaky, platy to blocky; silt content low, varies throughout; upper contact sharp, lower contact gradational.

b Bituminous shale (121.5cm); black (N1), weathers dark reddish brown (10R 3/4); fissile, phosphatic; phosphate nodules concentrated in upper middle part of unit; mottled (bioturbated); Dunbarella fragments and conodonts; gradational contacts (very clay-rich).

c Claystone (7cm); light gray (N7) to medium gray (N5), weathers pale yellowish orange (10YR 8/6); blocky to platy, flaky; gradational upper contact, sharp lower contact; fossiliferous packstone rubble with brachiopod shell fragments (some pyritized) occurs near top of interval; plant fragments(?).



Locality Description: Strat. Sec. 881

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

3 a Coal (8cm); black (N1), weathers dark yellowish orange (10YR 6/6); blocky to platy; dark yellowish orange plant fragments, and shell fragments(?); sharp contacts.

b Claystone (80cm); light gray (N7) to light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6); plant fragments, root traces, and burrows(?) throughout; sharp upper contact, gradational lower contact; basal 10cm shows faint, pale yellowish orange clay laminae.

Blackjack Creek Limestone Member

4 a Fossiliferous, rooted(?), peloid-rich wackestone to packstone (31cm); light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6); massive (weathered); mottled; fractured; Linoproductus (articulated and shell fragments), productid spines, crinoid fragments, ramose bryozoan fragments, fusulinids; rhizocretions throughout, concentrated in uppermost part of unit; sharp contacts with wavy clay/shale partings containing unconsolidated clay- and silt-size grains.

b Fossiliferous, peloid-rich wackestone (101cm); light gray (N7) to pale yellowish brown (10YR 6/2), weathers pale yellowish orange (10YR 8/6); massive with local fractures throughout; fossil density increases upward; Linoproductus (articulated), foraminiferids (Tetrataxis, fusulinids), ramose bryozoan fragments, crinoid fragments, Composita (shell fragments), productid spines; large crinoid fragments and productid shell fragments(?) concentrated along base of unit; sharp contacts.

c Claystone (8cm); dusky yellow (5Y 6/4); flaky to platy; slightly calcareous; sharp contacts; upper part of unit contains discontinuous, peloid-rich wackestone rubble (2-4cm) interbedded with unconsolidated clay-to sand-size grains; wackestone is light gray (N7) to light olive gray (5Y 6/1) with dark yellowish orange (10YR 6/6) clay seams; fusulinids, brachiopod shell fragments, productid spines, and ramose bryozoan fragments.

d Sparsely fossiliferous, peloid-rich wackestone (8cm); light gray (N7) to pale yellowish orange (10YR 8/6); nodular bed; fossils fragmented and abraded; brachiopod shell fragments, ramose and fenestrate bryozoan fragments, foraminiferids (Tetrataxis); discontinuous clay seams throughout; horizontal to nearly vertical burrows filled with silt-size quartz grains and unidentifiable fossil debris; undulatory, sharp contacts.

Excello shale

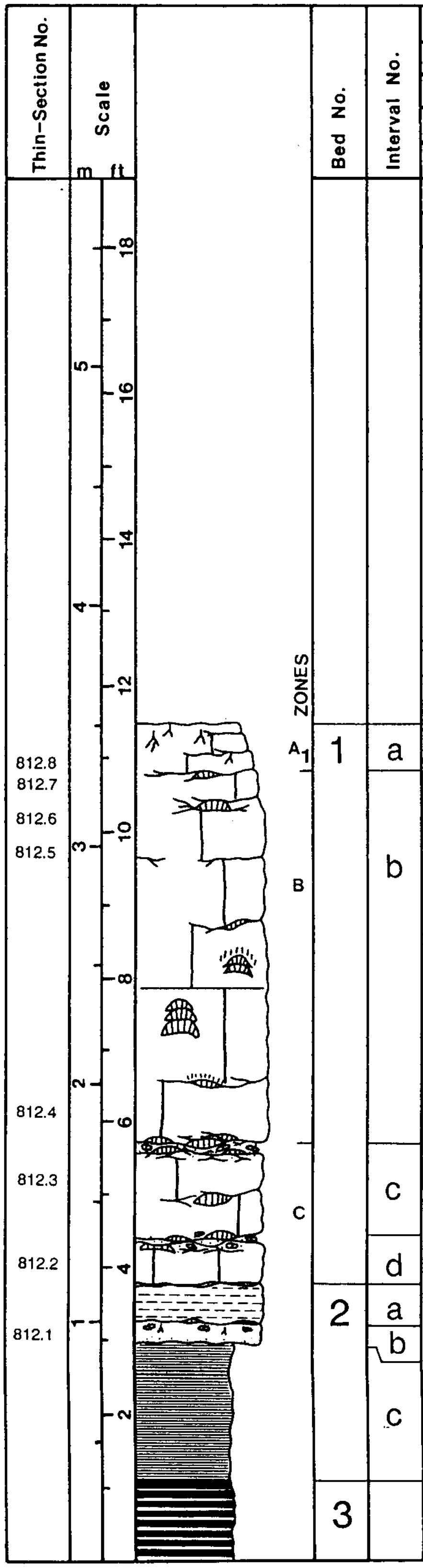
5 a Silty clay-shale (11.5-14cm); very light gray (N8) to light olive gray (5Y 6/1); calcareous; platy to flaky with very poor fissility; abraded brachiopod shell fragments; sharp upper contact, gradational lower contact.

b Bituminous shale (74cm); black (N1), weathers dark reddish brown (10R 3/4) to very light gray (N8); fissile, phosphatic; conodonts; phosphate nodules present throughout, but concentrated in middle part of unit; gradational upper contact, sharp lower contact.

Mulky coal

6 a Coal (41cm); black (N1), weathers dark yellowish orange (10YR 6/6); blocky, but breaks into thin plates; sharp contacts.

b Claystone (18cm); medium gray (N5) to light olive gray (5Y 6/1); blocky to flaky; brachiopod shell fragments and dark yellowish orange (10YR 6/6) root traces; sharp upper contact.



Locality Description: Strat. Sec. 812,

road cut along U.S. Hwy. 69, S. of Ft. Scott, Kansas, and due W. of Arcadia, Kansas.

Location: N1/2, SE1/4, SE1/4, Sec. 6, T.28S., R.25E.,

Crawford Co., Kansas.

Measured By: S. Roth 1989

Remarks:

Description

Bed No.

Fort Scott Formation

Little Osage Shale Member

Bituminous shale(?); black (N1) flakes rest on uppermost part of underlying unit; conodonts.

Blackjack Creek Limestone Member

1 a Fossiliferous, rooted(?) packstone to grainstone (20cm); pale yellowish orange (10YR 8/6); massive (weathered); brachiopod shell fragments, smooth-shelled ostracodes (shell fragments), gastropod fragments, bryozoan fragments, crinoid fragments, gastropod fragments, echinoid spines, unidentifiable fossil debris (partially filling rhizocretions); vertical rhizocretions throughout (up to 16cm long, 3-5cm wide); lower contact gradational.

b Fossiliferous packstone (155cm); pale yellowish orange (10YR 8/6); massive with clay/shale partings dividing unit; Composita (articulated and shell fragments), Crurithyris, Meekella (shell fragments), crinoid fragments, ramose and fenestrate bryozoan fragments, productid spines, foraminiferids (Tetrataxis, palaeotextulariids, fusulinids), bivalve fragments(?), phylloid algal blades, trilobite fragments, horn corals, Neosyringopora (often on top of chaetetids), isolated, low-domical to laminar Chaetetes often draped by clay/shale partings; upper contact gradational, lower contact sharp.

c Fossiliferous wackestone to packstone (41cm); pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive with microstyolitic clay seams; mottled; fenestrate and ramose bryozoan fragments, crinoid fragments, echinoid spines, Composita (shell fragments), fusulinids, high-spired gastropods, Neosyringopora, Chaetetes; sharp contacts filled with carbonate-rich, silt- to clay-size grains; upper contact contains laminar Chaetetes, fossiliferous clay/shale partings, and packstone rubble; often partings drape chaetetids and packstone rubble; some of chaetetids are overturned; low-domical to laminar Chaetetes also found within partings in center of unit.

d Fossiliferous mudstone to wackestone (19.3cm); light gray (N7) to medium light gray (N6); thick bed, fractured; fossil density and diversity increase upward with many fossils abraded; Composita, Crurithyris (shell fragments), phylloid algal blades, ramose bryozoan fragments, crinoid fragments, foraminiferids, laminar Chaetetes; sharp, clay-rich contacts; upper contact consists of numerous fossiliferous (brachiopods, crinoids, and fusulinids) clay/shale partings, with laminar Chaetetes, interbedded wackestone rubble, and unidentifiable fossil debris; other partings microstyolitic and in places, drape fossil grains; clay content decrease downward.

Excello shale

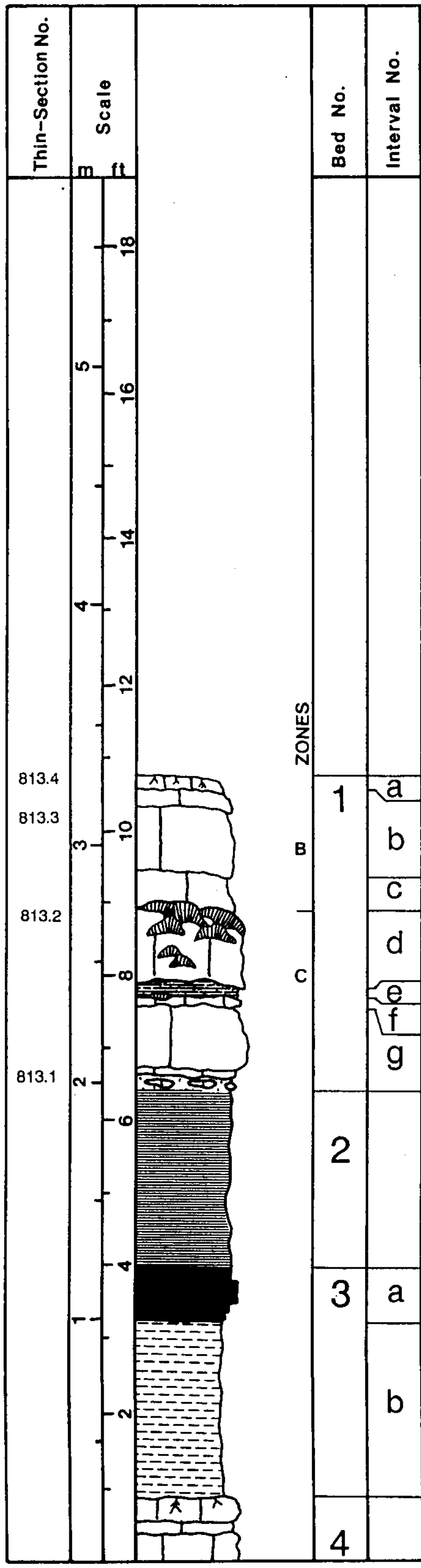
2 a Fossiliferous claystone (14-16cm); light gray (N7) to medium light gray (N6), weathers pale yellowish orange (10YR 8/6); massive, dense; mottled (bioturbated); poorly preserved fossil fragments; brachiopod shell fragments, crinoid fragments, productid spines; sharp contacts; upper contact contains unconsolidated to laminated, silt- and clay-size grains.

b Sparsely fossiliferous siltstone with (1-2cm) micritic clasts (10cm); dark gray (N3) to medium dark gray (N4); thick bed with clay seams; mottled [bioturbation - root casts(?) and vertical burrows, pale yellowish orange (10YR 8/6) and dark yellowish orange (10YR 6/6)]; weathers into flakes; ramose bryozoan fragments, thin-shelled brachiopod fragments; sharp contacts; lower contact clay-rich with poor fissility.

Stratigraphic Section 812
(Descriptions continued from previous page)

2 c Bituminous shale (58cm); black (N1), weathers light gray (N7) and pale yellowish orange (10YR 8/6); conodonts; fissile, phosphatic; round to laminar phosphate nodules increase upward from base; sharp upper contact, slightly gradational lower contact.

3 Mulky coal
Coal-shale(?) (32cm); black (N1), stains dark yellowish orange (10YR 6/6); poorly developed; silt-size grains throughout; brittle, platy to fissile; small (2cm) plant fragments; slightly gradational upper contact.



Locality Description: Strat. Sec. 813, road cut and ditch of east-west county road near Bone Creek E. of Farlington, Kansas, and W. of U.S. Hwy. 69.

Location: SW1/4, SE1/4, Sec. 10, T.28S., R.25E., Crawford Co., Kansas.

Measured By: S. Roth 1989

Remarks:

Description

Bed No.

Fort Scott Formation

Blackjack Creek Limestone Member

1 a Fossiliferous packstone (6cm); light gray (N7) to very pale yellowish orange (10YR 8/6); thin bed; fossils abraded, fragmented; brachiopod shell fragments, crinoid fragments, foraminiferids (Tetrataxis, fusulinids, ophthalmids), echinoid spines, phylloid algal blades(?), ramose bryozoan fragments, high-spired gastropods, unidentifiable fossil debris; lower contact sharp, wavy.

b Fossiliferous packstone (34.5cm); light gray (N7), weathers very pale orange (10YR 8/2); two massive beds; in places, fossils abraded; crinoid fragments, phylloid algal blades, fusulinids, Composita (articulated and shell fragments), Crurithyris (shell fragments), Cleiothyridina (articulated and shell fragments), productid spines, ramose bryozoan fragments; sharp, irregular contacts.

c Sparsely fossiliferous, peloid-rich wackestone to packstone (8-14cm); light gray (N7) to medium gray (N5), weathers pale yellowish orange (10YR 8/6) in places; massive; crinoid fragments, Composita, Crurithyris (shell fragments), foraminiferids (fusulinids, Tetrataxis), productid spines, ramose and fenestrate bryozoan fragments; fills in low spots of underlying "chaetetid mound"; thins to 8cm over top of "chaetetid mound"; sharp contacts.

d "Chaetetid mound" in a fossiliferous packstone (30-34cm); light gray (N7) to medium gray (N5); massive; fusulinids, crinoid fragments, Composita (shell fragments), ramose bryozoan fragments, high-spired gastropods, low-domical Chaetetes; mound disappears laterally (approximately 300cm wide); mound consists of intergrown low-domical Chaetetes; coarse crystalline calcite fills vugs and fractures; white (N9) chert fills small fractures in chaetetids; wavy, sharp contacts.

e Silty clay-shale (8cm); brownish black (5YR 2/1); calcareous; slightly fissile, flaky, and 'grainy'; sharp, undulatory contacts.

f Fossiliferous, peloid-rich packstone (4cm); pale yellowish orange (10YR 8/6); thin bed; fossils abraded; Composita (shell fragments), crinoid fragments, fusulinids, laminar Chaetetes fragments (overturned) on top of bed; sharp, undulatory contacts.

g Fossiliferous wackestone to packstone (35cm); pale yellowish orange (10YR 8/6); bedded to massive with lowest 4cm nodular, packstone rubble; slightly mottled; fossils abraded, fragmented; crinoid fragments, brachiopod shell fragments, phylloid algal blades; wavy, sharp contacts; lower contact filled with dark yellowish orange (10YR 6/6) unconsolidated, silt- and clay-size grains.

Excello shale

2 Bituminous shale (75cm); black (N1), weathers dark reddish brown (10R 3/4) to dark yellowish orange (10YR 6/6); flaky to fissile, phosphatic; nodules and shale fissility decrease upward as clay content increases; conodonts, Dunbarella (articulated), Orbiculoidea; sharp contacts; small, light olive gray (5Y 6/1) Chondrites burrows (up to 2cm long) throughout.

Mulky coal

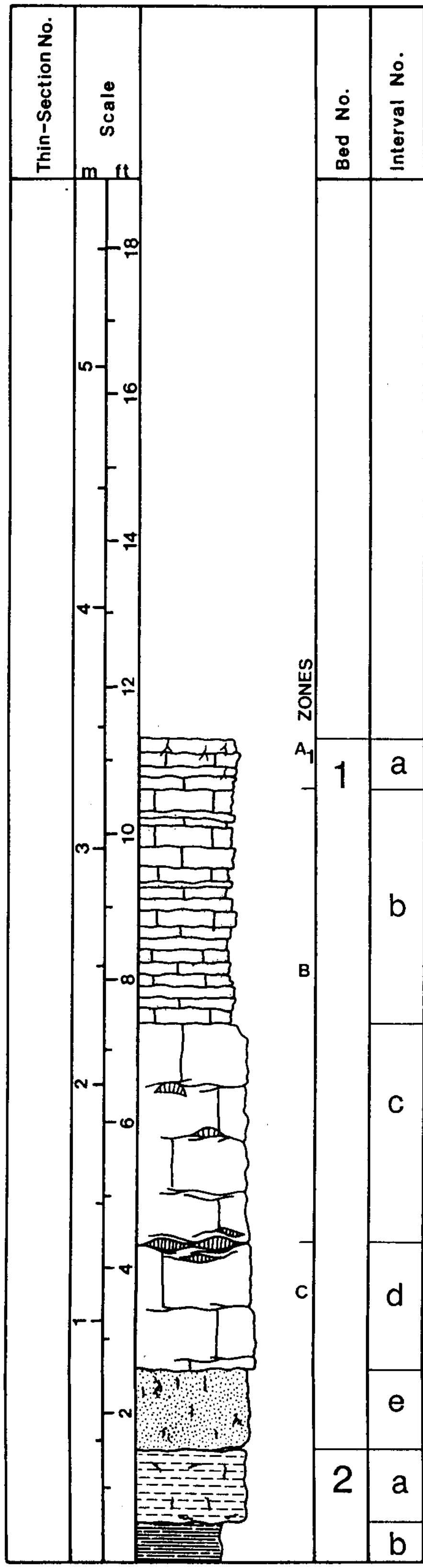
3 a Coal (22cm); black (N1), weathers dark reddish brown (10R 3/4) to dark yellowish orange (10YR 6/6); very blocky to flaky; dark yellowish orange plant fragments; sharp contacts.

b Claystone (73cm); olive gray (5Y 4/1), weathers dark yellowish orange (10YR 6/6) thinly laminated to blocky and flaky; brachiopod shell fragments, plant fragments; sharp contacts.

Stratigraphic Section 813
(Descriptions continued from previous page)

Cabaniss Formation
Breezy Hill Limestone Member

4 Fossiliferous, silty, dolomitic mudstone to siltstone (50cm); pale yellowish orange (10YR 8/6); massive to thickly bedded; mottled; Composita and other brachiopod shell fragments, smooth-shelled ostracodes, crinoid fragments; coarse crystalline, hematitic-rich calcite, dolomite confined to filling rhizocretions (burrows?), vugs.



Locality Description: Strat. Sec. 886,
cut bank of Neosho River near power plant, (7.5 mi.) E. of Parsons,
Kansas, on Hwy. 160, then (6.75 mi.) S. to power plant. Down ladder.

Location: C, NW1/4, NE1/4, Sec. 33, T.31S., R.21E.,
Labette Co., Kansas.

Measured By: S. Roth 1989

Remarks:

Description

Bed No.

Fort Scott Formation
Blackjack Creek Limestone Member

1 a Fossiliferous, rooted(?) packstone (22cm); pale yellowish orange (10YR 8/6); thinly bedded, fractured due to weathered clay/shale partings; Neospirifer, Composita (shell fragments), phylloid algal blades, crinoid fragments, foraminiferids (palaeotextulariids); poorly preserved rhizocretions (weathered); lower contact gradational.

b Fossiliferous wackestone to packstone (98cm); pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); thinly bedded; fossil diversity greatest near base; Neospirifer (shell fragments), Composita (articulated, some with spiralia present, and shell fragments), Derbyia (shell fragments), phylloid algal blades, crinoid fragments; many beds fractured, friable, not laterally persistent; abundant silt- to coarse sand-size grains between beds; locally, microstyolitic clay seams occur; contacts gradational.

c Fossiliferous packstone (92cm); pale yellowish orange (10YR 8/6) to dark reddish brown (10R 3/4); massive; mottled; isolated laminar and low-domical Chaetetes, crinoid fragments, Composita, Cleiothyridina (articulated and shell fragments), ramose and fenestrate bryozoan fragments, foraminiferids (Tetrataxis, palaeotextulariids, ophthalmids, fusulinids), phylloid algal blades, horn corals, very small gastropod fragments; numerous fossiliferous (crinoids, brachiopods, fusulinids) clay/shale partings and microstyolitic clay seams break up unit producing thickly bedded appearance; well developed parting occurs 10cm from base of unit; gradational upper contact, sharp lower contact.

d Fossiliferous wackestone (55cm); pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive, blocky; foraminiferids (fusulinids, Tetrataxis), Composita (articulated and shell fragments), crinoid fragments, bryozoan fragments, and laminar to low-domical Chaetetes (persist laterally within clay/shale parting along upper part of unit); height of chaetetids range from 3cm (laminar) to 39cm (low-domical); dark yellowish orange (10YR 6/6), fossiliferous (fusulinid) packstone drapes chaetetid heads; well developed partings occur at 5cm and 25cm from base of unit; sharp contacts.

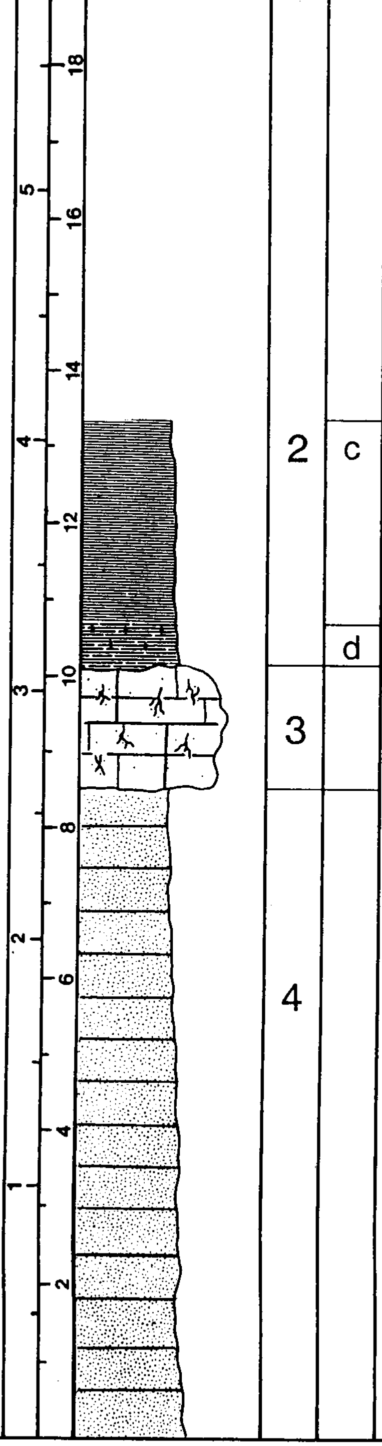
e Fossiliferous, micritic siltstone to a clay/silt-rich mudstone (34cm); medium gray (N5) to medium light gray (N6); massive bed; Linoproductus (shell fragments), Desmoinesia (articulated), thin-shelled bivalve and brachiopod fragments; sharp contacts with fossiliferous, clay/shale parting within upper contact (up to 4cm thick); vertical burrows throughout, (5mm wide; 1 to 3cm long), dark gray (N3) to grayish black (N2); most fossil fragments poorly preserved (abraded).

Excello shale

2 a Silt-rich, burrowed claystone (30cm); dark gray (N3) to medium gray (N5), weathers pale yellowish orange (10YR 8/6) in spots and along contacts; massive; mottled; very few fossils; Linoproductus (articulated), straight-shelled cephalopods(?); slightly calcareous; silt-size quartz grains increase upwards; contacts sharp, upper contact contains large amount of weathered clay; most burrows are horizontal, dark gray (N3) to grayish black (N2).

b Silty clay-shale (15cm); dark gray (N3) to olive gray (5Y 4/1); calcareous; laminated to slightly fissile; bioturbated (burrowed); abraded brachiopod shell fragments; lower contact very gradational, upper contact slightly gradational to sharp.

Thin-Section No.	Scale (m / ft)		Bed No.	Interval No.	Locality Description: Strat. Sec. 886
					(Continued from previous page)
					Location:
					Measured By:
					Remarks:



Description

Bed No.

2 c Bituminous shale (82cm); black (N1), stained dark reddish brown (10R 3/4) to white (N9); fissile, blocky, and phosphatic; conodonts, <u>Orbiculoidea</u>, brachiopod shell fragments; gradational, clay-rich upper contact with fair fissility, sharp lower contact; very few phosphate nodules in lowest 23cm (relatively barren), increasing in size and number to center of unit, about 49cm from the base, then decreasing such that upper 19cm is free of phosphate nodules.

d Silty clay-shale (15.5-19cm); olive gray (5Y 4/1) to medium gray (N5), weathers pale yellowish orange (10YR 8/6); plant fragments(?); pebble-size, black (N1) shale chips and small (1-2cm), dark yellowish orange (10YR 6/6) vertical root(?) traces occur throughout; calcareous; contacts sharp to slightly gradational.

<u>Cabaniss Formation</u>
<u>Breezy Hill Limestone Member</u>

3 Silt-rich, bioturbated mudstone (48-52cm); pale red (10YR 6/2) to very pale orange (10YR 8/2); massive (highly weathered); contacts slightly gradational and incorporate a lot of silt- and clay-size grains; very porous, friable; "ped" structures common along with rhizocretions; clay- to silt-size quartz grains fill poorly preserved rhizocretions.

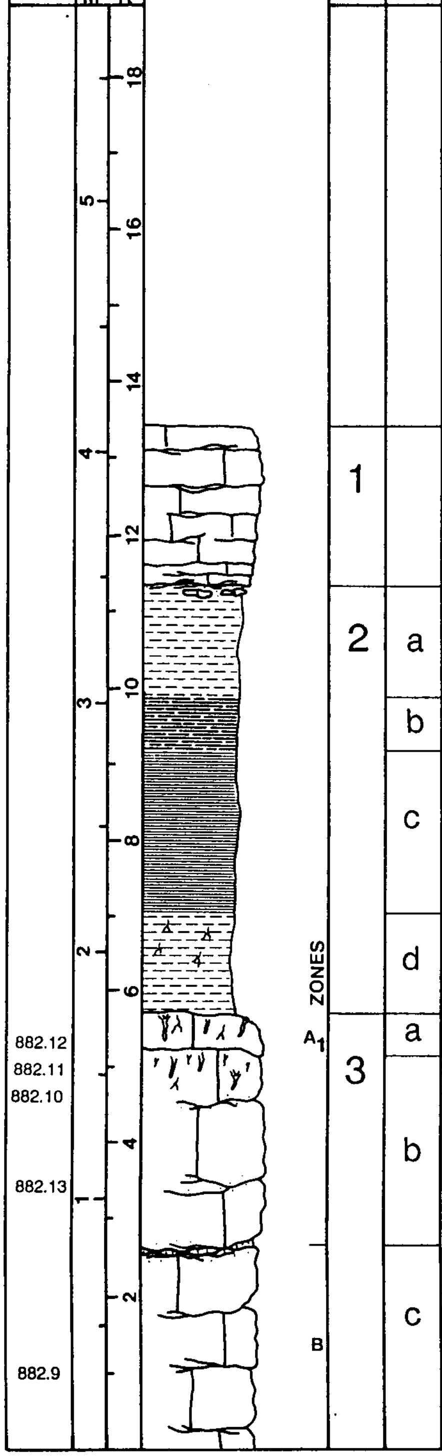
4 Siltstone (249cm); olive gray (5Y 4/1) to light olive gray (5Y 6/1), weathers dark yellowish orange (10YR 6/6); laminated; plant fragments; upper contact gradational, undulatory in places; fossiliferous wackestone rubble incorporated locally, approximately 15cm to 20cm below upper contact.

Thin-Section No.	Scale (m ft)		Bed No.	Interval No.	Locality Description: Strat. Sec. 882, road cut on Hwy. 59 at S. edge of Oswego, Kansas.

Location: E. of Ctr., Sec. 21, T.33S., R.21E., Labette Co., Kansas.

Measured By: S. Roth 1989

Remarks: same as Suchy's (1987) SOS



Description

Bed No.

Fort Scott Formation

Houx-Higginsville Limestone Member

1 Fossiliferous (algal) packstone (64cm); medium light gray (N6), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive; phylloid algal blades, Composita (articulated and shell fragments), Crurithyris (articulated), Cleiothyridina (shell fragments), ramose and fenestrate bryozoans, crinoid fragments, echinoid spines, gastropod fragments; weathered clay/shale partings give unit a bedded appearance; all beds within unit separated by partings; lower contact gradational with abundant clay/shale partings.

Little Osage Shale Member

2 a Claystone (45cm); olive gray (5Y 4/1), weathers brownish gray (5YR 4/1) and dark yellowish orange (10YR 6/6); blocky, flaky to laminated; plant fragments; gradational contacts with pale yellowish orange (10YR 8/6), fossiliferous packstone rubble just below upper contact with phylloid algal blades, Composita, Crurithyris (shell fragments), ramose bryozoan fragments.

b Clay-shale (21cm); olive gray (5Y 4/1) with black (N1) shale streaks throughout; calcareous; slightly fissile and flaky; gradational contacts; medium gray (N5) burrows (Chondrites?), Orbiculoidea.

c Bituminous shale (65cm); black (N1), weathers moderate yellowish brown (10YR 5/4); conodonts, Orbiculoidea, Dunbarella, plant fragments; fissile, phosphatic, flaky in spots; phosphate nodules randomly dispersed; upper contact gradational, lower contact sharp.

d Claystone (41cm); olive gray (5Y 4/1), weathers dark yellowish orange (10YR 6/6); plant fragments, root(?) traces conspicuous throughout; upper 10cm with fossil fragments; brachiopod shell fragments, ostracodes (articulated), plant fragments; slightly calcareous; blocky, flaky to laminated; contacts sharp.

Blackjack Creek Limestone Member

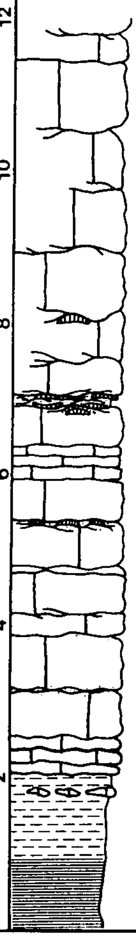
3 a Fossiliferous, rooted(?) packstone to grainstone (14cm); brownish gray (5YR 4/1), weathers dark yellowish orange (10YR 6/6); massive (weathered); fossils occur as broken debris; fusulinids, productid spines, crinoid fragments, Composita (thin-shelled fragments), echinoid spines; pebble- to cobble-size, pale yellowish orange (10YR 8/6) "nobs" on upper surface; "nobs" appear where well developed rhizocretions reach upper surface; sharp contacts.

b Fossiliferous, rooted(?) packstone to grainstone (81.5cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) with small dark reddish brown (10YR 3/4) root(?) traces (up to 6cm long and 2cm wide); massive; mottled; foraminifera (fusulinids, Tetrataxis), crinoid fragments, ostracodes (articulated), phylloid algal blades, Composita (shell fragments), productid and echinoid spines, abundant unidentifiable fossil debris; wavy, sharp contacts; local clay/shale partings throughout; randomly oriented, pale yellowish orange (10YR 8/6) rhizocretions concentrated in upper part (1 to 5cm wide; up to 10cm long).

c Fossiliferous packstone (80cm); light gray (N7), weathers dark yellowish orange (10YR 6/6); massive; mottled; isolated areas of dolomite; crinoid fragments (including calyx), phylloid algal blades, foraminifera (fusulinids, palaeotextulariids), Composita (shell fragments), ramose bryozoan fragments, echinoid and productid spines; localized, undulatory clay/shale partings; wavy, sharp contacts.

Thin-Section No.	Scale (m, ft)		Bed No.	Interval No.
	3		B	
882.7			3	c, d, e
882.6	2		C	f
882.5				g, h
882.4				i
882.3	1			j, k
882.2				l
882.1			4	a, b

Scale: m 1–5; ft 2–18



Locality Description: Strat. Sec. 882

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

3 d Fossiliferous packstone (78cm); light brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6); massive; mottled; crinoid fragments, fusulinids, Composita, Crurithyris (articulated and shell fragments), echinoid and productid spines, ramose bryozoan fragments, phylloid algal blades; coarse blocky calcite fills vugs and fractures; wavy, sharp contacts.

e Fossiliferous wackestone to packstone (58.5cm); light gray (N7), weathers pale yellowish orange (10YR 8/6) (weathering concentrated along contacts and clay/shale partings); massive to thinly bedded; highly weathered, mottled; crinoid fragments, foraminiferids (fusulinids, Tetrataxis), phylloid algal blades, Composita, Cleiothyridina (articulated and shell fragments), productid and echinoid spines, ramose and fenestrate bryozoan fragments, horn corals, and laminar Chaetetes in central part of unit; contacts wavy, sharp.

f Fossiliferous wackestone to micritic packstone (20cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6); massive; Composita, Crurithyris (articulated and shell fragments), crinoid fragments, foraminiferids (Tetrataxis); sharp, wavy contacts; upper contact consists of fossiliferous clay/shale partings, clay-rich microstyolites, laminar Chaetetes (some chaetetids overturned).

g Fossiliferous, peloid-rich wackestone to packstone (14cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6); thin beds; fusulinids, Composita (articulated and shell fragments), crinoid fragments, ramose bryozoan fragments, productid and echinoid spines; sharp, wavy contacts; beds have rounded edges.

h Fossiliferous, peloid-rich wackestone to packstone (16cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) with prominent dark yellowish orange (10YR 6/6) staining; massive with fossiliferous clay laminations; phylloid algal blades, fusulinids, crinoid fragments, productid spines, Crurithyris (articulated), brachiopod shell fragments, ramose bryozoan fragments, echinoid spines, gastropod fragments; wavy, sharp contacts; fossils, clay content decrease downward; numerous brachiopod, gastropod geopetals.

i Fossiliferous wackestone to packstone (19.5cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) with dark yellowish orange (10YR 6/6) stains; massive to thickly bedded; phylloid algal blades, fusulinids, crinoid fragments, brachiopod shell fragments, ramose bryozoan fragments, Neosyringopora (normally on top of chaetetids); coarse crystalline calcite fills vugs and fractures; sharp, wavy contacts with clay/shale partings and laminar Chaetetes.

j Fossiliferous wackestone (29cm); light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6); two massive beds with uppermost 1.5cm forming third, laterally distinct bed; fossils mainly abraded fragments; large crinoid fragments, echinoid spines and plates, phylloid algal blades, brachiopod shell fragments, fusulinids, ramose bryozoan fragments; vugs throughout lower part of unit; beds have rounded edges; wavy, sharp contacts.

k Fossiliferous packstone (42cm); light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6); two massive beds (weathered); fusulinids, Composita (shell fragments), Crurithyris (articulated), brachiopod shell fragments, crinoid fragments, ramose bryozoan fragments, phylloid algal blades; sharp, wavy contacts with abundant unconsolidated silt- and clay-size grains.

<u>Stratigraphic Section 882</u>

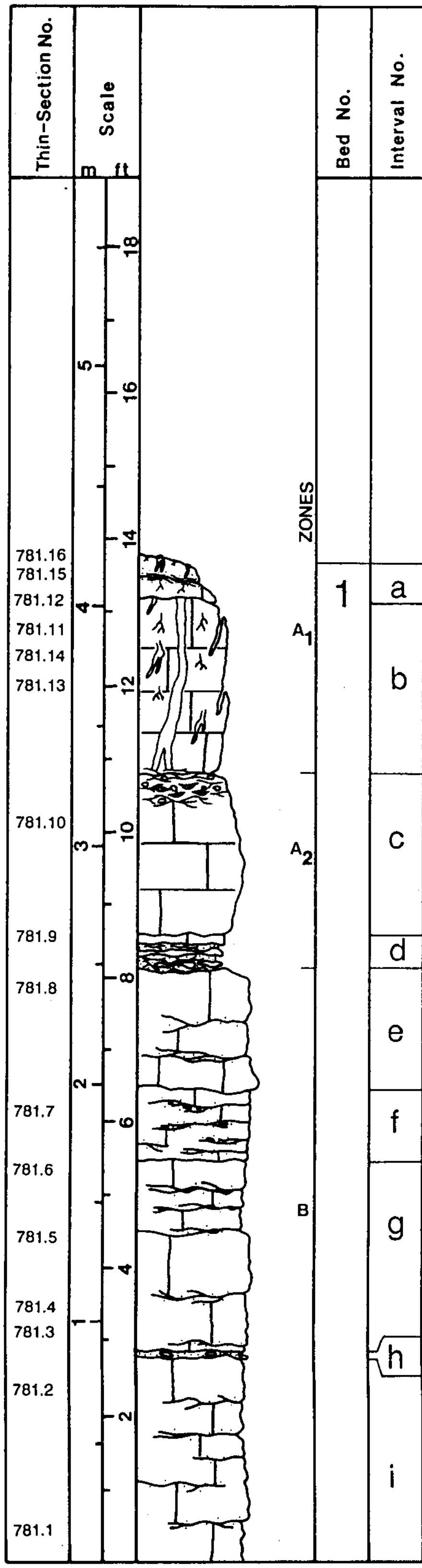
(Descriptions continued from previous page)

3 I Fossiliferous wackestone to packstone (14cm); light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); thinly to thickly bedded; fossils abraded; phylloid algal blades, fusulinids, crinoid fragments, brachiopod shell fragments; beds have rounded edges; sharp contacts with fossiliferous (fusulinids) clay/shale partings.

<u>Excello shale</u>

4 a Claystone (36cm); greenish gray (5GY 6/1) to pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); fossiliferous packstone rubble (10YR 8/6 to 10YR 6/6) at 29cm above base of unit with ramose bryozoan fragments, crinoid fragments, <u>Composita</u> and other brachiopod shell fragments; claystone slightly calcareous; upper contact sharp, lower contact slightly gradational.

b Bituminous shale (28cm); black (N1) to greenish black (5GY 2/1); fissile to flaky, phosphatic; conodonts; phosphate nodules abundant, dispersed throughout; upper contact gradational.



Locality Description: Strat. Sec. 781,
in quarry (1/4mi) N. of Hwy. 166, (3mi) W. of Chetopa, Kansas. Near radio tower. Section continues beneath floor of quarry with781 CORE.

Location: NE1/4, Sec. 30, T.34S., R.21E., Labette Co., Kansas.

Measured By: S. Roth 1989

Remarks: Quarry owned by Keith Brothers.

Description

Bed No.

Fort Scott Formation
Blackjack Creek Limestone Member

1 a Peloid-rich, rooted(?), fossiliferous wackestone to packstone (18.2cm); brownish black (5YR 2/1) to dark yellowish orange (10YR 6/6), weathers pale yellowish orange (10YR 8/6); lower part is massive, upper part thinly bedded to laminated with numerous vertical rhizocretions; fossil abundance decreases upward with densely packed peloids increasing; crinoid fragments, foraminiferids (fusulinids, *Tetrataxis*, globivalvulinids), productid spines, phylloid algal blades, *Composita* (articulated), *Linoproductus* (shell fragments), ramose bryozoan fragments, echinoid spines; gradational lower contact; carbonate-rich "nobs" on upper surface along with mudcracks(?).

b Rooted(?), fossiliferous wackestone to packstone with abundant peloids (73cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6); massive bed (very weathered); most rhizocretions vertical or just slightly off vertical (1-2cm wide; 5-30cm long); crinoid fragments, foraminiferids (fusulinids, *Tetrataxis*), phylloid algal blades, echinoid and productid spines, ramose bryozoan fragments, brachiopod shell fragments; contacts wavy, slightly gradational; sediment within rhizocretions is white (N9) with fossil debris (crinoid fragments, brachiopod shell fragments, fusulinids, articulated ostracodes).

c Fossiliferous, peloid-rich mudstone to wackestone with localized micritic clasts (68.5cm); light gray (N7) to white (N9); highly mottled; crinoid fragments, *Composita* (articulated and shell fragments), bivalve shell fragments(?), foraminiferids (fusulinids, *Tetrataxis*), productid spines, ramose bryozoan fragments, phylloid algal blades, echinoid spines; laminar *Chaetetes* (within upper 11.5cm) upside-down; smaller chaetetid fragments randomly dispersed around larger heads; in places, micritic clasts lying directly on chaetetid fragments; *Chaetetes* fractures filled with white (N9) chert; sharp, wavy contacts consist of crenulated, fusulinid-rich clay/shale partings and mudstone clasts; clay/shale partings occur in upper 5cm of unit.

d Fossiliferous wackestone (top) interbedded with clay/shale partings (base) (14.5cm); wackestone is very light gray (N8), weathers pale yellowish orange (10YR 8/6); thick to nodular beds; wackestone rubble contains crinoid fragments, productid spines, brachiopod shell fragments; clay/shale is dark gray (N3) to black (N1); bedding is nodular to lenticular at base, then becomes thick near top; poorly preserved fossil debris concentrated along crenulated clay/shale laminations.

e Fossiliferous, peloid-rich wackestone to packstone (48.5cm); light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6); massive with discontinuous, weathered clay/shale partings that give unit bedded appearance; fossils densely packed, but poorly preserved (abraded, fragmented); phylloid algal blades, crinoid fragments, bivalve (pectin?) and brachiopod shell fragments, ramose bryozoan fragments, productid spines, foraminiferids; wavy, sharp contacts.

f Fossiliferous, peloid-rich wackestone to packstone (30.5cm); light gray (N7), weathers white (N9); massive, but broken up by four to five clay/shale partings; mottled; fossils poorly preserved; crinoid fragments, foraminiferids (fusulinids, *Tetrataxis*), *Composita* (shell fragments), bivalve shell fragments, productid and echinoid spines, ramose bryozoan fragments, broken phylloid algal blades; silt- to sand-size grains, fossil debris, light gray (N7) chert cobbles concentrated within discontinuous partings; sharp contacts.

Stratigraphic Section 781

(Descriptions continued from previous page)

1 g Fossiliferous, peloid-rich wackestone to packstone (80cm); light gray (N7) to light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6) to white (N9) along contacts and clay/shale partings; lower 50cm massive, upper 30cm appear bedded due to weathered, fossiliferous clay/shale partings, and often fractured; mottled; fossil diversity decreases upward; phylloid algal blades, fenestrate bryozoan fragments, Composita, Crurithyris (shell fragments), echinoid spines, fusulinids; upper 30cm contain irregular chert nodules within partings; in places, partings microstyolitic; contacts sharp and contain clay-size grains and unidentifiable fossil debris.

h Fossiliferous wackestone rubble with clay- to silt-size grains (3cm); nodular wackestone is medium gray (N5) and sometimes laterally continuous (locally); clay and silt are pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); mainly crinoid debris throughout wackestone rubble along with Crurithyris, Cleiothyridina (articulated and shell fragments), ramose bryozoan fragments, broken phylloid algal blades; sharp contacts.

i Fossiliferous, peloid-rich wackestone (85cm); medium gray (N5) to very light gray (N8), weathers pale yellowish orange (10YR 8/6); massive with isolated clay/shale partings; phylloid algal blades, Composita (articulated), Crurithyris (shell fragments), Neospirifer(?) (shell fragments), crinoid fragments with calyx plates, ramose and fenestrate bryozoan fragments, echinoid spines, foraminiferids (fusulinids, Tetrataxis), gastropod fragments(?), productid spines, unidentifiable fossil debris; algal blades increase in size upwards; most elongated biotic constituents oriented perpendicular to up-direction; micrite content increases upward, and, in places, coats fossil grains; sharp contacts.

Thin-Section No.	Scale (m, ft)		Bed No.	Interval No.	

Locality Description: Core 781,
(see section location for 781).

Location:

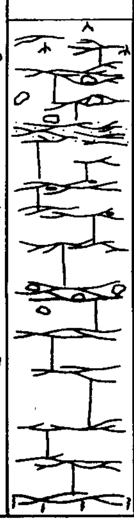
Measured By:

Remarks:

ZONES

C

Scale: m 1, 2, 3, 4, 5; ft 2, 4, 6, 8, 10, 12, 14, 16, 18



Bed No. 1; Interval No. a, b, c, d, e, f

Description

Bed No.

Fort Scott Formation
Blackjack Creek Limestone Member

1 a Fossiliferous, micritic wackestone (40.1cm); light gray (N7); phylloid algal blades, crinoid fragments, foraminiferids, brachiopod shell fragments, fenestrate bryozoan fragments, and bivalve shell fragments(?) densely packed, in some cases; isolated micrite clasts and root(?) traces; unit dominated by wavy clay/shale partings; sharp contacts.

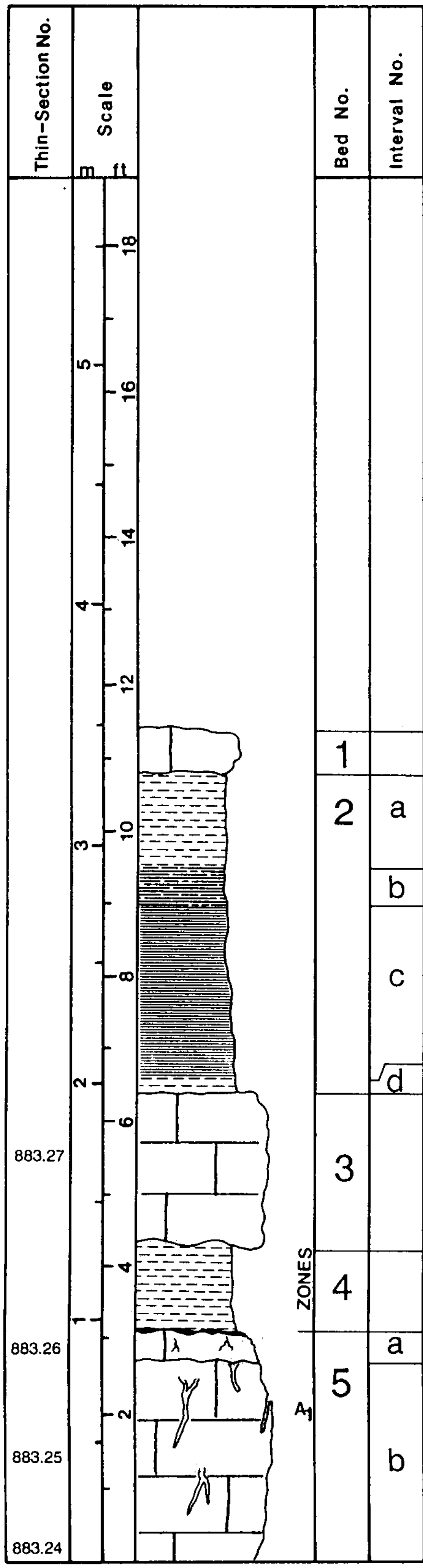
b Fossiliferous clay/shale parting (8cm); medium gray (N5) to medium dark gray (N4); fissile; partings drape fusulinids, crinoid fragments, and phylloid algal blades; partings contain silt-to clay-size quartz grains, rounded fossil fragments; sharp upper contact, gradational lower contact.

c Fossiliferous, micritic wackestone with interbedded clay/shale partings (56.8cm); medium light gray (N6) to light gray (N7) with medium dark gray (N4) to dark gray (N3) fossiliferous clay/shale partings which drape phylloid algal blades, fusulinids, crinoid fragments, fenestrate and ramose bryozoan fragments, brachiopod and bivalve shell fragments; fossils poorly preserved; small isolated shale clasts occur within partings; gradational contacts.

d Fossiliferous, micritic wackestone interbedded with fossiliferous clay/shale partings (33.8cm); wackestone, light gray (N7) and very light gray (N8) with medium gray (N5) to dark gray (N3) fossiliferous clay/shale partings; mottled; phylloid algal blades, bryozoan fragments, crinoid fragments, fusulinids, brachiopod shell fragments; mudstone and wackestone clasts along with fusulinids concentrated in upper 13cm; gradational contacts.

e Fossiliferous wackestone to micritic packstone (53.9cm); medium gray (N5) to medium dark gray (N4); fossils abraded; brachiopod shell fragments, phylloid algal blades, crinoid fragments, and fenestrate bryozoan fragments; micrite increases upward; clay/shale partings interbedded with limestone throughout unit; upper contact gradational, lower contact sharp.

f Fossiliferous, burrowed clay-shale (4.2cm); grayish black (N2) with dark gray (N3) _Chondrites_ burrows; brachiopod shell fragments, fusulinids and other foraminiferids, fenestrate bryozoan fragments, phylloid algal blades, unidentifiable fossil debris and burrows; sharp upper contact.



Locality Description: Strat. Sec. 883,

composite of road cut and ditch along the north and south side

of Hwy. 166, (4mi) W. of Chetopa, Kansas.

Location: NE1/4, NE1/4, NE1/4, Sec. 36, T.34S., R.21E.;

S1/4, SW1/4, Sec. 30, T.34S., R.21E., Labette Co., Kansas.

Measured By: S. Roth 1989

Remarks:

Description

Bed No.

Fort Scott Formation

Houx-Higginsville Limestone Member

1 Fossiliferous packstone to grainstone (20cm); pale yellowish orange (10YR 8/6); massive; phylloid algal blades, crinoid fragments, Cleiothyridina (articulated and shell fragments), productid shell fragments, productid spines, ostracodes (articulated), foraminiferids (Tetrataxis), fenestrate and ramose bryozoan fragments, echinoid spines, abundant unidentifiable fossil debris; unit poorly exposed and pinches out over top of outcrop to east; lower contact smooth, sharp.

Little Osage Shale Member

2 a Claystone (0-40cm); light gray (N7) to olive gray (5Y 4/1), weathers dark yellowish orange (10YR 6/6); plant fragments; unit disappears toward the east; middle part of unit contains black (N1) shale laminae with poor fissility.

b Clay-shale (0-14cm); brownish gray (5YR 4/1); plant fragments, conodonts; calcareous; unit disappears toward the east; flaky to slightly blocky, poor fissility; smooth, sharp upper contact, gradational lower contact.

c Bituminous shale (0-72cm); black (N1), weathers dark yellowish orange (10YR 6/6); conodonts; unit disappears toward the east; fissile, phosphatic; phosphate nodules increase upward until clay-shale dominates; gradational contacts.

d Claystone (0-7cm); light gray (N7) to dark yellowish orange (10YR 6/6); calcareous; unit pinches toward the east; blocky to laminated; highly weathered; upper contact gradational, lower contact sharp.

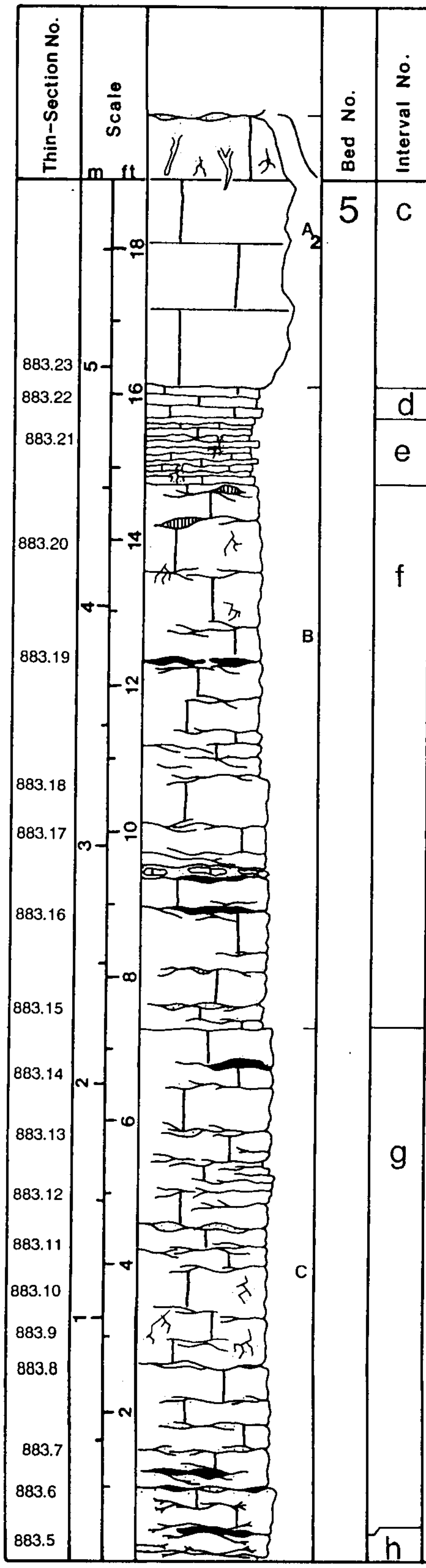
Blackjack Creek Limestone Member

3 Fossiliferous packstone to grainstone (0-64cm); light gray (N7) to pale yellowish orange (10YR 8/6); massive, but thins and disappears toward the east; Neospirifer (articulated and shell fragments), ostracodes (articulated), productid spines, foraminiferids (palaeotextulariids), bivalve shell fragments; in places, coated grains are present (ooids?); hematitic stains on some fossil grains; smooth, sharp upper contact, sharp, wavy lower contact; contacts contain unconsolidated silt- and clay-size grains.

4 Claystone (5-39cm); light gray (N7) to dark yellowish orange (10YR 6/6); plant fragments; slightly calcareous; unit disappears toward the east; slightly blocky to flaky; contacts sharp.

5 a Fossiliferous, rooted(?), peloid-rich wackestone to packstone (13cm); dark yellowish orange (10YR 6/6) to black (N1); thick bed with numerous vertical rhizocretions; densely packed gastropod fragments, crinoid fragments, foraminiferids (fusulinids, palaeotextulariids), Composita (shell fragments), ostracodes (articulated and shell fragments); upper surface very weathered, consists of thin calcrete-like crust, light gray (N7) and olive gray (5Y 4/1) to dark reddish brown (10R 3/4), irregular chert band (occurs only where overlying fossiliferous grainstone and claystone occur); sharp contacts.

b Fossiliferous, rooted(?), micritic packstone (84cm); light gray (N7) to light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6); massive; densely packed peloids; gastropod fragments, crinoid fragments, foraminiferids (fusulinids, Tetrataxis), Composita and productid shell fragments, ostracodes (articulated and shell fragments); highly fractured; micrite occurs as coatings and in partially recrystallized peloids; rhizocretions filled with extremely coarse, blocky calcite; wavy, sharp contacts.



Locality Description: Strat. Sec. 883

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

5 c Fossiliferous, peloid-rich wackestone (115cm); light gray (N7) to light olive gray (5Y 6/1) [lower 80cm], and yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1) [upper 35cm]; massive; phylloid algal blades, crinoid fragments, Composita (articulated and shell fragments), foraminiferids (fusulinids, palaeotextulariids), fenestrate bryozoan fragments, ostracodes (articulated and shell fragments), Linoproductus (articulated); [fossils common in both intervals]; peloids occur in lower zone; upper zone contains yellowish gray root(?) traces; unit intensely weathered in places; smooth, sharp contacts.

d Sparsely fossiliferous wackestone to packstone (15cm); pinkish gray (5YR 8/1) to light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6); three thin, blocky beds; fossils poorly preserved (abraded and fragmented); phylloid algal blades, fusulinids, ramose bryozoan fragments, productid spines, Crurithyris, Composita (shell fragments), crinoid fragments, ostracodes (articulated and shell fragments); smooth, sharp contacts.

e Sparsely fossiliferous packstone (26cm); dark yellowish orange (10YR 6/6); thinly bedded; beds range from less than 1cm to 5cm thick; phylloid algal blades, foraminiferids (fusulinids, globivalvulinids), ostracodes (articulated), crinoid fragments, echinoid spines, brachiopod shell fragments, very fine-grain unidentifiable fossil debris; fractured; sharp contacts; hematitic stains on fossil fragments.

f Fossiliferous, peloid-rich wackestone to packstone (232cm); grayish yellow (5Y 8/4) to light olive gray (5Y 6/1) and light gray (N7), weathers pale yellowish orange (10YR 8/6); massive to thickly bedded with weathered, fossiliferous clay/shale partings producing bedded appearance; densely packed sponge spicules (monoaxon to polyaxon), Composita (articulated and in life position?), Crurithyris, Cleiothyridina (articulated and shell fragments), phylloid algal blades, crinoid fragments, ramose and fenestrate bryozoan fragments, bivalve shell fragments, ostracodes (articulated), productid and echinoid spines, horn corals, foraminiferids (fusulinids, Tetrataxis, palaeotextulariids, globivalvulinids); laminar Chaetetes occur in uppermost clay/shale partings and within upper contact; chert concretions occur throughout partings; random areas of fine-grain dolomite and silt-size quartz occur within microstyolitic clay seams and geopetals; locally, vertical fractures conspicuous; wavy, sharp contacts filled with unconsolidated silt- and clay-size grains.

g Fossiliferous, dolomitic wackestone to packstone (212.5cm); pale yellowish orange (10YR 8/6); massive; fractured; unit broken up by fossiliferous clay/shale partings, especially near base; Composita (articulated and shell fragments), Crurithyris (shell fragments), phylloid algal blades, crinoid fragments, pectin shell fragments, fusulinids, echinoid spines, fenestrate and ramose bryozoan fragments, productid spines, gastropod fragments; contacts sharp, wavy with chert concretions and unconsolidated clay- and silt-size grains throughout; laterally, partings separate into numerous local clay laminations.

h Fossiliferous, peloid-rich wackestone to packstone (5-8.5cm); pale yellowish orange (10YR 8/6); thick bed; Composita (articulated and shell fragments), crinoid fragments, phylloid algal blades, ramose and fenestrate bryozoan fragments, sponge spicules (monoaxon to polyaxon), productid spines, foraminiferids (Tetrataxis); very wavy, sharp contacts with clay/shale partings; fossils have micritic coatings.

Thin-Section No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Strat. Sec. 883

(Continued from previous page)

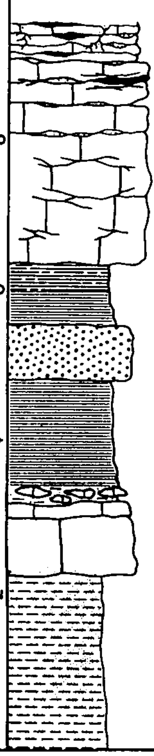
Location:

Measured By:

Remarks:

Thin-Section No.	Bed No.	Interval No.
883.4	5	i
883.3		j
883.2		j
883.1		k
	6	a
		b
	7	
	8	

Scale: m 1–5; ft 2–18



c

Description

Bed No.

5 i Fossiliferous packstone (18cm); pale yellowish orange (10YR 8/6); thinly bedded with numerous local fractures; weathered, friable; phylloid algal blades, Crurithyris (articulated and shell fragments), crinoid fragments, fenestrate bryozoan fragments; chert concretions, unconsolidated clay- and silt-size grains within most bed contacts; dolomitic-rich, microstyolitic clay seams common throughout; contacts of unit wavy, sharp.

j Sparsely fossiliferous, dolomitic packstone (30.2cm); dark yellowish orange (10YR 6/6) with medium light gray (N6) streaks; thinly bedded with abundant unconsolidated silt- to clay-size grains between beds; Crurithyris, Composita (articulated and shell fragments), crinoid fragments, fenestrate bryozoan fragments, thin-shelled bivalve fragments, productid spines, trilobite fragments, unidentifiable fossil debris; upper 18cm is divided into two beds separated by an olive gray (5 Y 4/1) to light gray (N7) chert band and clay/shale partings; vertical fractures common; smooth, sharp contacts.

k Sparsely fossiliferous wackestone to packstone (54cm); dark yellowish orange (10YR 6/6) with medium light gray bands (N6) throughout; bands thin upwards; massive to thickly bedded with local clay/shale partings throughout; fossil content increases upwards with only brachiopod and crinoid fragments near base. Crurithyris (articulated and shell fragments), crinoid fragments, bivalve shell fragments, productid spines, ramose and fenestrate bryozoan fragments, trilobite fragments, phylloid algal blades; sharp contacts.

Excello shale

6 a Clay-shale (10cm); pale yellowish orange (10YR 8/6) to light olive gray (5Y 6/1); slightly calcareous; blocky to flaky, laminated; plant fragments; upper contact wavy, sharp, lower contact gradational.

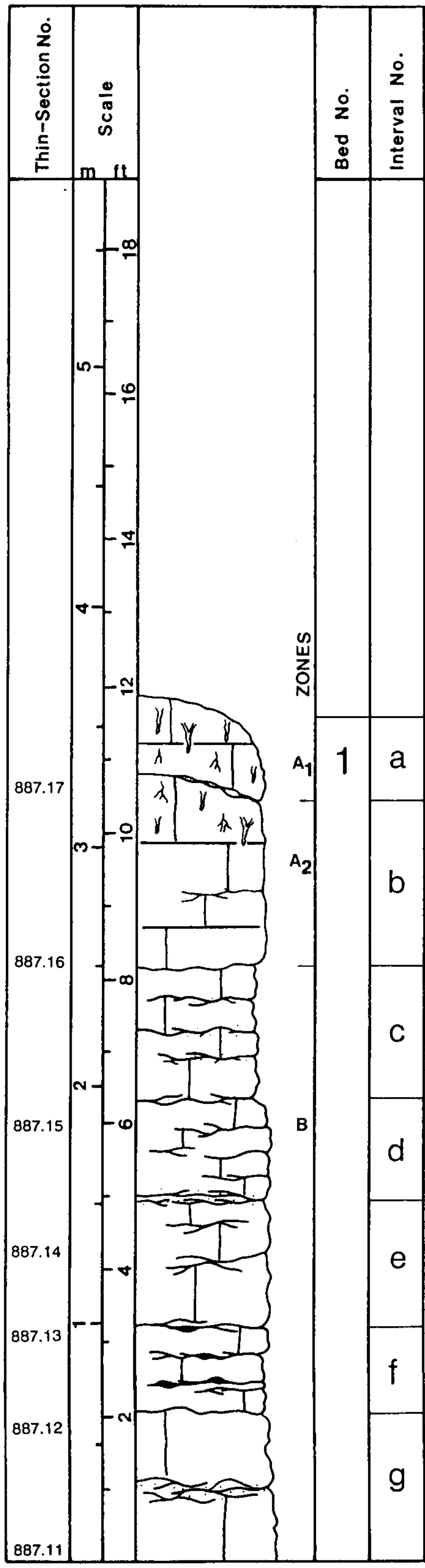
b Bituminous shale (82.3cm); black (N1), weathers dark yellowish orange (10YR 6/6) to white (N9); fissile, phosphatic; conodonts, Orbiculoidea, plant debris(?); phosphate nodules randomly distributed, but decrease toward contacts; upper contact gradational, lower contact sharp; at 18cm below upper contact, massive, dark yellowish orange (10YR 6/6), silty sandstone bed (33cm) occurs with bivalve fragments, echinoid spines, crinoid fragments.

Cabaniss Formation

Breezy Hill Limestone Member

7 Fossiliferous packstone to (33.5cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); massive to thinly bedded to nodular rubble; bivalve and brachiopod shell fragments, crinoid fragments; rubble interbedded with dark yellowish orange (10YR 6/6) claystone along upper contact; upper contact gradational with abundant unconsolidated silt- and clay-size grains, lower contact sharp.

8 Silty claystone (871.7cm); olive gray (5Y 4/1), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); upwards, unit is light olive gray (5Y 6/1) to light gray (N7) with local black (N1) and dark reddish brown (10R 3/4) stains; top of unit is light gray (N7) with medium gray (N5) seams conspicuous; laminated, blocky; mottled; plant and shell? fragments (near the upper surface); vertical fractures occur just above base of unit and increase in number upwards; silt content increases upwards; upper contact sharp.



Locality Description: Strat. Sec. 887,
quarry S. of east-west county road, approximately (2 mi) S. of
Hwy. 166 (due S. of strat. sec. 883).

Location: NE1/4, NW1/4, Sec. 6, T.35S., R.21E.,
Labette Co., Kansas.

Measured By: S. Roth 1989

Remarks: same as Knight's (1985) BQ.

Description

Bed No.

Fort Scott Formation
Blackjack Creek Limestone Member

1 a Fossiliferous, intraclastic packstone to grainstone (33cm); pale yellowish orange (10YR 8/6) to grayish orange pink (5YR 7/2); massive; mottled; weathered, friable; local laminated calcrete-like crust on top; Linoproductus (articulated), productid shell fragments, ramose bryozoan fragments, foraminiferids (fusulinids, globivalvulinids); pale yellowish orange rhizocretions (4-9cm, long) throughout unit, but concentrated in upper part; pebble-size mudstone intraclasts within and around fossil fragments; lower contact wavy, sharp.

b Fossiliferous mudstone (82cm); light brownish gray (5YR 6/1) to brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive; large (8cm) Linoproductus (articulated and shell fragments) extremely common, phylloid algal blades, foraminiferids (palaeotextulariids, globivalvulinids, fusulinids), sponge spicules, ramose bryozoan fragments; micrite (peloids) content increases upward; isolated vertical rhizocretions (up to 6cm, long) in upper part of unit; sharp contacts; fenestral-like porosity throughout.

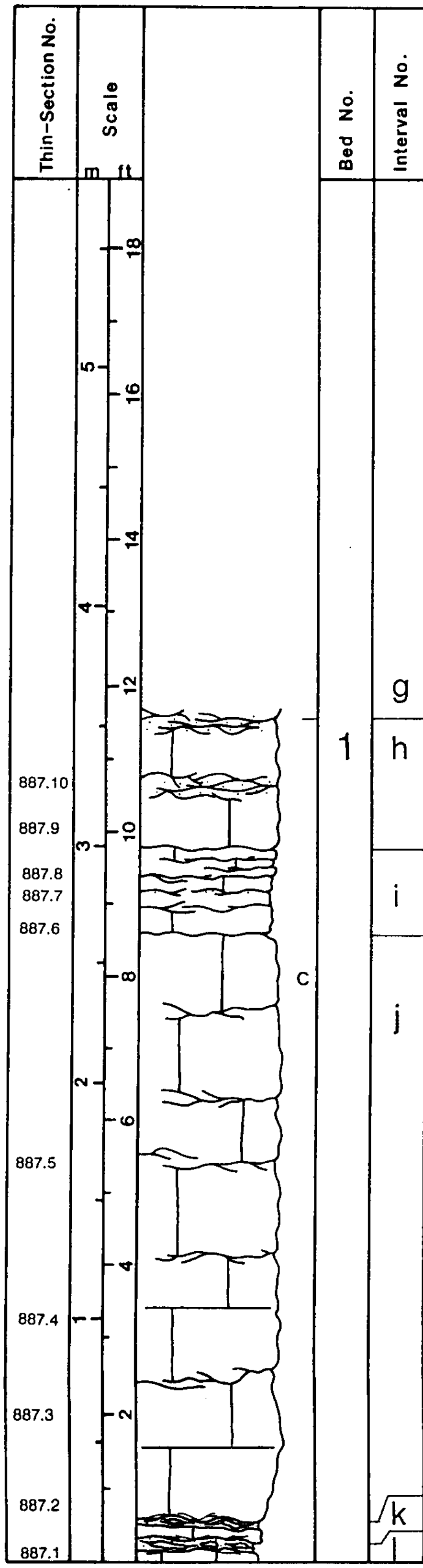
c Fossiliferous packstone (56cm); light gray (N7), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); thickly to thinly bedded; fossils poorly preserved (abraded and fragmented); Composita (shell fragments), phylloid algal blades, crinoid fragments, fusulinids, ramose bryozoan fragments, productid spines; hematitic stains cover vugs and fossil molds; fossiliferous, black (N1) to dark gray (N3) clay/shale partings between individual beds irregular, wavy, flaky and fissile; sharp contacts.

d Fossiliferous wackestone to packstone (40cm); light gray (N7) to light olive gray (5Y 6/1), weathers white (N9); massive; mottled; fossil diversity decreases upward; Fistulipora, ramose bryozoan fragments, Composita, Crurithyris (shell fragments), phylloid algal blades, crinoid fragments, productid spines, horn corals (concentrated at base of unit); clay/shale partings occur throughout with silt- to clay-size quartz grains commonly associated with partings; micrite content increases upward; sharp, wavy contacts.

e Fossiliferous, peloid-rich wackestone to fossiliferous packstone (55cm); very light gray (N8) to light olive gray (5Y 6/1), weathers white (N9) (concentrated along weathered clay/shale partings); massive with numerous partings that persist laterally; Composita (shell fragments), Cleiothyridina (articulated and shell fragments), phylloid algal blades, crinoid fragments, echinoid spines, Fistulipora fragments, foraminiferids (palaeotextulariids), productid spines; wavy, sharp contacts; upper 10-15cm contain partings with most concentrated in upper 4-5cm.

f Fossiliferous packstone (35.5cm); light gray (N7) to light olive gray (5Y 6/1); massive to thinly bedded with bedding produced by weathered fossiliferous clay/shale partings; Composita (articulated composita and shell fragments), Cleiothyridina (articulated), Crurithyris (articulated and shell fragments), brachiopod shell fragments, foraminiferids (fusulinids, palaeotextulariids, globivalvulinids), phylloid algal blades, crinoid fragments, echinoid spines, fenestrate and ramose bryozoan fragments (echinoid and crinoid fragments concentrated along clay/shale partings); micrite (peloids) content increases upward; contacts undulatory, sharp; isolated chert concretions within some partings; clay/shale partings are black (N1), flaky, slightly fissile; fossils increase in abundance upward; microstyolitic clay seams occur with abraded fossil fragments.

g Fossiliferous packstone (67cm); light gray (N7) to light olive gray (5Y 6/1), weathers pale yellowish orange (10YR 8/6) to yellowish gray (5Y 8/1); massive; mottled; Composita (articulated and shell fragments), fusulinids, phylloid algal blades, crinoid and echinoid fragments (mainly at clay/shale partings), Crurithyris, Cleiothyridina (shell fragments), fenestrate bryozoan fragments; sharp contacts.



Locality Description: Strat. Sec. 887

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

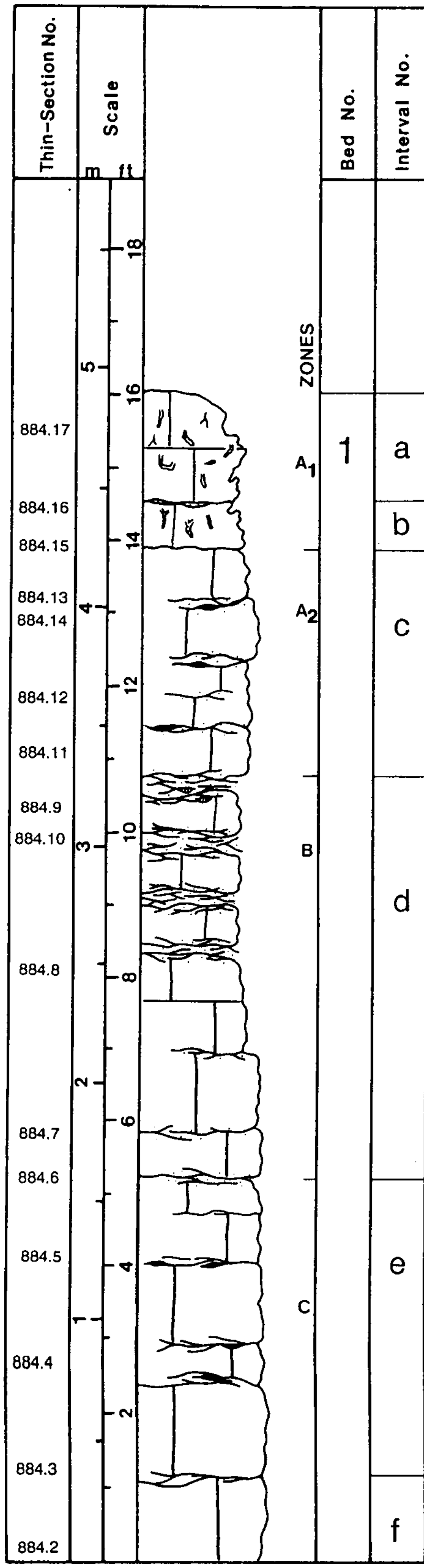
1 h Fossiliferous, peloid-rich wackestone (55.5cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); massive to thickly bedded; beds produced by clay/shale partings, not laterally traceable; mottled; most articulated Composita and phylloid algal blades are coated (micrite?); Composita (articulated), Crurithyris (articulated and shell fragments), phylloid algal blades, fusulinids, crinoid fragments; micrite decreases upward; isolated silt- to clay-size quartz grains occur throughout partings; microstyolitic clay seams with concentrated fossil debris; fractures common around partings; sharp contacts.

i Fossiliferous, peloid-rich wackestone (interbedded with flaky, fissile clay/shale partings) (36cm); wackestone is light gray (N7), weathers pale yellowish orange (10YR 8/6); massive to thinly bedded where beds are produced by discontinuous, fossiliferous clay/shale partings; densely packed ramose bryozoan fragments, crinoid fragments, echinoid spines, phylloid algal blades, Composita, Crurithyris (shell fragments), foraminiferids (fusulinids, Tetrataxis), productid spines, horn corals; clay/shale partings are black (N1), contain large amount of fossil debris (same biota as wackestone) and micritic intraclasts; partings concentrated in upper part of unit; mottled; uppermost 11cm of unit separated from lower 24cm by major clay/shale parting; contacts wavy, sharp.

j Fossiliferous, peloid-rich wackestone (247cm); light gray (N7) to brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) to white (N9); massive, but appears bedded in places due to irregular, local brownish black (5YR 2/1) clay/shale partings; phylloid algal blades, Composita (articulated and shell fragments), Crurithyris (shell fragments), fusulinids, ramose bryozoan fragments, productid spines, crinoid fragments, echinoid spines, horn coral fragments; peloid-rich micrite increases upward as do microstyolitic clay seams; irregular chert concretions, unidentifiable fossil debris occur within some partings; fossils randomly oriented, with many elongated fragments vertical; sharp upper contact, gradational lower contact.

k Fossiliferous, peloid-rich wackestone (7.5cm); medium gray (N5); thin bed; phylloid algal blades, brachiopod (productids) shell fragments, crinoid fragments, ramose bryozoan fragments; upper contact (3.5cm) gradational with interbedded, medium gray (N5) to dark gray (N3) fossiliferous wackestone rubble, and brownish black (5YR 2/1) clay/shale partings; sharp, wavy lower contact with unconsolidated silt- and clay-size grains.

l Fossiliferous wackestone (5cm); medium gray (N5) interbedded with fossiliferous clay/shale partings; Crurithyris, Composita (articulated and shell fragments), ramose bryozoan fragments, crinoid fragments, echinoid spines, phylloid algal blades; in places, fossils parallel laminations, however, most biota randomly dispersed; crinoid fragments within partings abraded; Composita geopetals do not exhibit consistent up-directions; sharp upper contact.



Locality Description: Strat. Sec. 884,

Wall of old strip pit, (1mi)S. of Hwy. 60 at intersection of east-west and north-south county roads; quarry along S. side of Hwy. 60.

Location: SW1/4, SW1/4, Sec. 35, T.26N., R.17E.;

NE1/4, NW1/4, Sec. 34, T.26N.,R.17E., Nowata Co., Oklahoma.

Measured By: S. Roth 1989

Remarks: same as Knight's (1985) MON.

Description

Bed No.

Fort Scott Formation

Blackjack Creek Limestone Member

1 a Fossiliferous, rooted(?) mudstone to wackestone (46cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); dark yellowish orange (10YR 6/6) concentrated within rhizocretions with coarse, blocky calcite, dolomite, fossil debris; Linoproductus (articulated and shell fragments), foraminiferids (fusulinids, globivalvulinids), productid spines, bivalve shell fragments; rhizocretions oriented vertical, nearly horizontal, and U-shaped; chert nodules occur locally, some partially infilling presumed roots; irregular upper surface (weathered); lower contact sharp.

b Fossiliferous, rooted(?) mudstone (19cm); brownish gray (5YR 4/1) to light brownish gray (5YR 6/1), weathers dark yellowish orange (10YR 8/6); massive; foraminiferids (globivalvulinids), Linoproductus (articulated and shell fragments), productid spines, crinoid fragments; dark yellowish orange (10YR 6/6) rhizocretions (not as abundant as in overlying unit) filled with calcite, dolomite, and unconsolidated clay-size grains; contacts slightly gradational to sharp.

c Fossiliferous, peloid-rich wackestone (96cm); brownish gray (5YR 4/1) to light brownish gray (5YR 6/1), weathers pale yellowish orange (10YR 8/6); massive, appears thickly bedded due to weathered clay/shale partings; mottled; fusulinids, Linoproductus, Composita (articulated and shell fragments), crinoid fragments, sponge spicules, bivalve shell fragments, Fistulipora bryozoan fragments, productid spines, trilobite fragments; chert concretions and fusulinids concentrated along partings; contacts slightly gradational, wavy; small (5mm to 5cm), vertical burrows(?) throughout.

d Fossiliferous, peloid-rich wackestone to packstone (169cm); brownish gray (5YR 4/1) and light brownish gray (5YR 6/1) to medium light gray (N6), weathers very light gray (N8) and pale yellowish orange (10YR 8/6); weathering concentrated along fusulinid-rich clay/shale partings which break up unit; massive to nodular bedding (upper 76cm); mottled; fossils best preserved near base; crinoid fragments, Cleiothyridina (articulated and shell fragments), Composita (thin-shelled fragments), marginiferids (articulated), Punctospirifer (articulated), bivalve shell fragments; foraminiferids (fusulinids, globivalvulinids), Wilkingia (articulated), echinoid spines, Fistulipora and ramose bryozoan fragments; clay/shale partings concentrated in upper 76cm; very small (4cm wide), laminar Chaetetes fragments occur within and around partings (not very common) as do silt-size quartz grains; mud-rich clasts along base; fossiliferous microstylolitic clay seams prominent; micrite decreases upward; upper contact slightly gradational due to abundant partings, lower contact sharp.

e Fossiliferous, peloid-rich wackestone (128cm); brownish gray (5YR 4/1) and light brownish gray (5YR 6/1) to medium light gray (N6), weathers very light gray (N8) and pale yellowish orange (10YR 8/6); weathering concentrated along fossiliferous clay/shale partings which break up unit; massive to thickly bedded; mottled; phylloid algal blades, crinoid fragments, Composita, Cleiothyridina (shell fragments), productid spines, ramose bryozoan fragments, foraminiferids (fusulinids, Tetrataxis), echinoid spines; microstyolitic clay seams contain small amount of dolomite; silt-size quartz grains and small, irregular chert nodules concentrated within clay/shale partings; micrite content and size of peloids increase upward; coarse, blocky calcite fills vugs, fractures, and large fossil fragments; contacts sharp with unconsolidated silt- to clay-size grains and fossil debris (mainly fusulinids).

f Fossiliferous wackestone to packstone (34cm); very light gray (N8) to pale yellowish orange (10YR 8/6); massive, with fossiliferous (fusulinid) clay/shale partings at upper and lower contacts; fossils fragmented and abraded; Crurithyris, Composita (shell fragments), Fistulipora bryozoan fragments, productid and echinoid spines, phylloid algal blades; contacts sharp with abundant unconsolidated silt-to clay-size grains.

Thin-Section No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Strat. Sec. 884

(Continued from previous page)

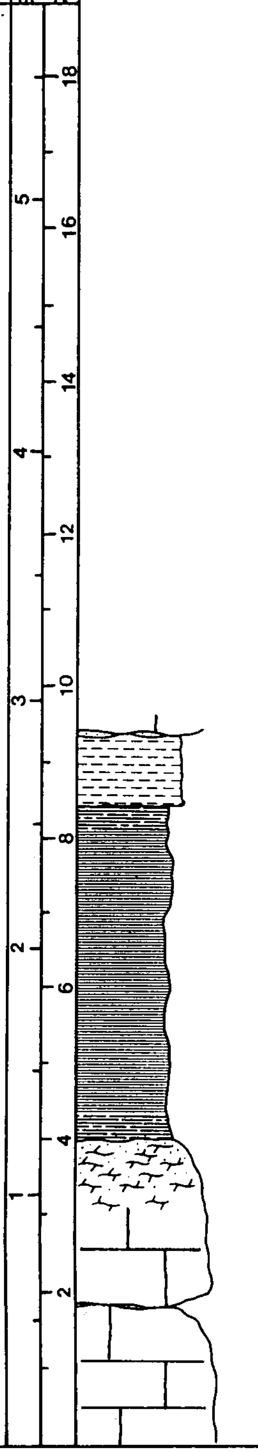
Location:

Measured By:

Remarks:

Bed No. | Description

884.1



Bed No.	Interval No.
1	f
2	a
	b
	c
	d
3	

Excello shale

2 a Fossiliferous, silt-rich claystone (28cm); grayish black (N2), weathers pale yellowish orange (10YR 8/6) to white (N9); blocky to flaky, slightly fissile; brachiopod and bivalve shell fragments, phylloid algal blades(?), productid spines; clay laminae occur throughout; sharp contacts; horizontal and vertical burrows? (1-6cm) throughout; most fossils parallel clay laminae.

b Clay-shale (10cm); black (N1) and dark gray (N3) to olive gray (5Y 4/1) and greenish gray (5GY 6/1), weathers pale yellowish orange (10YR 8/6) in spots; calcareous; flaky to fissile; plant fragments; upper contact sharp, lower contact gradational.

c Bituminous shale (115cm); black (N1), weathers dark yellowish orange (10YR 6/6) to dusky yellow (5Y 6/4) to white (N9); fissile, phosphatic; conodonts; phosphate nodules concentrated in middle of unit and decrease toward contacts where shale breaks into small (4mm) platelets; as nodules increase in size, they also become flatter; upper contact gradational with unconsolidated silt- and clay-size grains, lower contact sharp (slightly gradational).

d Clay-shale (11cm); olive gray (5Y 4/1) to grayish black (N2) weathers pale yellowish orange (10YR 8/6); calcareous; flaky to fissile; contacts sharp; unconsolidated silt-and clay-size grains concentrated along contacts.

Cabaniss Formation

Breezy Hill Limestone Member

3 Fossiliferous, dolomitic wackestone to packstone (122cm); light gray (N7) to light olive gray (5Y 6/1) to greenish gray (5GY 6/1), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive unit with upper 35cm thinly bedded to laminated, weathered, and dolomitic-rich; bivalve shell fragments, fenestrate and ramose bryozoan fragments; upper contact gradational with unconsolidated clay- and silt-size grains.

Locality Description: Strat. Sec. 851

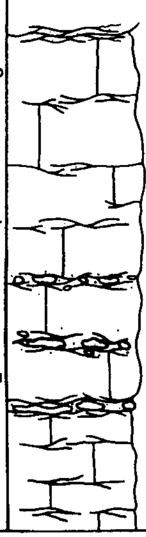
(Continued from previous page)

Location:

Measured By:

Remarks:

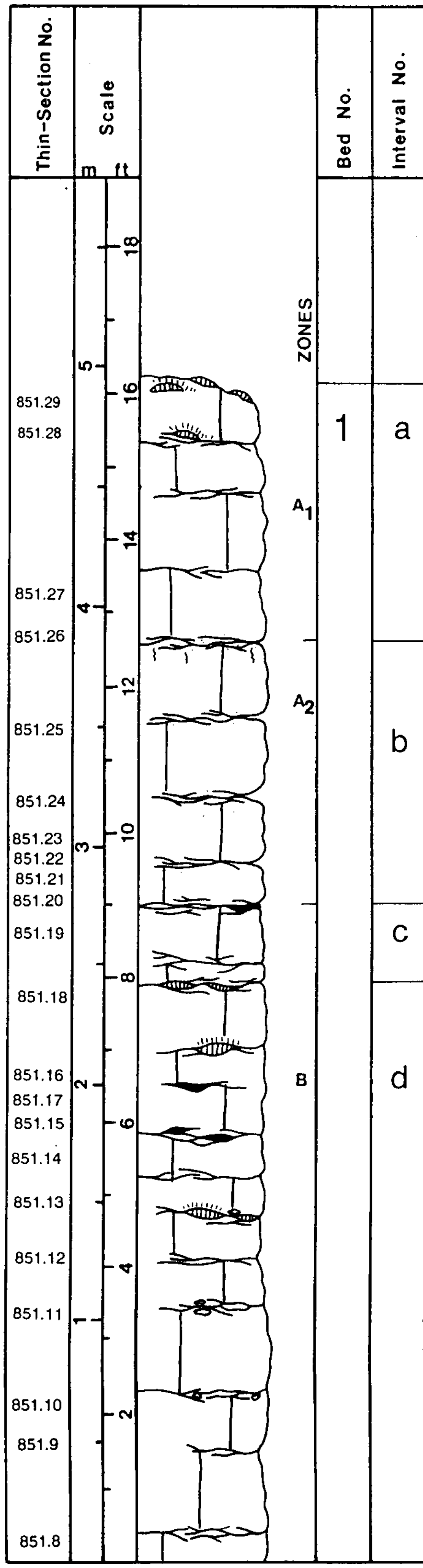
Thin-Section No.	Scale (m / ft)		Bed No.	Interval No.
	5 / 18, 16			
	4 / 14, 12			
	3 / 10, 8			
	2			d
851.7	6		1	e
851.5				
851.6		c		
851.4	4			
	1			
851.3				
	2			
851.2				f
851.1				



Bed No. — **Description**

1 e Fossiliferous, peloid-rich wackestone to packstone (150cm); medium light gray (N6) to light gray (N7), weathers white (N9); massive unit broken up by clay/shale partings, some microstyolitic; mottled; densely packed crinoid fragments, echinoid spines, Composita (articulated and shell fragments), phylloid algal blades, ramose bryozoan fragments, gastropod fragments, productid spines (fossils occur within partings and limestone); wavy, sharp contacts with well developed clay/shale partings; at 21.5cm and 45.5cm from base of unit, fossiliferous wackestone rubble is interbedded with fossiliferous clay/shale partings; partings contain clay- to silt-size quartz grains with patches of micrite.

f Fossiliferous, peloid-rich wackestone (48cm); medium gray (N5) and dark gray (N3) to very light gray (N8), weathers white (N9) in spots; massive with numerous clay/shale partings; phylloid algal blades, foraminiferids (fusulinids, Tetrataxis), crinoid fragments, productid spines, ramose bryozoan fragments, Composita (shell fragments); upper contact (2cm) contains fossiliferous, peloid-rich, wackestone rubble interbedded with clay/shale partings; clay-size quartz grains dispersed throughout partings; sharp contacts.



Locality Description: Strat. Sec. 851,
S. wall of active quarry on N. side of east-west county road E. of Lake Oolagah.

Location: SW1/4, SE1/4, Sec. 33, T.23N., R.16E., Rogers Co., Oklahoma.

Measured By: S. Roth 1989

Remarks: same as Knight's (1985) OOW.

Description

Bed No.

Fort Scott Formation

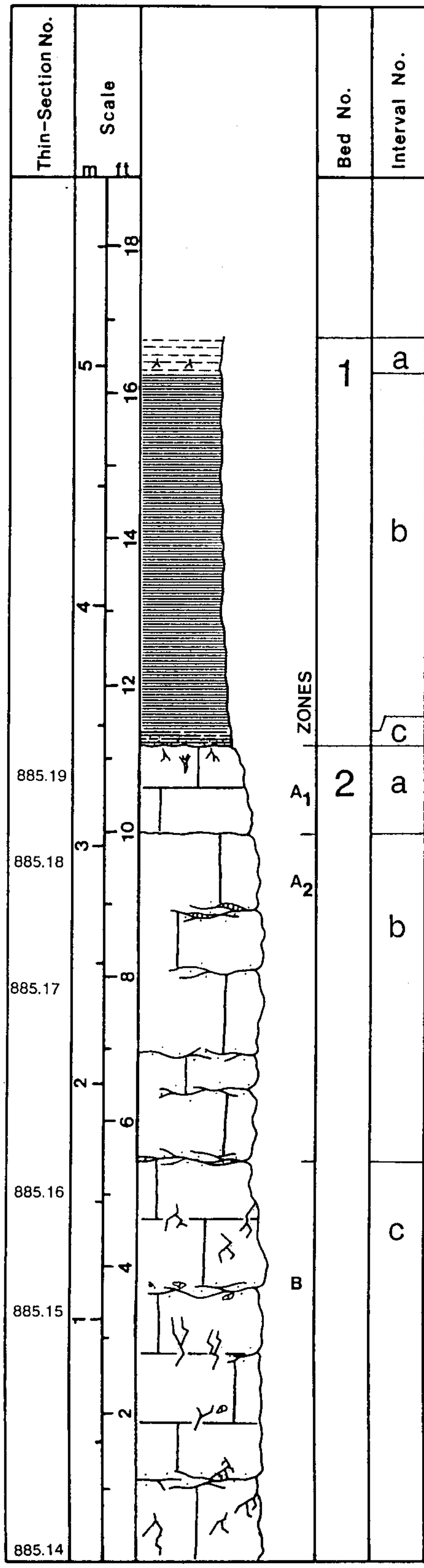
Blackjack Creek Limestone Member

1 a Fossiliferous, micritic (peloids) wackestone (111cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); massive with wavy, fossiliferous clay/shale partings breaking up unit; densely packed, fragmented fossils; foraminiferids (fusulinids, Tetrataxis, palaeotextulariids), large (11cm) bellerophontid (Composita within aperture), low-spire gastropods, bivalve shell fragments, crinoid fragments, productid shell fragments, ostracodes (articulated), ramose and fenestrate bryozoan fragments, phylloid algal blades, productid spines, Neosyringopora; thin laminar Chaetetes occur within upper part and on top of unit; lower contact wavy, slightly gradational.

b Sparsely fossiliferous wackestone (112cm); brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) to very pale orange (10YR 8/2); thick lenticular beds; foraminiferids (Tetrataxis, fusulinids, globivalvulinids, palaeotextulariids), sponge spicules, productid spines, ostracodes (articulated), bivalve shell fragments, low-spire gastropod fragments, Composita (articulated and shell fragments), Linoproductus (shell fragments), crinoid fragments; individual beds cannot be traced laterally, broken up by fusulinid-rich clay/shale partings; contacts wavy, slightly gradational; lower contact contains clay/shale partings, abundant fossil debris, (fusulinids), chert concretions; uppermost part of unit contains small (5-10cm) burrows(?).

c Fossiliferous, peloid-rich wackestone to packstone (35cm); brownish gray (5YR 4/1) to dark gray (N3); massive with clay/shale partings throughout; densely packed fusulinids, Composita (shell fragments), sponge spicules, bivalve shell fragments, gastropod fragments, phylloid algal blades; microstyolitic clay seams with dolomite crystals common; contacts wavy, gradational with numerous clay/shale partings.

d Fossiliferous, peloid-rich packstone (247cm); light olive gray (5Y 6/1) to brownish gray (5YR 4/1), weathers pale yellowish orange (10YR 8/6) to white (N9); massive with bedded appearance produced by weathered, discontinuous clay/shale partings; foraminiferids (fusulinids, globivalvulinids, Tetrataxis), Composita (articulated and shell fragments), horn corals, fenestrate, Fistilipora and ramose bryozoan fragments, crinoid fragments, Neospirifer(?) (shell fragments), phylloid algal blades, Chaetetes, Neosyringopora (on top of chaetetids), productid spines, articulated ostracodes; infrequent peloids; contacts undulatory, sharp with well developed fossiliferous clay/shale partings; chert concretions, and in places, limestone rubble within partings; At 145.5cm, 218.5cm, and 242.5cm from base of unit, laminar chaetetids occur.



Locality Description: Strat. Sec. 885,
composite of: S. bank of Verdigris River along "Claremore Mound" E.
of railroad bridge; bank of Verdigris River beneath wooden bridge.

Location: Approx. C, Section 13, T.22N., R.15E.; Ctr. of
Section 14, T.22N., R.15E., Rogers Co., Oklahoma.

Measured By: S. Roth 1989

Remarks: same as Schell's (1955) S5.

Description

Bed No.

Fort Scott Formation

Little Osage Shale Member

1 a Claystone (17cm); olive gray (5Y 4/1), weathers dark yellowish orange (10YR 6/6); blocky; highly weathered with minor amounts of silt; flaky to fissile; lower contact slightly gradational; dark yellowish orange root(?) traces.

b Bituminous shale (151cm); black (N1) to dark gray (N3); fissile, phosphatic; phosphate nodules distributed throughout, decrease with increasing clay content toward contacts (clay-shale); conodonts, Orbiculoidea, plant fragments(?) in upper most part of unit; contacts smooth, gradational.

c Clay-shale (6cm); olive gray (5Y 4/1), weathers dark yellowish orange (10YR 6/6); calcareous; unit highly weathered with abundant unconsolidated clay-size grains; upper contact gradational, lower contact sharp.

Blackjack Creek Limestone Member

2 a Fossiliferous wackestone to micritic packstone (37cm); light gray (N7) to medium gray (N5), weathers pale yellowish orange (10YR 8/6), in spots; massive (weathered); fusulinids, Linoproductus (articulated and shell fragments), Composita (shell fragments), ostracodes (articulated), productid spines, gastropod fragments; upper surface very weathered, undulatory; rhizocretions(?) present, but not abundant (1-2cm wide; 4-7cm long); fusulinids throughout matrix and rhizocretions; upper contact sharp, lower contact gradational.

b Fossiliferous, peloid-rich wackestone to micritic packstone (135.7cm); light gray (N7) to medium light gray (N6), weathers pale yellowish orange (10YR 8/6); massive to lenticular bedding; clay/shale partings break-up unit into discontinuous beds; fossils mainly broken fragments of Composita (shell fragments), Linoproductus, Annuliconcha cf. A. interlineata (shell fragment), bellerophontid fragments, productid spines, sponge spicules, gastropod fragments, phylloid algal blades, Neosyringopora, crinoid fragments; micrite, clay coat individual fossil grains; coarse, blocky calcite fills fractures and small vugs; micrite content decreases upwards; isolated silt-size quartz grains occur as micrite decreases; upper contact gradational, lower contact sharp; within upper 32cm, laminar Chaetetes occur, most commonly beneath weathered clay/shale partings.

c Fossiliferous packstone (170cm); light gray (N7), weathers pale yellowish orange (10YR 8/6); massive to thickly bedded, highly fractured; fossils poorly preserved (mainly fragments); foraminiferids (Tetrataxis, fusulinids), phylloid algal blades, crinoid fragments, ramose bryozoan fragments, productid spines, Composita, Crurithyris (shell fragments); isolated peloid-rich wackestone clasts occur locally; sharp contacts.

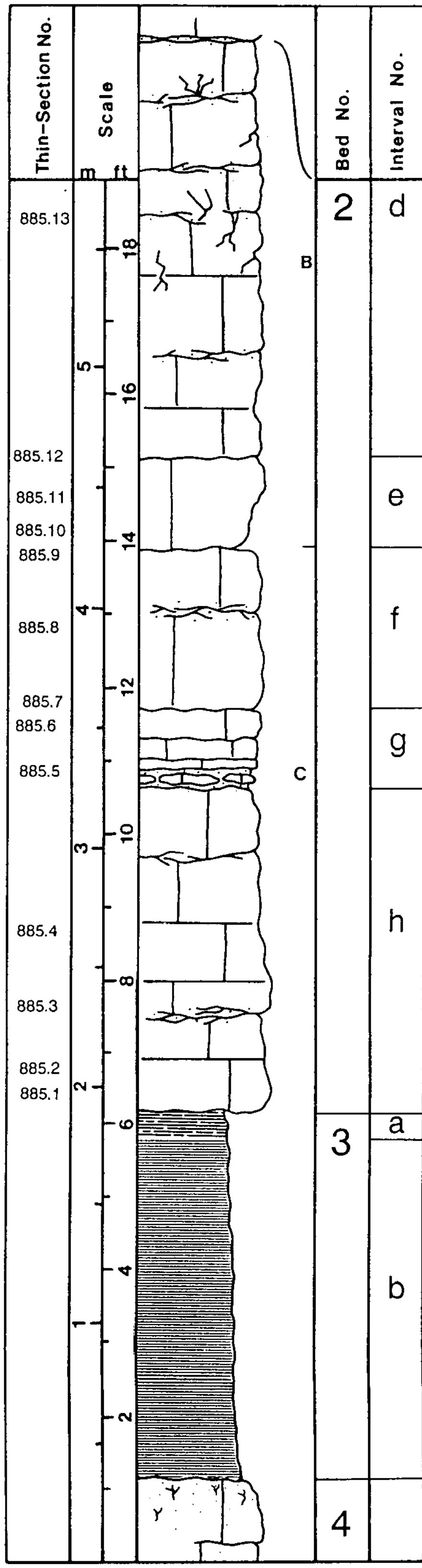
Locality Description: Strat. Sec. 885

(Continued from previous page)

Location:

Measured By:

Remarks:



Description

Bed No.

2 d Fossiliferous peloid-rich packstone (177cm); medium light gray (N6) to light gray (N7), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); massive with numerous fractures; mottled; foraminiferids (fusulinids, Tetrataxis), phylloid algal blades, productid and echinoid spines, Crurithyris (articulated and shell fragments); flattened peloids; clay occurs as microstyolitic seams; sharp contacts; good brachiopod geopetals.

e Fossiliferous packstone (37cm); massive to thickly bedded; light gray (N7), weathers pale yellowish orange (10YR 8/6); Composita (articulated and shell fragments), Crurithyris (articulated), foraminiferids (fusulinids, Tetrataxis, palaeotextulariids), gastropod fragments, productid and echinoid spines, ramose and fenestrate bryozoan fragments, crinoid fragments, Echinaria(?) (shell fragment), unidentifiable fine-grain fossil debris; areas of peloid-rich micrite, concentrated in fractures and vugs; microstyolitic clay seams drape fossil grains in places; upper contact sharp, lower contact gradational.

f Fossiliferous wackestone to packstone (67cm); pale yellowish orange (10YR 8/6); massive to thickly bedded; ramose bryozoan fragments, Crurithyris (articulated and shell fragments), phylloid algal blades (concentrated along and parallel to clay seams), productid spines, crinoid fragments, foraminiferids (palaeotextulariids); coarse crystalline calcite fills vugs and fractures; many fossil grains have micritic coatings, especially foraminiferids; gradational contacts.

g Fossiliferous, peloid-rich wackestone to packstone (34cm); light gray (N7), weathers dark yellowish orange (10YR 6/6); massive to nodular rubble (very weathered) with interbedded unconsolidated, dark yellowish orange, silt- and clay-size grains; productid spines, Crurithyris, Composita (shell fragments), and crinoid fragments; dolomite occurs within brachiopod geopetals; coarse calcite and dolomite(?) fill vugs and fractures along with isolated micrite; gradational contacts.

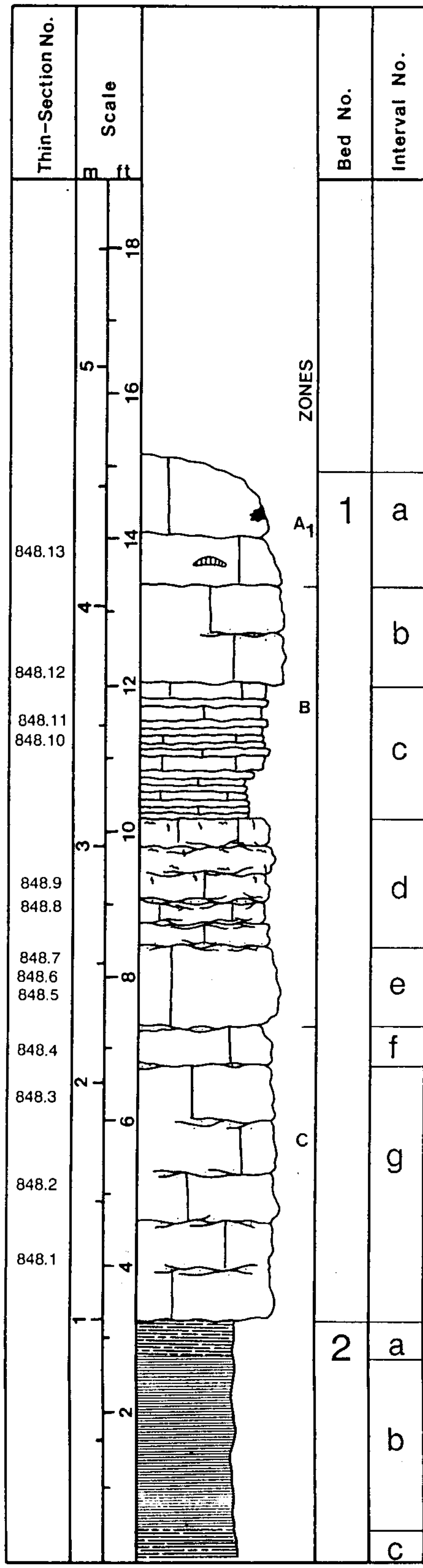
h Fossiliferous, peloid-rich wackestone to packstone (136cm); light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6); massive to thick lenticular beds (due to weathered clay/shale partings); fossils fragmented and abraded; crinoid fragments, Foraminiferids (Tetrataxis), phylloid algal blades, ramose bryozoan fragments, Composita (shell fragments), productid spines; peloids concentrated along microstyolitic clay seams, and in most places, flattened; fossil fragments concentrated near top of unit; gradational upper contact, sharp lower contact.

Excello shale

3 a Clay-shale (12cm); olive gray (5Y 4/1) and light olive gray (5Y 6/1) to black (N1); calcareous; flaky to platy, poor fissility; upper most 1.3cm is pale yellowish orange (10YR 8/6), friable, flaky clay-shale; sharp upper contact, gradational lower contact.

b Bituminous shale (144.8cm); black (N1), weathers dark yellowish orange (10YR 6/6) and moderate reddish brown (10R 4/6); fish fragments(?), conodonts; fissile, phosphatic; fissility decreases toward contacts, especially upward where clay dominates; phosphate nodules common throughout; upper contact gradational, lower contact sharp.

4 Fossiliferous, dolomitic siltstone to wackestone (60cm); olive gray (5Y 4/1) and light olive gray (5Y 6/1), weathers very pale orange (10YR 8/2); massive (weathered); mottled (bioturbated); brachiopod and bivalve shell fragments, fusulinids, algal blades(?); poorly preserved rhizocretions, silt-size quartz grains, and peloids throughout; sharp upper contact.



Locality Description: Strat. Sec. 848,

S. cut bank of Bird Creek beneath Hwy. 167 bridge, S. of Catoosa,

Oklahoma.

Location: NW1/4, Sec. 19, T.20N., R.15E.,

Rogers Co., Oklahoma.

Measured By: S. Roth 1989

Remarks: near Knight's (1985) BC.

Description

Bed No.

Fort Scott Formation

Blackjack Creek Limestone Member

1 a Fossiliferous, peloid-rich wackestone to packstone (55cm); pale yellowish brown (10YR 6/2), weathers very pale orange (10YR 8/2) and pale yellowish orange (10YR 8/6); two massive beds; Composita (shell fragments), ramose bryozoan fragments, crinoid fragments, foraminiferids (fusulinids, Tetrataxis), productid spines, Chaetetes; upper bed contains irregular, dark reddish brown (10R 3/4) chert concretions, lower bed contains isolated laminar Chaetetes; lower contact sharp, undulatory.

b Fossiliferous, micritic packstone (42cm); pale yellowish brown (10YR 6/2), weathers very pale orange (10YR 8/2) to pale yellowish orange (10YR 8/6) with dark yellowish orange (10YR 6/6) stains; massive with discontinuous break in center due to weathered clay/shale parting; mottled; fossils fragmented and abraded; phylloid algal blades, Composita (shell fragments), productid shell fragments, ramose bryozoan fragments; sharp contacts.

c Fossiliferous wackestone (58cm); light gray (N7) to pale yellowish brown (10YR 6/2), weathers pale yellowish orange (10YR 8/6); thin nodular beds; Crurithyris, Composita (shell fragments), bivalve shell fragments(?), productid spines, ramose bryozoan fragments, crinoid fragments; peloids, fine-grain dolomite and fossil debris concentrated along microstyolitic clay seams; contacts sharp, undulatory.

d Fossiliferous wackestone to packstone (54cm); pale yellowish brown (10YR 6/2), weathers pale yellowish orange (10YR 8/6); massive to lenticular bedding with discontinuous clay/shale partings; fossil diversity decreases upward; crinoid fragments, productid spines, foraminiferids (Tetrataxis, fusulinids), ramose bryozoan fragments, echinoid spines; basal part of unit weathered; mottled with horizontal and vertical burrows(?); sharp contacts; burrows(?) contain micrite and extremely fine-grain fossil debris (mainly crinoid and brachiopod fragments).

e Fossiliferous packstone (35cm); pale yellowish brown (10YR 6/2), weathers very pale orange (10YR 8/2) and pale yellowish orange (10YR 8/6); massive; mottled; Composita, Crurithyris (articulated and shell fragments), bivalve (pectin?) shell fragments, ramose bryozoan fragments, crinoid fragments, productid and echinoid spines, low-spire gastropod fragments, foraminiferids (Tetrataxis, fusulinids, palaeotextulariids); micrite (peloids) decreases upward as clay content increases; sharp contacts; three brachiopod geopetals not consistent with up-direction (not consistent with each other).

f Fossiliferous wackestone (14cm); pale yellowish brown (10YR 6/2), weathers pale yellowish orange (10YR 8/6) to very pale orange (10YR 8/2); massive; phylloid algal blades, Crurithyris (articulated and shell fragments), Composita (articulated), productid spines, crinoid fragments, ramose bryozoan fragments, foraminiferids (Tetrataxis); coarse crystalline calcite occurs in fractures, vugs, and fossil fragments; sharp contacts with unconsolidated silt- and clay-size grains.

g Fossiliferous, peloid-rich wackestone to packstone (107cm); pale yellowish brown (10YR 6/2) to light gray (N7), weathers pale yellowish orange (10YR 8/6); massive; unit broken up by clay/shale partings; mottled; densely packed fossil debris; phylloid algal blades, Composita (shell fragments), crinoid fragments, productid and echinoid spines, ramose bryozoan fragments; micrite decreases upward as clay content increases; coarse calcite and dolomite concentrated in fossil fragments and fractures; phylloid algal blades, large brachiopod fragments shelter areas where fossil debris, peloids accumulate.

Stratigraphic Section 848

(Descriptions continued from previous page)

Excello shale

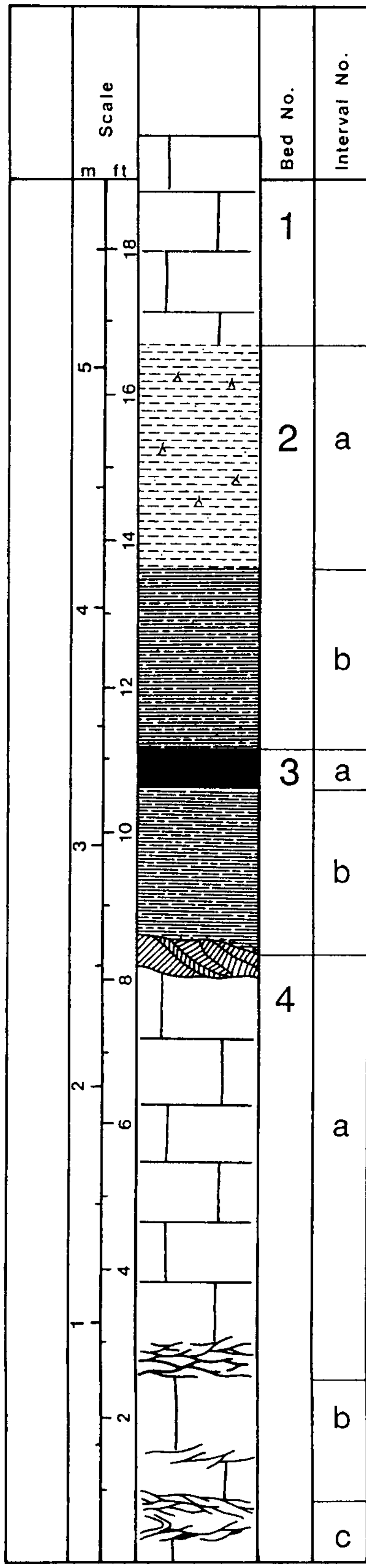
2 a Clay-shale (15cm); dark gray (N3) to medium dark gray (N4) and, in places, weathers pale yellowish orange (10YR 8/6); blocky to flaky, poor fissility; gradational contacts; upper contact contains pebble-size limestone clasts and unconsolidated clay-size grains.

b Bituminous shale (70cm); black (N1), weathers dark yellowish orange (10YR 6/6) to dark reddish brown (10YR 3/4); fissile, phosphatic; conodonts; phosphate nodules distributed randomly throughout; platy to flaky; shale weathers into small, brittle platelets; gradational upper contact, sharp lower contact.

c Clay-shale (12cm); dark gray (N3) to medium dark gray (N4) and, in places, weathers pale yellowish orange (10YR 8/6); calcareous; blocky to flaky; plant fragments(?); poor fissility; sharp upper contact.

APPENDIX B

Core Descriptions
Used in Regional Study
In Conjunction With
Stratigraphic Sections



Locality Description: Core C-33,
S. end of Fort Scott reservoir dam. Surface elevation is 260m (853ft).

Location: SE1/4, SE1/4, Sec. 5, T.26S., R.24E.,
Bourbon Co., Kansas.

Measured By: S. Roth 1989

Remarks: core obtained from U.S. Army Core of Engineers.

Description

Bed No.

1 Labette Shale Formation
Fossiliferous, peloid-rich wackestone (85cm); medium light gray (N6), weathers very pale orange (10YR 8/2) to light gray (N7); phylloid algal blades, crinoid fragments; sharp lower contact.

2 a Silty claystone (96cm); light gray (N7) to light olive gray (5Y 6/1), weathers moderate reddish brown (10R 4/6); clay- to silt-size quartz grains throughout; slightly calcareous; blocky to flaky; sharp upper contact, gradational lower contact; moderate reddish brown root(?) traces (10R 4/6) throughout.

b Clay-shale (75cm); light gray (N7) to light olive gray (5Y 6/1), weathers moderate reddish brown (10R 4/6); calcareous; blocky, flaky to fissile with fissility better at base; silt content increases downward (varies throughout); gradational contacts.

3 a Coal (16cm); black (N1), weathers bluish white (5B 9/1) to moderate reddish brown (10R 4/6); silt-size quartz grains interbedded with coal; plant fragments; laminated, flaky to fissile; upper contact gradational, lower contact sharp.

b Fossiliferous clay-shale (60.2-68cm); medium gray (N5) and medium light gray (N6) to medium dark gray (N4); crinoid fragments, Composita and Punctospirifer (articulated), and plant fragments; grain size varies, but generally increases toward base of unit; calcareous; slightly blocky, flaky to fissile with fissility better at base; sharp contacts; fossils concentrated in basal 5-10cm.

Fort Scott Formation
Houx-Higginsville Limestone Member

4 a Fossiliferous, peloid-rich wackestone to packstone (188.7cm); very light gray (N8) and light gray (N7) to yellowish gray (5Y 8/1) to light olive gray (5Y 6/1); mottled; fossil grain size increases upward; phylloid algal blades, crinoid fragments, Composita (shell fragments), gastropod fragments, fusulinids, horn corals, ramose bryozoan fragments; uppermost 13cm is laminar Chaetetes; interbedded clay/shale partings concentrated in lowest 15cm with crinoid fragments, fusulinids, and brachiopod shell fragments; upper contact sharp, lower contact gradational.

b Fossiliferous (algal) wackestone (48.8cm); very light gray (N8) and light gray (N7) to medium light gray (N6); phylloid algal blades, fusulinids, brachiopod shell fragments; phylloid algal blades with large (4cm) blades concentrated along base within clay/shale partings, most often perpendicular to up-direction; gradational contacts.

c Fossiliferous wackestone with clay/shale partings (31cm); very light gray (N8) to brownish gray (5YR 4/1); Crurithyris and Composita (shell fragments), ramose bryozoan fragments, fusulinids, crinoid fragments; chert nodules (1mm to 1cm) within partings; upper contact gradational, lower contact sharp.

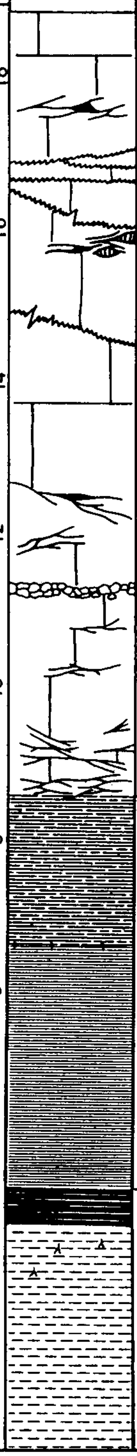
Locality Description: Core C-33

(Continued from previous page)

Location:

Measured By:

Remarks:

Scale (m / ft)		Bed No.	Interval No.
5, 4, 3, 2, 1 (m); 18, 16, 14, 12, 10, 8, 6, 4, 2 (ft)		4	d
			e
			f
		5	a
			b
		6	a
			b

Description

Bed No.

4 d Fossiliferous wackestone (230.2cm); medium light gray (N6) to light olive gray (5Y 4/1), weathers very light gray (N8) along clay/shale partings; mottled (mottling decreases downward); fossil debris concentrated in basal 32cm; phylloid algal blades, brachiopod shell fragments, crinoid fragments, ramose bryozoan fragments, unidentifiable fossil debris; chert concretions and laminar <u>Chaetetes</u> fragments occur within partings; five styolized to microstyolized clay/shale partings separate unit; sharp contacts.

e Intraclastic packstone to grainstone (5.5cm); medium gray (N5) to very light gray (N8); mudstones, wackestones clasts draped by crenulated clay/shale partings; clasts align relatively perpendicular to up-direction; clasts range from 3.2cm to less than 1mm; sharp contacts.

f Fossiliferous wackestone (79.2cm); medium gray (N5) and medium light gray (N6) to very light gray (N8); mottled; phylloid algal blades, crinoid fragments, <u>Composita</u> shell fragments, fusulinids, unidentifiable fossil debris; silt- to clay-size quartz grains occur within fossiliferous, grayish black (N2) to black (N1) clay/shale partings, concentrated in basal part of unit; sharp upper contact, gradational lower contact.

<u>Little Osage Shale Member</u>

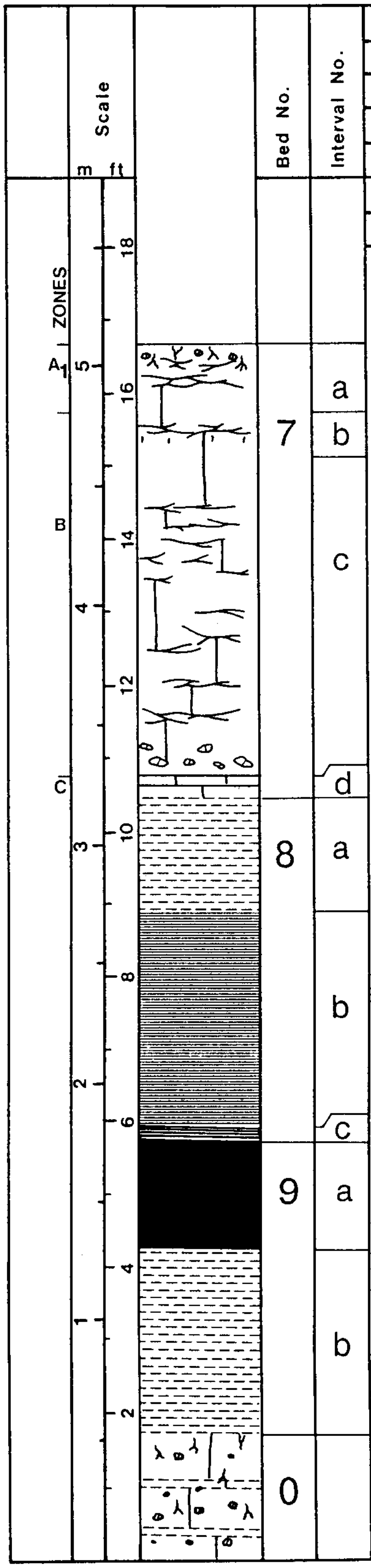
5 a Silty clay-shale (61.5cm); light olive gray (5Y 6/1) to dark gray (N3) and grayish black (N2) to medium gray (N5) and light gray (N7); fossil debris, mainly brachiopod shell fragments, concentrated in upper most 30cm where shell fragments are flat-lying (perpendicular to up-direction); slightly calcareous; laminated to slightly fissile; burrows (1-3cm long) occur near base of unit; gradational contacts.

b Bituminous shale (98.5cm); black (N1) to grayish black (N2); fissile, phosphatic; phosphate nodules dispersed randomly; upper and lower limits contain large amount of clay (clay-shale); gradational contacts.

<u>Summit coal</u>

6 a Coal (14cm); poorly developed; grayish black (N2) to dark gray (N3), weathers white (N9); interbedded with silt-size quartz grains; laminated to fissile, flaky; upper contact gradational, lower contact sharp.

b Claystone (underclay) (89cm); medium light gray (N6) to light olive gray (5Y 6/1); blocky to laminated with "ped" structures; irregular micritic clasts; pale yellowish (10YR 8/6) root(?) traces, and grayish black (N2) to black (N1) plant fragments; sharp upper contact, gradational lower contact.



Locality Description: Core C-33

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

Blackjack Creek Limestone Member

7 a Rooted(?) mudstone (29cm); light olive gray (5Y 6/1) to grayish black (N2); mottled; top of unit very clay-rich with abundant limestone rubble; clay/shale partings throughout; rounded micritic clasts, peloids, clay concentrate in rhizocretions and partings; upper contact slightly gradational, lower contact very gradational.

b Fossiliferous mudstone to wackestone (19cm); light olive gray (5Y 6/1) to dark gray (N3); mottled; fossils poorly preserved; fusulinids, Crurithyris(?) (shell fragments), crinoid fragments, and unidentifiable fine-grain fossil debris; clay/shale partings concentrated in upper-middle part of unit; small vertical borings/burrows(?), less than 1cm long, in central part of unit; gradational contacts.

c Fossiliferous wackestone (135.1cm); light olive gray (5Y 6/1) to dark gray (N3); mottled; fossil diversity decreases upward; foraminiferids (fusulinids), crinoid fragments, Composita (shell fragments), ramose and fenestrate bryozoan fragments, phylloid algal blades, unidentifiable fine-grain fossil debris; mottled; light gray (N7) to dark gray (N3), mudstone clasts(?), concentrated in lowermost 18cm; gradational contacts; in places, algal blades appear to have micritic coating.

d Laminated, clay-rich mudstone (8cm); medium dark gray (N4) to grayish black (N2); mottled; platy, flaky to laminated; gradational contacts; [transitional bed].

Excello shale

8 a Claystone (48cm); medium light gray (N6) to medium dark gray (N4); slightly calcareous; platy to flaky, slightly fissile; pyritized plant fragments, unidentifiable fossil debris; upper 10-15cm micritic; thin, laminar, brownish gray (5YR 4/1) phosphate nodules, within lower 20cm; gradational contacts.

b Bituminous shale (91cm); black (N1) to grayish black (N2); fissile, phosphatic; laminar to rounded phosphate nodules throughout except in lowermost 11cm; clay becomes prominent at base, to where it dominates (clay-shale); flattened, medium gray (N5) burrows (Chondrites?) concentrated in uppermost shale; gradational contacts.

c Fossiliferous shale (6cm); grayish black (N2), weathers white (N9); fissile; shell fragments?, and Orbiculoidea concentrated along fissile bedding planes; gradational upper contact, sharp lower contact.

Mulky coal

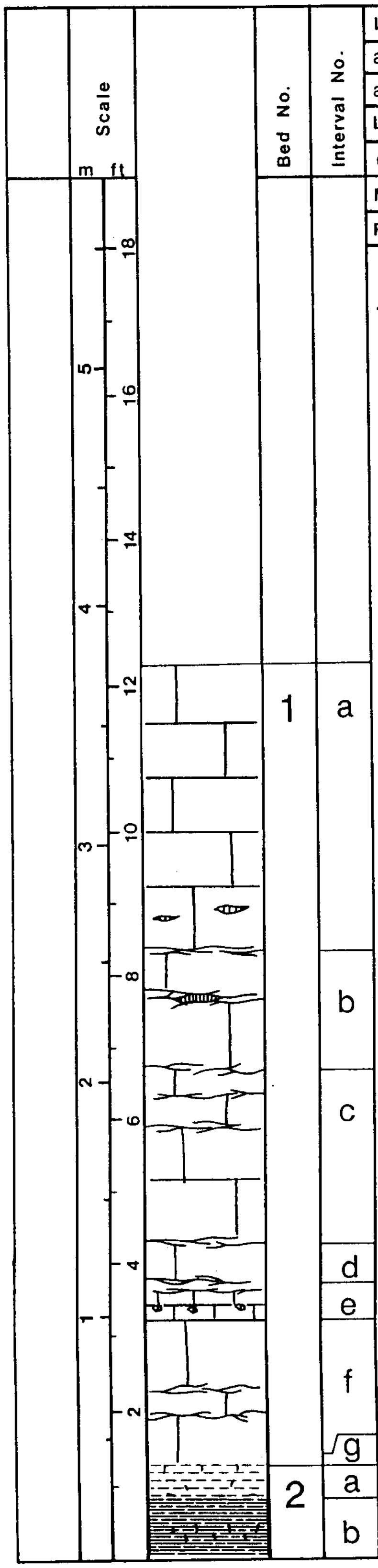
9 a Coal (46cm); black (N1) weathers white (N9); blocky to slightly fissile in uppermost part; upper contact gradational, lower contact sharp.

b Claystone (underclay) (78cm); light gray (N7) to light olive gray (5Y 6/1); plant fragments; blocky to slightly laminated; mottled; upper contact sharp, lower contact gradational.

Cabaniss Formation

Breezy Hill Limestone Member

0 Clay-rich mudstone to silty claystone (52cm); greenish gray (5GY 6/1) to olive black (5Y 2/1) to brownish black (5YR 2/1), weathers grayish orange (10YR 7/4); mottled; "ped" structures common with numerous mudcracks(?) and microfractures; brownish black (5YR 2/1) micritic clasts and grayish orange root traces throughout.



Locality Description: Core 706,
above abandoned quarry (now filled in with water), (1/2mi) S.
and (1/2mi) W. of Englevale, Kansas. Surface elevation is 295m (968ft).

Location: NW1/4, NW1/4, Section 25, T. 28S., R. 24E.,
Crawford Co., Kansas.

Measured By: S. Roth 1989

Remarks: Quarry owned by Rose Cukjati.

Description

Bed No.

Fort Scott Formation

Houx-Higginsville Limestone Member

1 a Fossiliferous (fusulinid) packstone to grainstone (118.5cm); light olive gray (5Y 4/1) and light gray (N7) to very light gray (N8), weathers pale yellowish orange (10YR 8/6) and grayish orange (10YR 7/4) in upper 13cm; densely packed fusulinids, with crinoid fragments, Composita, Derbyia, Neospirifer (shell fragments), phylloid algal blades, laminar Chaetetes; coarse crystalline calcite fills vugs and fractures; sharp lower contact (thin clay/shale parting).

b Fossiliferous (algal) wackestone (50cm); very light gray (N8) to light gray (N7), weathers pale yellowish orange (10YR 8/6) and yellowish gray (5Y 8/1), concentrated along clay/shale partings; phylloid algal blades, Fistulipora, foraminiferids, Composita (articulated and shell fragments), productid shell fragments, crinoid fragments, horn corals; at 19.5cm from upper contact, fossiliferous clay/shale parting (7.5cm thick) occurs with laminar Chaetetes; upper contact sharp, lower contact gradational; both contacts consist of weathered clay/shale partings.

c Sparsely fossiliferous, dolomitic mudstone (75.5cm); light gray (N7) to very light gray (N8) with pale yellowish orange (10YR 8/6) dolomite; mottled; Composita (articulated and shell fragments), Neospirifer? (shell fragments), phylloid algal blades, ramose bryozoan fragments, fusulinids; gradational contacts; at upper contact and at 12cm from upper contact, fossiliferous clay/shale partings occur.

d Fossiliferous (peloid-rich) wackestone to packstone (14.5cm); light gray (N7) to very light gray (N8); densely packed fossils along base of unit (clay/shale parting); phylloid algal blades (some with micritic coatings), crinoid fragments, Composita (shell fragments), fusulinids, bryozoan fragments, echinoid spines(?); sharp contacts with weathered clay/shale partings.

e Sparsely fossiliferous, dolomitic mudstone (14.8cm); light gray (N7) to very light gray (N8), stains pale yellowish orange (10YR 8/6); brachiopod (productid) shell fragments, phylloid algal blades, fusulinids; sharp contacts; upper contact contains fossiliferous clay/shale partings; at 4.4cm from upper contact, second microstyolitic clay/shale parting occurs; throughout basal 8cm, angular, light gray (N7) wackestone intraclasts occur.

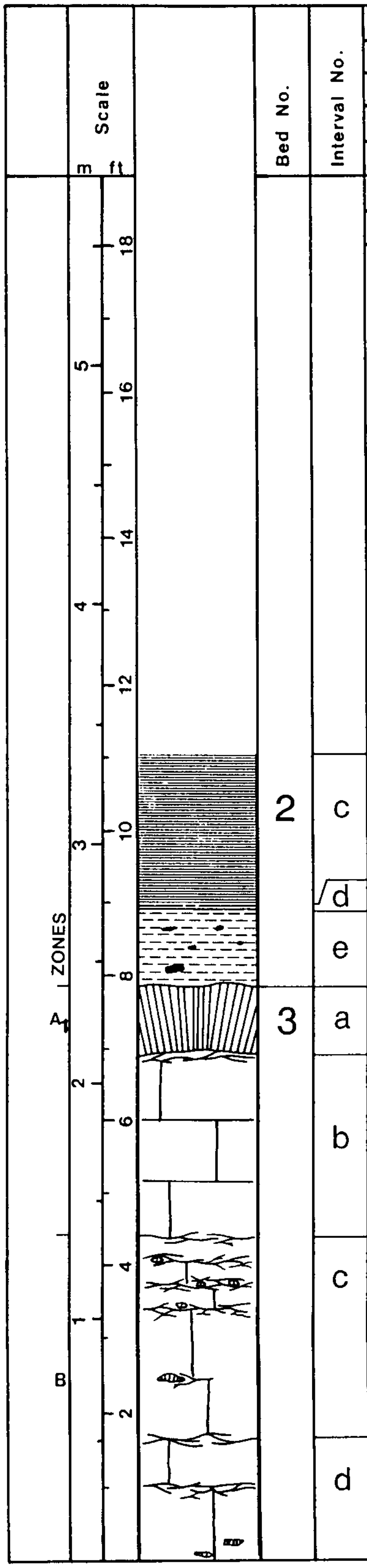
f Fossiliferous (algal) wackestone to packstone (56cm); medium light gray (N6) and very light gray (N8) to medium gray (N5); interbedded medium gray (N5) to dark gray (N3) clay/shale partings, at 33.6cm and at 42cm from upper contact; phylloid algal blades (up to 3cm long), Composita, Punctospirifer (articulated and shell fragments), crinoid fragments, gastropod fragments, fenestrate bryozoan fragments; sharp upper contact, gradational lower contact.

g Fossiliferous wackestone to packstone (5.7cm); medium light gray (N6) to medium gray (N5); brachiopod shell fragments, phylloid algal blades, foraminiferids; gradational contacts; abundant, silt- to very fine sand-size, unidentifiable fossil debris throughout.

Little Osage Shale Member

2 a Burrowed claystone (13cm); medium gray (N5) to light olive gray (5Y 4/1) with medium dark gray (N4) burrows; horizontal and vertical burrows (1-3cm long; 1-5mm wide); horizontal burrows flattened and concentrated along base of unit; blocky to flaky; gradational contacts.

b Sparsely fossiliferous clay-shale (24cm); medium gray (N5) to grayish black (N2); calcareous; flaky, fissile; brachiopod shell fragments, crinoid fragments, productid shell fragments, horn coral fragments; intensely burrowed; burrows are medium light gray (N6); burrows most abundant at 17cm to 19cm from upper contact; gradational contacts.



Locality Description: Core 706

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

2 c Bituminous shale (65cm); black (N1); fissile, phosphatic; light olive brown (5Y 5/6) plant fragments, root traces(?); laminar to round phosphate nodules throughout except within 10cm of upper contact; burrows concentrated in upper 8cm, however, not nearly as abundant as in overlying unit; gradational contacts.

d Fossiliferous clay-shale (3cm); grayish black (N2) to medium gray (N5); brachiopod and bivalve shell fragments; calcareous; fissile, flaky; fossils (N9) aligned perpendicular to up-direction, concentrated along fissile planes; gradational upper contact, sharp lower contact.

e Claystone (33cm); light gray (N7) to light olive gray (5Y 6/1); abundant coarse sand- to pebble-size, angular, black (N1) shale clasts; unit poorly consolidated; pieces of black (N1) coal (up to 5cm long) randomly dispersed; sharp contacts with slickensides/styolites(?) developed along lower contact.

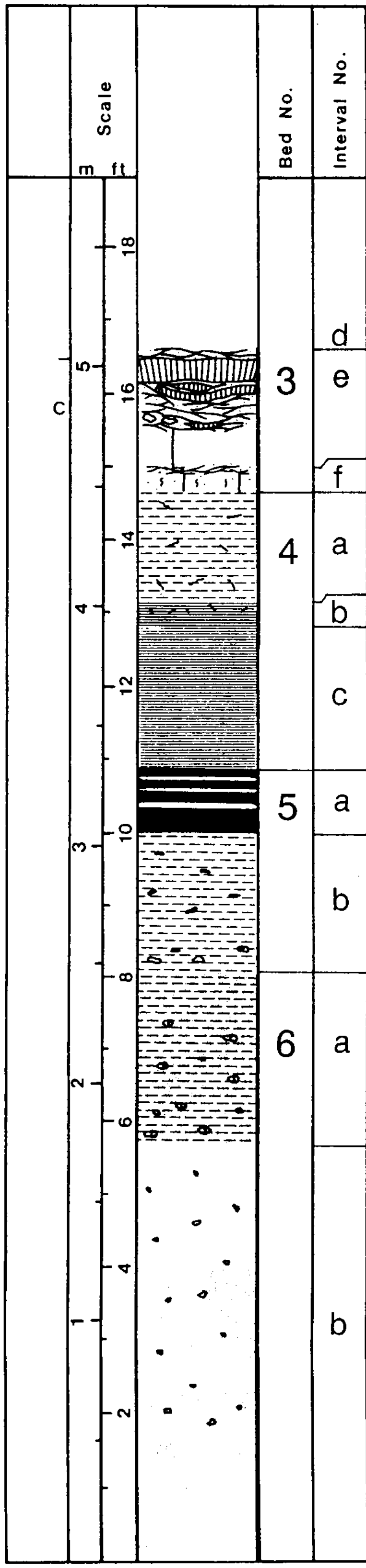
Blackjack Creek Limestone Member

3 a Chaetetes (27.5cm); brownish gray (5YR 4/1); low-domical; thin clay/shale partings along base; white (N9) chert fills in vugs and fractures in chaetetid; sharp contacts.

b Fossiliferous, micritic packstone (76.5cm); medium light gray (N6) to yellowish gray (5Y 8/1); mottled; coarse-grain; moderate brown (5YR 3/4) and brownish gray (5YR 4/1) coarse calcite replaces original fossil material; most fossils 'algal' coated (coatings decrease downward) and less than 1cm long; low- and high-spire gastropods (concentrated in 22cm interval directly below chaetetid), foraminiferids (fusulinids, Tetrataxis), crinoid fragments, productid spines, brachiopod and bivalve fragments; fusulinids most abundant at base, decrease upward; sharp contacts.

c Fossiliferous, peloid-rich wackestone to packstone (85.5cm); medium light gray (N6) to light olive gray (5Y 6/1) to yellowish gray (5Y 8/1); mottled, especially below interval dominated by clay/shale partings; in places, isolated fossils 'algal' coated; fossil diversity decreases in upper 34cm; foraminiferids (fusulinids, Tetrataxis, palaeotextulariids), phylloid algal blade fragments, crinoid fragments, Composita (shell fragments), Cleiothyridina (articulated and shell fragments), low-spire gastropods, productid spines, isolated laminar Chaetetes fragments (60cm below upper contact), fenestrate bryozoan fragments, ostracodes (articulated), horn corals; fossiliferous partings, dusky yellowish brown (10YR 2/2) to brownish gray (5YR 4/1), concentrated in upper 25.5cm, and in places, contain limestone clasts; sharp contacts; along partings, phylloid algal blades mimic laminae.

d Fossiliferous wackestone interbedded with fossiliferous clay/shale partings (50.2cm); medium gray (N5) to yellowish gray (5Y 8/1), concentrated in upper 23cm, then medium gray (N5) to light olive gray (5Y 6/1) to olive gray (5Y 4/1) with grayish black (N2) partings; mottled, with mottling decreasing downward; along base of unit and within clay/shale partings, fossils abraded, fragmented; foraminiferids (fusulinids, palaeotextulariids), crinoid fragments, bivalve shell fragments, fenestrate and ramose bryozoan fragments, ostracodes (articulated and shell fragments), gastropod fragments, Crurithyris, Composita (articulated and shell fragments), other brachiopod shell fragments, phylloid algal blade fragments; fusulinids increase downward; in isolated areas, fossil grains have micritic coatings, especially algal blades; at 7cm and 11cm from lower contact, laminar Chaetetes fragments occur; fossiliferous (crinoids, brachiopods, globivalulinids, productid spines) clay/shale partings occur throughout with limestone clasts(?), clay- to silt-size quartz grains, organics; upper contact gradational, lower contact sharp.



Locality Description: Core 706

(Continued from previous page)

Location:

Measured By:

Remarks:

Description

Bed No.

3 e Fossiliferous wackestone (48.9cm); medium gray (N5) to light olive gray (5Y 6/1) and olive gray (5Y 4/1); upper 10.2cm-14.5cm is laminar Chaetetes with fossiliferous, grayish black (N2) clay/shale partings above and below, where compaction of clay/shale partings was greater beneath chaetetid; fossils abraded and fragmented, especially in partings; crinoid fragments, foraminiferids (palaeotextulariids, fusulinids), brachiopod and bivalve (pectin?) fragments, fenestrate bryozoan fragments, phylloid algal blade fragments; at 13.6cm above lower contact, thin laminar chaetetid fragments interbedded with fossiliferous (fenestrate bryozoan fragments, shell fragments, unidentifiable debris) clay/shale partings; upper contact sharp, lower contact gradational.

f Fossiliferous wackestone to packstone (9cm); dark gray (N3) to medium dark gray (N4); bioturbated (burrowed?); gradational contacts with lower contact irregular (bioturbated); silt- to fine sand-size unidentifiable fossil debris.

Excello shale

4 a Burrowed claystone (48.1cm); medium gray (N5) with dark gray (N3) burrows; mottled/bioturbated; fossils very rare; Linoproductus (articulated), other brachiopod shell fragments, ostracodes (articulated); numerous small (1-6cm long), horizontal burrows throughout; silt- to clay-size quartz grains, laminated in places; gradational contacts.

b Clay-rich shale (9.2cm); black (N1) to grayish black (N2); fossils very rare; conodonts, brachiopod shell fragments, and fish scales(?); fissile; medium dark gray (N4) burrows parallel and cut across bedding planes; in places, shell fragments and burrows pyritized; gradational contacts.

c Bituminous shale (60.5cm); black (N1); conodonts; fissile, phosphatic; laminar to round phosphate nodules (1 to 4cm across) randomly dispersed, many have partial pyritized coatings; large (3 to 4cm) coal pieces occur at 9 to 12cm from base of unit; gradational upper contact, sharp lower contact.

Mulky coal

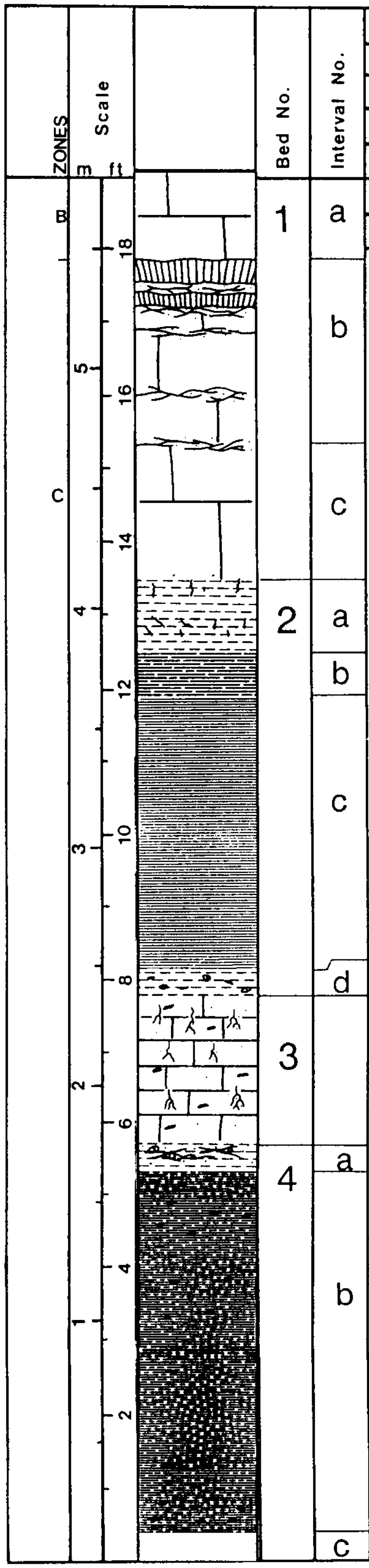
5 a Coal (26.4cm); black (N1) with interbedded black (N1) to grayish black (N2) shale throughout upper 12cm of unit; slightly fissile to blocky; pyritic bands, flakes throughout; upper contact gradational, lower contact slightly gradational to sharp.

b Claystone (underclay) (58.5cm); medium gray (N5) to light olive gray (5Y 6/1), throughout upper 15cm, to very light gray (N8), throughout rest of unit; blocky to flaky; plant fragments (4cm long), pebble-size coal fragments, and fine sand- to pebble-size, angular shale clasts, dark gray (N3) to black (N1) throughout; light olive brown (5Y 5/6), horizontal root(?) traces along laminated surfaces; slightly gradational to sharp upper contact, gradational lower contact.

Cabaniss Formation
Breezy Hill Limestone Member

6 a Intermixed micritic claystone and siltstone (74.6cm); light olive gray (5Y 6/1) to greenish gray (5GY 6/1) and light greenish gray (5G 8/1); heavily bioturbated/mottled; in places, clay and pale yellowish brown (10YR 6/2) micrite are thinly bedded to laminated with laminae broken up by clay and micrite clasts; fine sand- to pebble-size grains occur throughout unit; gradational contacts.

b Clay-rich, dolomitic siltstone (174.8cm); light olive gray (5Y 6/1) to greenish gray (5GY 6/1) and light greenish gray (5GY 8/1), stained dark yellowish brown (10YR 4/2); unit consists of laminated silt- and clay-size quartz and muscovite grains with traces of dolomite (10YR 4/2); fine sand- to pebble-size clay clasts occur throughout, but decrease downward, absent in basal 30cm; overall, clay and carbonate content decrease downward; gradational upper contact.



Locality Description: Core 766, above abandoned quarry (now filled in with water), N. of Sherman, Kansas. Surface elevation is 274m (898ft).

Location: NW1/4, SW1/4, NE1/4, Sec. 13, T.32S., R.21E., Cherokee Co., Kansas.

Measured By: S. Roth 1989

Remarks: Owned by Paul Walker.

Description

Bed No.

Fort Scott Formation

Blackjack Creek Limestone Member

1 a Fossiliferous wackestone to packstone (37cm); pale yellowish brown (10YR 6/2), weathers pale yellowish orange (10YR 8/6) to dark yellowish orange (10YR 6/6); weathered; fractured; crinoid fragments, phylloid algal blades, foraminiferids (fusulinids, Tertrataxis), Composita, Meekella, Crurithyris (shell fragments), other brachiopod shell fragments, bivalve shell fragments, ramose and fenestrate bryozoan fragments; lower contact sharp (with underlying chaetetid).

b Fossiliferous, peloid-rich wackestone to packstone (77cm); moderate yellowish brown (10YR 5/4), medium gray (N5) and olive gray (5Y 4/1), weathers pale yellowish orange (10YR 8/6); weathered; in places, mottled/bioturbated; vertical fractures; upper 20cm consists of interbedded laminar Chaetetes fragments and fossiliferous (crinoid-rich) clay/shale partings (weathered dark yellowish orange, 10YR 6/6); in places, chaetetids appear up-side down; mottling is most intense beneath chaetetids; fossil diversity increases upward from base, to a maximum at 28cm, then decreases; phylloid algal blades, crinoid fragments, foraminiferids (fusulinids, palaeotextulariids, globuvalvulinids), Composita (shell fragments), ostracodes (articulated and shell fragments), productid spines, bivalve shell fragments, ramose and fenestrate bryozoan fragments; contacts sharp; lower contact consists of dark yellowish orange, fossiliferous clay/shale partings (weathered), and a fossil lag(?) dominated by crinoid fragments, bivalve and brachiopod shell fragments, fusulinids, productid spines (all fragmented and abraded).

c Fossiliferous wackestone to packstone with varying amounts of micrite (56cm); pale yellowish orange (10YR 8/6) and dark yellowish orange (10YR 6/6); numerous fossiliferous clay/shale partings throughout (at 11cm, 20cm, 35cm from upper contact); fossils highly abraded, fragmented, and concentrated around clay/shale partings; crinoid fragments, bivalve and brachiopod shell fragments, phylloid algal blades, fusulinids; carbonate content decreases downward, clay content, bioturbation increase; sharp upper contact, gradational lower contact.

Excello shale

2 a Sparsely fossiliferous, silt-rich claystone (32.6cm); dark gray (N3) to olive gray (5Y 4/1); mottled/bioturbated; Composita (shell fragments), productid spines; blocky, platy to laminated; horizontal and vertical, grayish black (N2) burrows throughout upper 22cm; in places, claystone is micritic; sharp upper contact, gradational lower contact.

b Clay-shale (18cm); dark gray (N3); mottled/bioturbated; Derbyia? (shell fragments); calcareous; platy, fissile; gradational contacts.

c Bituminous shale (116.1cm); black (N1) to grayish black (N2); fissile, phosphatic; plant fragments and conodonts; round phosphate and pyrite nodules occur randomly, density decreases toward contacts; upper contact gradational, lower contact sharp.

d Clay-shale (9.2cm); light olive gray (5Y 6/1); plant fragments; carbonate is restricted to small, irregular (non-rounded) micritic nodules; shale (N1) clasts randomly dispersed throughout unit; sharp contacts.

Cabaniss Formation

Breezy Hill Limestone Member

3 Sparsely fossiliferous clay-rich mudstone (63.5cm); olive gray (5Y 4/1) to greenish black (5G 2/1), medium dark gray (N4) and greenish gray (5GY 6/1); mottled, intense bioturbation (rhizocretions?); grain size and micrite content decrease downward, clay content increases; micrite and clay- to silt-size quartz grains fill rhizocretions; pyritic shale clasts, black (N1) to grayish black (N2), common in rhizocretions and matrix; sharp upper contact, gradational lower contact.

Core 766

(Descriptions continued from previous page)

4 a Claystone (11.2cm); greenish gray (5GY 6/1) to light gray (N7); weathered; micritic clasts throughout; clay/shale partings commonly "wrap" around clasts; clay- to silt-size quartz grains common, especially within clay/shale laminae; gradational contact.

b Laminated claystone (153.7cm); light greenish gray (5G 8/1) to greenish gray (5GY 6/1); laminated with silt-size quartz and micrite lenses; uppermost 10cm and lowermost 8cm contain sand-size micritic clasts; pyrite clasts/nodules occur throughout, except in micritic zones; silt-size quartz grains increase toward base; gradational contacts.

c Thinly laminated siltstone with carbonate-rich lenses (1066.8cm); grayish black (N2) and olive gray (5Y 4/1) to light gray (N7) and very light gray (N8); matrix varies from clay- to fine sand-size quartz grains with micritic lenses; in places, ripples and overturned ripples (convolute bedding) present; other laminae appear interrupted by burrows; gradational upper contact.

APPENDIX C

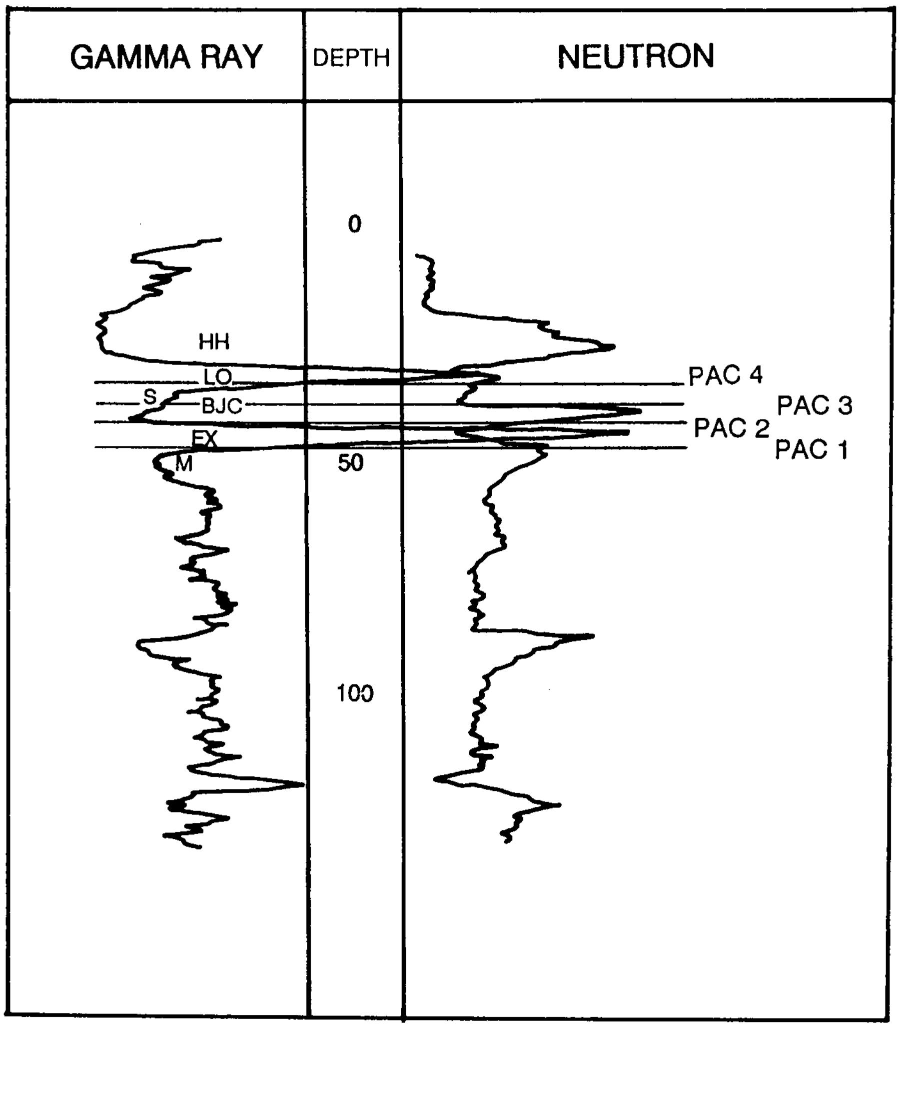
Well Log Data
Used in Regional Study

HH = Houx-Higginsville Limestone
LO = Little Osage Shale
S = Summit Coal
BJC = Blackjack Creek Limestone
EX = Excello Shale
M = Mulky Coal
BH = Breezy Hill Limestone

Depths are in feet

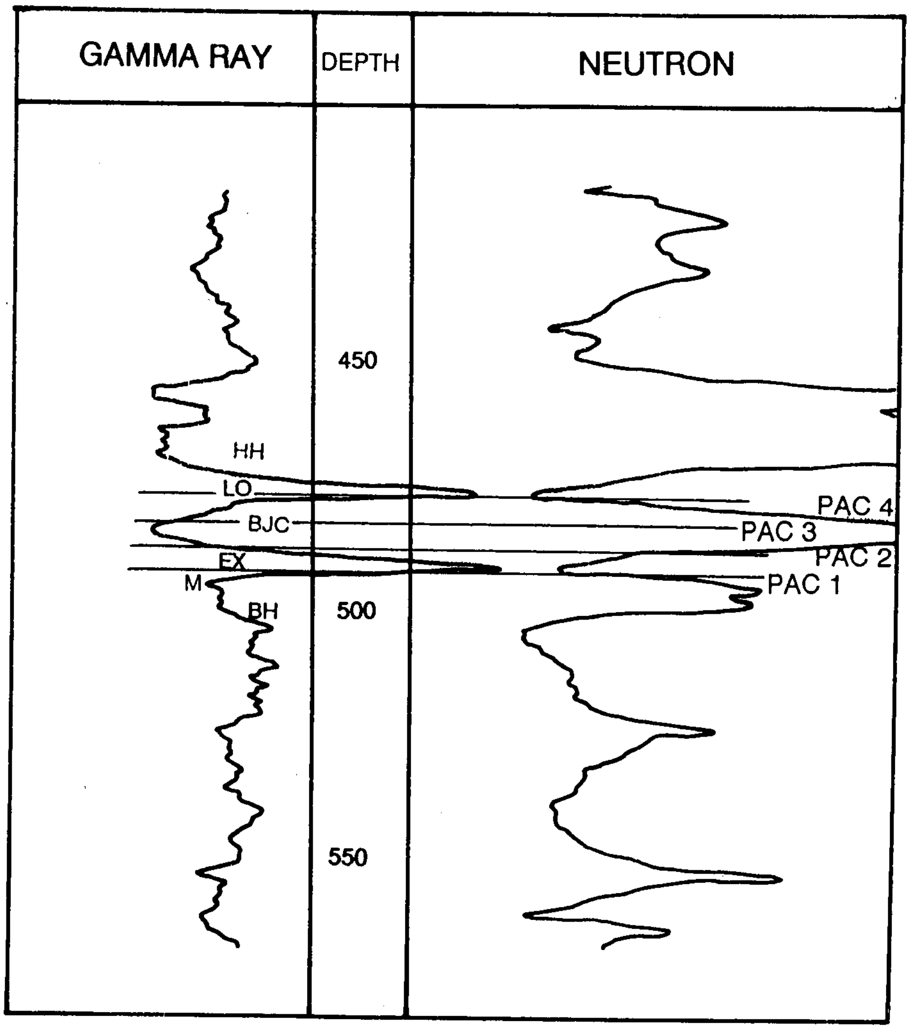
A

LOCATION: SE1/4, SE1/4, NE1/4, section 32, T.23S., R.25E.
Bourbon County



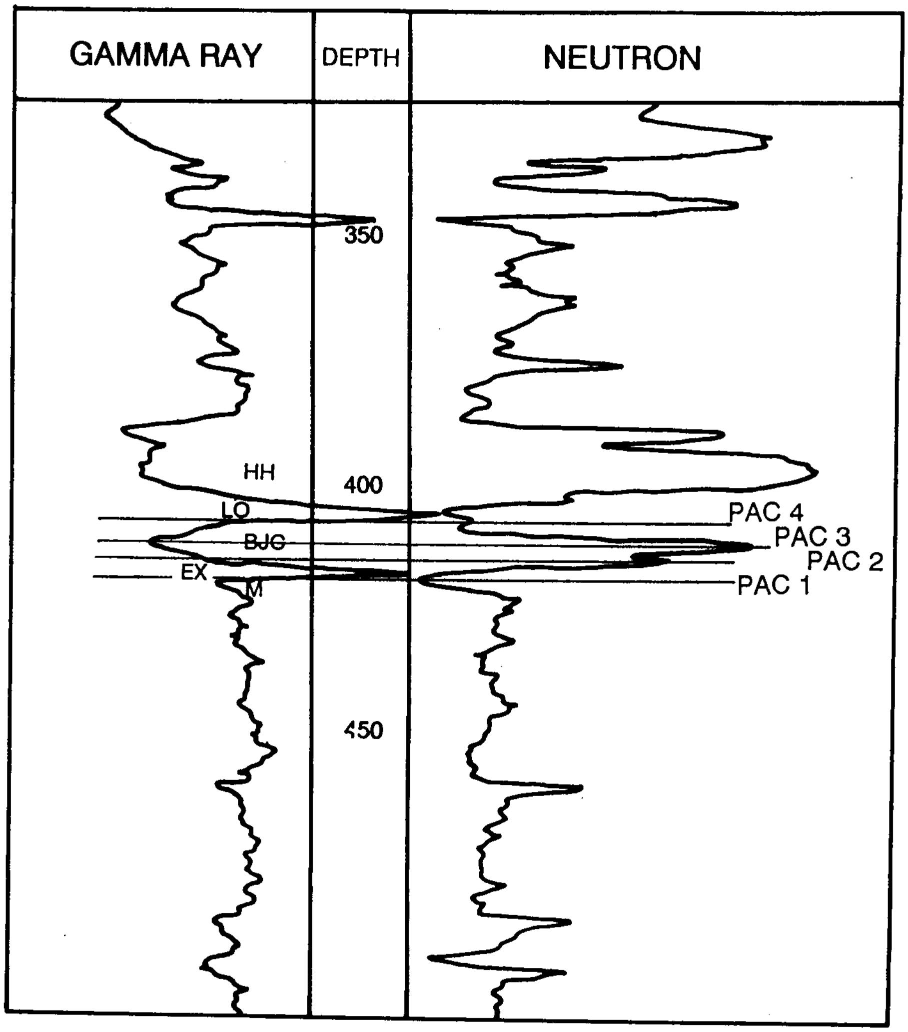
B

LOCATION: Section 35, T.23S., R.21E.
Bourbon County



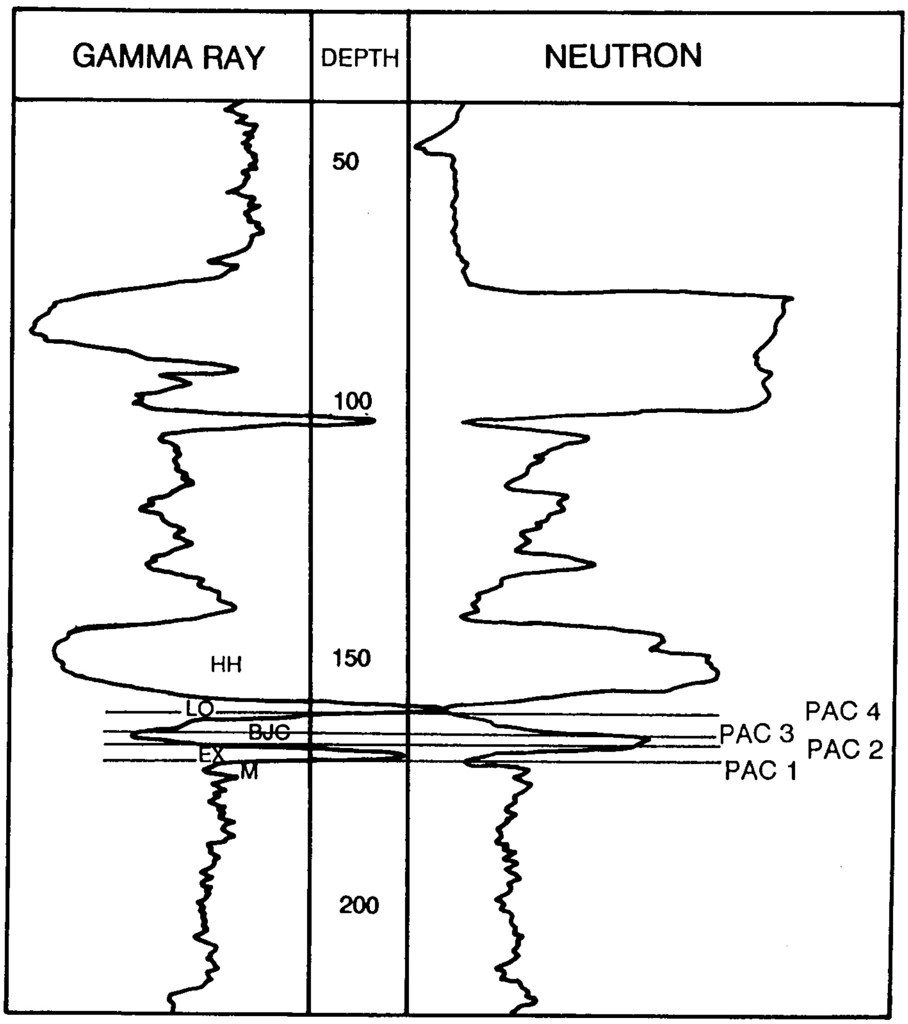
C

LOCATION: W1/2, NE1/4, section 24, T.24S., R.24E.
Bourbon County



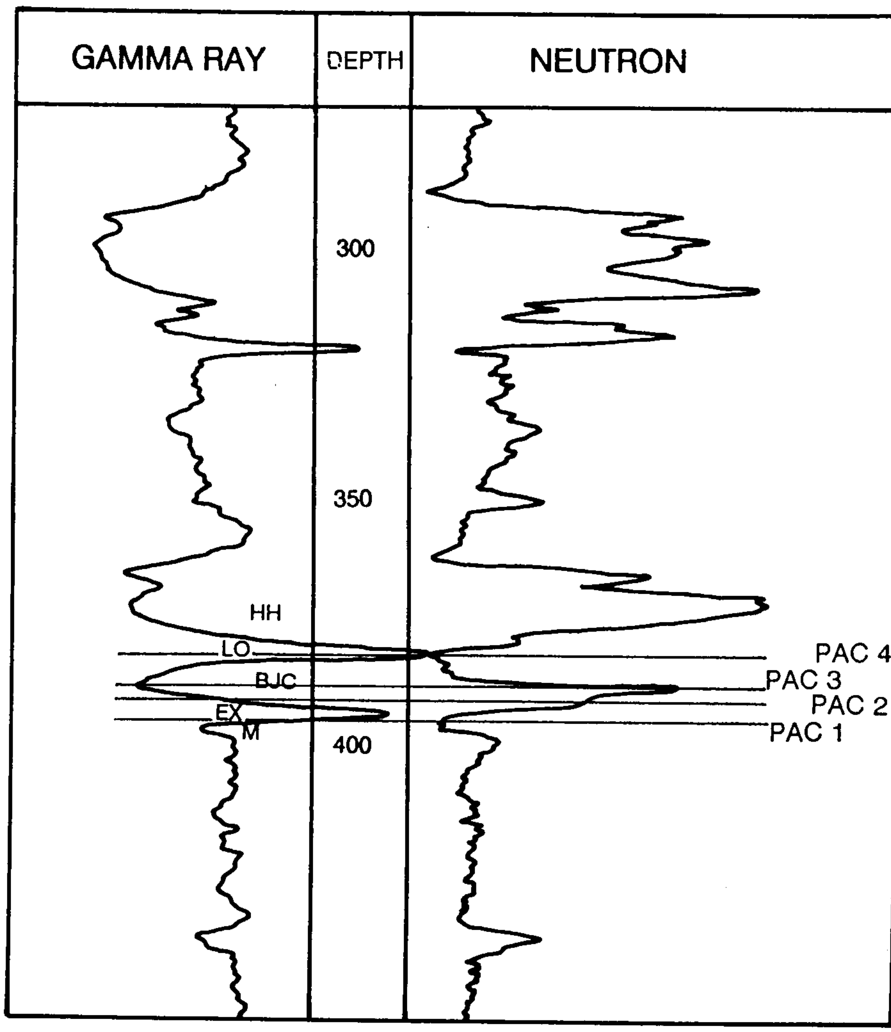
D

LOCATION: SE1/4, NW1/4, SE1/4, section 1, T.24S., R.23E.
Bourbon County



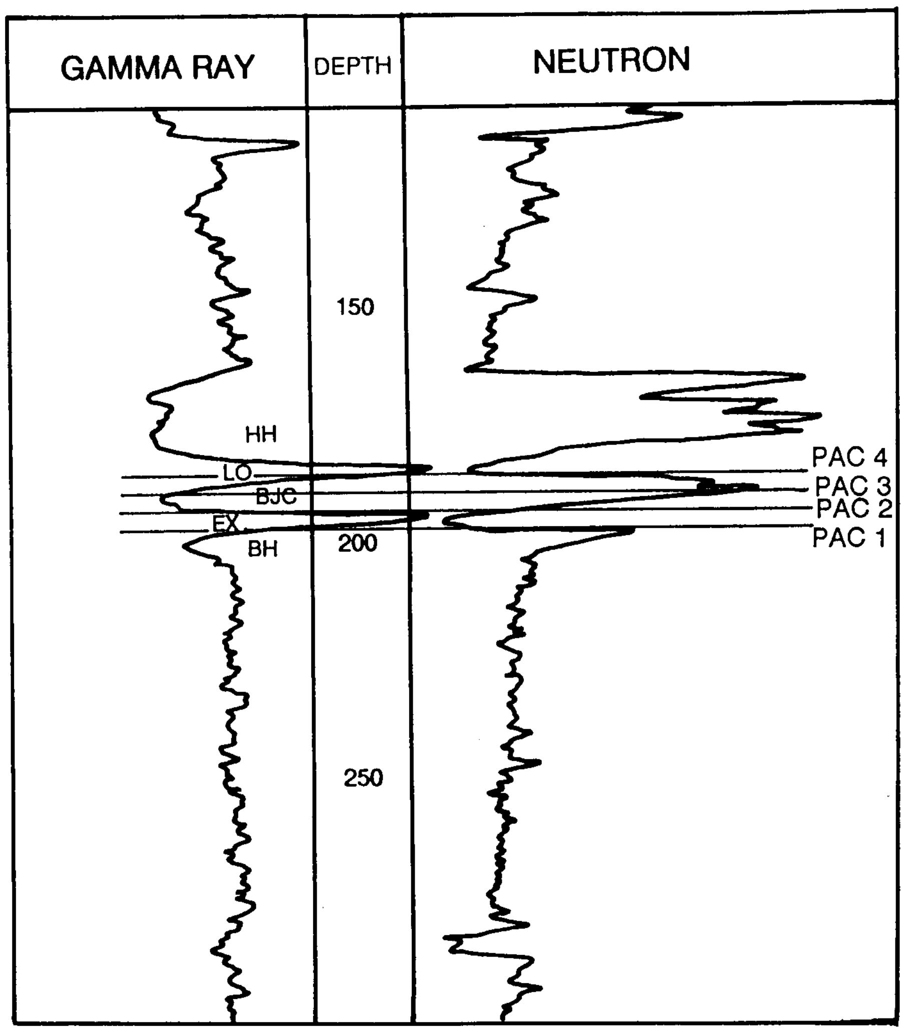
E

LOCATION: Section 19, T.24S., R.22E.
Bourbon County



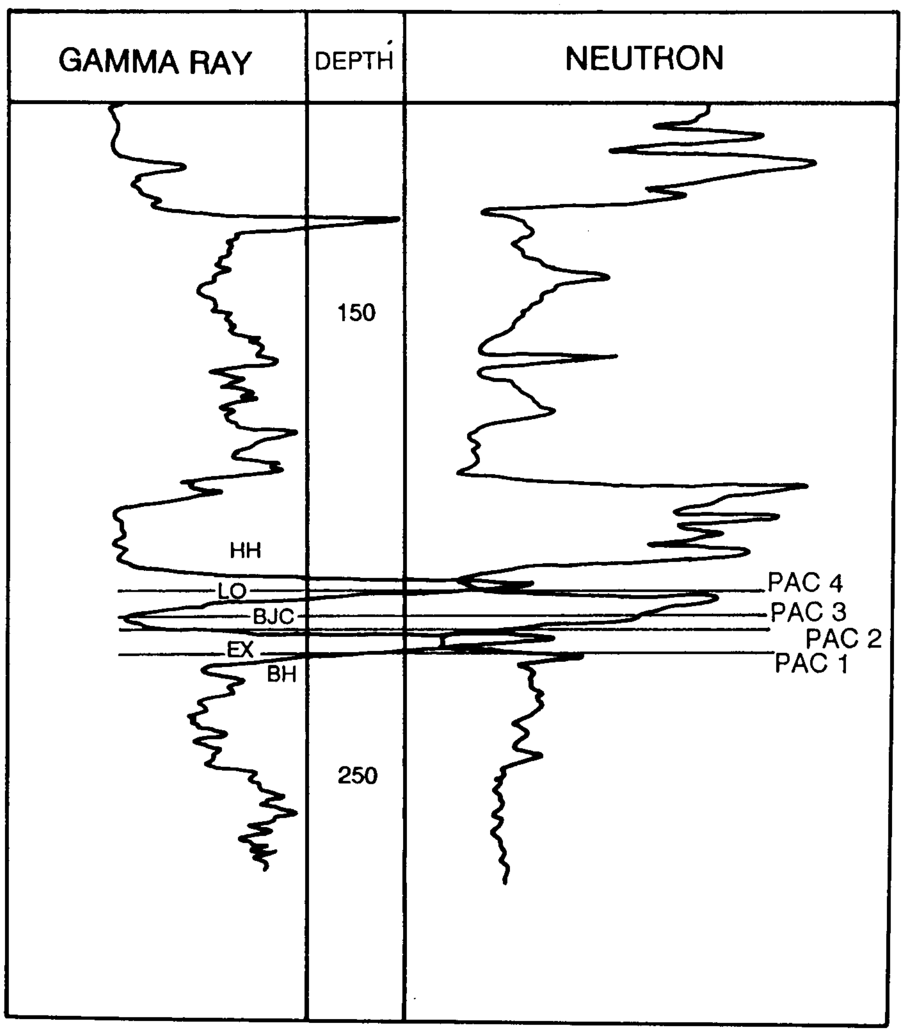
F

LOCATION: C, NE1/4, NE1/4, section 20, T.26S., R.23E.
Bourbon County



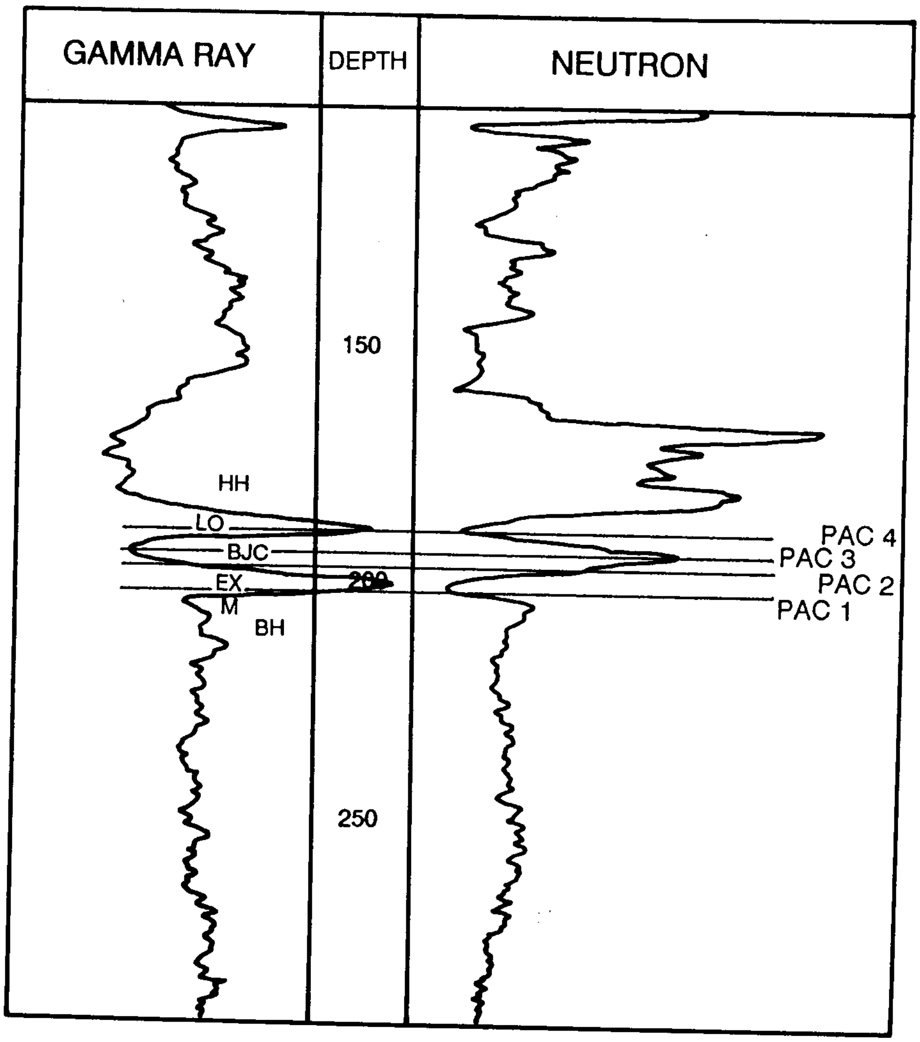
G

LOCATION: NW1/4, NW1/4, SE1/4, section 28, T.27S., R.23E.
Crawford County

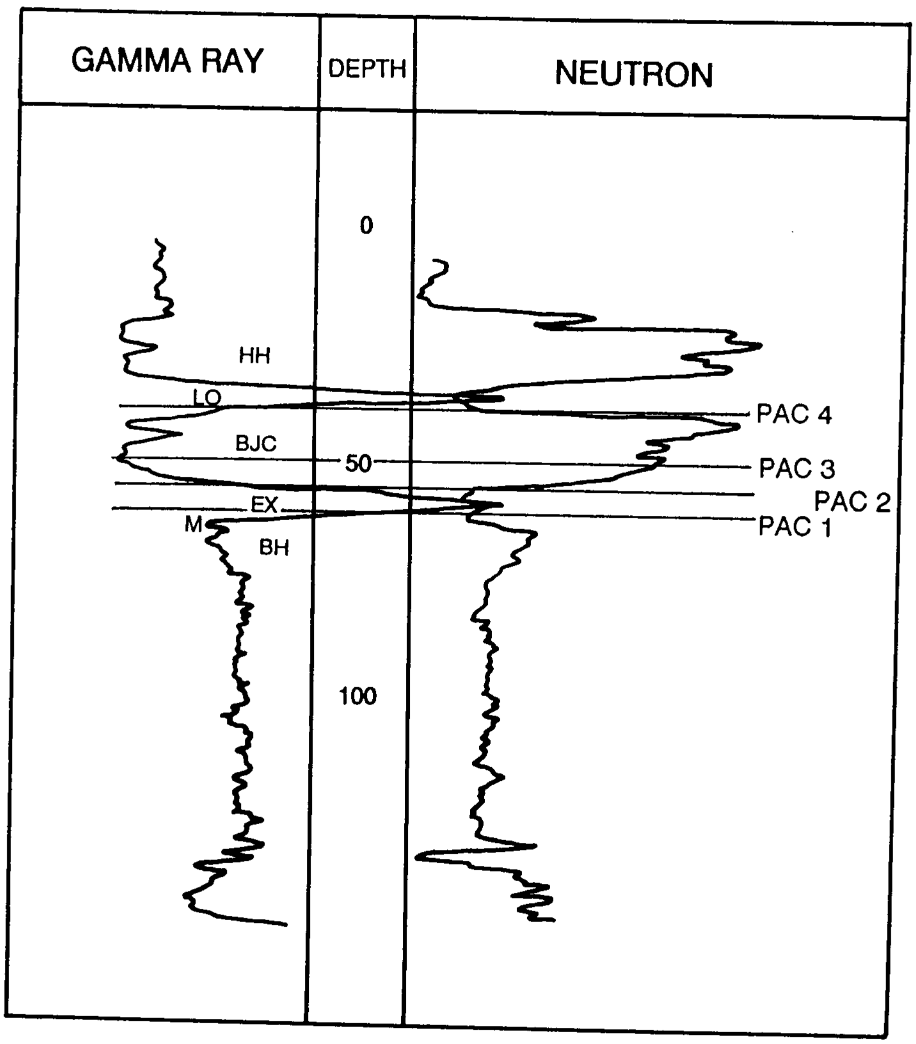


H

LOCATION: Section 26, T.28S., R.22E.
Crawford County

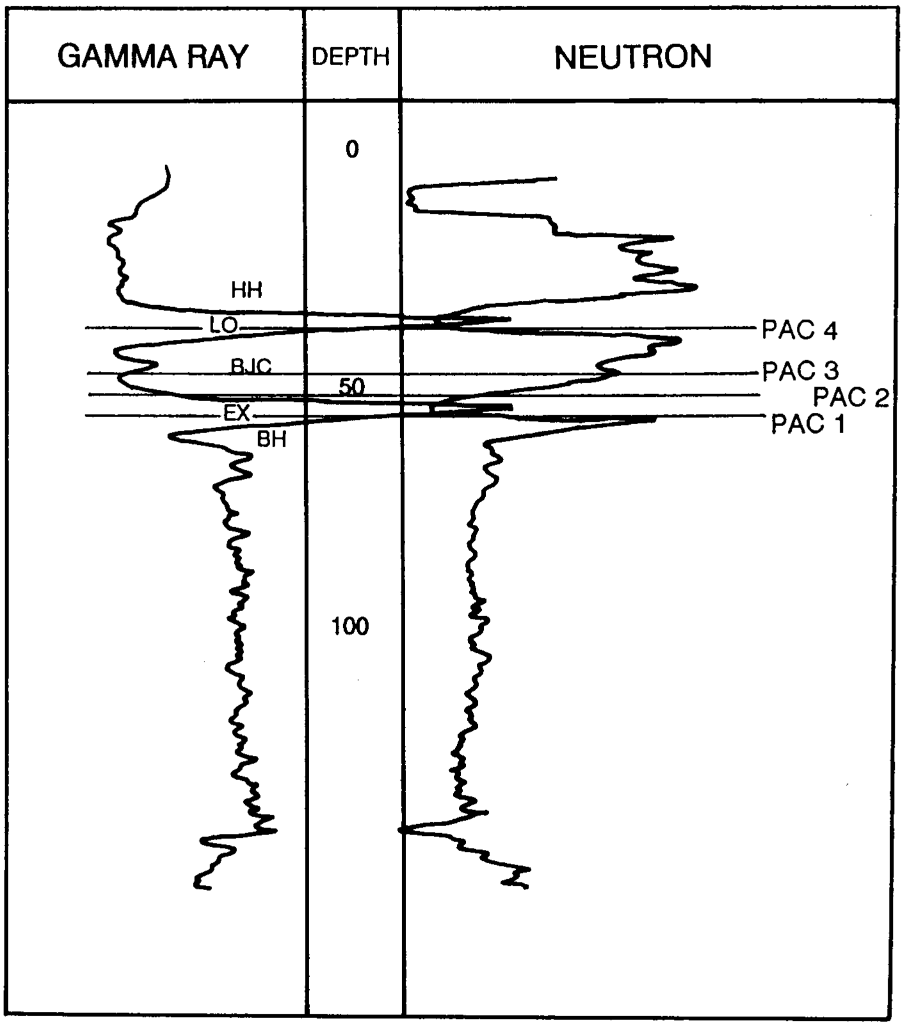


LOCATION: SW1/4, NW1/4, section 35, T.30S., R.21E.
Crawford County



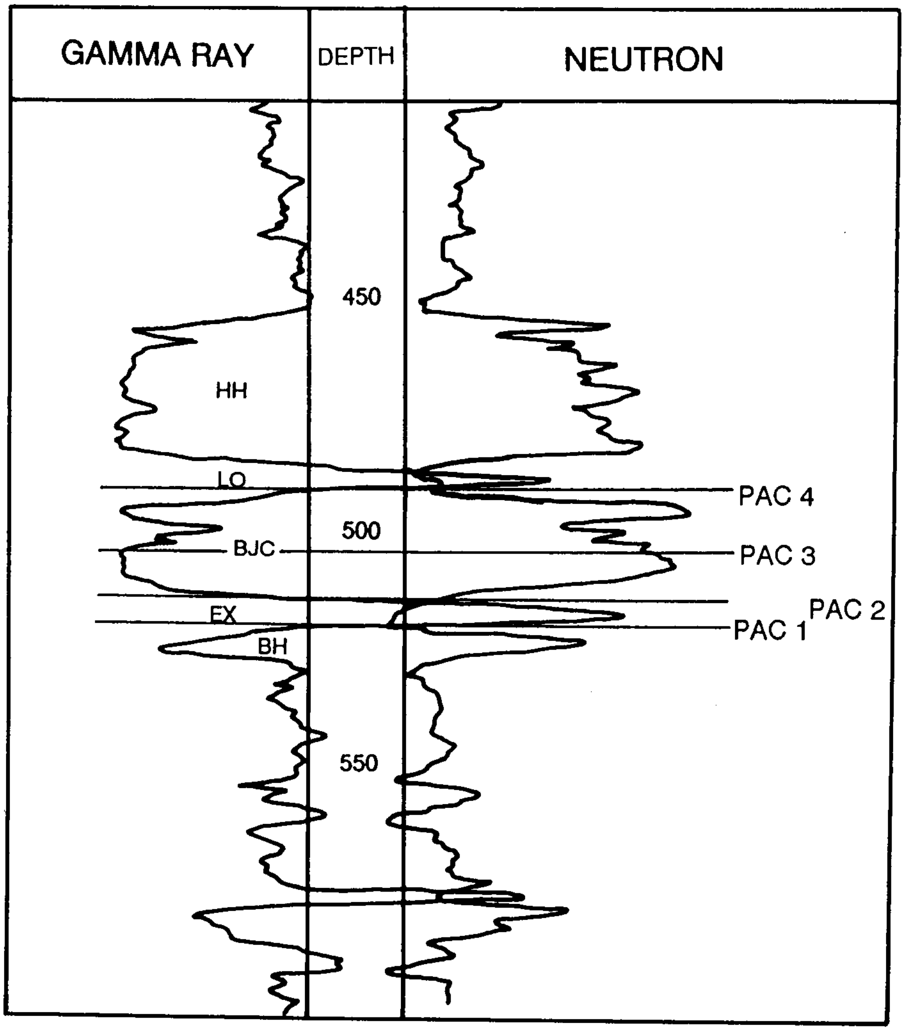
J

LOCATION: NE1/4, SW1/4, section 3, T.31S., R.21E.
Labette County



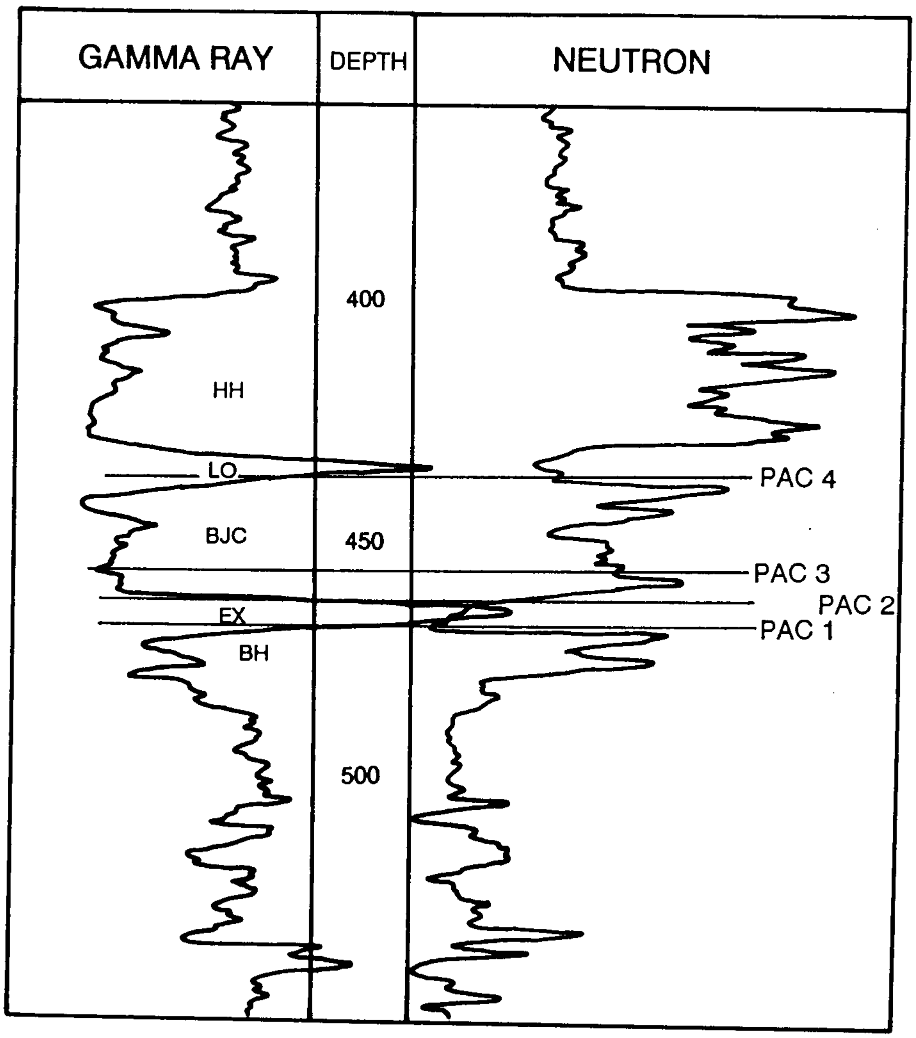
K

LOCATION: SW1/4, NE1/4, section 29, T.31S., R.17E.
Labette County



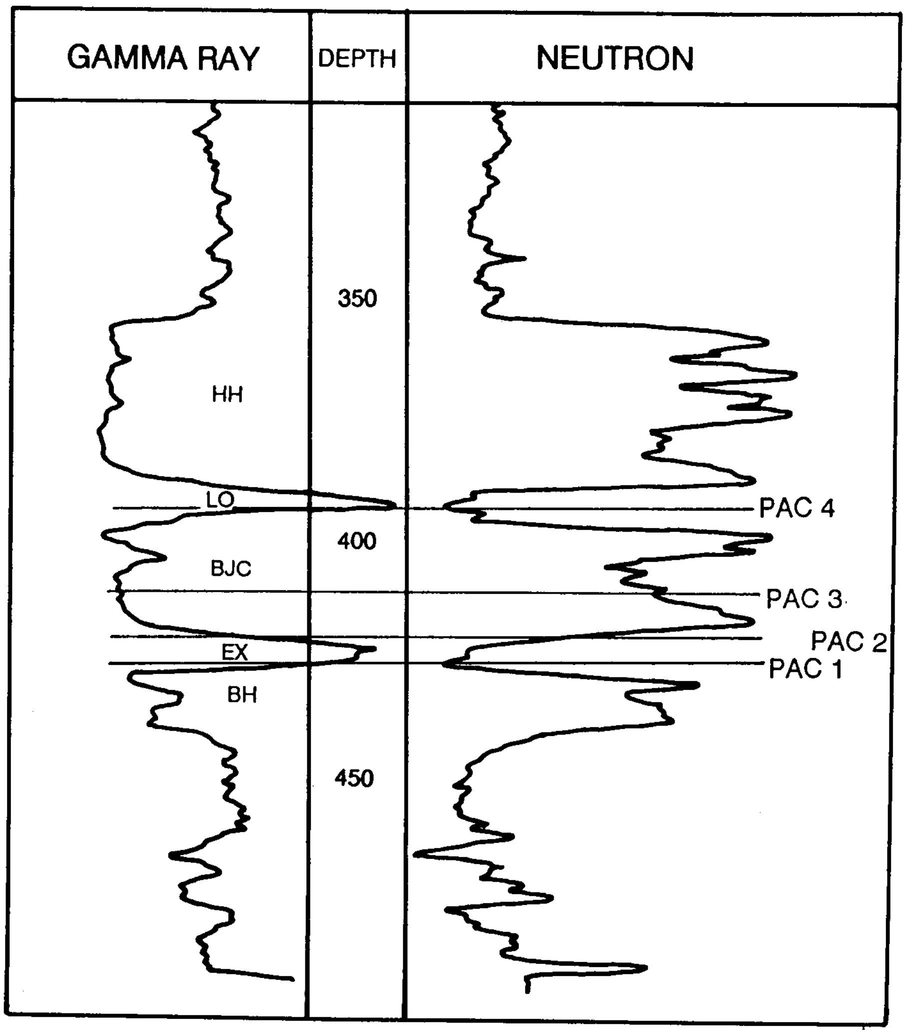
L

LOCATION: SW1/4, section 34, T.32S., R.18E.
Labette County



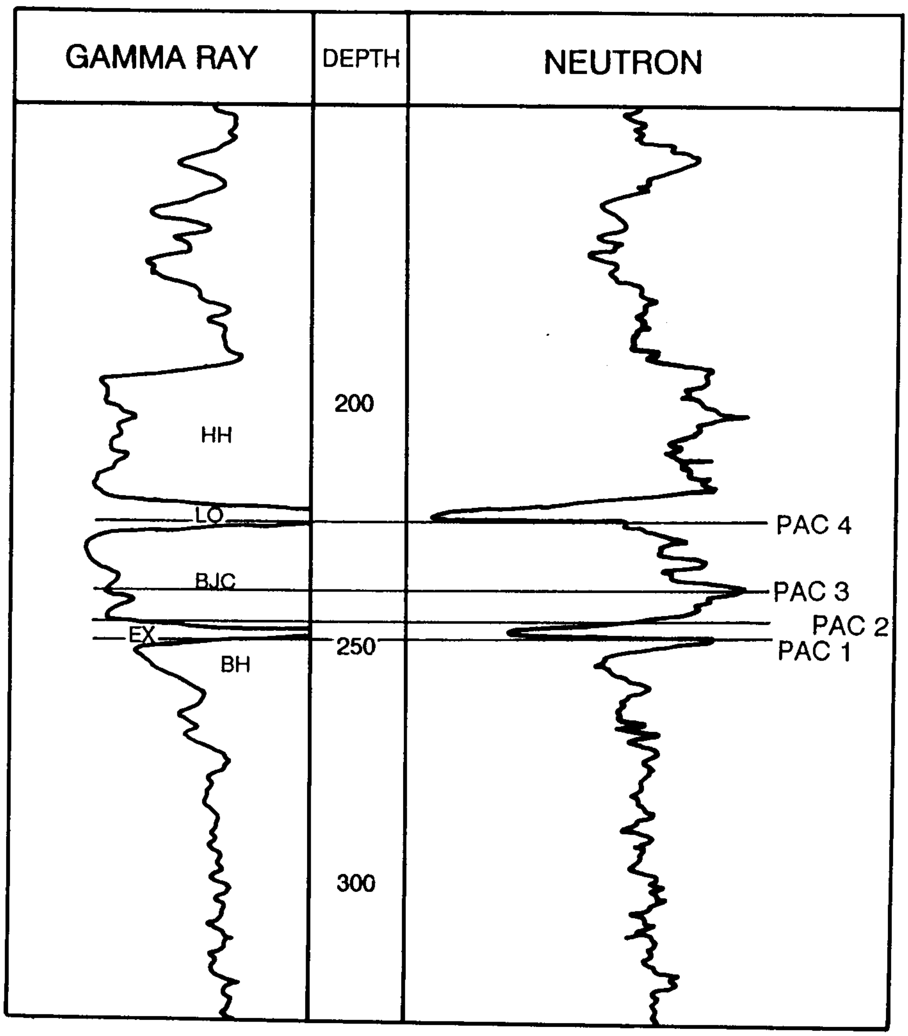
M

LOCATION: Section 4, T.33S., R.18E.
Labette County



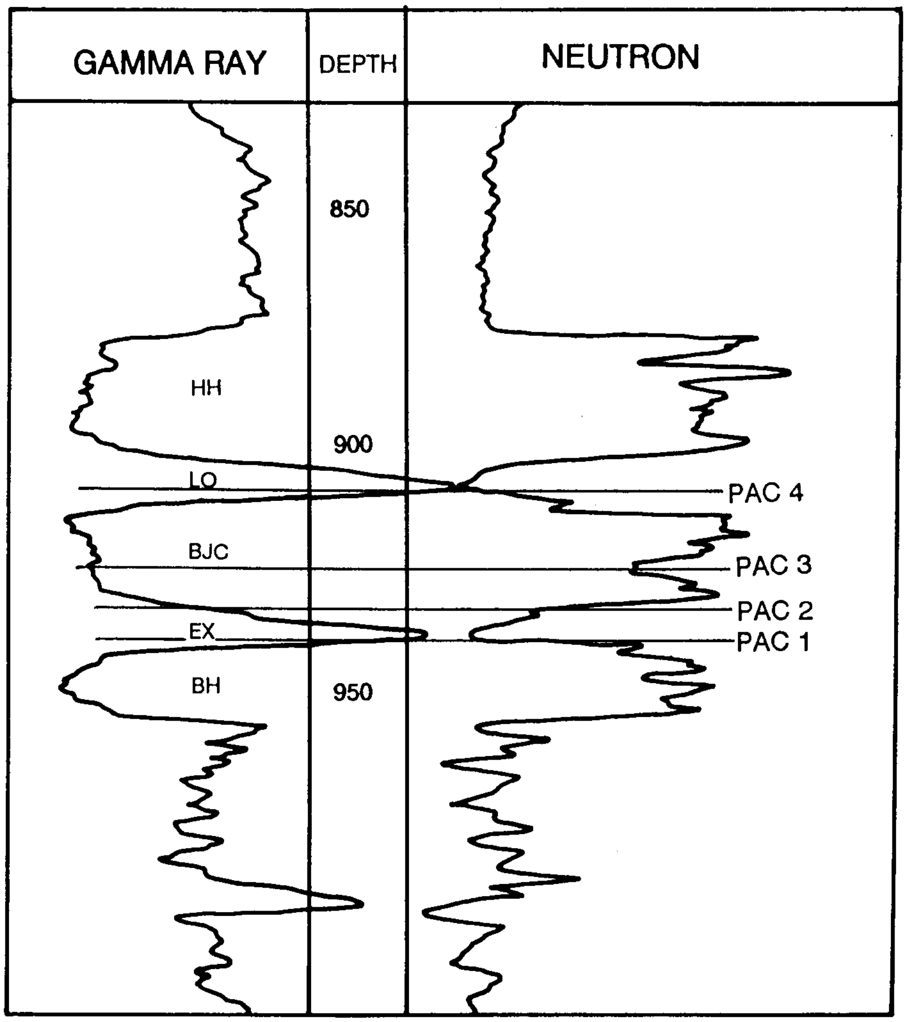
N

LOCATION: SE1/4, section 4, T.34S., R.19E.
Labette County



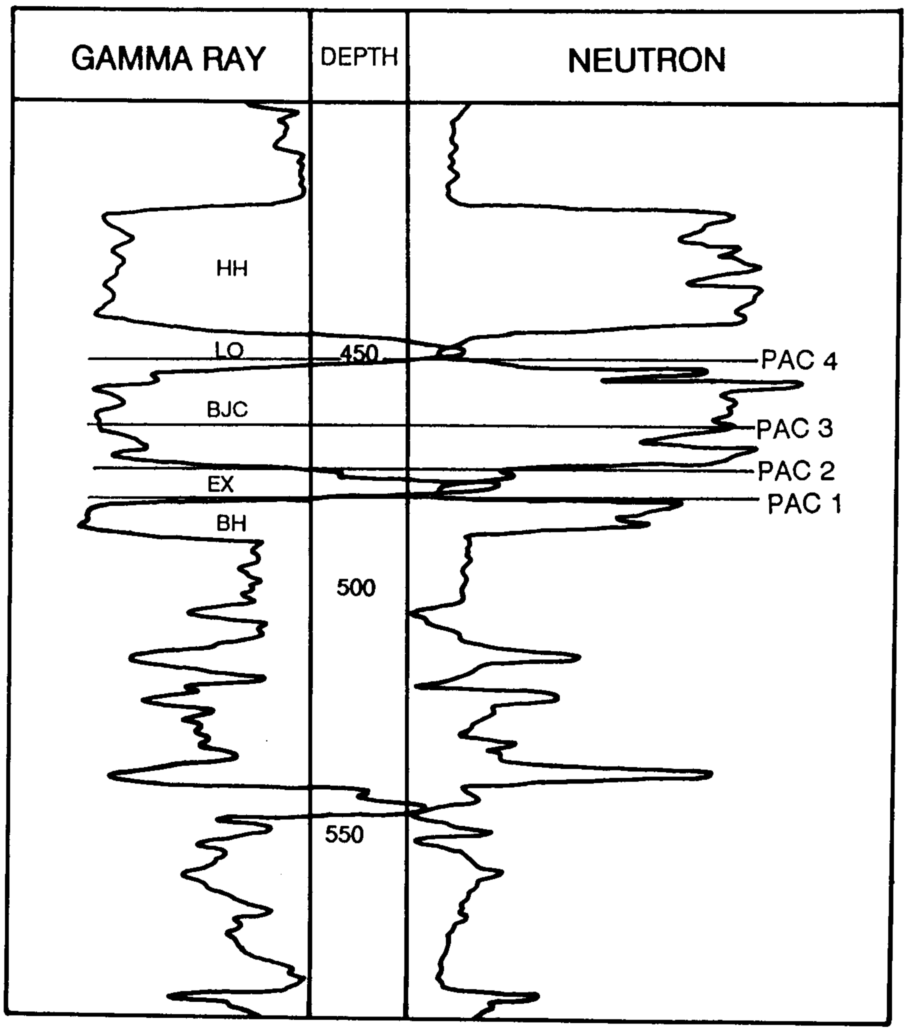
o

LOCATION: SW1/4, SE1/4, section 29, T.29N., R.14E.
Craig County



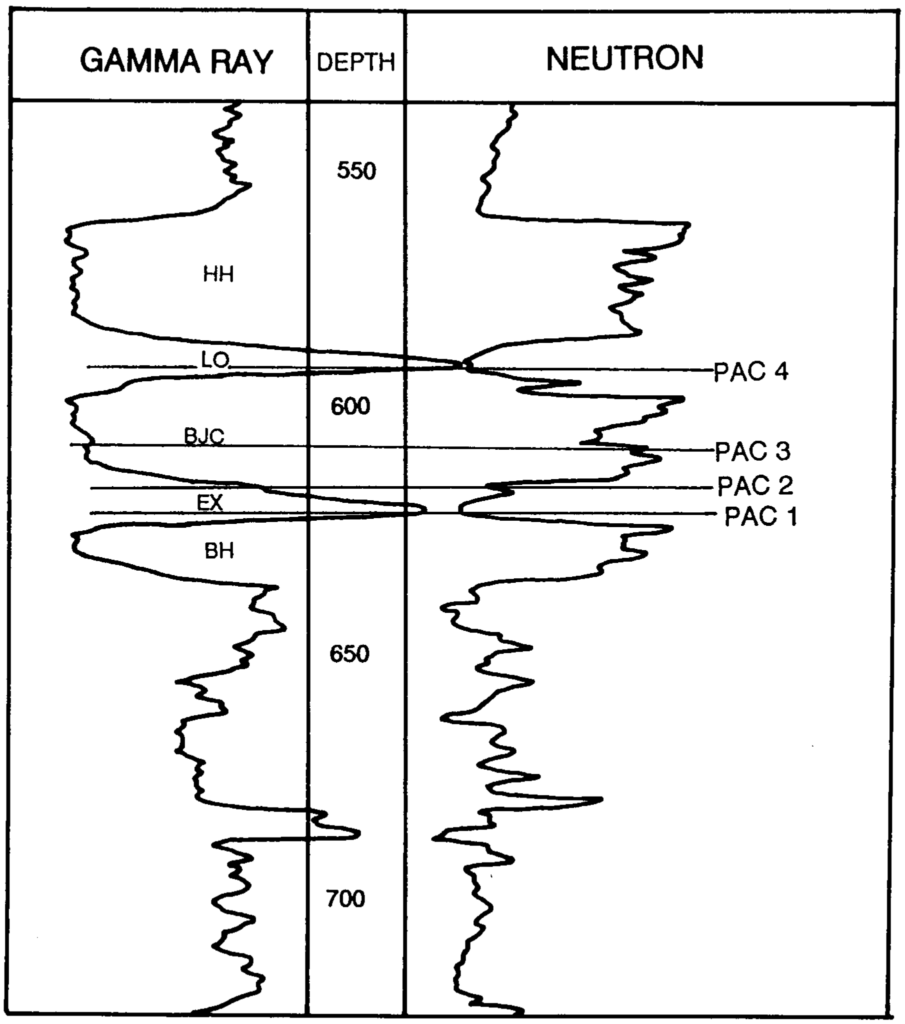
P

LOCATION: C, NW1/4, SE1/4, SW1/4, section 29, T.29N., R.15E.
Nowata County



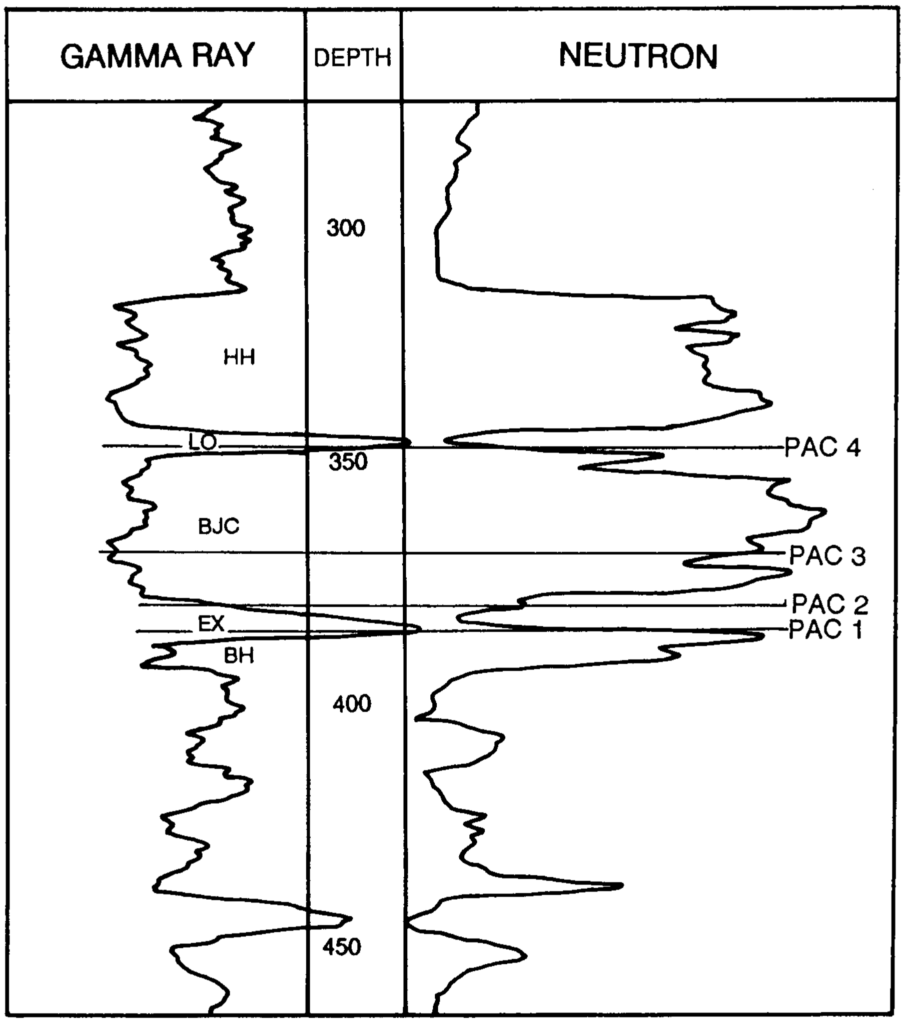
Q

LOCATION: NE1/4, SW1/4, SW1/4, section 22, T.29N., R.16E.
Nowata County



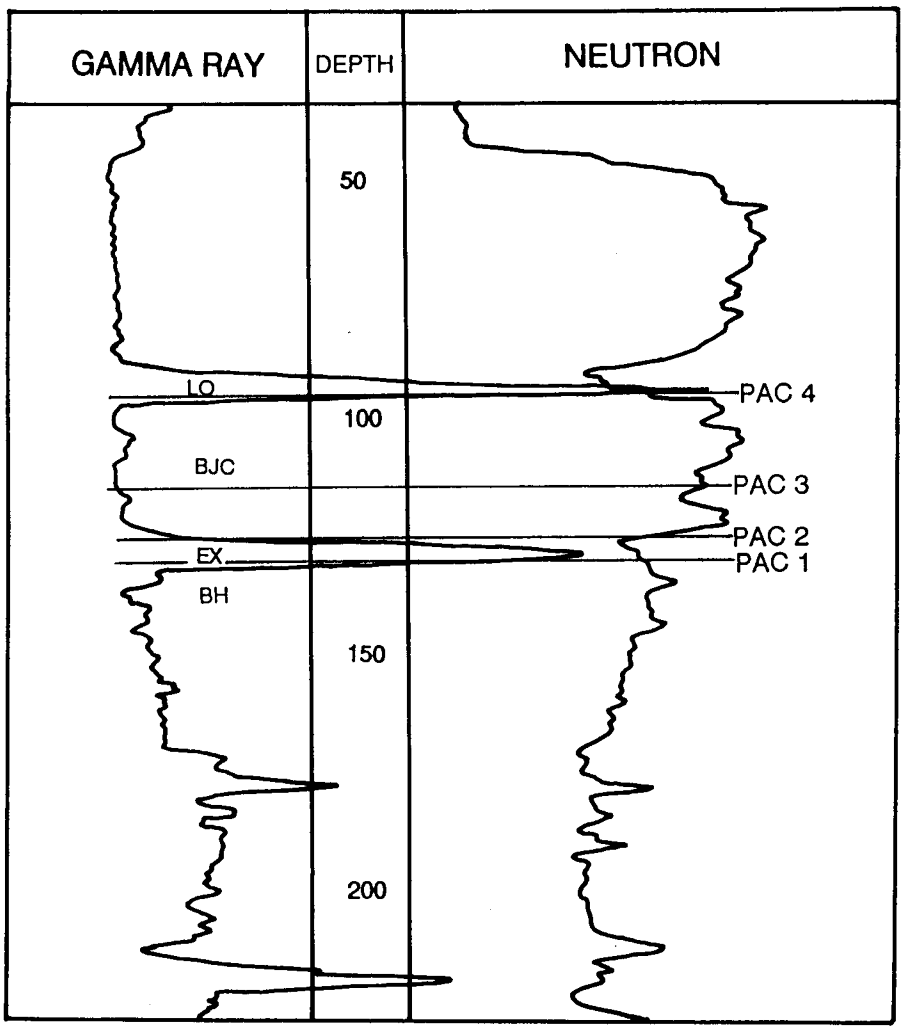
R

LOCATION: SW1/4, SW1/4, NE1/4, section 19, T.29N., R.17E.
Nowata County



S

LOCATION: NE1/4, section 18, T.29N., R.19E.
Craig County



T

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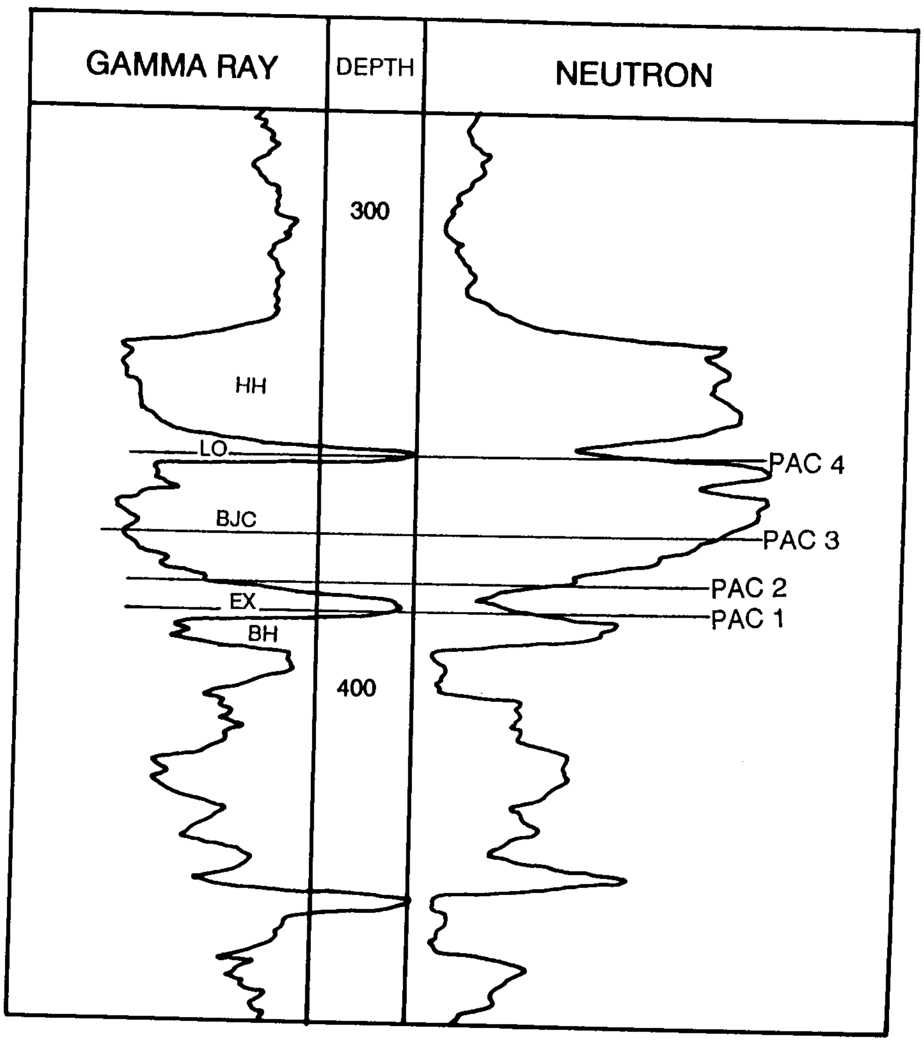
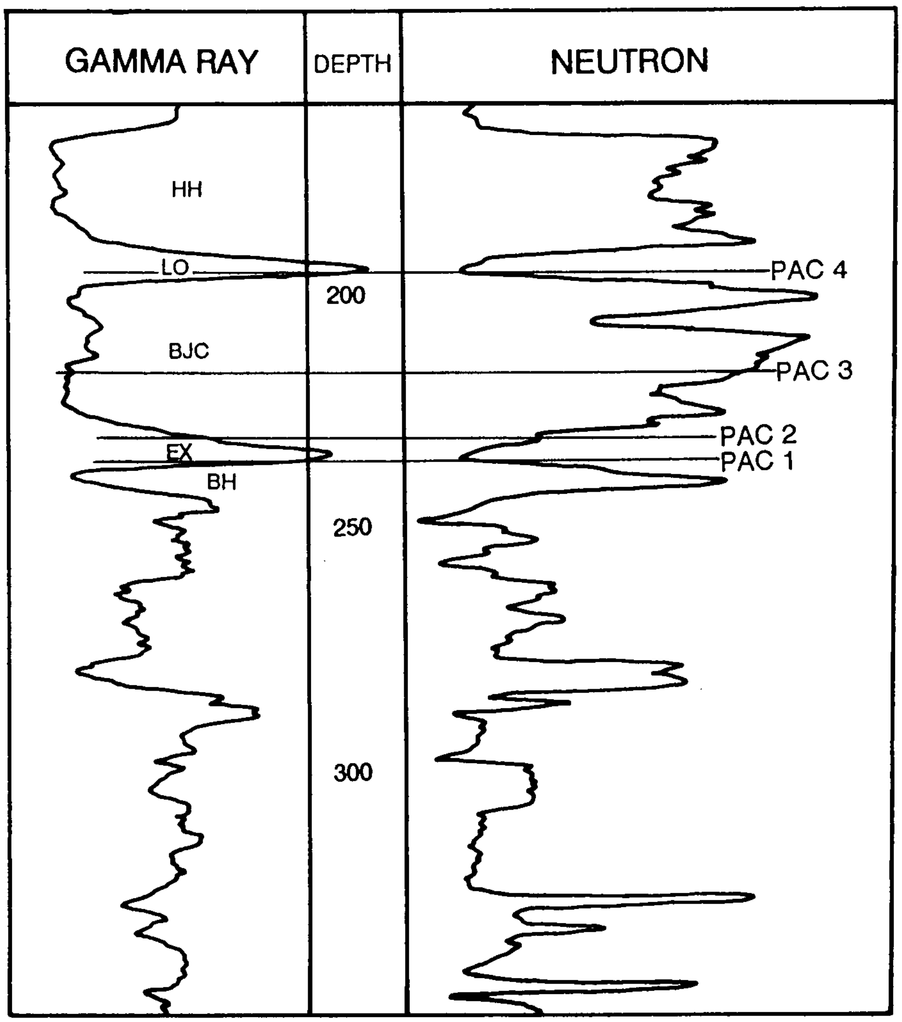
Nowata County



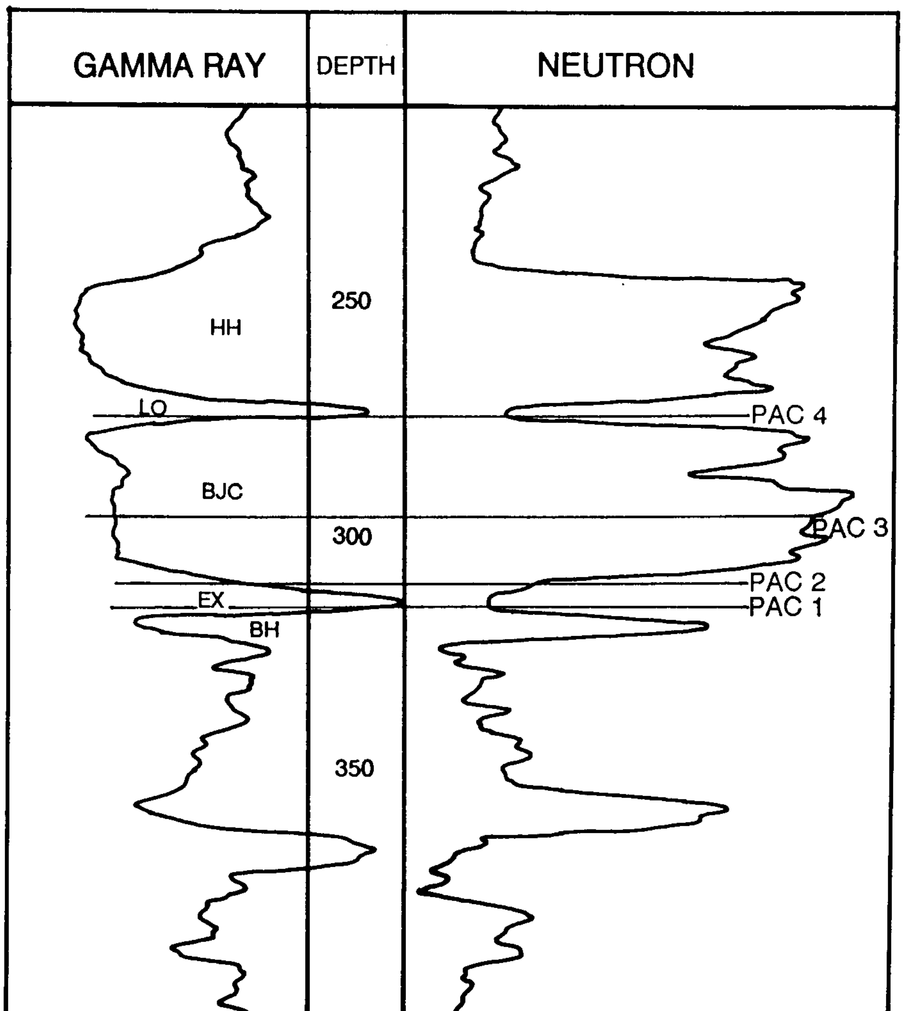
U

LOCATION: SE1/4, SE1/4, section 19, T.28N., R.18E.
Craig County



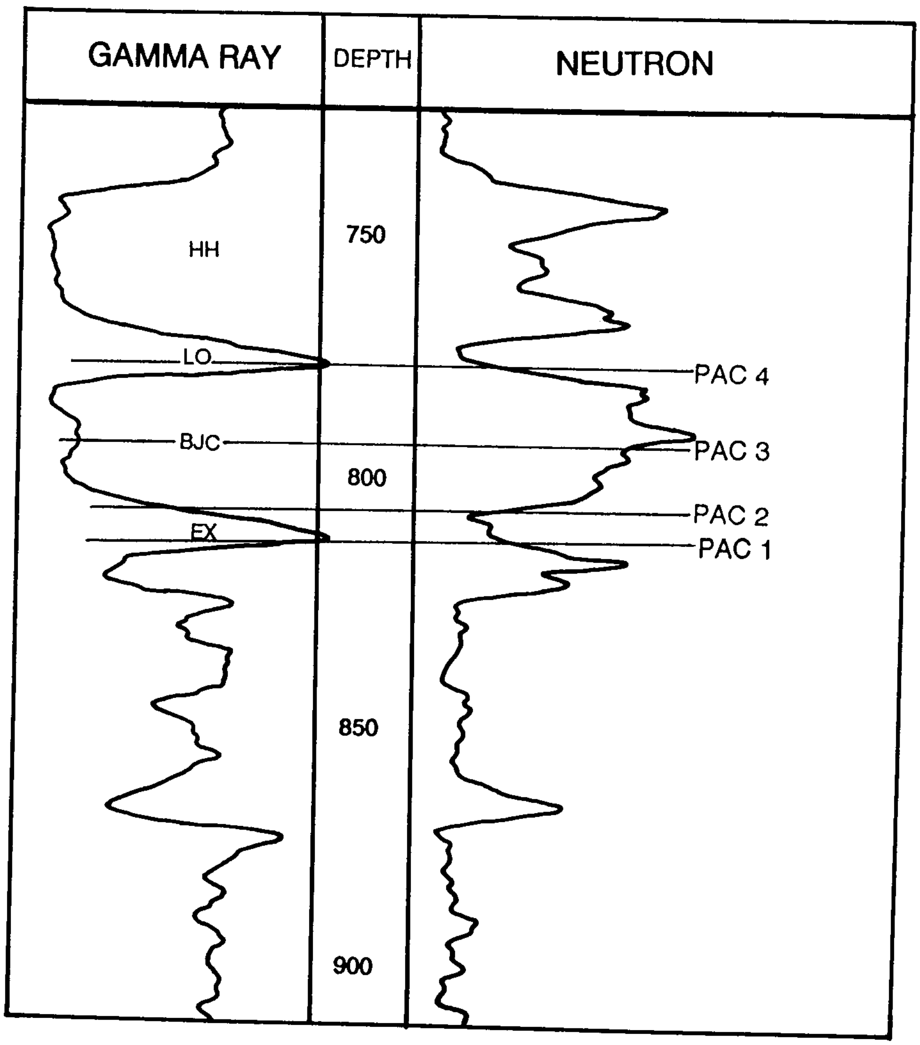
V

LOCATION: SE1/4, NE1/4, SW1/4, section 4, T.27N., R.17E.
Nowata County



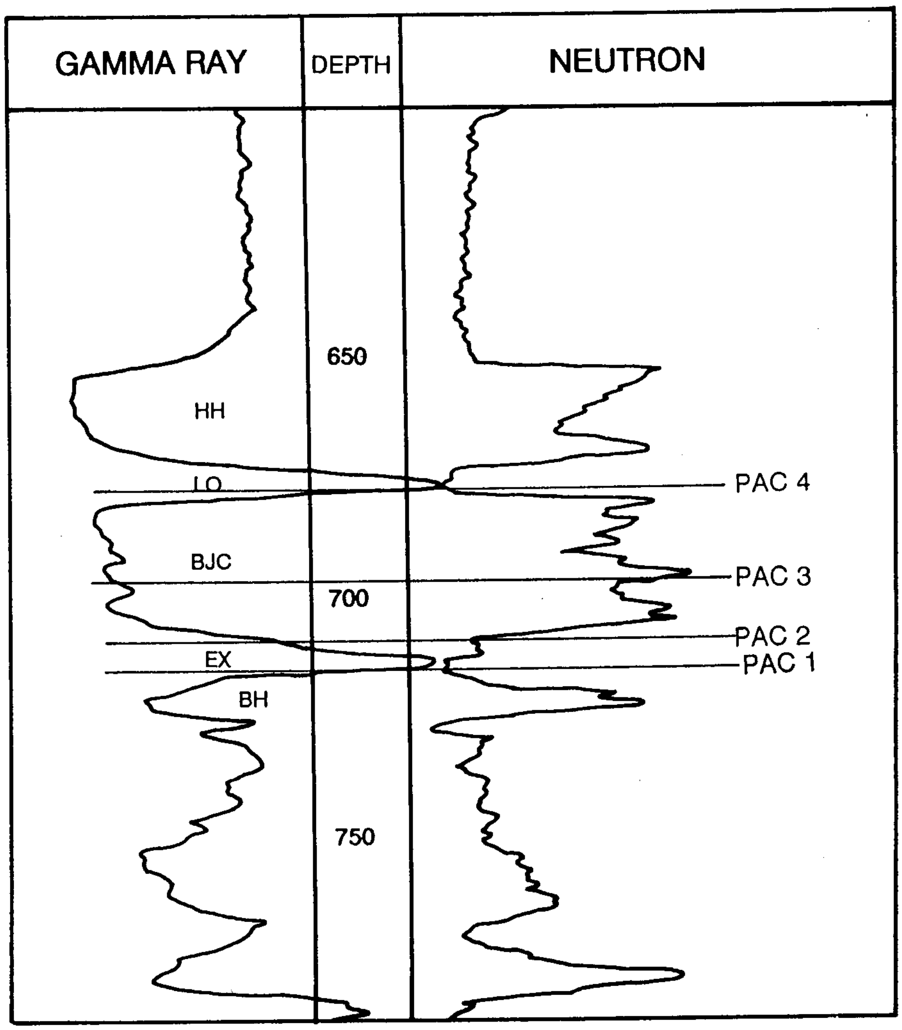
W

LOCATION: Section 6, T.26N., R15E.
Nowata County



X

LOCATION: Section 35, T.26N., R.14E.
Nowata County



Y

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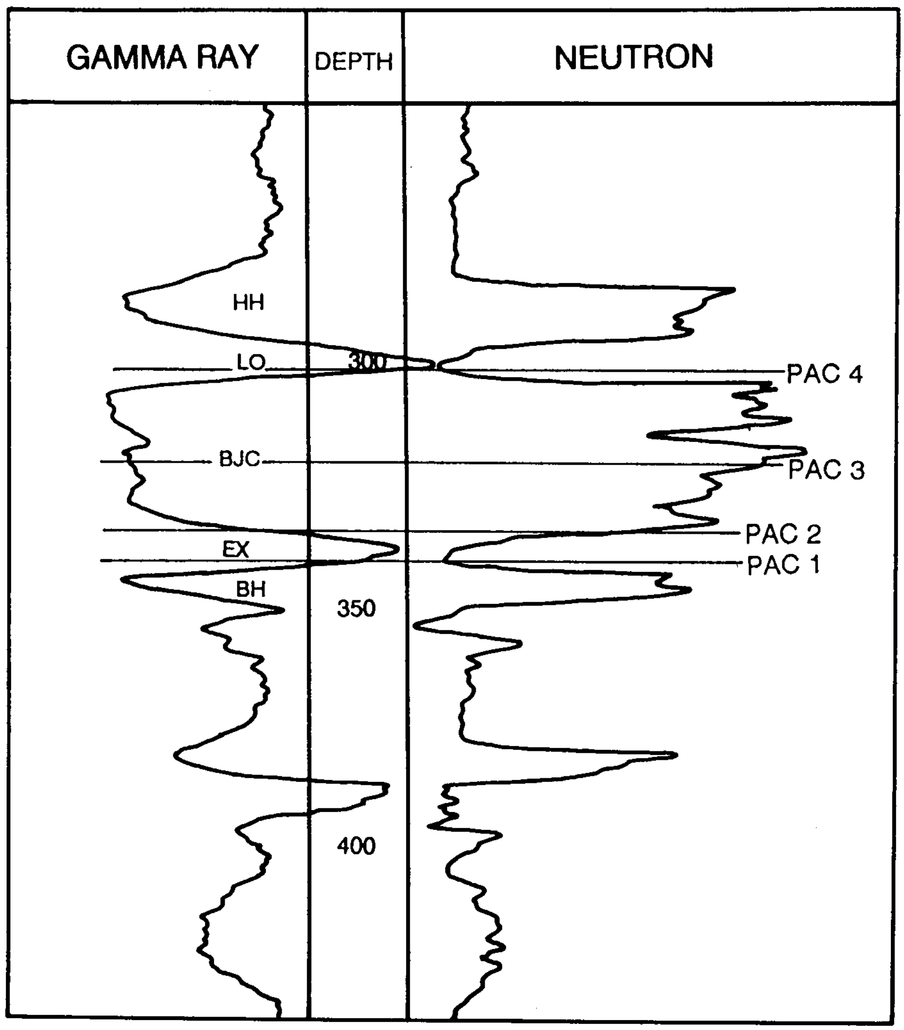
Nowata County



Z

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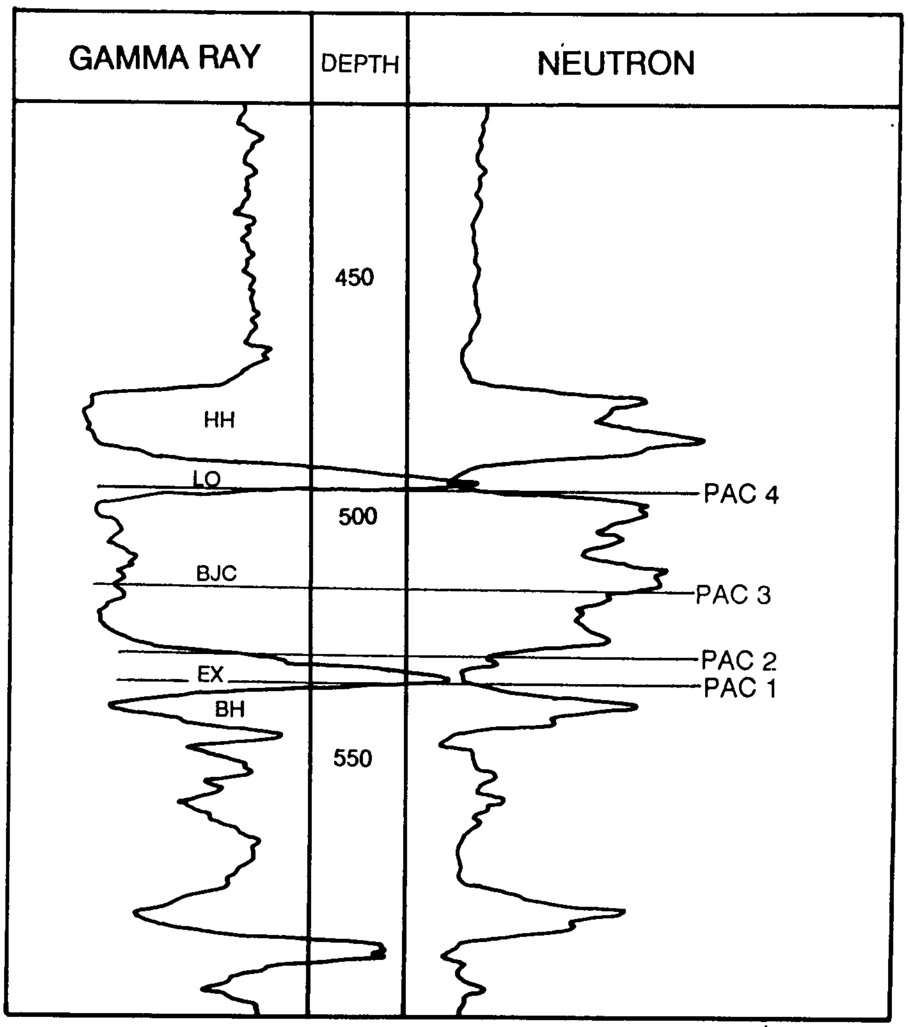
Nowata County



AA

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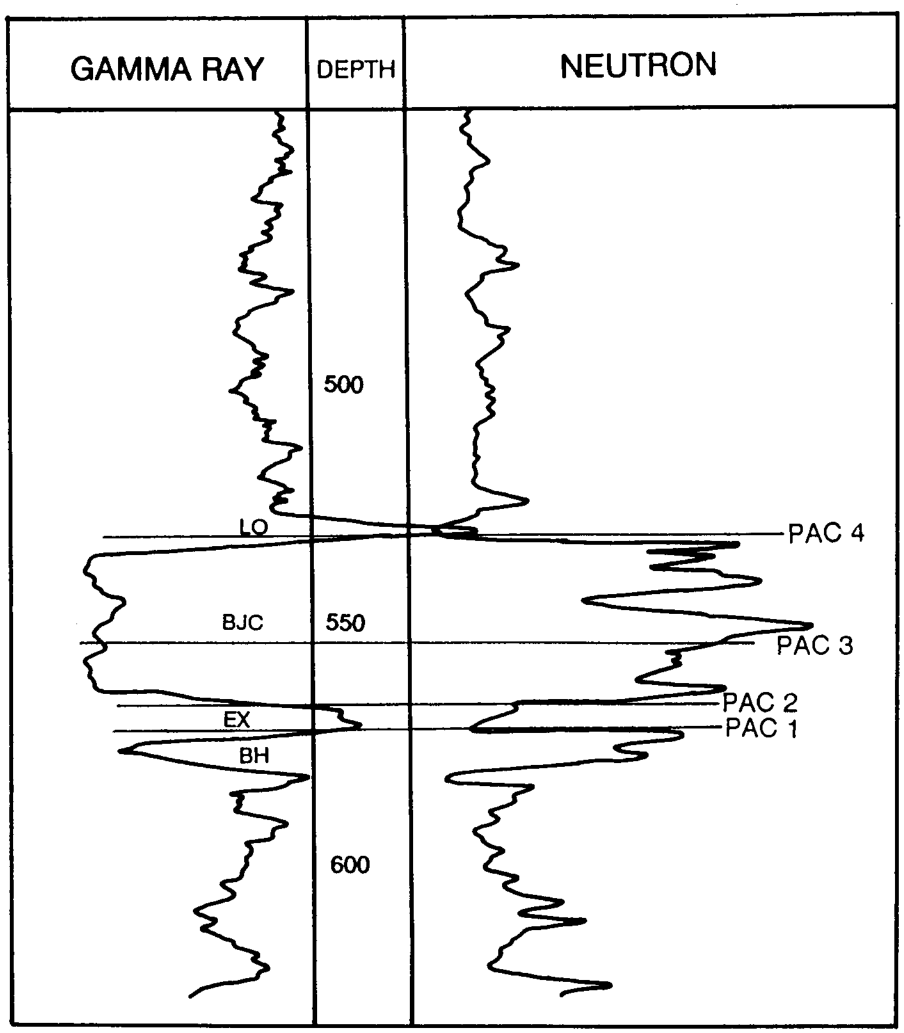
Rogers County



BB

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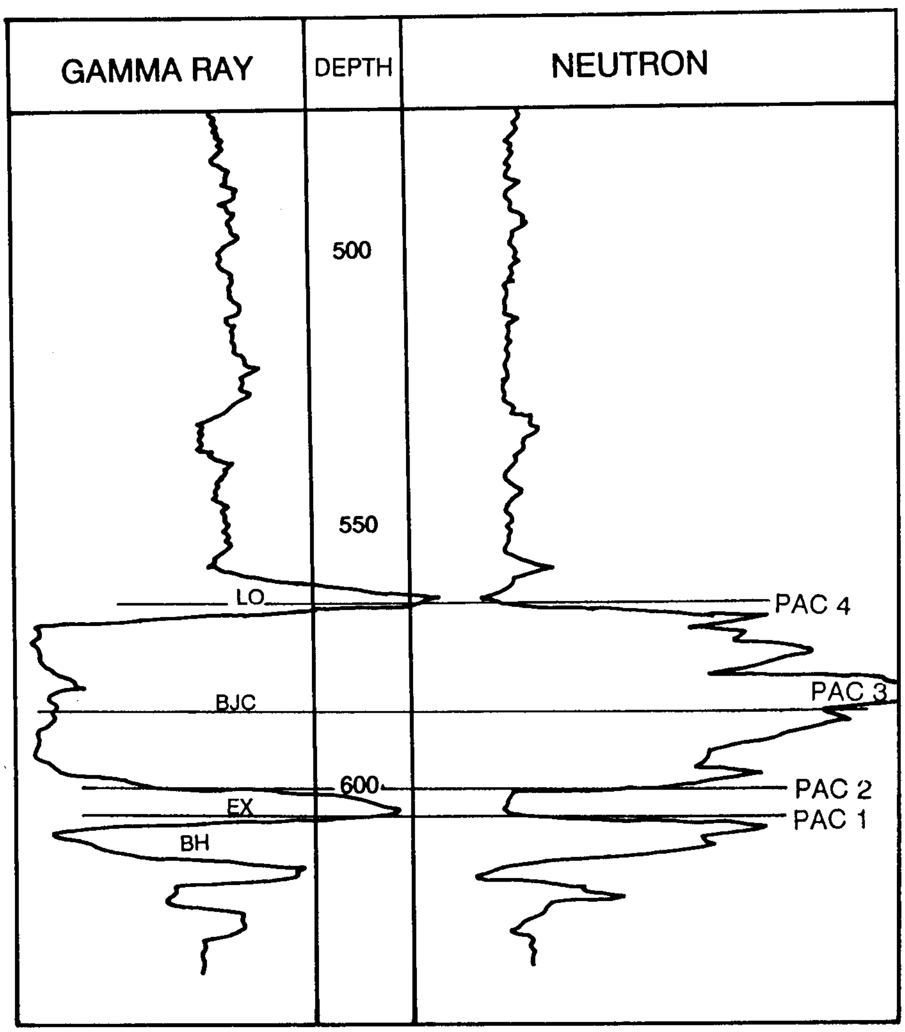
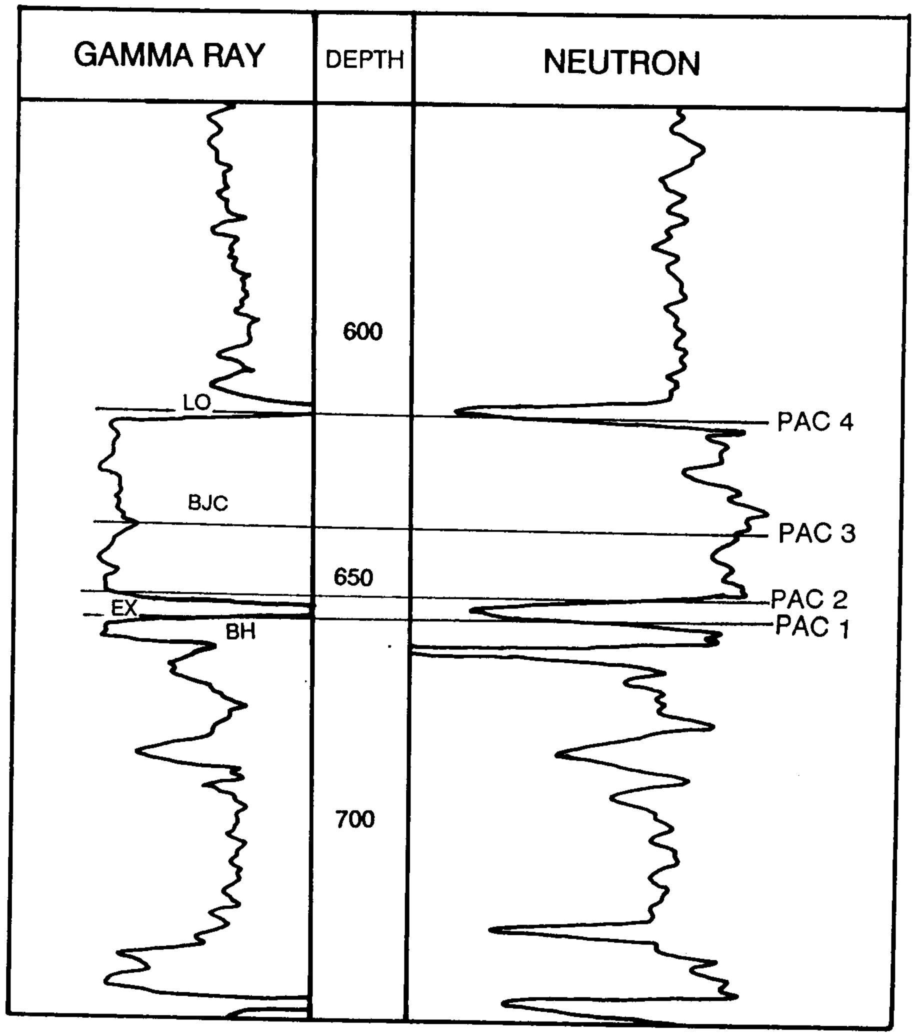
Rogers County



CC

LOCATION: SE1/4, section 7, T.21N., R.13E.
Tulsa County



DD

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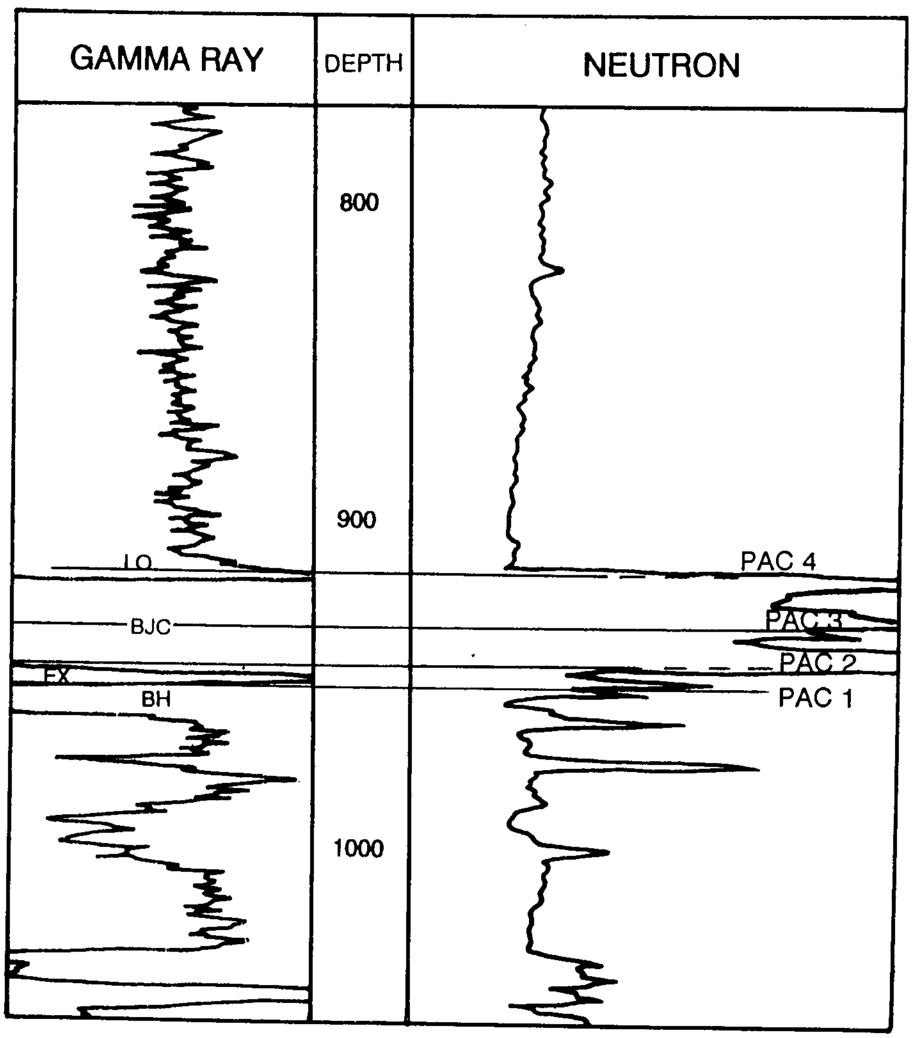
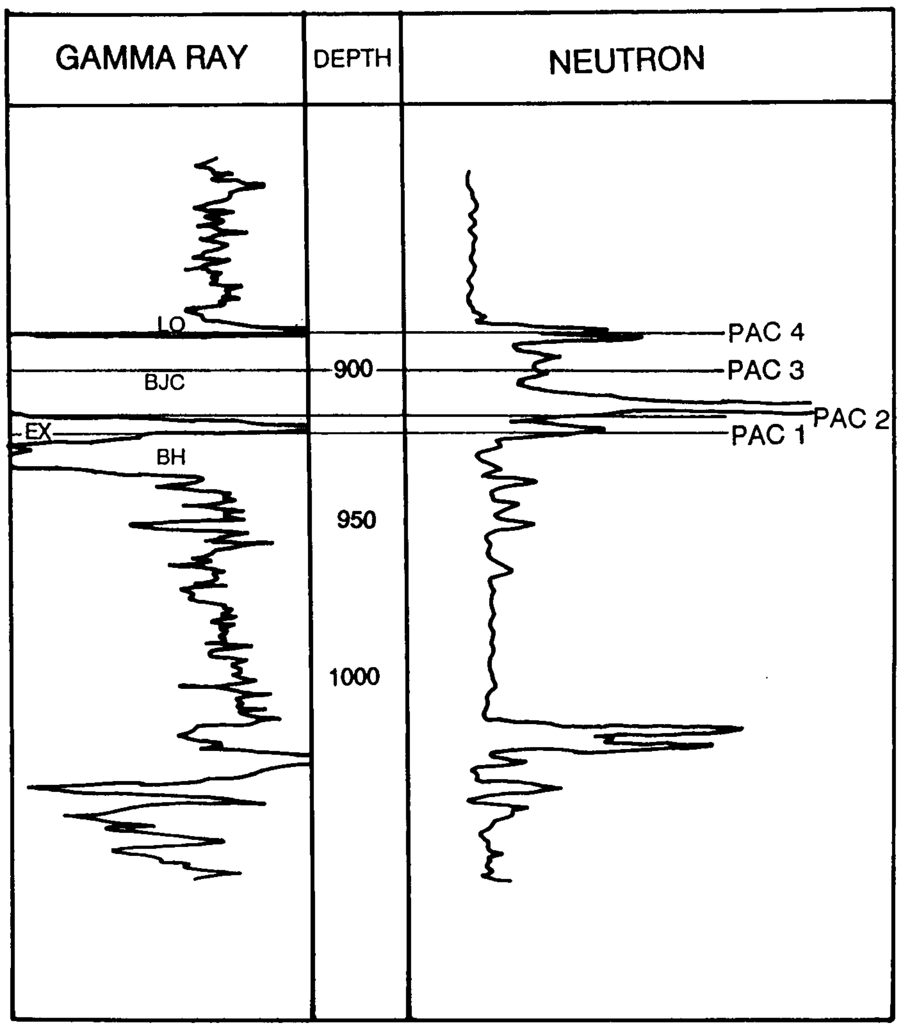
Tulsa County



EE

LOCATION: Section 21, T.19N., R.12E.
Tulsa County



APPENDIX D

Thin-Section Descriptions

Locality 881

881.1

Fossiliferous mudstone to wackestone; in places, laminated; clay "pods" conspicuous; horizontal burrow filled in with clay-size quartz; brachiopod fragments, ramose, fenestrate bryozoan fragments, fusulinids; fossils in horizontal burrow same as in matrix, more fragmented, abraded.

881.2

Peloid-rich, fossiliferous wackestone; fusulinids, brachiopod shell fragments, productid spines, ramose bryozoan fragments; much more fossil debris than in 881.1; clay is present as pods and seams.

881.3

Fossiliferous mudstone to wackestone; slightly mottled; foraminiferids (fusulinids, Tetrataxis), ramose bryozoan fragments, articulated brachiopods and shell fragments, productid spines, crinoid fragments; not as clay-rich as 881.2; coarse spar fills vugs.

881.4

Fossiliferous wackestone; productid spines, brachiopod shell fragments, ramose bryozoan fragments, fusulinids.

881.5

Fossiliferous mudstone; micrite matrix; mottled; productid spines, brachiopod shell fragments, crinoid fragments; 2 to 4 mm mudstone intraclasts in matrix.

Locality 812

812.1

Fossil poor siltstone; traces of micrite; bioturbated/mottled; ramose bryozoans, brachiopod shell fragments; clay seams throughout.

812.2

Fossiliferous mudstone; in places, silt- and clay-rich; mottled/burrowed; brachiopod shell fragments, crinoid fragments, fenestrate, ramose bryozoan fragments, productid spines.

812.3

Fossiliferous mudstone to wackestone; uppermost part of thin-section contains interbedded mudstone, clay, fossil debris; clay seams microstyolitic; fossils, clay decrease downward, carbonate increases; brachiopod shell fragments, ramose fragments, crinoid fragments, bivalve fragments, foraminiferids.

812.4

Fossiliferous wackestone to packstone; mottled; brachiopod shell fragments, fusulinids, ramose, fenestrate bryozoan fragments, crinoid fragments, high-spire gastropod fragment, laminar chaetetid fragments, echinoid spines (fossils concentrated along clay seams); iron stains (hematite) conspicuous; clay seams concentrated along basal part of thin-section.

812.5

Fossiliferous packstone; mud-rich matrix with coarse calcite filling vugs; articulated brachiopods and shell fragments, crinoid fragments, ramose bryozoan fragments, productid spines, foraminiferids.

812.6

Fossiliferous packstone; matrix dominated by fine inequigranular calcite; coarse, blocky spar fills larger vugs; fibrous calcite, hematite fill elongated openings; foraminifera (fusulinids, Tetrataxis), ramose, fenestrate bryozoan fragments, articulated brachiopods and shell fragments, productid spines, phylloid algal blades, trilobite fragments, crinoid fragments.

812.7

Fossiliferous packstone; matrix is equigranular and crystalline calcite with iron stains common; crinoid fragments, ramose, fenestrate bryozoan fragments, foraminiferids, brachiopod shell fragments, productid spines, phylloid algal blades.

812.8

Fossiliferous packstone; fusulinids, crinoid fragments, articulated brachiopods and shell fragments, ramose bryozoan fragments, echinoid and productid spines, gastropod fragment.

Locality 813

813.1

Wackestone to packstone; very fine-grain calcite spar with traces of micrite, clay; slightly mottled.

813.2

Chaetetes within a fossiliferous packstone; matrix is sparry calcite with isolated patches of micrite; botryoidal, iron-rich calcite fills vugs, fractures; fusulinids, crinoid fragments, brachiopod shell fragments, ramose bryozoan fragments, high-spire gastropod fragments.

813.3

Fossiliferous packstone; matrix is fine to coarse calcite; highly fossiliferous; articulated brachiopods and shell fragments, fusulinids, crinoid fragments, phylloid algal blades, productid spines, ramose bryozoan fragments.

813.4

Fossiliferous packstone; matrix is fine crystalline calcite; coarse calcite, hematite fill interparticle and intraparticle porosity; hematite stains within vugs; brachiopod shell fragments, foraminiferids (fusulinids, Tetrataxis), crinoid fragments, phylloid algal blades, ramose bryozoan fragments, echinoid spines, unidentifiable fossil debris; silt-size quartz grains fill isolated vug.

Locality 882

882.1

Fossiliferous packstone; extremely fine-grain calcite spar matrix with isolated clay patches; few fossils; crinoid fragments concentrated along top of thin-section, ramose bryozoan fragments, brachiopod shell fragments.

882.2

Fossiliferous wackestone to packstone; fine crystalline calcite matrix with clay seams throughout; brachiopod shell fragments, crinoid fragments, fusulinids, ramose bryozoan fragments, phylloid algal blades.

882.3

Fossiliferous wackestone to packstone; fine-grain calcite, micrite matrix with fine-grain fossil debris; phylloid algal blades, brachiopod shell fragments, crinoid fragments, fusulinids, ramose bryozoan fragments.

882.4

Fossiliferous wackestone to packstone; matrix is fine-grain, equigranular calcite with clay-rich, hematitic patches; coarse spar fills large vugs; foraminiferids (fusulinids, palaeotextulariids), crinoid fragments, brachiopod shell fragments, productid spines, phylloid algal blades.

882.5

Fossiliferous packstone; matrix is fine-grain calcite spar, peloids, coarse calcite in fossil molds; uppermost part of thin-section has laminated clay/carbonate with unidentifiable fossil debris parallel to laminations; clay, fossil content decrease downward; crinoid fragments, productid spines, articulated brachiopods and shell fragments, ramose bryozoan fragments, echinoid spines, phylloid algal blades, gastropod fragments; brachiopod and gastropod geopetals.

882.6

Fossiliferous wackestone to packstone; micrite and fine-grain calcite spar matrix with clay seams conspicuous; in places, fossils parallel to crenulated clay seams; articulated brachiopods and shell fragments, crinoid fragments, foraminiferids (<u>Tetrataxis</u>), laminar chaetetid fragment, productid spines, ramose bryozoan fragments, unidentifiable fossil debris.

882.7

Fossiliferous packstone; mottled; alternating patches of coarse, hematitic stained calcite with fine-grain calcite spar; crinoid fragments, brachiopod shell fragments; ramose bryozoan fragments; fusulinids, unidentifiable fossil debris concentrated along clay seams.

882.8

Fossiliferous packstone; fine-grain calcite spar matrix with 25% clay-rich; mottled (hematite stains); productid and echinoid spines, crinoid fragments, articulated brachiopods and shell fragments, ramose bryozoan fragments.

882.9

Fossiliferous, clay-rich packstone; hematite stains and clay seams throughout; mottled; foraminiferids (fusulinids, palaeotextulariids), ramose bryozoan fragments, productid spines, crinoid fragments, brachiopod shell fragments, echinoid spines.

882.10

Fossiliferous packstone; calcite spar matrix (iron stains); brachiopod shell fragments, productid spines, crinoid fragments, fusulinids, echinoid spines.

882.11

Fossiliferous packstone; fine- to coarse-grain inequigranular calcite and dolomite matrix; mottled (irregular iron stains); fossil debris fragmented, abraded; crinoid fragments, brachiopod shell fragments, fusulinids.

882.12

Fossiliferous packstone; fine, inequigranular calcite spar with coarser spar filling vugs; productid spines, crinoid fragments, fusulinids, brachiopod shell fragments, ramose bryozoan fragments.

882.13

Fossiliferous packstone; fine-grain, equigranular calcite spar matrix with hematite stains throughout; foraminiferids (fusulinids, *Tetrataxis*), crinoid fragments, productid and echinoid spines, brachiopod shell fragments.

882.14

Fossiliferous packstone; fine-grain, equigranular calcite spar matrix with coarse inequigranular calcite filling fossil fragments and fractures; iron stains throughout; fossils are poorly preserved (fragmented); productid spines, crinoid fragments, fusulinids, brachiopod shell fragments, ramose bryozoan fragments.

Locality 781

781.1

Fossiliferous wackestone; micrite and neomorphic spar matrix with clay seams conspicuous; neomorphic spar replaces crinoids; crinoid fragments, articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, ramose bryozoan fragments, foraminiferids (Tetrataxis, palaeotextulariids); very fossiliferous along clay seams.

781.2

Fossiliferous, peloid-rich wackestone; micrite (peloids) and fine-grain spar matrix; mud decreases upward; clay/shale partings throughout base of slide; elongated brachiopod shell fragments parallel to clay/shale partings; in places, micrite covers fossil fragments; brachiopod shell fragments, foraminiferids, crinoid fragments, ramose bryozoan fragments, phylloid algal blades, productid spines.

781.3

Fossiliferous wackestone; mud-rich matrix with fine neomorphic spar throughout; micrite increases downward; clay seams throughout lower half of thin-section; mottled; fossils concentrate along clay seams; brachiopod shell fragments, crinoid fragments, bryozoan fragments, phylloid algal blades, productid spines.

781.4

Fossiliferous wackestone; micrite matrix with patches of coarse blocky calcite, clay seams; coarse calcite crystals have dark (mud-rich?) rims; brachiopod shell fragments, phylloid algal blades, crinoid fragments, productid spines.

781.5

Fossiliferous wackestone; neomorphic spar, micrite matrix with isolated patches of clay; fenestrate, ramose bryozoan fragments, brachiopod shell fragments, productid spines, crinoid fragments, phylloid algal blades, foraminiferids.

781.6

Fossiliferous, mud-rich wackestone; neomorphic spar matrix with areas dominated by peloids; crenulated clay seams at top and bottom of thin-section drape fossil grains; mottled; brachiopod shell fragments perpendicular to up-direction with fibrous calcite crystals 'growing' off upper surface; fusulinids, brachiopod shell fragments, echinoid spines, phylloid algal blades, ramose bryozoan fragments, crinoid fragments, productid spines.

781.7

Fossiliferous wackestone; micrite matrix with areas dominated by coarse, blocky calcite; peloids densely packed in places; clay seams conspicuous with fossil debris concentrated along seams; mottled; foraminiferids (fusulinids, globivalvulinids, palaeotextulariids), ramose bryozoan fragments, brachiopod shell fragments, echinoid spines, phylloid algal blades, crinoid fragments, productid spines.

781.8

Fossiliferous, peloid-rich wackestone; micrite and neomorphic spar matrix with coarse calcite filling vugs, fossil fragments; fossils poorly preserved; ramose bryozoan fragments, crinoid fragments, productid spines, phylloid algal blades, foraminiferids, brachiopod shell fragments; phylloid algal blades parallel to clay seams.

781.9

Fossiliferous, peloid-rich wackestone; neomorphic spar, micrite matrix with clay seams throughout; fossils concentrated along crenulated clay seams; fossils poorly preserved; ramose bryozoan fragments, fusulinids, productid spines, crinoid fragments, phylloid algal blades, brachiopod shell fragments.

781.10

Fossiliferous, peloid-rich wackestone to packstone with intraclasts; neomorphic spar matrix with peloids; coarse spar fills vugs; clasts consist of fossiliferous, peloid-rich wackestones to packstones, fossil grains; microstyolitic clay seams drape around clasts; articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, foraminiferids (fusulinids, Tetrataxis), chaetetid fragments, productid spines, crinoid fragments, ramose bryozoan fragments, echinoid spines; chert fills isolated fractures within chaetetid.

781.11

Fossiliferous wackestone to packstone; micrite, neomorphic (micro) spar matrix; micrite dominated areas are peloid-rich; echinoid and productid spines, ramose bryozoan fragments, phylloid algal blades, crinoid fragments, articulated brachiopods and shell fragments.

781.12

Fossiliferous, mud-rich packstone; neomorphic spar matrix with micrite throughout; coarse, blocky calcite fills vugs; in places, micrite coats fossil grains; mottled; microstyolitic clay seams along base of thin-section; productid spines, foraminiferids, ramose bryozoan fragments, phylloid algal blades, crinoid fragments.

781.13

Fossiliferous packstone; fine- to medium-grain calcite spar matrix; in places, poorly preserved peloids occur in vugs; micrite coats fossil grains; crinoid fragments, ramose bryozoan fragments, fusulinids, echinoid and productid spines, brachiopod shell fragments.

781.14

Fossiliferous packstone; fine- to medium-grain calcite spar with only traces of micrite (coatings); crinoid fragments, fusulinids, echinoid and productid spines.

781.15

Peloid-rich, fossiliferous wackestone; micrite and neomorphic spar matrix; fossils decrease upward as peloids increase; brachiopod shell fragments, crinoid fragments, fusulinids, ramose bryozoan fragments, productid spines.

781.16

Peloid-rich, wackestone; neomorphic spar and peloid-rich mud matrix; in places, peloids recrystallized, densely packed; vugs filled with chert, coarse calcite; unidentifiable fossil debris.

Locality 883

883.1

Sparsely fossiliferous to fossiliferous packstone; fine crystalline calcite spar to fine equigranular spar matrix with local hematite stains; brachiopod, bivalve shell fragments, productid shell fragments, ramose, fenestrate bryozoan fragments, phylloid algal blades, trilobite fragments.

883.2

Sparsely fossiliferous packstone; fine to coarse inequigranular calcite spar with traces of micrite, dolomite; articulated brachiopods and shell fragments, articulated bivalve and shell fragments, trilobite fragments, productid spines.

883.3

Sparsely fossiliferous packstone; fine crystalline calcite, fine inequigranular calcite spar with traces of dolomite; neomorphic spar concentrated in bottom part of thin-section; articulated brachiopods and shell fragments, crinoid fragments, ramose, fenestrate bryozoan fragments, bivalve shell fragments, echinoid spines.

883.4

Sparsely fossiliferous packstone; matrix is neomorphic spar, fine to coarse equigranular calcite spar; microstyolitic clay seams conspicuous; ramose, fenestrate bryozoan fragments, brachiopod shell fragments, crinoid fragments.

883.5

Fossiliferous, mud-rich wackestone to packstone; matrix is very fine neomorphic (micro) spar, micrite (peloids); coarse inequigranular spar, with fine to coarse, blocky calcite fill fossil fragments, fractures; in places, fossils, peloids densely packed; articulated brachiopods and shell fragments, crinoid fragments, ramose, fenestrate bryozoan fragments, bivalve shell fragments, sponge spicules, productid spines; calcite overgrowth on crinoid fragments.

883.6

Fossiliferous packstone; fine crystalline calcite, fine inequigranular calcite spar with traces of dolomite; neomorphic spar concentrated in bottom part of thin-section; articulated brachiopods and shell fragments, crinoid fragments, ramose, fenestrate bryozoan fragments, bivalve shell fragments, articulated ostracodes, echinoid and productid spines.

883.7

Fossiliferous packstone; neomorphic spar with traces of micrite, dolomite; articulated brachiopods and shell fragments, crinoid fragments, ramose, fenestrate bryozoan fragments, bivalve shell fragments, echinoid and productid spines.

883.8

Fossiliferous, peloid-rich wackestone to packstone; matrix varies from peloid-rich micrite to neomorphic spar; fine to coarse equigranular calcite, chert, silt-size quartz grains fill vugs, fractures, fossil fragments; fossils densely packed; sponge spicules, articulated brachiopods and shell fragments, Fistulipora, ramose, fenestrate bryozoan fragments, phylloid algal blades, bivalve shell fragments, crinoid fragments, productid spines.

883.9

Fossiliferous, peloid-rich wackestone to packstone; peloid-rich micrite matrix with isolated patches of fine to coarse equigranular calcite, fibrous quartz; peloids most common in brachiopod, gastropod geopetals; articulated brachiopods and shell fragments, bivalve shell fragments, gastropod shell fragments, ramose, fenestrate bryozoan fragments, productid spines, crinoid fragments, unidentifiable fossil debris.

883.10

Fossiliferous, peloid-rich wackestone to packstone; peloid-rich micrite matrix with isolated patches of fine to coarse equigranular calcite, fibrous quartz; peloids most common in brachiopod, gastropod geopetals; sand-size quartz grains fill brachiopod geopetal; articulated brachiopods and shell fragments, bivalve shell fragments, gastropod shell fragments, ramose, fenestrate bryozoan fragments, productid spines, crinoid fragments.

883.11

Fossiliferous packstone; matrix is very fine to fine equigranular calcite spar with traces of micrite; micrite coats fossil fragments; ramose bryozoan fragments, articulated brachiopods and shell fragments, foraminiferids (fusulinids, globivalvulinids), productid and echinoid spines; microstyolitic clay seams conspicuous.

883.12

Fossiliferous, peloid-rich wackestone to packstone; matrix varies from peloid-rich micrite to neomorphic spar with isolated patches of micrite; medium to coarse equigranular calcite spar fills fractures, vugs; brachiopod shell fragments, ramose, fenestrate bryozoan fragments, crinoid fragments, echinoid spines.

883.13

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with patches of neomorphic spar, coarse equigranular calcite spar; articulated brachiopods and shell fragments, fenestrate bryozoan fragments, crinoid fragments, productid spines.

883.14

Fossiliferous wackestone; neomorphic spar matrix with coarse equigranular calcite spar, traces of micrite; sand-size quartz grains conspicuous; articulated brachiopods and shell fragments, fenestrate bryozoan fragments, crinoid fragments, fusulinids, productid spines, bivalve shell fragments.

883.15

Sparsely fossiliferous wackestone; matrix is peloid-rich micrite with patches of neomorphic spar, coarse equigranular calcite spar; brachiopod shell fragments, bryozoan fragments, crinoid fragments, foraminiferids (globivalvulinids, Tetrataxis), articulated ostracodes.

883.16

Sparsely fossiliferous, mud-rich wackestone; micrite matrix, with fine to coarse equigranular calcite spar; peloid-rich intraclasts conspicuous; brachiopod shell fragments, bryozoan fragments, crinoid fragments, foraminiferids (globivalvulinids), articulated ostracodes.

883.17

Fossiliferous, peloid-rich wackestone to packstone; peloid-rich micrite matrix with neomorphic spar, fine to coarse equigranular calcite spar; articulated brachiopods and shell fragments, ramose, fenestrate bryozoan fragments, foraminiferids (Tetrataxis), crinoid fragments, ostracodes, productid spines.

883.18

Fossiliferous, mud-rich packstone; neomorphic spar matrix with fine, equigranular calcite spar, traces of micrite (peloids); in places, fossils densely packed; articulated brachiopods and shell fragments, fenestrate bryozoan fragments, articulated ostracodes, crinoid fragments, foraminiferids (palaeotextulariids, fusulinids), phylloid algal blades.

883.19

Fossiliferous packstone; neomorphic spar matrix with traces of micrite (covers fossil grains); foraminiferids (Tetrataxis, palaeotextulariids, fusulinids), ramose, fenestrate bryozoan fragments, crinoid fragments, brachiopod shell fragments, productid spines.

883.20

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with patches of neomorphic spar; brachiopod shell fragments, ramose bryozoan fragments, foraminiferids (Tetrataxis, fusulinids), crinoid fragments, productid spines, articulated bivalves, ostracode fragments.

883.21

Fossiliferous, peloid-rich wackestone to packstone; peloid-rich micrite matrix with patches of neomorphic spar; articulated brachiopods (geopetals) and shell fragments, ramose bryozoan fragments, foraminiferids (globivalvulinids, fusulinids), crinoid fragments, productid spines, bivalve shell fragments, ostracode fragments.

883.22

Fossiliferous wackestone; fine equigranular calcite spar, neomorphic spar matrix; fusulinids, articulated ostracodes, crinoid fragments, echinoid spines, brachiopod shell fragments, phylloid algal blades, ramose bryozoan fragments, unidentifiable fossil debris.

883.23

Sparsely fossiliferous wackestone to packstone; very fine equigranular calcite spar matrix with traces of micrite; crinoid fragments, brachiopod shell fragments, phylloid algal blades, ramose bryozoan fragments, productid spines, unidentifiable fossil debris.

883.24

Fossiliferous packstone; fine equigranular calcite spar, neomorphic spar matrix with traces of peloid-rich micrite (clasts); hematite stains conspicuous; articulated ostracodes and shell fragments, foraminiferids (<u>Tetrataxis</u>), crinoid fragments, productid spines, ramose bryozoan fragments, phylloid algal blades.

883.25

Fossiliferous, mud-rich packstone; fine equigranular calcite spar matrix with areas dominated by peloid-rich micrite (covers fossils); in places, fossils, peloids densely packed; fossils abraded; articulated ostracodes and shell fragments, foraminiferids (fusulinids, <u>Tetrataxis</u>), crinoid fragments, brachiopod shell fragments, gastropod fragments.

883.26

Fossiliferous, peloid-rich wackestone to packstone; fine equigranular calcite spar matrix with areas dominated by peloid-rich micrite; chert grains conspicuous.

883.27

Fossiliferous packstone; fine equigranular calcite spar matrix with traces of peloid-rich micrite; hematite stains throughout vugs, fractures; articulated ostracodes, productid spines, foraminiferids (palaeotextulariids), bivalve shell fragments.

Locality 887

887.1

Fossiliferous wackestone; fine neomorphic spar, fine crystalline calcite, peloid-rich micrite matrix; fossiliferous clay/shale partings along base of thin section with clay- to silt-size quartz grains; articulated brachiopods and shell fragments, ramose bryozoan fragments, crinoid fragments, echinoid spines, phylloid algal blades.

887.2

Fossiliferous wackestone interbedded with fossiliferous clay/shale partings; fine neomorphic spar matrix; brachiopod shell fragments, ramose bryozoan fragments, crinoid fragments, echinoid spines, phylloid algal blades.

887.3

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with isolated patches of fine calcite spar, coarse, blocky calcite; elongated fossil fragments vertical; foraminiferids (fusulinids, globivalvulinids), ramose bryozoan fragments, brachiopod shell fragments, low-spire gastropod fragments, productid spines, crinoid fragments.

887.4

Fossiliferous wackestone; very fine neomorphic (micro) spar with isolated patches of peloid-rich micrite; fossils concentrated along clay/shale partings; fusulinids, brachiopod shell fragments, ramose bryozoan fragments, productid and echinoid spines; peloid content, clay seams increase upward.

887.5

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with fine to coarse inequigranular calcite spar; coarse spar fills geopetals, vugs; in places, fossils densely packed; articulated brachiopods (with spiralia) and shell fragments, foraminiferids (fusulinids, globivalvulinids), crinoid fragments, Fistulipora(?) and ramose bryozoan fragments, phylloid algal blades; silt-size quartz grains within articulated brachiopods.

887.6

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with fine to coarse calcite spar; mottled; brachiopod shell fragments, phylloid algal blades, crinoid fragments, foraminiferids (Tetrataxis), productid spines, ramose bryozoan fragments; fossils concentrated along microstyolitic clay seams.

887.7

Fossiliferous, peloid-rich wackestone; equally mixed peloid-rich micrite, fine-grain calcite spar matrix; coarse calcite fills vugs, fossil fragments; mottled; brachiopod shell fragments, phylloid algal blades, crinoid fragments, productid spines, ramose bryozoan fragments.

887.8

Fossiliferous, peloid-rich wackestone with mudstone intraclasts; neomorphic spar matrix; areas dominated by recrystallized peloids; in places, fossils densely packed; brachiopod shell fragments, phylloid algal blades, crinoid fragments, bivalve fragments.

887.9

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with isolated areas of neomorphic spar; coarse calcite spar fills fossil fragments; mottled; microstyolitic clay seams conspicuous; brachiopod shell fragments, productid spines, crinoid fragments.

887.10

Fossiliferous, peloid-rich wackestone; fine to coarse calcite spar matrix mixed with peloids; coarse, blocky calcite fills fossils and vugs; fossils concentrate along microstyolitic clay seams; brachiopod shell fragments, phylloid algal blades have mud coatings.

887.11

Fossiliferous wackestone to packstone; neomorphic spar matrix with isolated patches of peloid-rich micrite; coarse calcite spar within fossil fragments; crinoid fragments, brachiopod shell fragments, phylloid algal fragments.

887.12

Fossiliferous packstone; very fine-grain equigranular calcite spar matrix; isolated clay- to silt-size quartz grains, microstyolitic clay seams conspicuous; crinoid fragments, articulated brachiopods and shell fragments.

887.13

Fossiliferous wackestone to packstone; fine-grain calcite spar with isolated patches of micrite (peloid); foraminiferids (palaeotextulariids), phylloid algal blades, crinoid fragments, articulated brachiopods and shell fragments, productid spines, ramose bryozoan fragments.

887.14

Fossiliferous, peloid-rich wackestone to packstone; microstyolitic, fossiliferous clay/shale partings conspicuous; brachiopod shell fragments, phylloid algal blades, crinoid fragments, foraminiferids, Fistulipora, ramose bryozoan fragments, productid spines.

887.15

Fossiliferous, silt-rich wackestone; neomorphic spar, micrite matrix with clay- to silt-size quartz grains; micrite increases upward; mottled; microstyolitic clay/shale partings throughout; Fistulipora, ramose bryozoan fragments, phylloid algal blades, crinoid fragments, productid spines.

887.16

Fossiliferous packstone; neomorphic spar matrix with trace of micrite, dolomite?; ramose bryozoan fragments, brachiopod shell fragments, crinoid fragments, foraminiferids (fusulinids, palaeotextulariids, globivalvulinids), productid spines.

887.17

Sparsely fossiliferous mudstone; peloid-rich micrite matrix with neomorphic spar concentrated along base of thin-section; micrite increases upward; phylloid algal blades (fragmented), foraminiferids (fusulinids, globivalvulinids), ramose bryozoan fragments.

Locality 884

884.1

Fossiliferous siltstone; clay- to silt-size quartz grain matrix with isolated patches of carbonate mud; brachiopod and bivalve shell fragments, productid spines; fossil fragments parallel clay laminae.

884.2

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with fine crystalline calcite spar, neomorphic spar; coarse, blocky spar fills fossil fragments, vugs; peloids, microstyolitic clay seams along base of thin-section; fossils densely packed; articulated brachiopods and shell fragments, Fistulipora, ramose bryozoan fragments, productid spines, phylloid algal blades, foraminiferids (globivalvulinids, Tetrataxis), crinoid fragments, echinoid spines.

884.3

Fossiliferous, peloid-rich wackestone with abundant microstyolitic clay seams; micrite, neomorphic spar matrix; coarse, calcite spar fills vugs, fossil fragments; mottled; articulated brachiopods and shell fragments, productid spines, ramose bryozoan fragments, phylloid algal blades, bivalve shell fragments.

884.4

Fossiliferous, peloid-rich wackestone to fossiliferous wackestone; micrite content increases upward; mottled; dolomitic clay seams conspicuous; foraminiferids (Tetrataxis), brachiopod shell fragments, crinoid fragments, ramose bryozoan fragments, productid spines, phylloid algal blades.

884.5

Fossiliferous, peloid-rich wackestone with abundant microstyolitic clay seams; micrite matrix mixed with coarse crystalline calcite spar, inequigranular calcite spar; fossils concentrated along seams; mottled; crinoid fragments, foraminiferids (fusulinids, Tetrataxis), articulated brachiopods and shell fragments, productid spines, ramose bryozoan fragments, echinoid spines, phylloid algal blades.

884.6

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with isolated patches of neomorphic spar; silt-size quartz grains along microstyolized clay seams; ramose bryozoan fragments, crinoid fragments, fusulinids, brachiopod shell fragments, phylloid algal blades.

884.7

Fossiliferous, peloid-rich wackestone; neomorphic spar matrix with areas dominated by micrite (peloids); fossils concentrated in upper part of thin section; mud-rich intraclasts along clay seams; brachiopod shell fragments, crinoid fragments, Fistulipora(?), ramose bryozoan fragments, phylloid algal blades.

884.8

Fossiliferous, peloid-rich wackestone; clay-rich seams dominant in upper, lower parts of thin-section; phylloid parallel clay seams; mottled; foraminiferids (globivalvulinids), crinoid fragments, phylloid algal blades.

884.9

Fusulinid, mud-rich packstone; fine neomorphic spar matrix with isolated patches of micrite; microstyolitic clay seams along base; foraminiferids (globivalvulinids), crinoid fragments, brachiopod shell fragments; fossils concentrated along clay seams.

884.10

Fossiliferous (fusulinid), silt-rich, clay/shale parting; clay- to silt-size quartz grains throughout thin-section; microstyolitic clay/shale partings drape fusulinids; fusulinids (densely packed), crinoid fragments, brachiopod and bivalve shell fragments, echinoid spines, ramose bryozoan fragments.

884.11

Sparsely fossiliferous, burrowed mudstone to wackestone; micrite, fine-grain neomorphic spar matrix; fusulinids, ramose bryozoan fragments.

884.12

Fossiliferous, peloid-rich wackestone; fine neomorphic spar, peloid-rich micrite matrix; clay seams along base of thin-section; mottled; micrite increases upward; fusulinids, brachiopod shell fragments, phylloid algal blades, bivalve shell fragments, ramose bryozoan fragments.

884.13

Sparsely fossiliferous mudstone; micrite, fine neomorphic spar matrix; very few fossils; fusulinids, articulated brachiopods and shell fragments, productid spines, crinoid fragments, trilobite fragments.

884.14

Fossiliferous, peloid-rich wackestone interbedded with clay/shale partings; peloid-rich micrite matrix with fine to coarse inequigranular calcite spar; most fossils concentrated along clay/shale partings; <u>Fistulipora</u> bryozoan fragments, productid spines, foraminiferids, articulated brachiopods and shell fragments.

884.15

Fossiliferous mudstone to wackestone; micrite matrix with isolated patches of neomorphic spar; clay seams in upper, lower parts of thin-section; fossils concentrated along clay seams; crinoid fragments, productid spines, brachiopod and bivalve shell fragments, foraminiferids.

884.16

Rooted(?) mudstone with fossiliferous, intraclastic packstone rhizocretions; micrite, neomorphic spar, dolomite matrix; roots? filled with inequigranular calcite, dolomite, clay; fossils in rhizocretions: productid spines, foraminiferids (globivalvulinids), crinoid fragments, bivalve fragments.

884.17

Fossiliferous, rooted(?) mudstone with fossiliferous, intraclastic packstone rhizocretions; micrite, neomorphic spar matrix; coarse, blocky calcite, dolomite, unidentifiable fossil debris fill rhizocretions; foraminiferids (fusulinids, globivalvulinids), productid spines.

Locality 851

851.1

Fossiliferous, peloid-rich wackestone interbedded with clay/shale partings; peloid-rich micrite matrix with fine to coarse, inequigranular calcite spar.

851.2

Fossiliferous, peloid-rich wackestone; matrix is intermixed neomorphic spar, fine to coarse, inequigranular calcite, peloid-rich micrite; clay-size quartz grains conspicuous; clay seams at top, bottom of thin-section; foraminiferids (Tetrataxis), crinoid fragments, echinoid and productid spines, ramose bryozoan fragments, articulated brachiopods and shell fragments, phylloid algal blades.

851.3

Fossiliferous, quartz-rich wackestone; micrite matrix with traces of neomorphic spar; coarse calcite spar fills vugs, fractures; clay- to silt-rich quartz concentrated along clay/shale partings; micrite, fossil content increases upward; articulated brachiopods and shell fragments, bivalve shell fragments, phylloid algal blades, crinoid fragments, productid spines, ramose bryozoan fragments.

851.4

Fossiliferous, peloid-rich wackestone to fossiliferous packstone; matrix is peloid-rich micrite, neomorphic spar, fine to coarse, inequigranular calcite spar; microstyolitic clay seams conspicuous; mottled; ramose bryozoan fragments, crinoid fragments, articulated brachiopods and shell fragments.

851.5

Fossiliferous wackestone to packstone; matrix is neomorphic spar, micrite (peloids); microstyolitic clay seams drape fossil fragments; ramose bryozoan fragments, crinoid fragments, brachiopod shell fragments.

851.6

Fossiliferous wackestone; matrix varies from dominately micrite to intermixed micrite, fine equigranular calcite spar, neomorphic spar; coarse calcite fills vugs, fractures, fossil fragments; articulated brachiopods and shell fragments, ramose bryozoan fragments, crinoid fragments, gastropod fragments, productid spines, bivalve shell fragments, phylloid algal blades, echinoid spines; gastropod, brachiopod geopetals.

851.7

Fossiliferous wackestone to packstone; neomorphic spar matrix with isolated peloid-rich micrite; microstyolitic clay seams conspicuous; fossils concentrated along clay seams; mottled; ramose bryozoan fragments, brachiopod shell fragments, crinoid fragments, bivalve shell fragments, productid shell fragments.

851.8

Fossiliferous, peloid-rich wackestone to fossiliferous packstone; fine to coarse inequigranular calcite spar matrix with peloids concentrated along base of thin-section; fossiliferous (bryozoan fragments), microstyolitic clay seams conspicuous; Fistulipora, ramose bryozoan fragments, articulated brachiopods and shell fragments, crinoid fragments, phylloid algal blades, productid spines, foraminiferids (globivalvulinids).

851.9

Fossiliferous, peloid-rich packstone; very fine neomorphic (micro) spar matrix with patches of peloid-rich micrite, coarse calcite spar; articulated brachiopods and shell fragments, ramose bryozoan fragments, crinoid fragments, foraminiferids (fusulinids, globivalvulinids); fossils concentrated along microstyolitic clay seams.

851.10

Fossiliferous, peloid-rich packstone; neomorphic spar, coarse calcite spar matrix with areas dominated by peloid-rich micrite; fossiliferous, dolomitic, microstyolitic clay seams conspicuous; Fistulipora, ramose bryozoan fragments, articulated brachiopods and shell fragments, fusulinids, crinoid fragments, productid spines, phylloid algal blades.

851.11

Fossiliferous, peloid-rich wackestone to packstone; matrix is micrite, coarse, inequigranular calcite spar, fine to coarse neomorphic spar; mottled; articulated brachiopods and shell fragments, bivalve shell fragments, phylloid algal blades, Fistulipora, ramose bryozoan fragments, crinoid fragments, fusulinids, gastropod fragments.

851.12

Fossiliferous, peloid-rich packstone; fine to coarse inequigranular calcite spar matrix with patches of peloid-rich micrite; brachiopod, bivalve shell fragments, phylloid algal blades, articulated ostracodes and shell fragments, echinoid spines.

851.13

Fossiliferous, wackestone to mud-rich packstone; matrix consists of micrite, coarse neomorphic spar, coarse inequigranular calcite spar, patches of dolomite crystals; fossiliferous, microstyolitic clay seams conspicuous; phylloid algal blades, unidentifiable fossil debris.

851.14

Fossiliferous wackestone to packstone; neomorphic spar matrix with traces of peloid-rich micrite; micrite content decreases downward; chaetetid fragment across upper half of thin-section; above chaetetid - fusulinids, ramose bryozoan fragments; below chaetetid - Fistulipora, crinoid fragments, ostracode fragments, brachiopod shell fragments.

851.15

Fossiliferous, peloid-rich wackestone interbedded with clay/shale partings; peloid-rich micrite matrix with patches of neomorphic spar; clay/shale partings contain laminated clay- to silt-size quartz grains, peloid-rich clasts; crinoid fragments, brachiopod shell fragments, foraminiferids (Tetrataxis, globivalvulinids), fenestrate bryozoan fragments, echinoid and productid spines, trilobite fragments, articulated ostracodes and shell fragments, bivalve shell fragments.

851.16

Fossiliferous, peloid-rich packstone; fine to coarse inequigranular calcite spar matrix with areas dominated by peloid-rich micrite; coarse, blocky calcite fills vugs, fossil fragments; microstyolitic clay, silt seams conspicuous; ramose, fenestrate bryozoan fragments, articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, crinoid fragments, productid spines.

851.17

Fossiliferous, peloid-rich wackestone to packstone; matrix is peloid-rich micrite with coarse, blocky calcite spar, fine to coarse inequigranular calcite spar; micrite coats fossil fragments; foraminiferids (fusulinids, globivalvulinids, Tetrataxis), articulated brachiopods (with spiralia) and shell fragments, ramose bryozoan fragments, productid spines, bivalve shell fragments, phylloid algal blades, echinoid spines; foraminiferids concentrated along uppermost clay seam.

851.18

Fusulinid wackestone interbedded with clay/shale partings; peloid-rich micrite matrix with isolated fractures, vugs filled with coarse, blocky calcite spar; foraminiferids (fusulinids, globivalvulinids), chaetetid fragments, ramose bryozoan fragments, crinoid fragments, Neosyringopora, articulated ostracodes, productid spines; fusulinids concentrated along clay/shale partings.

851.19

Fossiliferous, peloid-rich wackestone to packstone; peloid-rich micrite matrix, with neomorphic spar; dolomitic, microstyolitic clay seams conspicuous; fossils densely packed; fusulinids, brachiopod shell fragments, sponge spicules, bivalve shell fragments, gastropod fragments, phylloid algal blades.

851.20

Fossiliferous (fusulinid), peloid-rich wackestone; matrix is peloid-rich micrite, fine inequigranular calcite spar; fossils densely packed; fusulinids, sponge spicules, gastropod fragments (low-, high-spire), ostracode, brachiopod, bivalve shell fragments.

851.21

Sparsely fossiliferous mudstone; micrite matrix with trace of neomorphic (micro) spar; foraminiferids (palaeotextulariids), productid spines, articulated ostracodes, bivalve shell fragments, sponge spicules.

851.22

Fossiliferous, peloid-rich wackestone; matrix is peloid-rich micrite, isolated patches of fine to coarse inequigranular calcite spar; basal part of thin-section contains laminated clay seams with ostracode fragments, echinoid spines, shell fragments; articulated brachiopods (geopetal) and shell fragments, foraminiferids (palaeotextulariids), crinoid fragments.

851.23

Fossiliferous wackestone; micrite to neomorphic (micro) spar matrix; microstyolitic clay seam in center of thin-section; fossil debris concentrated along clay seam; foraminiferids (fusulinids, palaeotextulariids, globivalvulinids), crinoid fragments.

851.24

Fossiliferous (fusulinid) mudstone; clay/shale partings concentrated along base of thin-section; micrite matrix with silt-size quartz grains conspicuous; micrite increases upward; fine, inequigranular, hematitic-rich calcite spar fill cavities; fusulinids, brachiopod, bivalve shell fragments, low-spire gastropod fragments, crinoid fragments.

851.25

Fossiliferous, peloid-rich wackestone; neomorphic spar, peloid-rich micrite matrix; clay/shale partings along top of thin-section; micrite increases upward; fossils, peloid-rich intraclasts densely packed along bottom; foraminiferids (globivalvulinids, fusulinids), bivalve shell fragments, gastropod fragments, ostracode shell fragments.

851.26

Fossiliferous wackestone with local patches of fossiliferous packstone; micrite, neomorphic (micro) spar matrix; fossil debris densely packed, in places; brachiopod shell fragments, productid spines, sponge spicules, fusulinids, ostracode fragments.

851.27

Fossiliferous, mud-rich packstone; densely packed fossil debris; elongated fossil fragments (phylloid algal blades) in top part of thin-section vertical; foraminiferids (fusulinids, palaeotextulariids), low-spire gastropod fragments, bivalve shell fragments, crinoid fragments, unidentifiable fossil debris.

851.28

Fossiliferous wackestone; micrite matrix with isolated patches of neomorphic spar; mottled; laminar chaetetid fragments, brachiopod shell fragments, ramose, fenestrate bryozoan fragments, articulated ostracodes, fusulinids, crinoid fragments, *Neosyringopora*.

851.29

Fossiliferous, peloid-rich wackestone; peloid-rich micrite matrix with patches of fine to coarse inequigranular calcite spar, microstyolitic clay seams; seams concentrated in upper, lower part of thin-section; foraminiferids (fusulinids, palaeotextulariids), ramose, fenestrate bryozoan fragments, productid spines, brachiopod, bivalve shell fragments, crinoid fragments, phylloid algal blades.

Locality 885

885.1

Fossiliferous, peloid-rich wackestone; upper part neomorphic spar matrix free of peloids; coarse spar fills fractures and vugs; lower part is micritic with peloids concentrated along microstyolitic clay seams; crinoid fragments, phylloid algal blades, ramose bryozoan fragments, articulated brachiopods and shell fragments, productid spines.

885.2

Fossiliferous, peloid-rich wackestone; micrite, neomorphic spar matrix (similar to 885.1, more micrite); ramose bryozoan fragments, articulated brachiopods (geopetals) and shell fragments, crinoid fragments, productid spines, foraminiferids (*Tetrataxis*).

885.3

Fossiliferous, mud-rich packstone; coarse calcite spar matrix with peloid-rich micrite; two stages of cementation (fine, equigranular calcite spar, then coarse, blocky calcite); dolomitic clay seams; ramose bryozoan fragments, brachiopod shell fragments, phylloid algal blades, crinoid fragments.

885.4

Fossiliferous, peloid-rich wackestone to packstone; micrite content decreases upward, clay content increases; coarse calcite spar fills fractures, fossil fragments, vugs; ramose bryozoan fragments, brachiopod shell fragments, phylloid algal blades.

885.5

Fossiliferous, peloid-rich packstone; fine to coarse neomorphic spar matrix; micrite concentrated in 'trapped' areas (under fossil fragments); productid spines, crinoid fragments.

885.6

Fossiliferous wackestone to packstone; fine to coarse neomorphic spar matrix with isolated areas of micrite; productid spines, crinoid fragments, articulated brachiopods (geopetals) and shell fragments.

885.7

Fossiliferous wackestone to packstone; neomorphic spar matrix with micritic areas; clay seams in uppermost part of slide; foraminiferids (palaeotextulariids), productid spines, crinoid fragments, ramose bryozoan fragments, brachiopod shell fragments.

885.8

Fossiliferous wackestone to packstone; micrite, neomorphic spar matrix with clay seams; micrite covers fossil grains (micrite envelopes); fractures filled with coarse calcite; foraminiferids (palaeotextulariids), phylloid algal blades (concentrated along clay seams), crinoid fragments, productid spines, ramose bryozoan fragments, brachiopod shell fragments.

885.9

Fossiliferous wackestone to packstone; phylloid algal blades, articulated brachiopods and shell fragments, productid spines, ramose bryozoan fragments, crinoid fragments, foraminiferids (palaeotextulariids); coarse fossil fragments concentrated along phylloid algal blades.

885.10

Fossiliferous, clay-rich wackestone; microstyolitic clay seams throughout; fusulinids, gastropod fragments, unidentifiable fossil debris.

885.11

Fusulinid packstone; neomorphic (micro) spar matrix with microstyolitic clay seams; fossils poorly preserved; fusulinids, productid spines.

885.12

Fossiliferous, peloid-rich wackestone to packstone; neomorphic spar, micrite (peloid) matrix with abundant clay- to silt-size quartz grains; microstyolitic clay seams in upper part of thin-section; peloids, fossil debris, blocky calcite concentrated in fractures, vugs; fusulinids, articulated brachiopods and shell fragments, productid and echinoid spines, crinoid fragments, ramose bryozoan fragments.

885.13

Fossiliferous (fusulinid), peloid-rich wackestone to packstone; in places, micrite covers fossil fragments; clay seams concentrated in upper part of thin-section; fusulinids, phylloid algal blades, productid and echinoid spines, articulated brachiopods; geopetals; 1) peloid-rich (mud at base) 2) fine, equigranular calcite spar, 3) coarse, blocky calcite, 4) very coarse, blocky calcite.

885.14

Fossiliferous packstone; isolated areas of clay and micrite; mottled; fossils fragmented, densely packed; articulated brachiopods (geopetals) and shell fragments, productid spines, fusulinids, phylloid algal blades.

885.15

Fossiliferous, peloid-rich wackestone to packstone with peloid-rich wackestone clasts; in places, carbonate laminated with clay seams; foraminiferids (fusulinids, Tetrataxis), crinoid fragments, ramose bryozoan fragments, productid spines, brachiopod shell fragments, phylloid algal blades.

885.16

Fossiliferous packstone; neomorphic spar matrix with isolated areas of micrite; mottled; productid spines, ramose bryozoan fragments, fusulinids, crinoid fragments.

885.17

Fossiliferous, mud-rich wackestone; inequigranular to coarse, blocky calcite spar matrix with areas dominated by micrite (peloids?); fossils poorly preserved; brachiopod shell fragments, productid spines, ramose bryozoan fragments, gastropod fragments, phylloid algal blades.

885.18

Fossiliferous packstone; neomorphic spar matrix with isolated silt-size quartz grains; ramose bryozoan fragments, brachiopod shell fragments, crinoid fragments.

885.19

Fossiliferous wackestone to packstone; micrite, fine-grain neomorphic (micro) spar matrix with coarse calcite spar filling fractures and vugs; productid spines, ramose bryozoan fragments, crinoid fragments, brachiopod shell fragments, phylloid algal blades.

Locality 848

848.1

Fossiliferous wackestone to packstone; very fine, inequigranular calcite, neomorphic spar, micrite matrix with peloids in brachiopod geopetals; coarse calcite fills fossils, fractures; phylloid algal blades, articulated brachiopods (geopetals) and shell fragments, crinoid fragments, foraminiferids, productid and echinoid spines, gastropod fragments, ramose bryozoan fragments; unidentifiable fossil debris concentrated beneath brachiopod fragments, phylloid algal blades.

848.2

Fossiliferous wackestone to packstone; matrix is neomorphic spar with areas dominated by peloid-rich mud; basal part of thin-section mottled with clay seams; micrite decreases upward as clay increases; echinoid spines, articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, ramose bryozoan fragments, low-spire gastropod fragments, crinoid fragments, foraminiferids, productid spines, bivalve fragments.

848.3

Fossiliferous packstone; neomorphic spar matrix with dolomitic clay seams; crinoid fragments, articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, ramose bryozoan fragments; fossils, micrite concentrated along clay seams; hematite stain lines vugs.

848.4

Fossiliferous wackestone; peloid-rich micrite, neomorphic spar matrix with microstyolitic clay seams; mottled; articulated brachiopods (geopetals) and shell fragments, phylloid algal blades, ramose bryozoan fragments, crinoid fragments, productid and echinoid spines, bivalve fragments; geopetals not consistent with up-direction or with each other.

848.5

Fossiliferous packstone; fine neomorphic spar matrix with clay seams, isolated areas of micrite, coarse calcite spar; phylloid algal blades, articulated brachiopods and shell fragments.

848.6

Fossiliferous packstone; neomorphic spar with isolated areas of micrite; microstyolitic clay seams concentrated along upper part of thin-section; phylloid algal blades, brachiopod shell fragments, productid spines, crinoid fragments, ramose bryozoan fragments.

848.7

Fossiliferous packstone; neomorphic spar matrix; microstyolitic clay seams; brachiopod shell fragments, foraminiferids, crinoid fragments, ramose bryozoan fragments, phylloid algal blades.

848.8

Fossiliferous, mud-rich packstone; neomorphic spar matrix with areas dominated by coarse calcite spar; mottled (burrowed); productid spines, brachiopod shell fragments, phylloid algal blades, crinoid fragments, ramose bryozoan fragments.

848.9

Fossiliferous packstone; neomorphic spar matrix with coarse calcite throughout; microstyolitic clay seams trap fossil fragments; micrite in horizontal burrow; mottled; crinoid fragments, echinoid and productid spines, fusulinids, ramose bryozoan fragments; fossil content decreases upward.

848.10

Peloid-rich, fossiliferous wackestone; peloid-rich micrite matrix with patches of neomorphic spar; articulated brachiopods (geopetals) and shell fragments; geopetals not consistent with up-direction.

848.11

Fossiliferous wackestone to packstone; neomorphic spar matrix with areas dominated by peloids; fossils decrease downward; clay seams in upper half of thin-section; brachiopod shell fragments, crinoid fragments, fusulinids.

848.12

Fossiliferous, mud-rich packstone; phylloid algal blades, brachiopod shell fragments, ramose bryozoan fragments; mottled; hematitic stains line vugs, fractures.

848.13

Fossiliferous, peloid-rich packstone; in places, fossils densely packed; brachiopod shell fragments, crinoid fragments, ramose bryozoan fragments, phylloid algal blades, productid spines, bivalve shell fragments; fossils concentrated along clay seams.

REGIONAL STRATIGRAPHIC ANALYSIS
OF THE BLACKJACK CREEK LIMESTONE
(DESMOINESIAN, MIDDLE PENNSYLVANIAN) IN
SOUTHEAST KANSAS AND NORTHEAST OKLAHOMA

by

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ABSTRACT

Detailed regional stratigraphic analysis of the "lower Fort Scott cyclothem", Middle Pennsylvanian (Desmoinesian) was carried out in southeast Kansas and northeast Oklahoma, utilizing a hierarchal genetic stratigraphic approach (Busch et al., 1989). In this approach, lithostratigraphic, biostratigraphic, and sedimentologic data are used to define and correlate Punctuated Aggradational Cycles (PACs). Lithofacies and isopach maps, based on these correlated PACs, illustrate the development of the "lower Fort Scott cyclothem".

The "lower Fort Scott cyclothem", which is composed of the Blackjack Creek limestone (Fort Scott Formation, Marmaton Group) and the underlying Excello shale (upper most unit within the Cherokee Group), contains three PACs and is bounded above by the Little Osage shale (basal unit of the "upper Fort Scott cyclothem"), which constitutes a fourth PAC.

The lower boundary of PAC 3, which occurs in the middle part of the Blackjack Creek limestone, represents the most marine (or driest) phase within the interval studied, followed by a period of stasis, shallowing, or wetter climate.

The Excello and Little Osage (black) shales are recognized as shallow, marginal marine units, possibly deposited during inundation of peat swamps.

Chaetetids, which are common in the Blackjack Creek limestone, were found throughout the study area in the regressive (or drying) parts of PAC 2 and PAC 3. Laminar chaetetids represent turbid, shallow, marine environments with moderate water energy. Low-domical chaetetids represent slightly less turbid, possibly deeper marine water with slightly less energy.

Climate-change curves based on changing lithologies within the study interval were constructed and seemingly correlate, one-to-one, with relative water depth curves. Also, large-scale climate effects were suggested as the cause for the change from the coal-dominated Cherokee Group (Desmoinesian Stage) to the limestone-dominated section of the Missourian Stage. Furthermore, these large-scale changes were recorded in the Midcontinent before they occurred in the eastern United States.