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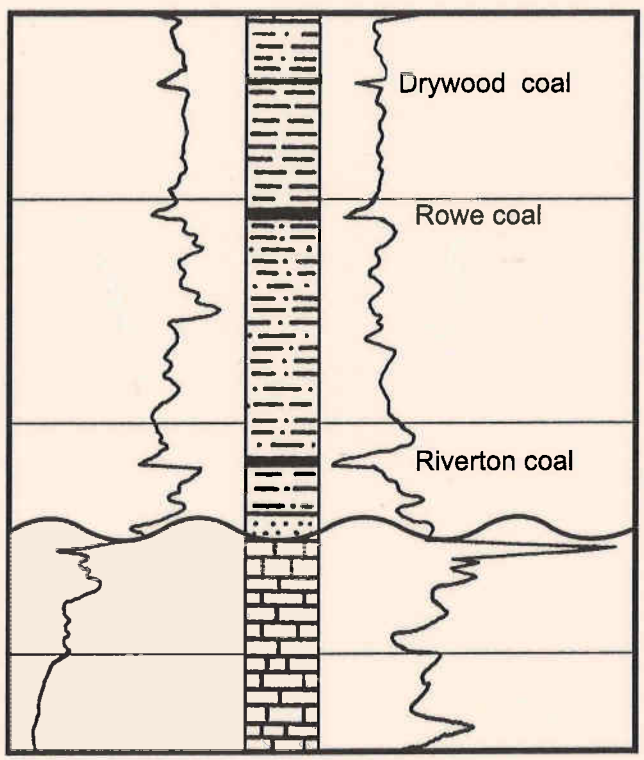
Surface to Subsurface Correlation of Methane-Producing Coal Beds, Northeast Oklahoma Shelf

LeRoy A. Hemish



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Surface to Subsurface Correlation of Methane-Producing Coal Beds, Northeast Oklahoma Shelf

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Prepared for a half-day workshop, this volume is part of a continuing series that provides information and technical assistance to Oklahoma's oil and gas operators.

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Front Cover

Excerpt from geophysical log showing bulk density (right) and gamma ray (left) deflections at three coalbed-methane-producing intervals in the lower Krebs Group (modified from Figure 11, p. 12, this volume).

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Surface to Subsurface Correlation of Methane-Producing Coal Beds, Northeast Oklahoma Shelf

LeRoy A. Hemish
Oklahoma Geological Survey

ABSTRACT. – Coalbed-methane production has been reported by operators from 10 named Pennsylvanian (Desmoinesian) coals in the northeast Oklahoma shelf area. They are (from oldest to youngest) the Riverton (McAlester Formation); Rowe, Drywood (Savanna Formation); Bluejacket (Boggy Formation); Weir–Pittsburg, Croweburg, Bevier, Iron Post, Mulky (Senora Formation); and Dawson (Holdenville Formation). Most of the production is from wells in Nowata, Osage, Rogers, Tulsa, and Washington Counties.

A subsurface stratigraphic framework, based primarily on gamma-ray, density, and neutron well logs and core-hole logs, is established to assist operators in correctly identifying methane-producing coal beds. Sixty-one high-quality well logs were used to construct six cross sections. Three west–east cross sections are oriented approximately parallel to present-day dip and represent lines extending about 60 mi westward from the coal-outcrop belt across Ts. 22, 25, and 28 N. Three south–north cross sections are oriented approximately parallel to present-day strike and represent lines extending about 50 mi from the Kansas–Oklahoma state line southward to T. 20 N.

Persistent markers such as the Checkerboard Limestone, Oologah Limestone (Big lime), Fort Scott Limestone (Oswego lime), Verdigris Limestone, Tiawah Limestone (Pink lime), and others—notably black shales—are used as reference strata to correlate the coal beds. Two type logs, one in the north-central part of the study area, and one in the southwestern part, are designated. They show the important marker beds (limestones, black shales, and persistent sandstones) as well as the stratigraphic positions of named coals.

INTRODUCTION

The purpose of this report is to provide insight into the stratigraphic relationship of methane-producing coal beds in the northeast Oklahoma shelf area. A subsurface study of coal beds in a 2,700-mi^2 area in six counties in Oklahoma directly south of the Kansas state line and west of the coal outcrop belt was made by the author, using existing well logs. Figure 1 shows the study area in relation to the coal belt of eastern Oklahoma.

Previous work in which correlation of coal beds in southeastern Kansas (Brady and others, 1994) and subsurface studies of coal beds in Osage County (Jacobs and Peterson, 1996) proved invaluable in making interpretations from logs and constructing cross sections for this study.

Six cross sections were constructed from the logs to provide a subsurface stratigraphic framework throughout the area (Fig. 2). Sixty-one well logs (gamma ray and bulk density or neutron) were selected from >200 logs examined at the Oklahoma Geological Survey (OGS) Log Library.

The correlation of named coals from previous surface studies (discussed later in this report) with those identified in this subsurface study will provide a much-needed basis for proper recognition of the 10 methane-producing coals in the shelf area. A determination of coal-bed thicknesses from the logs was not attempted. However, deflections in the log curves suggest that most of the beds are probably not more than 1 ft thick, with a few exceptions where the coal may be as thick as 4 ft.

COAL GEOLOGY

Introduction

Studies of the coal geology of the northern part of the northeast Oklahoma shelf area were carried out by the author, mostly during the late 1970s and early 1980s. The objective of these studies was to evaluate the coal resources and reserves of the northeast Oklahoma shelf area that are available for surface mining. Reports of the studies were published by the OGS (Hemish, 1986, 1989a, 1990). Subsurface interpretations in the present report

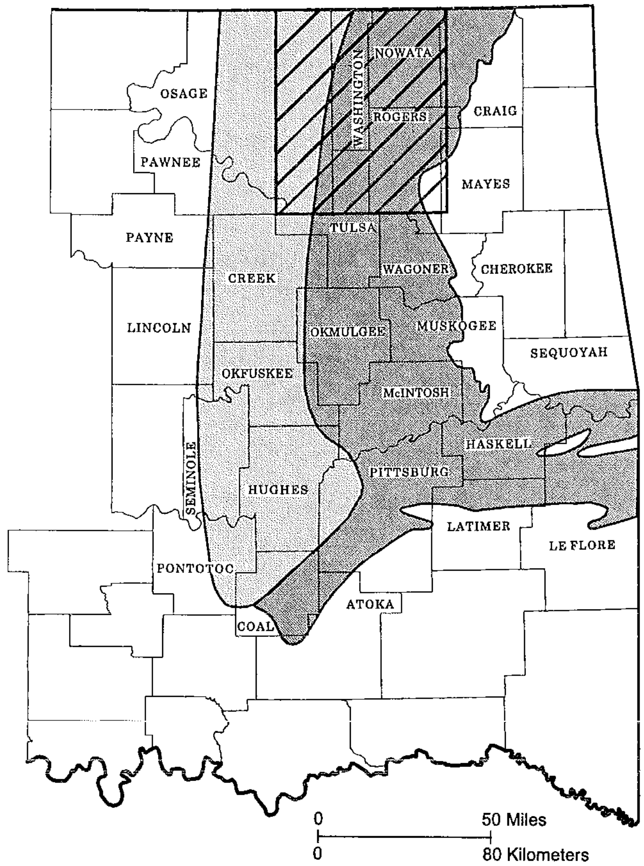


Figure 1. Index map of eastern Oklahoma, showing the Oklahoma bituminous coal field. Noncommercial coal belt is lightly shaded, commercial coal belt is darkly shaded, and subsurface-study area is hatched.

are based primarily on the coal stratigraphy from those earlier reports in Craig, Nowata, Rogers, Mayes, Tulsa, Wagoner, Creek, and Washington Counties. Information in the reports was compiled from 2,000 drill and core logs, provided mostly by coal companies, and from 247 sections measured by the author. This information was supplemented by other measured sections from earlier studies.

The study area included in the foregoing reports comprises about 1,800 mi^2 in the northern part of the coal belt of eastern Oklahoma (Fig. 3). The coal-producing area of the eight counties lies mostly within the Claremore Cuesta Plains geomorphic province. The region is characterized by resistant sandstones and limestones that dip gently westward and northwestward, forming cuestas between broad shale plains. Because of the low dips of the beds, the northeast Oklahoma shelf area is particularly amenable to strip mining.

Structural Geology and Cleat Orientation

The study area is on the northwest edge of the Ozark uplift (Fig. 3). Upper Mississippian and Pennsylvanian strata dip very gently westward and northwestward at 15–50 ft/mi (Huffman and others, 1958, p. 89), so the regional dip is <1°. Huffman believed that major deformation occurred during Middle Pennsylvanian time, and that the folds and faults are of early Desmoinesian age. Evidence of continued deformation throughout Desmoinesian time is present in the study area in the form of minor faults and small- and intermediate-scale anticlines and synclines.

A structure map of the Croweburg and Weir–Pittsburg coals (Hemish, 1986, p. 10, pl. 5) shows that numerous intermediate-scale synclines and anticlines are superimposed on the regional structure. Some of the folds reverse the regional dip. Closure on the anticlines is about 30–40 ft, and the structures generally occupy an area of 1–3 mi.

Rose diagrams were constructed from 37 Brunton-compass measurements of cleat direction in the Craig and Nowata Counties coal field (Fig. 4A), from 20 measurements in Rogers and Mayes Counties (Fig. 4B), and from 28 measurements in Tulsa and Wagoner Counties (Fig. 4C). Weighted averages of the 85 combined measurements show that the face cleats strike N. 47° W., and the butt cleats strike N. 49° E. The term *cleat* is defined as a vertical joint or system of joints along which coal naturally fractures. *Face cleat* is the major, well-defined joint in a coal bed, and *butt cleat* is the poorly defined joint, usually at right angles to the face cleat (McCulloch and others, 1974, p. 2).

Stratigraphy

General Statement

All of the minable coal zones in the area studied are in rocks of Desmoinesian (Middle Pennsylvanian) age. These rocks consist mostly of sandstone, siltstone, limestone, and shale. Coal constitutes a minor percentage of the whole.

The names of the various stratigraphic units and the types of rocks composing the units are shown in Figure 5. Thirty-four named coal beds and several unnamed coal beds are present in the northeast Oklahoma shelf area. Many of the coals were named either in Kansas or Missouri, particularly those that have any real economic potential at this time. Hemish (1987) presented a compendium of coal nomenclature in which he discussed the origin of the coal names and identified their stratigraphic positions in relation to associated markers. The coal beds themselves are excellent markers, and the application of coal-bed nomenclature is most useful in stratigraphic work.

The coal beds are separated by marine and nonmarine strata, indicating that they were laid down under cyclical conditions. According to Heckel (1991), vegetation that subsequently formed coal grew in coastal swamps near epeiric seas that covered northeastern Oklahoma during Desmoinesian time. Fluctuations of sea level caused oscillatory transgressions and regressions of the sea over the area. Channel sandstones, black shales, and interchannel coals here represent environments associated with deltas. Just as the shoreline oscillated back and forth, so did the delta environment. This accounts for the distribution, geometry, and relationships of the various rock units preserved across the area. The burial of these sediments resulted in alteration of vegetal matter to coal. Dif-

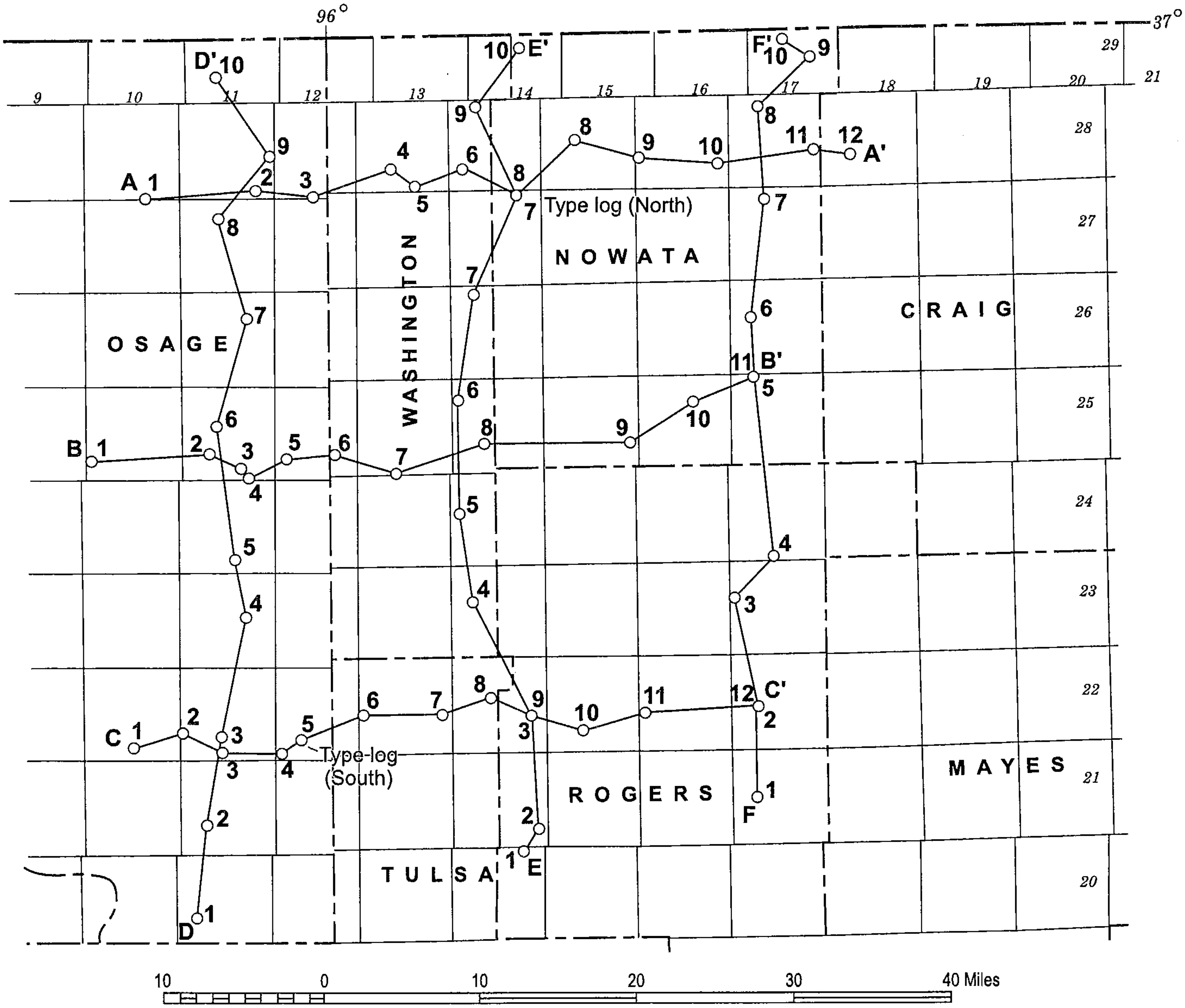


Figure 2. Index map showing location of wells and lines of cross sections for northeast Oklahoma shelf coalbed-methane subsurface study.

ferential compaction of coals, shales, and sandstones account for much of the pinch-outs and minor structures in the area.

Nine coal beds that have requisite thickness for surface mining are present in the northern part of the shelf area of northeastern Oklahoma. From oldest (lowest) to youngest (highest), these coals are the Rowe, Drywood, Bluejacket, Weir–Pittsburg, Mineral, Fleming, Croweburg, Iron Post, and Dawson coals (Fig. 5).

Seven of these beds produce coalbed methane in the northeast Oklahoma shelf area. There are 299 completions in the Rowe, 1 in the Drywood, 13 in the Bluejacket, 18 in the Weir–Pittsburg, 21 in the Croweburg, 36 in the Iron Post, and 12 in the Dawson. Additionally, gas is produced from three coal beds that are of no commercial importance for surface mining in Oklahoma. They are the Riverton (15 wells), the Bevier (11 wells), and the Mulky (315 wells). Methane also is being produced from one unidentified coal bed, for a total of 742 completions in the shelf area (Fig. 6) (B. J. Cardott, personal communication, August 28, 2001).

Reported gas production from the Mulky coal is enigmatic. Hemish (1986, p. 18) reported the occurrence of the Mulky in Oklahoma in only three drill holes in secs. 13 and 22, T. 28 N., R. 19 E., northern Craig County, where its maximum thickness is 10 in. The occurrence of the Mulky coal downdip to the west in Nowata, Washington, and Osage Counties has not been verified by the OGS from coring. It seems probable that the methane is being produced from the Excello black shale. If present, the Mulky occurs at the base of the Excello Shale (Hemish, 1986, fig. 4).

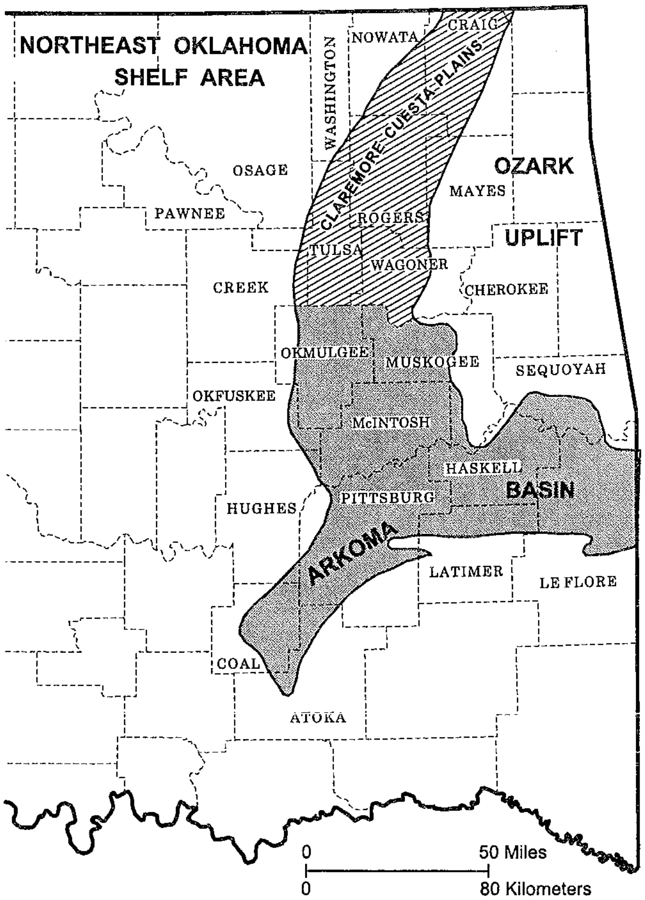


Figure 3. Index map of eastern Oklahoma, showing the coal field where coals are commercially minable (shaded), the eight-county-report area (hatched), and the geomorphic provinces discussed in the text.

Krebs Group

The Krebs Group is the oldest group that includes coal-bearing rocks in the study area (Fig. 5). This group has been subdivided into four formations, in ascending order: Hartshorne, McAlester, Savanna, and Boggy. Thin and discontinuous coals are present in the shelf area in the two oldest formations in the Krebs Group, but they have no importance for surface mining.

Two commercially important named coals and several thin, discontinuous unnamed coals are present in the Savanna Formation. The Rowe coal, which occurs near the middle of the Savanna (Fig. 5), is stratigraphically the lowest coal having surface-mining value in the study area. It has been mined chiefly in the area southeast of the town of Inola in the extreme southern part of Rogers County, where it ranges from 10 to 30 in. thick at a depth of <100 ft. It thins to the north, and in Craig County it has only limited economic promise in small areas. The outcrop line of the Rowe coal is shown in Figure 7.

The other commercial coal in the Savanna Formation is the Drywood coal, which occurs near the top of the formation (Fig. 5), just below the Bluejacket Sandstone Member of the Boggy Formation. The Drywood has been mined in past years in Craig County in sec. 13, T. 26 N., R. 19 E., where it was measured as 3 ft in thickness. The thickness of this coal varies, and along most of its outcrop boundary (Fig. 8) it is not of minable thickness. Core drilling in northeastern Craig County shows that at some places channels that were filled by the Bluejacket Sandstone have cut into or completely through the Drywood coal (Hemish, 1989b, fig. 5).

The Boggy Formation is the youngest formation in the Krebs Group. It contains only one coal bed with commercial value in the study area—the Bluejacket coal (Fig. 5), which occurs above the Bluejacket Sandstone and below the Inola Limestone. The Bluejacket coal is absent throughout all of Craig County except for a small area in the extreme southwestern corner. The Bluejacket bed is of minable thickness in eastern Rogers County and west-central Mayes County in T. 22 N., Rs. 17 and 18 E., where it ranges from 10 to 18 in. thick. Although the bed has not been mined in recent years, past underground mining is evidenced by several abandoned, caved-in drift openings in sec. 16, T. 22 N., R. 18 E. The outcrop line of the Bluejacket coal is shown in Figure 9.

Cabaniss Group

The Cabaniss Group is represented only by the Senora Formation on the platform area of northeastern Oklahoma (Branson and others, 1965, p. 34). This group includes the strata between the base of the Weir–Pittsburg coal and the base of the Fort Scott Formation (Fig. 5). Ten named coal beds are present in the Senora Formation, of which five are economically important for surface mining. Three of the other five beds—the Bevier, Mulky, and Scammon(?)—are too thin to be mined in Oklahoma but have been mined in Kansas and Missouri. The RC bed is also too thin to be mined and is known to be present only in Rogers and Wagoner Counties (Hemish, 1989a, 1990). The Tebo coal has limited economic value and in Oklahoma is thick enough for surface mining in only Wagoner and Muskogee Counties.

The oldest commercial coal in the Senora Formation is the Weir–Pittsburg. It crops out in a diagonal line from northeast to southwest across Craig County, but it is not mappable in southern Rogers County (Fig. 7). It is the thickest coal bed in the study area, with reported thicknesses ranging from 1.5 to 2.0 ft in northeastern Rogers County and northwestern Mayes County. It has a recorded maximum thickness of 6.2 ft at a depth of more than 400 ft in northwestern Craig County in T. 29 N., R. 18 E. (Hemish, 1986, pl. 4). The Weir–Pittsburg was mined extensively in the past west of Welch, in Craig County, and in more recent times near Estella, also in Craig County, and around the town of Chelsea in northeastern Rogers County and northwestern Mayes County.

The Mineral coal (Fig. 5) occurs stratigraphically above the Chelsea Sandstone, and, in northern Craig County, below the Russell Creek Limestone. In Rogers County, exposures of the Mineral coal are difficult to find, but reported thicknesses in the county vary from 6 in. to >2 ft. West of Chelsea, in Rogers County, the Mineral coal is 1–1.5 ft thick and was mined by Peabody Coal Co. in the

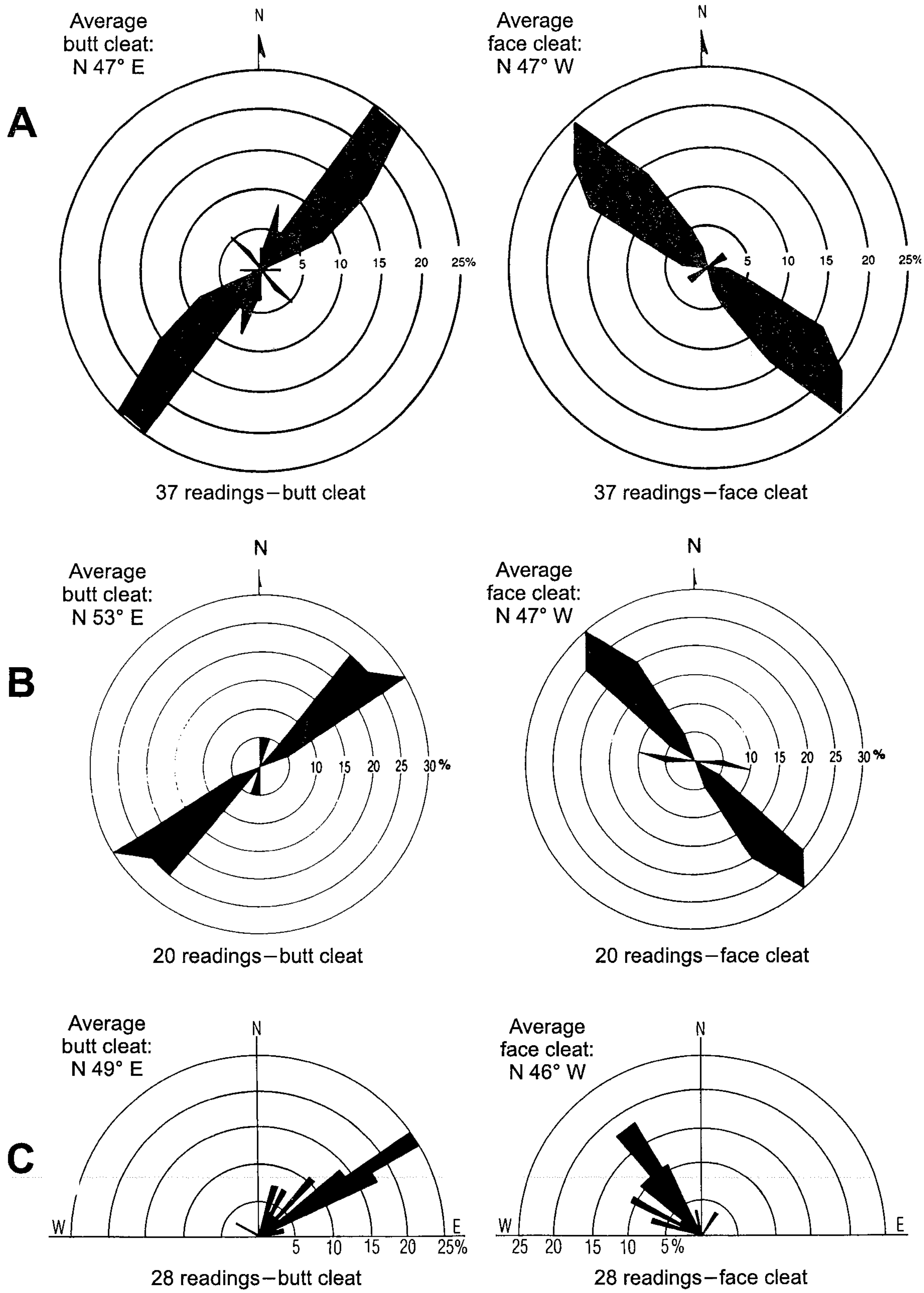


Figure 4. *A*—Rose diagrams of cleat orientations in coal beds of Craig and Nowata Counties (from Hemish, 1986, fig. 7, appendix 4). *B*—Rose diagrams of cleat orientations in coal beds of Rogers and Mayes Counties (from Hemish, 1989a, fig. 8, appendix 4). *C*—Rose diagrams of cleat orientations in coal beds of Tulsa and Wagoner Counties (from Hemish, 1990, fig. 8, appendix 4).

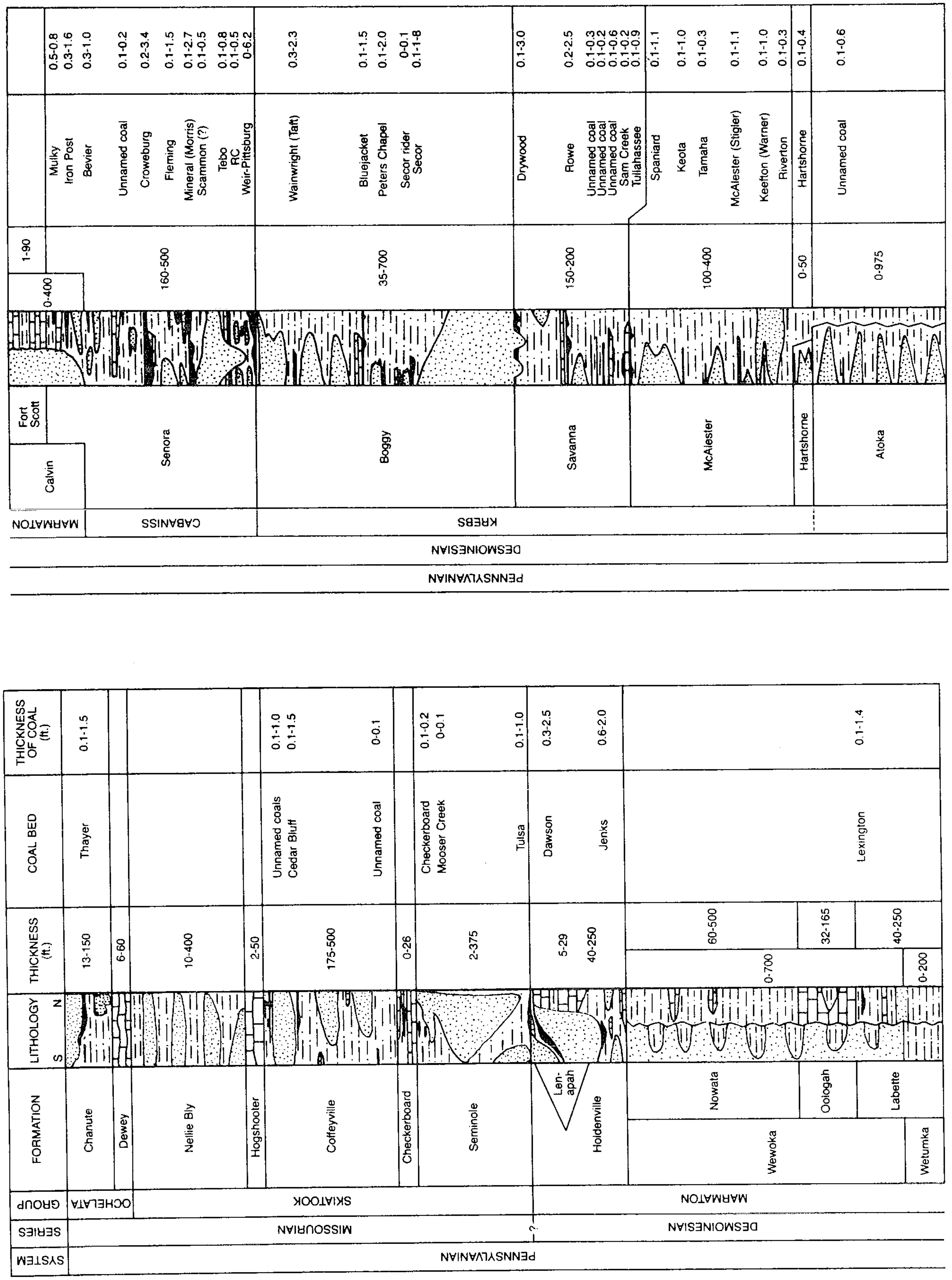


Figure 5. Generalized stratigraphic column of coal-bearing strata of northeast Oklahoma shelf (from Hemish, 1988, fig. 6). For explanation of lithologic symbols, see Figure 19.

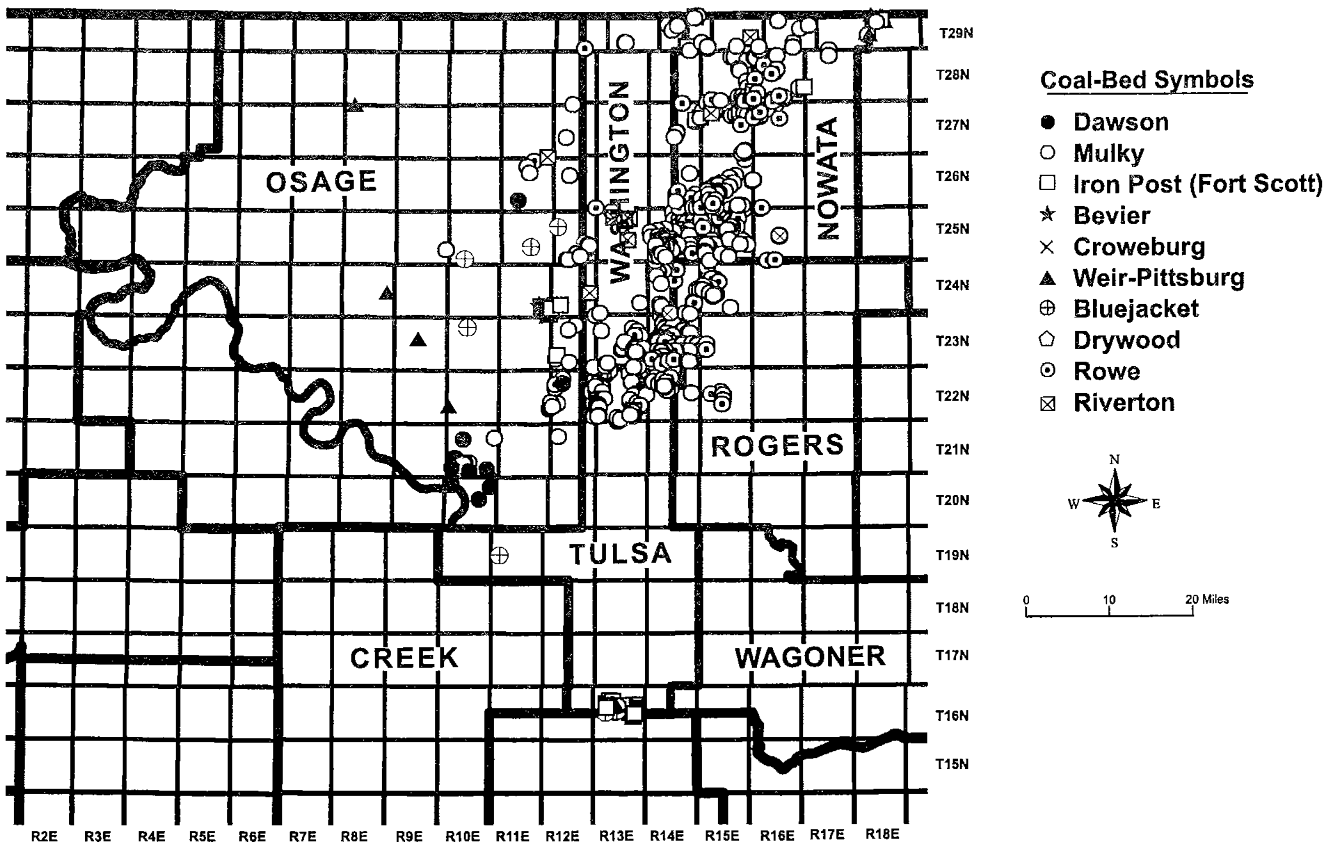


Figure 6. Distribution of coalbed-methane well completions, by coal bed, on northeast Oklahoma shelf (from Cardott, 2001, p. 104, fig. 6).

past. The Mineral was mined in the late 1970s in northern Craig County, where it reaches its maximum thickness of 27 in. Typically, it is 14–18 in. thick in that area. The outcrop line of the Mineral coal is shown in Figure 9.

The Fleming coal is present in Oklahoma only in the northern one-third of Craig County (Fig. 9). This coal is extremely variable in thickness. It locally attains thicknesses of 18 in. but tends to thin abruptly within a short distance. Its stratigraphic position is approximately midway between the underlying Mineral coal and the overlying Croweburg coal (Fig. 5); therefore, the Fleming coal is sometimes mined with one or the other, or with both.

The Croweburg coal crops out in a nearly continuous line extending diagonally from northeast to southwest through the middle of Craig County, the southeast corner of Nowata County, the middle of Rogers County, and the northwest corner of Wagoner County (Fig. 8). It averages about 18 in. in thickness and has long been prized for its high quality. The Croweburg has been extensively strip mined along the outcrop belt thoughout Craig, Nowata, Rogers, and Wagoner Counties, often to depths as great as 60–70 ft.

The Croweburg coal is readily identified in the field by the overlying succession of beds (Fig. 5). It is directly overlain by light gray silty shale that varies in thickness from as much as 50 ft in Nowata County and northern Rogers County, to about 30 ft in southern Rogers County, and to about 10 ft in northern Craig County. The light gray shale is overlain by black, fissile shale containing phosphatic nodules (Oakley Shale). The black shale is overlain in turn by the Verdigris Limestone, a persistent, dark gray fossiliferous limestone about 2–8 ft thick that weathers yellow brown.

The Iron Post coal is the uppermost commercial coal in the Senora Formation. It crops out across Craig, Nowata, and Rogers Counties in an irregular line roughly parallel to the outcrop line of the Croweburg coal (Fig. 7). The Iron Post coal lies about 30–50 ft above the Verdigris Limestone and is overlain by a few inches to a few feet of gray and/or black shale containing phosphatic nodules (Kinnison Shale). The shale is overlain in turn by an impure, dense, fossiliferous brown-weathering limestone 2–10 ft thick known as the Breezy Hill. Another black, phosphatic shale 4–8 ft thick (Excello Shale) separates the Breezy Hill Limestone from the base of the Blackjack Creek Limestone, the lowermost unit of the overlying Marmaton Group. If present, the Mulky coal occurs at the base of the Excello Shale.

Marmaton Group

The Marmaton Group overlies the Cabaniss Group and is at the top of the Desmoinesian Series (Fig. 5). Only one coal of economic importance is present in the Mar-

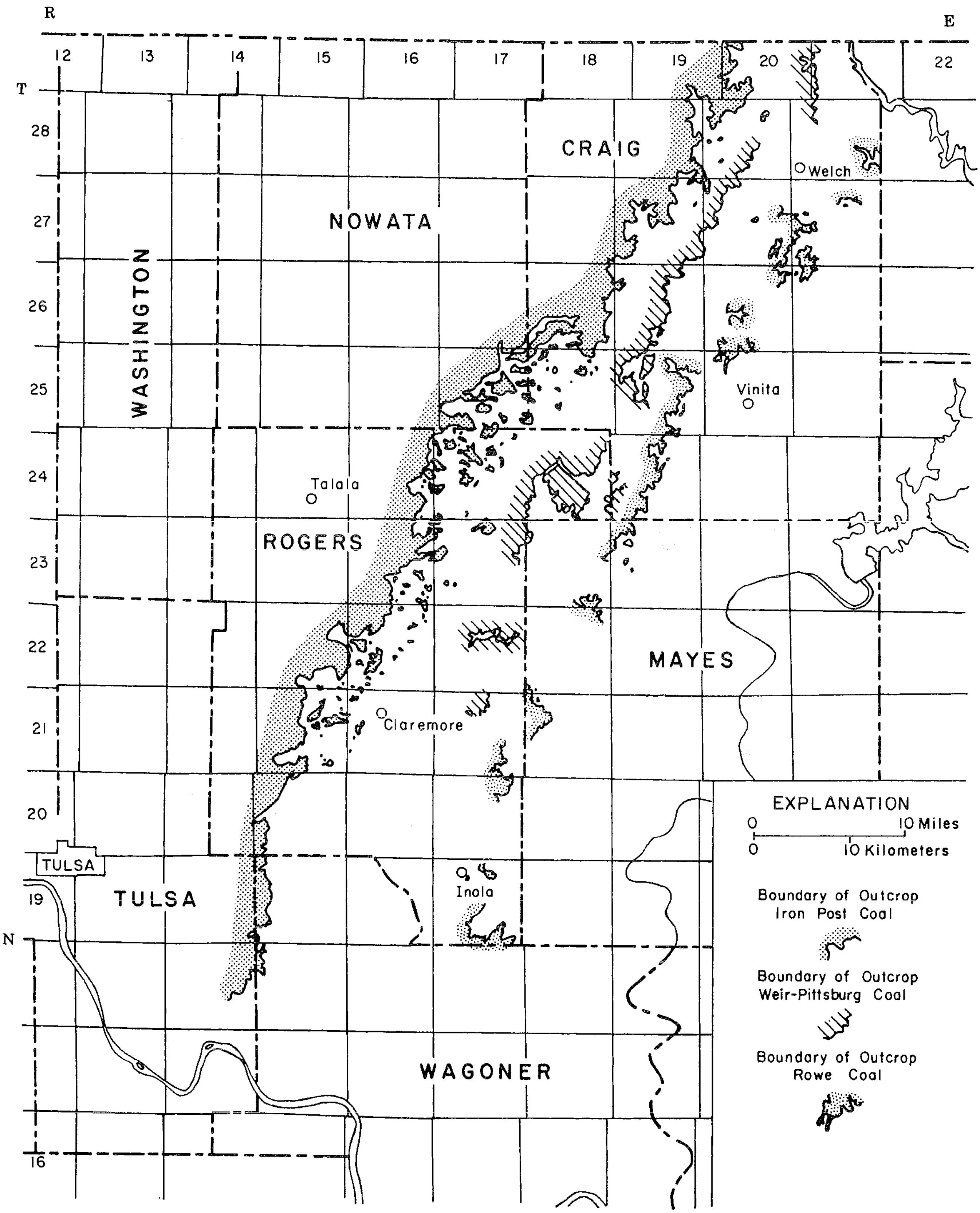


Figure 7. Coal-outcrop map of northeast Oklahoma shelf area, showing boundary lines of Iron Post, Weir–Pittsburg, and Rowe coal beds (from Hemish, 1984, fig. 3).

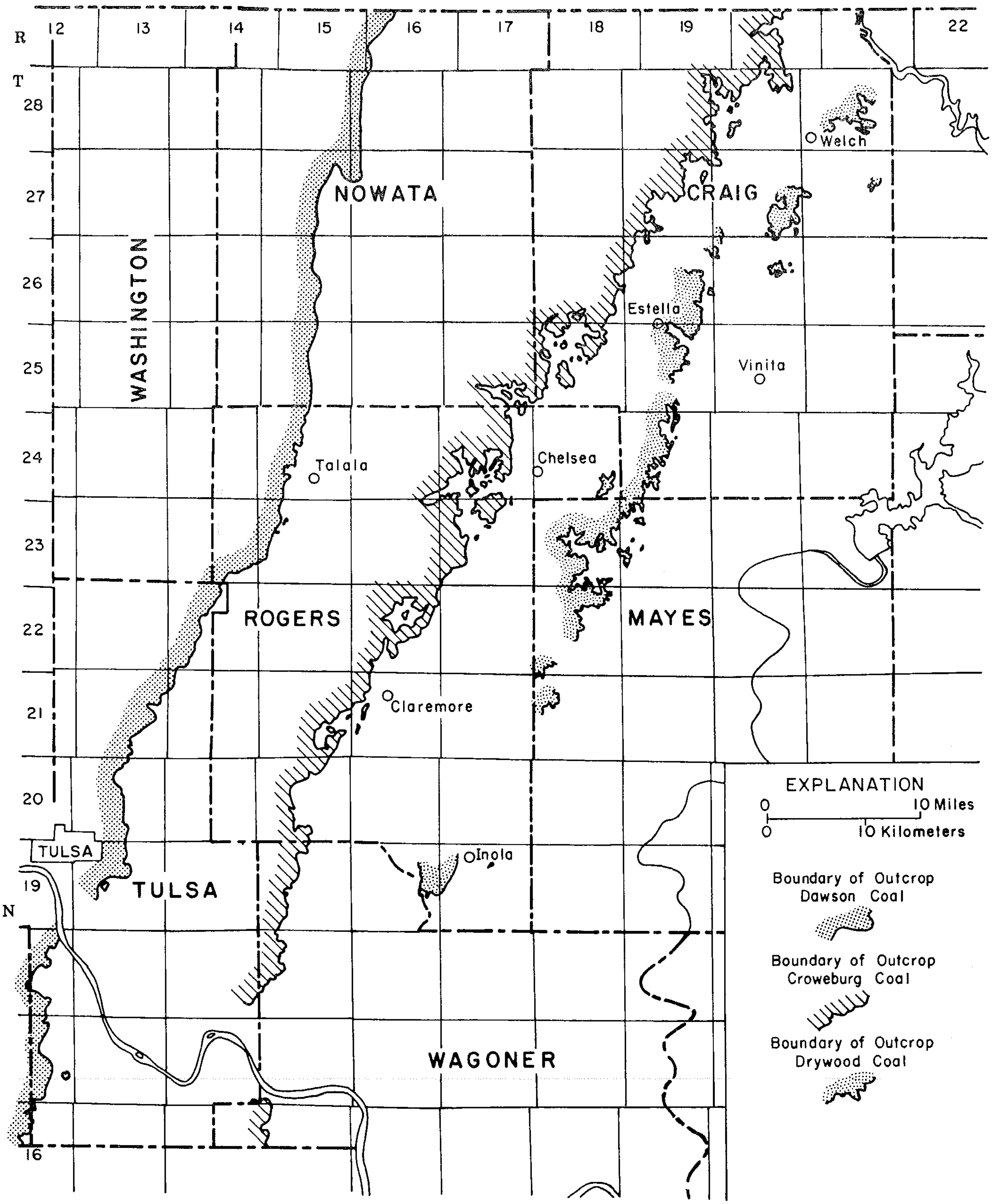


Figure 8. Coal-outcrop map of northeast Oklahoma shelf area, showing boundary lines of Dawson, Croweburg, and Drywood coal beds (from Hemish, 1984, fig. 2).

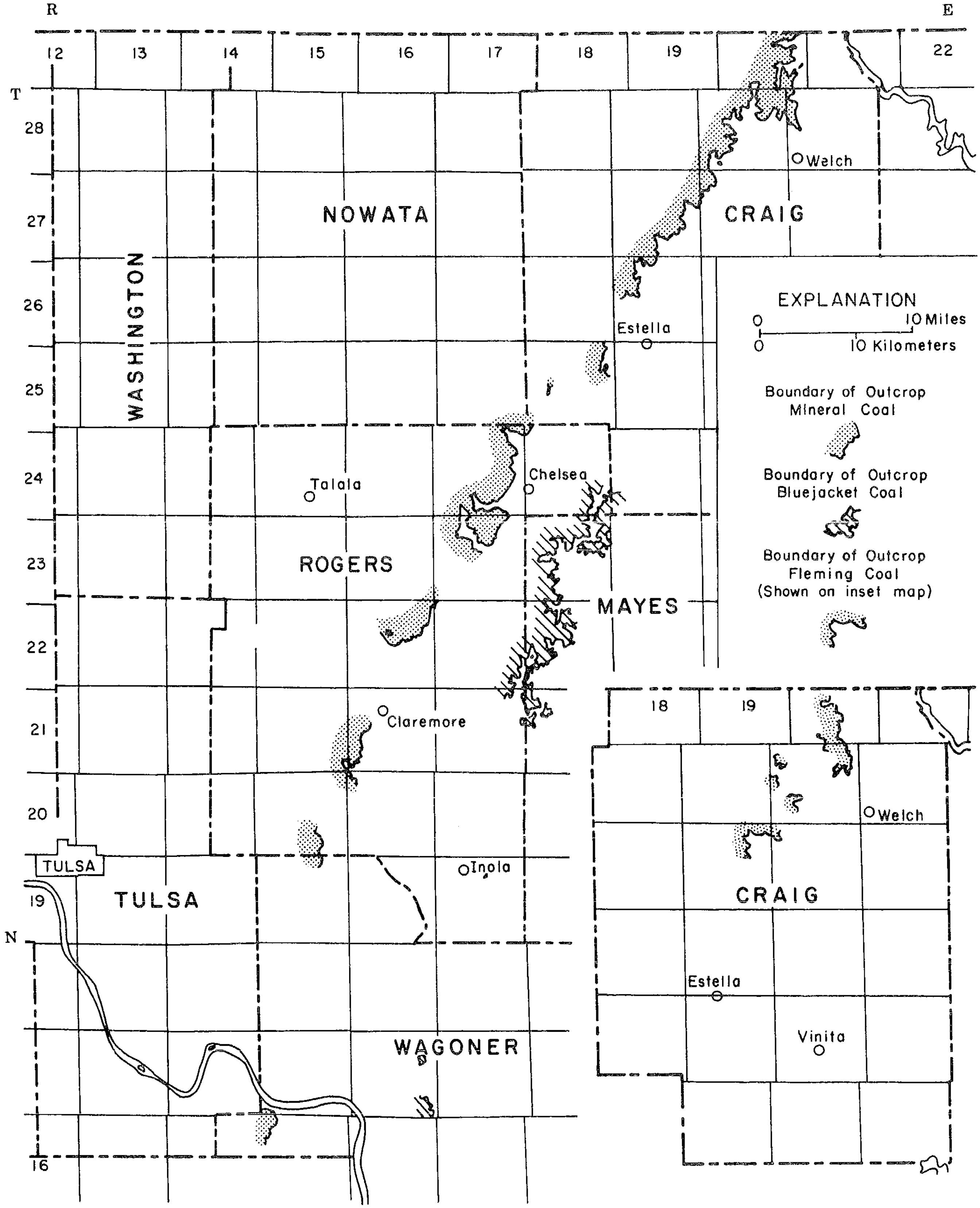


Figure 9. Coal-outcrop map of northeast Oklahoma shelf area, showing boundary lines of Fleming, Mineral, and Bluejacket coal beds (from Hemish, 1984, fig. 4).

maton Group in the study area—the Dawson coal, which crops out in western and north-central Tulsa County, northwestern Rogers County, and central Nowata County (Fig. 8). Its maximum known thickness is 30 in.

Depositional Environments

Operators who work in the northeastern Oklahoma shelf area frequently find the task of identifying methane-producing coal beds frustrating. Examination of existing logs and careful research of available literature do not always provide the answers. Why?

To find the answers, one must go back through geologic time and revisit the depositional environment. As discussed previously, epeiric seas periodically covered much of a large land mass that is now the Midcontinent of the United States. About 60 cycles of glacial-eustatic marine transgression and regression were recognized in the mid-Desmoinesian to mid-Virgilian along the Midcontinent outcrop belt (Heckel, 1989, p. 160). Differences in water depth during highstands, in the position of the shoreline during lowstands, in the encroachment of detrital clastics during regression, and in the thickness of the limestone facies formed at intermediate stands resulted in variations in the basic sequences of lithologic units. Stratigraphic patterns that resulted from periodic waxing and waning of glaciations show variable thicknesses, dependent on time. Delta shifting, which operated wherever the shoreline stood for a sufficient period of time, also introduced stratigraphic sequences that interrupted the typical cyclical successions.

A typical vertical succession of lithologic units consists of (1) terrestrial blocky mudstone commonly capped with coal, fluvial-deltaic sandstone, and shale; overlain by (2) thin, transgressive marine limestone; overlain by (3) thin, black phosphatic shale deposited in deep water; overlain by (4) thicker regressive, shoaling-upward marine limestone capped by a terrestrial mudstone paleosol or fluvial-deltaic clastics (Heckel, 1989, p. 162).

However, particularly in Oklahoma, ideal successions are seldom found in the stratigraphic record. Examination of cross sections A–A′ and B–B′ (Hemish, 1986, pl. 6) shows that shelf geology does not comprise strictly layer-cake strata. Coal beds and other markers are not invariably continuous. At places, coals merge to form one bed; at others, a bed may split to form two or more beds. In critical areas, markers could be absent. Lithologic intervals between markers can be extremely variable. (A shale unit 20 ft thick on one log might be 80 ft thick on another.) Sandstone channels commonly cut out markers and interrupt the typically cyclical succession of beds.

Surface to Subsurface Correlations

Three cross sections from west to east were constructed, representing the geology across the subsurface-study area, to correlate the 10 methane-producing coals with those identified in the outcrop belt (Fig. 10; Pls. 1–3, in envelope). Additionally, three other cross sections from south to north were constructed (Fig. 10; Pls. 4–6, in envelope) to establish an additional reference stratigraphic framework and to enhance the level of reliability of the interpretations. The recognition and identification of named coal beds were accomplished by first identifying easily recognizable markers. Figure 11 shows the coal beds that occur between the lowermost marker used in this study, the top of the Mississippian lime, and the base of the Bluejacket Sandstone Member of the Boggy Formation. The coals in this interval are the most difficult to identify because the top of the Mississippian is not a plane, nor is the base of the Bluejacket because of channel downcutting. (The base of the Bluejacket is not an identifiable horizon throughout the area, as the sandstone might not have been deposited at some places.) The McAlester–Savanna Formations (undifferentiated), which contain the Riverton, Rowe, and Drywood coals, vary considerably in thickness, as shown on Plates 1–6. The absence of any markers in the interval and the discontinuity of the coal beds compound identification problems.

The Bluejacket coal usually is recognizable because of its proximity to the underlying Bluejacket Sandstone and its association with the Inola Limestone (Fig. 12). Where the coal and/or the Inola is absent, a persistent radioactive shale occupies the interval and might mask the coal on the logs if the coal is thin.

The Weir–Pittsburg marker and/or the underlying Weir–Pittsburg coal occurs at the base of the Senora Formation (Fig. 5). On some logs the Wainwright coal and/or an associated radioactive shale in the upper Boggy Formation might be confused with the Weir–Pittsburg interval, but examination of logs from nearby wells will generally result in the correct interpretation. The Tebo coal occurs in the interval between a persistent radioactive shale and the Tiawah Limestone (Fig. 13).

The Croweburg coal is readily identified by its stratigraphic position just below a series of markers at the top of the Senora Formation—the Oakley Shale, Verdigris Limestone, Kinnison Shale, Breezy Hill Limestone, and Excello Shale (Fig. 14). Included in this series of markers within the Lagonda interval are the Bevier and Iron Post coals. If present, the Mulky coal occurs at the base of the Excello Shale, but it cannot be identified separately on the geophysical logs. Because this is a good gas-producing interval, it is referred to herein as the *Mulky marker.*

Of the gas-producing units, only the Mulky marker occurs within the Oswego lime interval. However, the series of limestones and radioactive shales the Oswego includes are so distinctive on the geophysical logs that they are the best of all the markers used in this study (Fig. 15). The Oswego is remarkably persistent and is so easily recognizable that the interval serves as the starting position for log-interpretation purposes.

The base of the Fort Scott Formation (Fig. 5) marks the division between the Cabaniss and Marmaton Groups. The lower part of the Marmaton includes a thick shale (Labette) that is overlain by a distinctive and persistent marker interval known as the *Big lime* in subsurface terminology (Fig. 16). There are no known gas-producing coals in this part of the Marmaton Group, but in the upper part a well-developed coal occurs above the Nowata Shale and the lower Cleveland sand. This coal is the Dawson, and it is identified by its association with the radio-

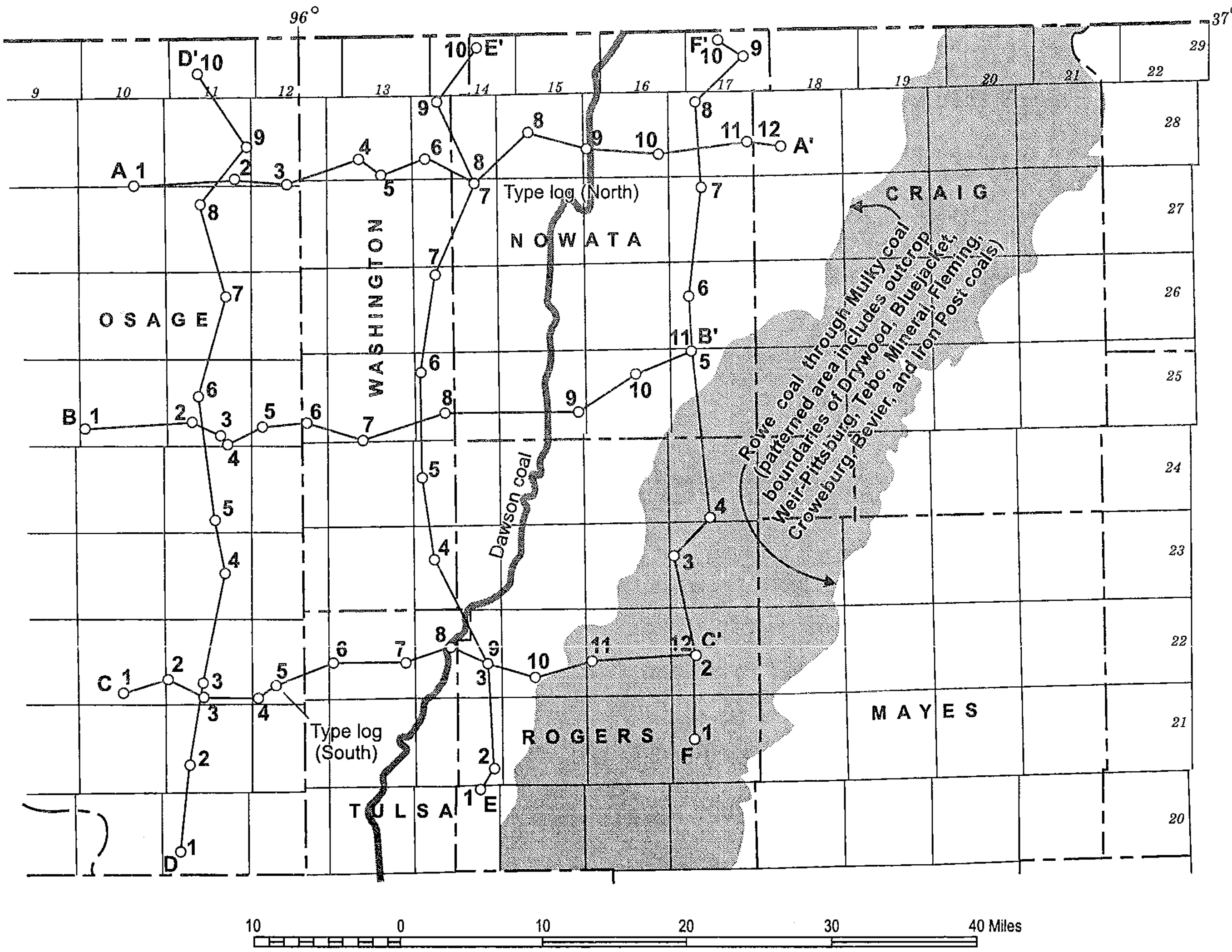
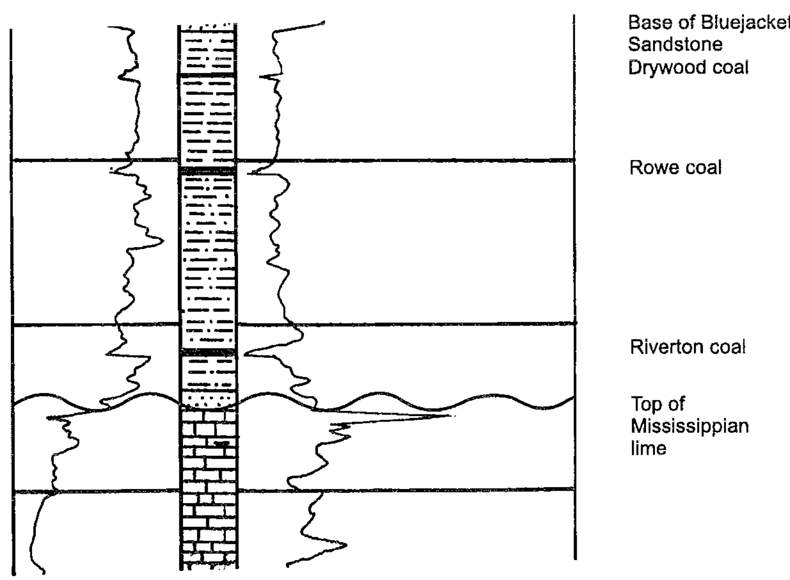


Figure 10. Index map showing wells and lines of cross sections in relation to coal-outcrop belt (shaded) in northeast Oklahoma shelf area.

Figure 11. Stratigraphic markers, including Mississippian–Pennsylvanian unconformity and base of Bluejacket Sandstone (lower part of Krebs Group). Excerpt from Miracle No. 2 F. Lutz College well, NW¼ sec. 2, T. 27 N., R. 14 E., Nowata County. For explanation of lithologic symbols, see Figure 19.



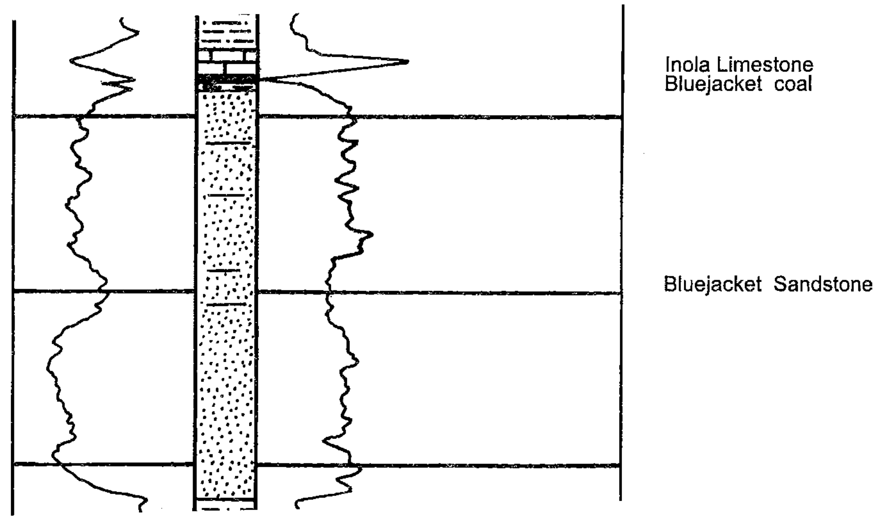


Figure 12. Stratigraphic markers in lower part of Boggy Formation (Krebs Group). Excerpt from Miracle No. 2 F. Lutz College well, NW¼ sec. 2, T. 27 N., R. 14 E., Nowata County. For explanation of lithologic symbols, see Figure 19.

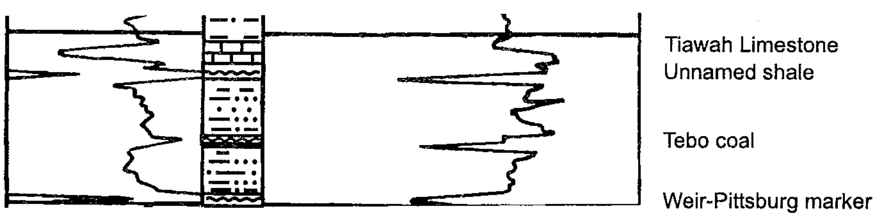


Figure 13. Stratigraphic markers in lower part of Senora Formation (Cabaniss Group). Excerpt from Perry No. 3 Pierce well, NE¼ sec. 30, T. 25 N., R. 11 E., Osage County. For explanation of lithologic symbols, see Figure 19.

Figure 14. Stratigraphic markers in upper part of Senora Formation (Cabaniss Group). Excerpt from Perry No. 3 Pierce well, NE¼ sec. 30, T. 25 N., R. 11 E., Osage County. For explanation of lithologic symbols, see Figure 19.

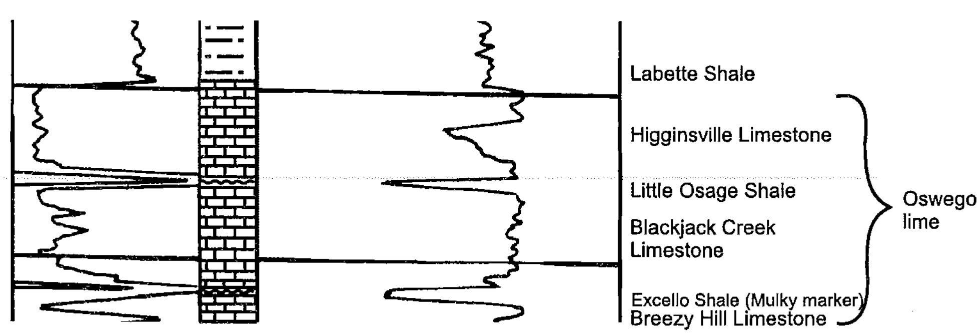


Figure 15. Stratigraphic markers in Oswego lime interval (Breezy Hill Limestone and Excello Shale of Senora Formation [Cabaniss Group] and Fort Scott Formation [Marmaton Group]). Excerpt from Perry No. 3 Pierce well, NE¼ sec. 30, T. 25 N., R. 11 E., Osage County. For explanation of lithologic symbols, see Figure 19.

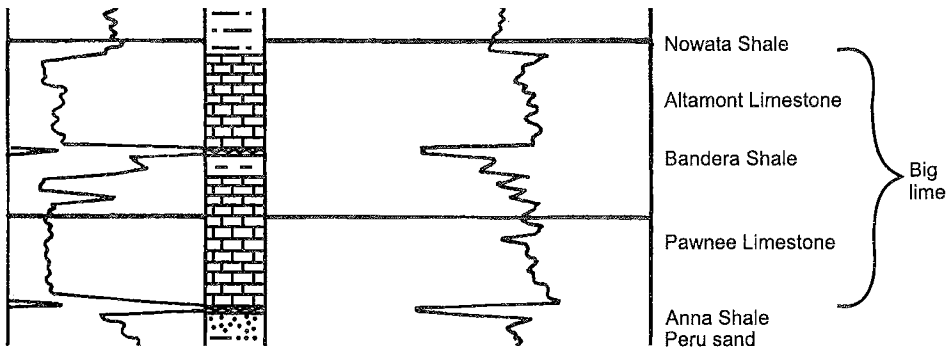


Figure 16. Big lime stratigraphic marker, underlain by radioactive Anna Shale marker (Marmaton Group). Excerpt from Perry No. 3 Pierce well, NE¼ sec. 30, T. 25 N., R. 11 E., Osage County. For explanation of lithologic symbols, see Figure 19.

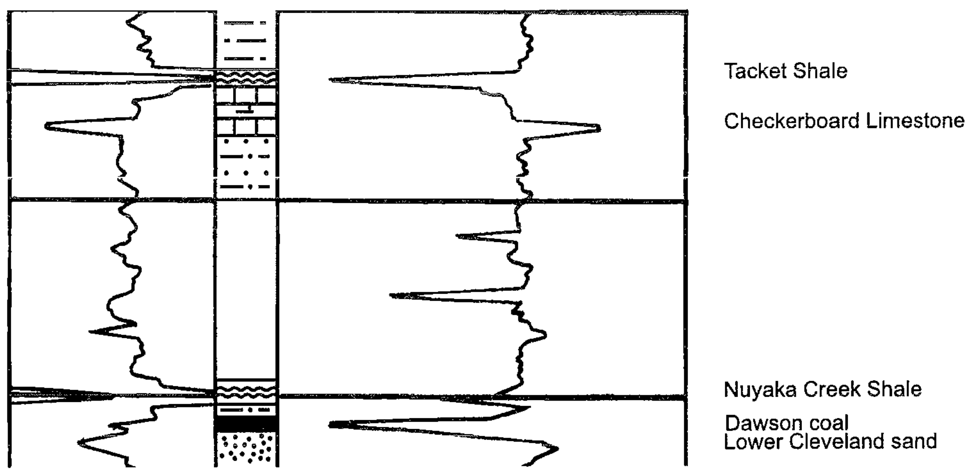


Figure 17. Stratigraphic markers in upper part of Marmaton Group (Desmoinesian) and lower part of Skiatook Group (Missourian) (Fig. 5). Excerpt from Greenwood No. 4 Phillips well, SE¼ sec. 29, T. 22 N., R. 12 E., Osage County. For explanation of lithologic symbols, see Figure 19.

active Nuyaka Creek Shale as well as by its position relative to the Checkerboard Limestone (Fig. 17).

Two type logs have been designated within the subsurface-study area. The northern type log (Fig. 18) is at the intersection of cross sections A–A′ and E–E′ (Pls. 1, 5; Fig. 2). It is part of the geophysical log from the Miracle No. 2 F. Lutz College well in the NW¼ sec. 2, T. 27 N., R. 14 E., Nowata County. Because of stratigraphic changes (formations tend to thicken southward; some beds that are absent to the north are present to the south, and vice versa; some bed thicknesses differ), a type log was also designated for the southern part of the study area (Fig. 20). It is part of the geophysical log from the Greenwood No. 4 Phillips well in the SE¼ sec. 29, T. 22 N., R. 12 E., Osage County (Fig. 2).

For purposes of this study, only the stratigraphic interval containing coals with methane-producing potential was selected from available geophysical logs. The interval extends from the Mississippian–Pennsylvanian unconformity (below) to the Checkerboard Limestone marker (above). The base of the Fort Scott Limestone was used as the datum on all six cross sections. On part of cross section C–C′ (Pl. 3), where the logs started below the Fort Scott Formation, the top of the Keefton coal bed was used as the datum. On part of cross section F–F′ (Pl. 6), where the logs started below the Fort Scott Formation, the top of the Weir–Pittsburg marker and/or the base of the Bluejacket (Bartlesville) Sandstone was used as the datum.

Cross Section A–A′

The northernmost cross section (A–A′; Pl. 1) shows that the Dawson coal is absent in that part of the study area. The Dawson coal bed is near the top of the Marmaton Group (Fig. 5), and it is stratigraphically the highest of the methane-producing coals.

The Mulky marker is continuous across the area and is easily identified by its position just below the Fort Scott Formation. The Mulky coal may or may not be present at the base of the Excello Shale; if it is, it does not give a signature on the geophysical logs. In the cross sections prepared for this report the Mulky–Excello interval is labeled *Mulky marker.*

The stratigraphically lower Iron Post coal can be traced from the outcrop boundary westward across Nowata County in this cross section, but it can be identified on only one well log from Washington County and on two well logs from Osage County. The Bevier coal, a short distance below the Iron Post coal, is discontinuous.

The next lower coal, the Croweburg, a short distance below the Oakley Shale, is also discontinuous and could not be identified on the northern type log (Fig. 18).

The Tebo coal occurs in the interval between the Tiawah Limestone (Pink lime) and the Weir–Pittsburg coal (Fig. 5). It is well developed and persistent throughout the study area, and is continuous in cross section A–A′. No methane production from the Tebo coal has been reported by operators, which suggests that it might have been misidentified as another coal in some wells.

The Weir–Pittsburg coal marks the base of the Senora Formation. This coal is overlain by a persistent, unnamed radioactive shale that has been called the *Weir–Pittsburg marker* for purposes of this report. This marker is useful for correlation in the absence of the Weir–Pittsburg coal. The Weir–Pittsburg marker is continuous in this cross section. The Weir–Pittsburg coal could not be identified on well logs in Nowata and Washington Counties in this cross section.

A coal bed interpreted to be the Wainwright is present in western Nowata County and eastern Osage County. On well log 1 it is split into two beds. The Wainwright coal occurs stratigraphically between the Inola Limestone and the Weir–Pittsburg coal (Fig. 5). Methane production has not been reported from the Wainwright coal.

The Bluejacket coal is closely associated with the Inola Limestone (Fig. 5), and although well developed where present, it can be identified on only three logs in cross section A–A′. The three methane-producing coals in the McAlester–Savanna Formations (undifferentiated)—the Riverton, Rowe, and Drywood—are well developed where present, but they are discontinuous. The stratigraphic relationship of these three coals, and their position relative to the Mississippian–Pennsylvanian unconformity and the Bluejacket (Bartlesville) Sandstone, are well shown on the northern type log (Fig. 18).

Cross Section B–B′

To the south, cross section B–B′ (Pl. 2) indicates that the Dawson coal occurs discontinuously in the interval between the Big lime and the Checkerboard Formation. The Mulky marker is continuously present, but again the Mulky coal is unidentifiable on the logs. The Iron Post coal can be identified on well logs from Osage, Washington, and Nowata Counties. The underlying Bevier coal can be identified on five adjacent logs from Osage and Washington Counties.

The Croweburg coal can be identified continuously across Nowata and Washington Counties, and the Tebo coal can be traced continuously across Nowata, Washington, and eastern Osage Counties. The Weir–Pittsburg marker is continuous, but the underlying Weir–Pittsburg coal can be identified on only five well logs from Osage and Washington Counties.

The occurrence of the Bluejacket coal is sporadic. Its best development is across Washington County, as shown in this cross section. The Drywood coal is continuous from Nowata County to eastern Osage County, where a paleotopographic high at the top of the Mississippian erosion surface precluded deposition of all but a few feet of strata below the Bartlesville sand. The Rowe coal is present at two wells in Nowata County and at one in Washington County. The Riverton coal was identified on one well log from Nowata County and on one log from Washington County.

Cross Section C–C′

West–east cross section C–C′ (Pl. 3) suggests that the extent of the Desmoinesian coal swamps was diminishing to the south and west in the study area. The Dawson coal can be identified on only one well log from Tulsa County and on two from Osage County. The Mulky marker is again continuously present eastward to the area where it was eroded away in Rogers County.

Neither the Iron Post nor the Bevier coal can be identified in the area of this cross section. The Croweburg coal is continuously present from its outcrop westward to sec. 30, T. 22 N., R. 11 E., where it was probably cut out by a fluvial channel in the ancient coal swamp. The Croweburg coal is once again identifiable in sec. 34, T. 22 N, R. 10 E.

The Tebo coal can be traced westward from the outcrop area across two townships. The Tebo interval appears to be occupied by a sand in R. 14 E., but to the west the coal can once again be traced westward through R. 12 E. in Osage County before it pinches out. The Weir–Pittsburg marker extends continuously across the study area in the cross section, but the associated Weir–Pittsburg coal occurs only discontinuously. In the Boggy Formation the Bluejacket coal occurs only sporadically.

In the Savanna–McAlester Formations (undifferentiated) the Drywood coal occurs discontinuously. The Rowe coal is identifiable on all but one of the well logs from Rogers County in cross section C–C′, but it is identifiable on only one well log from Tulsa County. The interval between the top of the Mississippian lime and the base of the Bluejacket (Bartlesville) Sandstone markedly decreases in thickness in Osage County, and the Rowe coal apparently was not deposited there. The Keefton coal, generally identified by its stratigraphic position just above the Warner (Booch) Sandstone, extends continuously westward across the study area in the cross section but is absent at wells 1 and 2. The Riverton coal was identified on the three easternmost well logs from Rogers County, and also on logs 5 and 6 from eastern Osage County and western Tulsa County, respectively. To the west the lower part of the Krebs Group was not deposited, owing to the higher elevation of the Mississippian paleo-erosion surface.

Cross Section D–D′

South–north cross section D–D′ (Pl. 4), the westernmost of the six cross sections, and entirely within Osage

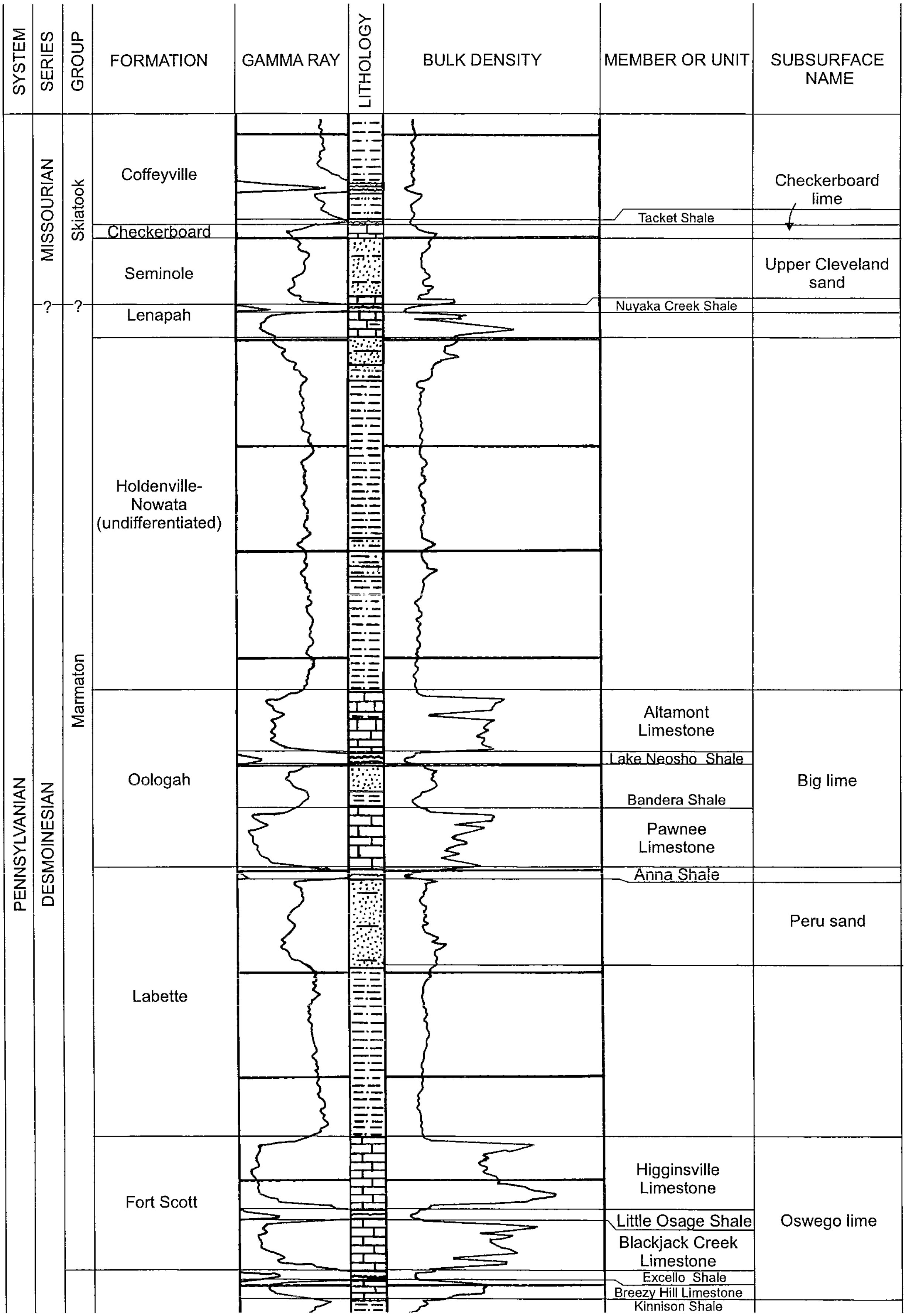
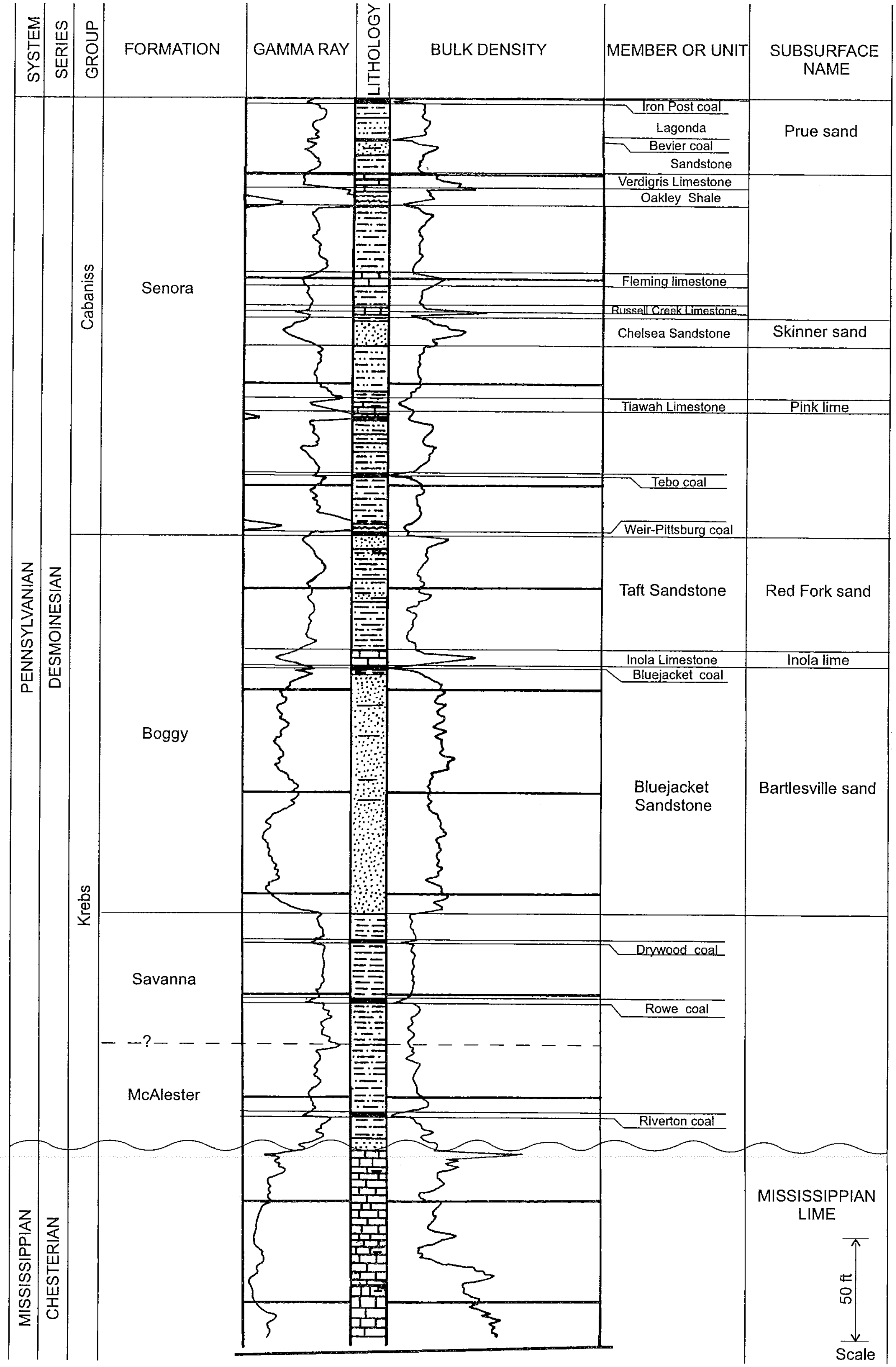


Figure 18 *(above and facing page)*. Type log for northern part of northeast Oklahoma shelf area—part of geophysical log from Miracle No. 2 F. Lutz College well, NW¼ sec. 2, T. 27 N., R. 14 E., Nowata County. Lithologic and stratigraphic interpretations are those of the author. For explanation of lithologic symbols, see Figure 19. For map location, see well E 8, Figure 2.


SYSTEM
SERIES
GROUP
FORMATION
GAMMA RAY
LITHOLOGY
BULK DENSITY
MEMBER OR UNIT
SUBSURFACE NAME
PENNSYLVANIAN
DESMOINESIAN
Cabaniss
Senora
Iron Post coal
Lagonda
Bevier coal
Sandstone
Prue sand
Verdigris Limestone
Oakley Shale
Fleming limestone
Russell Creek Limestone
Chelsea Sandstone
Skinner sand
Tiawah Limestone
Pink lime
Tebo coal
Weir-Pittsburg coal
Krebs
Boggy
Taft Sandstone
Red Fork sand
Inola Limestone
Inola lime
Bluejacket coal
Bluejacket Sandstone
Bartlesville sand
Savanna
Drywood coal
Rowe coal
?
McAlester
Riverton coal
MISSISSIPPIAN
CHESTERIAN
MISSISSIPPIAN LIME
50 ft
Scale

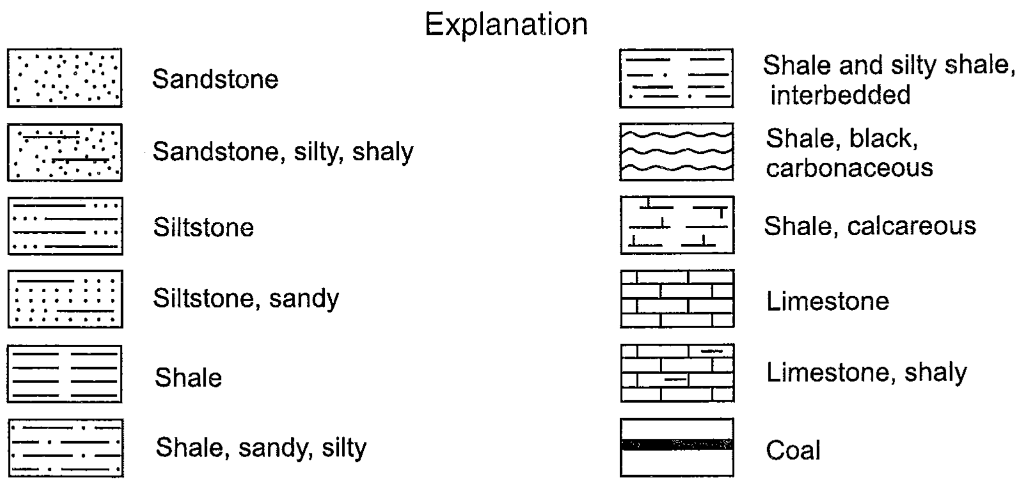


Figure 19. Explanation of lithologic symbols used in Figures 5, 11–18, and 20.

County, shows a progressive northward thinning of the stratigraphic interval between the top of the Mississippian lime and the Checkerboard Formation. The Dawson coal is well developed at wells 1 and 2, and 5 and 6, but it could not be identified north of T. 26 N. The Iron Post coal can be traced continuously northward on well logs 6–10. The Bevier coal is identifiable on only logs 9 and 10. The Croweburg coal can be identified on only well log 2, suggesting that the ancient swamp in which the coal formed did not extend very far westward into Osage County. Other methane-producing coals stratigraphically below the Tiawah Limestone–shale marker occur discontinuously, the Rowe coal being the most persistent.

Cross Section E–E′

Cross section E–E′ (Pl. 5) extends northward from Rogers County and approximately parallels the Washington–Nowata county border. The Mulky marker is present and continuous throughout the area. Both the Iron Post and Bevier coals are identifiable on well logs 7, 8, and 10 but are absent to the south. The Croweburg coal is identifiable on only logs 1–3 in the southern part of the area. The Tebo coal can be traced continuously from logs 2 through 8 and is again present on log 10. The Weir–Pittsburg shale marker is continuous across the area, but the Weir–Pittsburg coal is present only at wells 1 and 2 in western Rogers County, where it is well developed, occurring a few feet below the shale marker.

The Bluejacket coal is identifiable on well log 2 and occurs continuously on well logs 4–8, in the central part of the area. The Rowe coal is persistent across the southern part of the area and is present at all the wells drilled to depths sufficient to penetrate the coal except at well 1. Both the Drywood coal (stratigraphically above the Rowe) and the Riverton coal (stratigraphically below the Rowe) occur sporadically.

Cross Section F–F′

Cross section F–F′ (Pl. 6), the easternmost south–north cross section, shows well logs entirely east of the northwestward-dipping outcrop of the Dawson coal (Fig. 10). Wells 1–4 were spudded stratigraphically below the base of the Fort Scott Formation, but within the zone of outcrop of the Riverton through Mineral coals (Fig. 10; Pl. 6). In the northern part of the area the Mulky marker is continuous (wells 5–10). If present, the Iron Post and Bevier coals are too thin to identify with confidence. The Croweburg coal is present at wells 5–9, and the Mineral coal is identifiable on well logs 3, 5, 8, 9, and 10. Another discontinuous coal tentatively identified as the Scammon occurs at wells 3 and 6.

The Tebo coal is well developed at wells 3–6. The Weir–Pittsburg marker and/or coal bed is continuously correlatable on well logs 3–10.

In the Krebs Group (Figs. 5, 11, 12) the Bluejacket coal is identifiable on logs 6–8. The Drywood coal is discontinuous. The Rowe coal is present at all wells except well 5, which was not drilled sufficiently deep to penetrate the coal horizon. The Riverton coal is present at seven of the wells, and a coal at wells 1 and 2 in the stratigraphic interval between the Warner (Booch) Sandstone (above) and the Riverton coal (below) is called the *upper Riverton coal* for purposes of this report.

SUMMARY

Examination of the six cross sections (Pls. 1–6) shows why identification of methane-producing coals could be difficult. These difficulties include (1) a lack of continuity of some markers; (2) a lack of continuity of target coal beds; (3) local occurrence of additional, unnamed coal beds; (4) variable thicknesses of intervals between coal beds; (5) an absence of any markers in the McAlester–Savanna Formations; (6) a general increase in thickness of stratigraphic units southward toward the Arkoma basin; (7) local structures that might be superimposed on the regional structure; and (8) relief on the Mississippian–Pennsylvanian unconformity and its effect on the thickness of the Krebs Group.

Suggested methods for identification of methane-producing coal beds are given as follows:

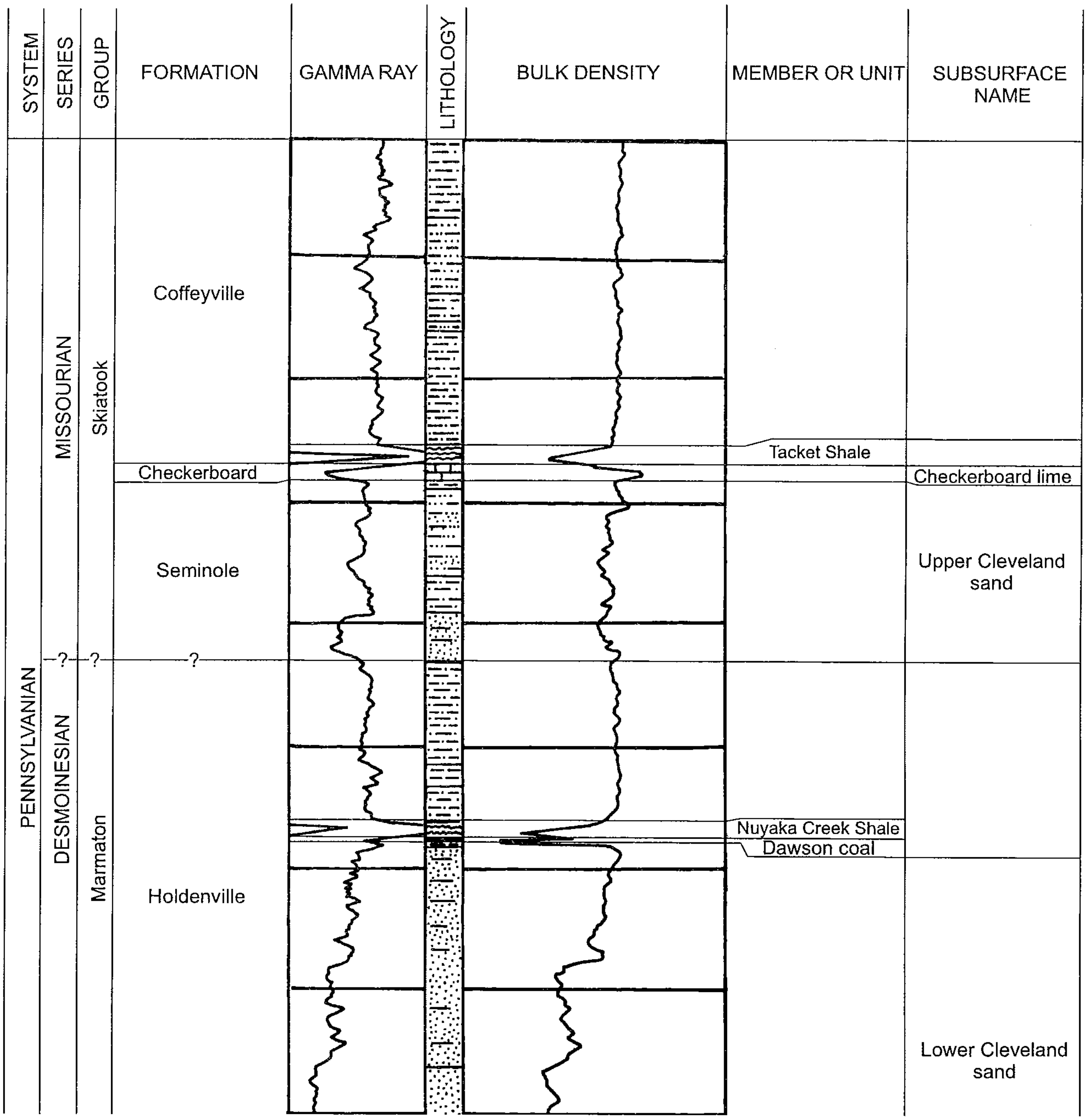


Figure 20 *(above and p. 20–21)*. Type log for southern part of study area—part of geophysical log from Greenwood No. 4 Phillips well, SE¼ sec. 29, T. 22 N., R. 12 E., Osage County. Lithologic and stratigraphic interpretations are those of the author. For explanation of lithologic symbols, see Figure 19. For map location, see well C 5, Figure 2.

1. Examine well log; compare with type log from area; identify markers; correlate with named coal beds on type log.
2. Correlate markers and coal beds with nearest logs in OGS cross sections.
3. Examine existing well logs (not used in OGS cross sections) from same area; construct new cross sections; correlate beds from existing OGS cross sections to methane well.
4. When making correlations, note thickness trends of stratigraphic units between markers.
5. Attempt to reconstruct depositional environments; channel sandstones might cut out target coal beds or markers.
6. Share information with other producers or investigators. Pooled knowledge is a valuable resource.

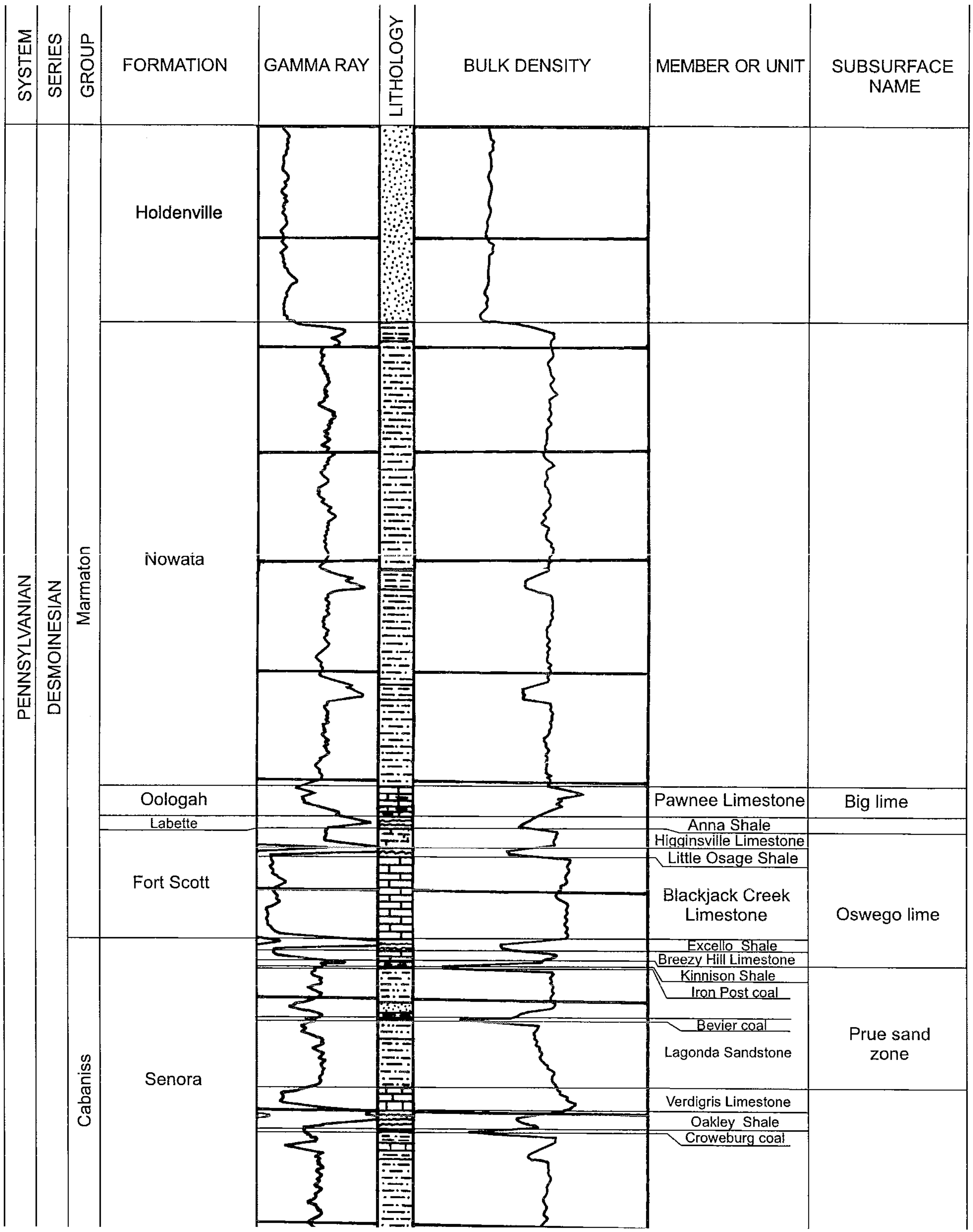
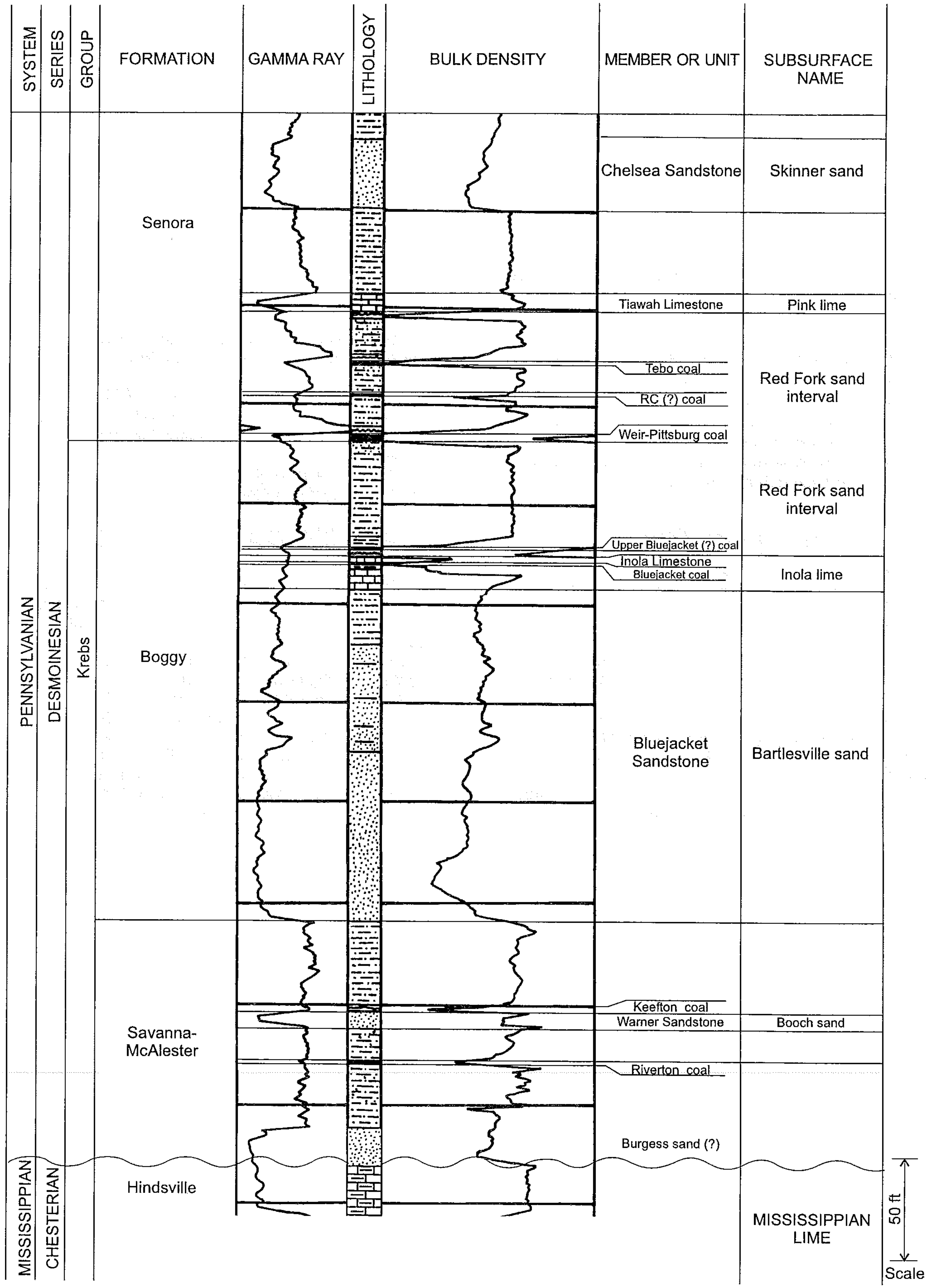


Figure 20. Continued *(above and facing page)*.


SYSTEM
SERIES
GROUP
FORMATION
GAMMA RAY
LITHOLOGY
BULK DENSITY
MEMBER OR UNIT
SUBSURFACE NAME
PENNSYLVANIAN
DESMOINESIAN
Krebs
Senora
Boggy
Savanna-McAlester
Chelsea Sandstone
Skinner sand
Tiawah Limestone
Pink lime
Tebo coal
RC (?) coal
Weir-Pittsburg coal
Red Fork sand interval
Red Fork sand interval
Upper Bluejacket (?) coal
Inola Limestone
Bluejacket coal
Inola lime
Bluejacket Sandstone
Bartlesville sand
Keefton coal
Warner Sandstone
Booch sand
Riverton coal
Burgess sand (?)
MISSISSIPPIAN
CHESTERIAN
Hindsville
MISSISSIPPIAN LIME
50 ft
Scale

CONCLUSIONS

Changing depositional environments related to sea-level fluctuations are the main cause of the problems facing workers who attempt to make accurate interpretations of the stratigraphy in the subsurface. The only sure way to correlate beds from surface to subsurface is through close-spaced drilling. However, because of the availability of numerous existing logs from the shelf area, exploration-drilling expenses can be greatly reduced, and interpretations can be made from existing logs with a reasonable degree of confidence. Construction of paleogeographic maps for areas for which sufficient data are available can lead to a better understanding of the distribution of coal beds in the subsurface, and hence a more accurate application of existing nomenclature.

Although a greater number of coal beds have methane-producing potential in the northeast Oklahoma shelf area, they are generally thinner and less widespread than those in the Arkoma basin. It is probable that future exploration will reveal that some of the coal beds discussed here will prove to be good reservoirs in areas such as the western part of the Arkoma basin as well as the southern part of the northeast Oklahoma shelf.

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