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Stratigraphy and Depositional Environments of the
Krebs Formation - Lower Cherokee Group
(Middle Pennsylvanian) in Southeastern Kansas

by

John W. Harris

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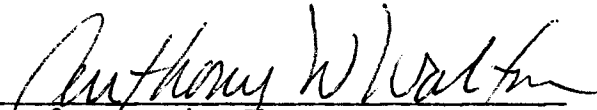
STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE
KREBS FORMATION - LOWER CHEROKEE GROUP
(MIDDLE PENNSYLVANIAN) IN SOUTHEASTERN KANSAS

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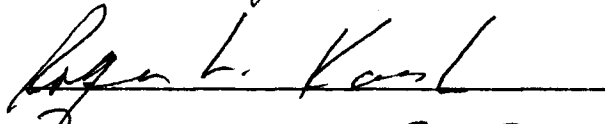
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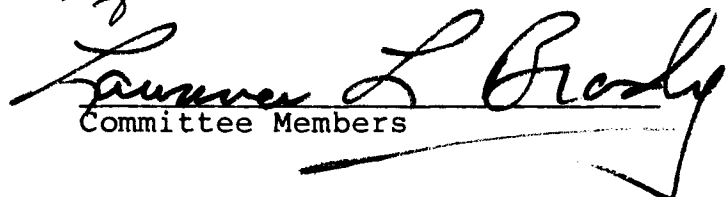
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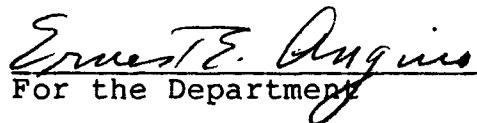


Professor in Charge





Committee Members



For the Department

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ABSTRACT

The Krebs Formation (Middle Pennsylvanian-Desmoinesian) forms the lower portion of the Cherokee Group in the Cherokee basin of southeastern Kansas. The Krebs Formation near its outcrop in Cherokee and Crawford counties consists of 78 percent shale and mudstone, 18 percent sandstone and siltstone, 3 percent coal, and 1 percent limestone, comprising a total thickness of 120 to 220 feet (37 to 67 m). Strata of the Krebs Formation were deposited unconformably over a karst surface developed on Mississippian limestone in southeastern Kansas and parts of adjacent states.

Integration of data from continuous cores, outcrops, and geophysical logs to produce net sandstone isolith maps provides a detailed stratigraphic framework and facilitates interpretation of depositional environments for the diverse lithofacies of the Krebs Formation. Coal beds and associated seatrock units, some having an areal extent of several thousand square miles, provide excellent stratigraphic marker beds. Radioactive dark-gray shale units and argillaceous limestone units often overlie coal beds and may be equally widespread. Coal beds commonly cap upwards-coarsening, mud-dominated sequences consisting of dark-gray shale with occasional argillaceous limestones overlain by lenticular-bedded shale or wavy-bedded siltstones. This vertical

transition of lithofacies is interpreted to result from the progradational infilling of large interdistributary bays. Coarsening-upwards sandstone sequences, consisting of lenticular-bedded shale grading upwards into wavy-bedded siltstone, flaser-bedded sandstone, and rippled or cross-bedded sandstone, represent distributary mouth bar or crevasse-splay deposits. Fining-upwards sequences, composed of a basal scour surface overlain by mud-clast conglomerates, large-scale, cross-bedded sandstone, and rippled or flaser-bedded sandstone, are interpreted to be channel fill or point bar deposits.

Net sandstone isolith maps reveal the presence of a lobate deltaic complex in southwestern Missouri characterized by both stacking and offset of major sandstone bodies. Comparison of structural contour maps developed for the top of the Mississippian limestone and of the Krebs Formation with a map showing distribution of basal Pennsylvanian sandstones suggests that most minor folding and faulting is post-depositional. These maps also indicate that the configuration of the Mississippian limestone surface had little if any control on the distribution of sandstones in the Krebs Formation. The inverse relationship between the net isopach map and the net sandstone isolith map suggests that the Cherokee and Forest City basins underwent more rapid structural subsidence than the area of the Bourbon arch.

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INTRODUCTION

Purpose of investigation

The Krebs Formation of the Cherokee Group (Desmoinesian Stage, Middle Pennsylvanian Series) consists of interbedded shales, sandstones, coals and thin limestones that were deposited disconformably over a karst surface developed on Mississippian limestone in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma. Sandstones of the Krebs Formation are economically important petroleum reservoirs, accounting for a large fraction of over 1.3 billion barrels of oil produced in eastern Kansas, western Missouri, and northern Oklahoma (Oros, 1979). In addition, more than 5 million tons of measured strippable coal reserves have been identified in the Krebs Formation of southeastern Kansas (Brady, Livingston, and Adams, 1976).

The primary objectives of this study are (1) to provide detailed rock-stratigraphic correlations between sandstone, shale, coal, and limestone units of the Krebs Formation in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma, and (2) to interpret sandstone depositional environments from examination of sedimentary structures, vertical and lateral lithofacies relationships of core and

outcrops, and maps of sandstone distribution. Southeastern Kansas is the critical area for future studies since most previous workers have focused their efforts there, and the stratigraphy of the upper Cherokee Group has been adequately defined through correlation between numerous coal strip-mine exposures and coal-exploration drillers logs. Stratigraphy of the Krebs Formation, however, has received less attention due to poor surface exposures and lack of shallow subsurface data. A wide variety of environmental interpretations, ranging from shallow marine to fluvial, has been proposed for sandstone bodies within the Krebs Formation.

An important feature of this study is the use of continuous cores that allow detailed stratigraphic correlation of thin units. The cores provide complete, unweathered, vertical sequences of lithofacies as well as the stratigraphic relationships necessary for interpretation of sandstone depositional environments. Study of cores and outcrops, combined with maps of sandstone distribution, allows the development of a depositional model to explain the distribution of sandstones and other lithologies within the Krebs Formation.

Area of investigation

The study area covers approximately 3,200 square miles (5,100 sq km) in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma (Fig. 1). The study area includes parts of Cherokee, Crawford, Bourbon, Labette, and Neosho counties in Kansas, Vernon and Barton counties in Missouri, and Craig and Ottawa counties in Oklahoma. Outcrops of the Krebs Formation occur in a 6-to 10-mile wide (10 to 16 km) belt trending northeast-southwest along the southeastern edge of the study area. From the outcrop of the Krebs Formation, the area of investigation extends northwestward for about 40 miles (64 km), where the Krebs is in the subsurface. The area of investigation extends approximately 80 miles (128 km) along strike.

Methods of investigation

Detailed verbal and graphic descriptions of more than 8,600 feet (2,600 m) of section from twenty-four continuous cores and ten outcrops in Cherokee and Crawford counties, Kansas, provided the initial stratigraphic framework for the investigation. Twenty-two cores were donated to the Kansas Geological Survey by Gulf Mineral Resources Company, and two additional cores were furnished by the U. S. Office of

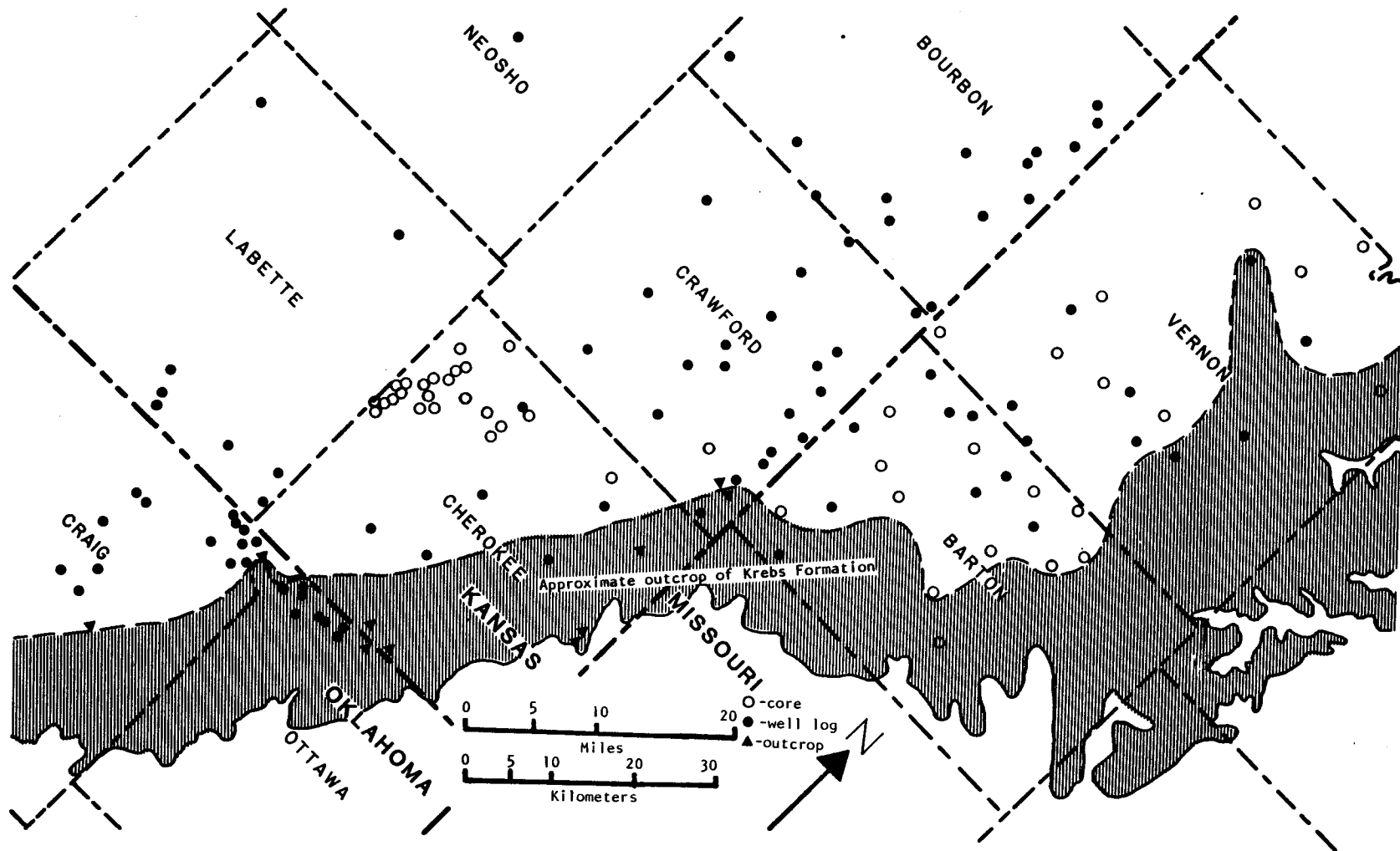


Figure 1 - Map of the study area illustrating the location and type of control used in this report.

Surface Mining. The 1 5/8 inch (4 cm) diameter cores extend from bedrock below the modern weathering horizon downward to the top of the Mississippian limestone, providing complete, unweathered sections of the Krebs Formation and parts of the overlying Cabaniss Formation. Initial verbal and graphic core descriptions were completed at a scale of one inch equals one foot (8 cm = 1 m), using a checklist to ensure adequate detail and uniformity in the descriptions. A rock color chart (Goddard and others, 1963) was used to express color differences in shales; samples were described dry. Cores and detailed descriptions completed during this study are on file at the Kansas Geological Survey. Abbreviated core descriptions are given in Appendix A for the reader's convenience.

Following detailed correlation of stratigraphic units observed in the cores and outcrops, core descriptions were compared with published core descriptions, geophysical logs and drillers logs from Ebanks, James, and Livingston (1977), Wells (1979), and Harrison and Roberts (1979), and logs on file at the Kansas Geological Survey. A series of looped cross sections was constructed to establish stratigraphic correlations for the study area. All subsurface information was also used to prepare structural contour maps, isopach maps, and net sandstone isolith maps for

various stratigraphic intervals of the Krebs Formation.

Twelve lithofacies were established from core and outcrop descriptions based upon sedimentologic parameters such as grain size, primary sedimentary structures, and faunal content, since these features provide the most direct record of depositional processes. Each lithofacies was interpreted in terms of the hydrodynamic conditions required to produce the observed bedforms (Harms and others, 1982; Allen, 1977). Depositional environments were established by considering three-dimensional lithofacies relationships, faunal evidence, and by comparison with published depositional models (Wanless and others, 1971; Shelton, 1973; Brown, 1973; Harms and others, 1975; Horne and Ferm, 1978; Brown, 1979; Walker, 1980; Jackson, 1981; Reading, 1981) and modern analogies (Coleman and Gagliano, 1965; Kanes, 1970; Donaldson and others, 1970; Coleman and Prior, 1980).

Previous investigations

Several previous works have dealt with the stratigraphy of the Cherokee Group. The original reference to the Cherokee Group was made by Haworth and Kirk (1894), following description of the section along the banks of the Neosho River in extreme southeastern Kansas. Later workers revised correlations between

individual stratigraphic units of the Cherokee Group, and several stratigraphic classification systems were proposed based upon the distribution of coal beds or sandstone units (Abernathy, 1936; 1937; Pierce and Courtier, 1937; Oakes, 1953; Searight and others, 1953; Searight, 1955; Howe, 1956; Branson, 1957; Searight and Howe, 1961). Abernathy (1936; 1937) subdivided the Cherokee Group of southeastern Kansas into fifteen cyclothems based upon the classic model proposed by Weller (1930) from the Pennsylvanian of western Illinois. Howe (1956) subdivided the Cherokee Group of southeastern Kansas into eighteen formations, each formation extending from the top of a coal bed to the top of the next stratigraphically higher coal bed. These earlier works provide the foundation for the current stratigraphic classification system. More recent studies dealing with stratigraphy and coal resources of the Cherokee Group were done by Robertson (1971), Brady, Livingston, and Adams (1976), and Hemish (1984). Seevers (1975) provided a good general discussion of the surficial rocks in Cherokee County, Kansas. Howe and Koenig (1961), and Nodine-Zeller and Thompson (1977), found foraminifera and other fauna that indicated an Atokan age for basal dark gray shale units of the Krebs Formation, suggesting that marine transgression was continuous across the

Atokan-Desmoinesian boundary.

Several previous works focus on the stratigraphy and petroleum potential of sandstones in the Cherokee Group (Branson, Huffman, and Strong, 1965, Harrison and Roberts 1979, and Harrison, Curlale and Roberts 1979. Howe (1951) redefined the type locality of the Bluejacket Sandstone in northeastern Oklahoma and suggested that the Bartlesville sandstone is its subsurface equivalent. Ebanks and James (1974), Ebanks, James and Livingston (1977), Ebanks, (1979), Wells, (1979), and Ebanks and Weber (1982) discussed sandstone distribution and heavy oil potential for various stratigraphic intervals of the Cherokee Group in southeastern Kansas and southwestern Missouri. Ebanks, James and Livingston (1977), Ebanks (1979), and Wells (1979) correlated and mapped sandstones within the study area and proposed the terms upper and lower Bluejacket and upper and lower Warner to represent more adequately the sandstones present in the section. Other subsurface studies dealing with stratigraphy and sandstone distribution in northeast and north-central Oklahoma include the works of Berg (1969), Cole (1969), Dogan (1970), and Visher, Siatta and Phares (1971). Visher, Siatta, and Phares (1971) suggested that a single river system with a northerly source was responsible for deposition of the deltaic sequences observed in the

Bartlesville sandstone of northeastern Oklahoma. Weirich (1953) proposed the shelf principle of oil migration and accumulation using the Cherokee Group of northeastern Oklahoma and southeastern Kansas as an example. Baker (1962) and James and Baker (1973) studied the organic geochemistry of various stratigraphic units of the Cherokee Group in the midcontinent.

Bass (1934), Bass, Leatherock, and Dillard (1937), Leatherock (1937), and Hayes (1963) concluded that some sandstones of the Cherokee Group were beach or barrier-bar sediments based upon gross sand body morphology, dipmeter data, and textural characteristics. Hayes (1963) interpreted various sandstones of southwestern Missouri to be of tidal-flat or tidal-channel origin based upon the presence of flaser, wavy, and lenticular bedded sediments. Cole (1969), Visher and others (1971), Wanless and others (1971), and Ebanks, James, and Livingston (1977) interpreted most sandstones of the Cherokee Group to be of fluvio-deltaic origin based upon sand body morphology and sandstone distribution patterns.

Petrography and sedimentology of various sandstone bodies in the Cherokee Group have been investigated by Scruton (1950), Hayes (1963), Worthington (1982), and Woody (1983). These studies

indicate that most sandstones of the Cherokee Group are very fine to medium-grained and quartz-rich, with minor, approximately equal amounts of feldspar and rock fragments.

REGIONAL GEOLOGIC SETTING

Structure

The study area covers approximately the eastern one-third of the Cherokee basin, an elongate northward extension of the stable, northeastern Oklahoma platform. Located on the west flank of the Ozark dome, the Cherokee basin is bounded on the west by the Nemaha uplift and is separated from the Forest City basin on the north by a broad positive structural feature known as the Bourbon arch (Jewett, 1951; Wanless, 1969; Cole, 1969; Moore, 1979). Sedimentary rocks of Pennsylvanian age in the Cherokee basin thicken gradually to the south into the thick Pennsylvanian sequence of the Arkoma basin (Gould, 1927; Ham and Wilson, 1967). The structural setting of the study area and other structural features of the midcontinent mentioned in the text are illustrated in Fig. 2.

The structural and depositional framework for Pennsylvanian strata in the Cherokee basin was directly influenced by orogenic activity associated with the convergent Ouachita system. The Appalachian, Ouachita, and Arbuckle-Wichita mountains, as well as the Canadian shield, provided terrigenous sediment to the system, and subsidence in foreland areas maintained the delicate balance between sedimentation

Figure 2 - Map of the midcontinent showing the location of the study area (crosshatched) and major structural features mentioned in the text (modified from Wanless, 1969; Moore, 1979.)

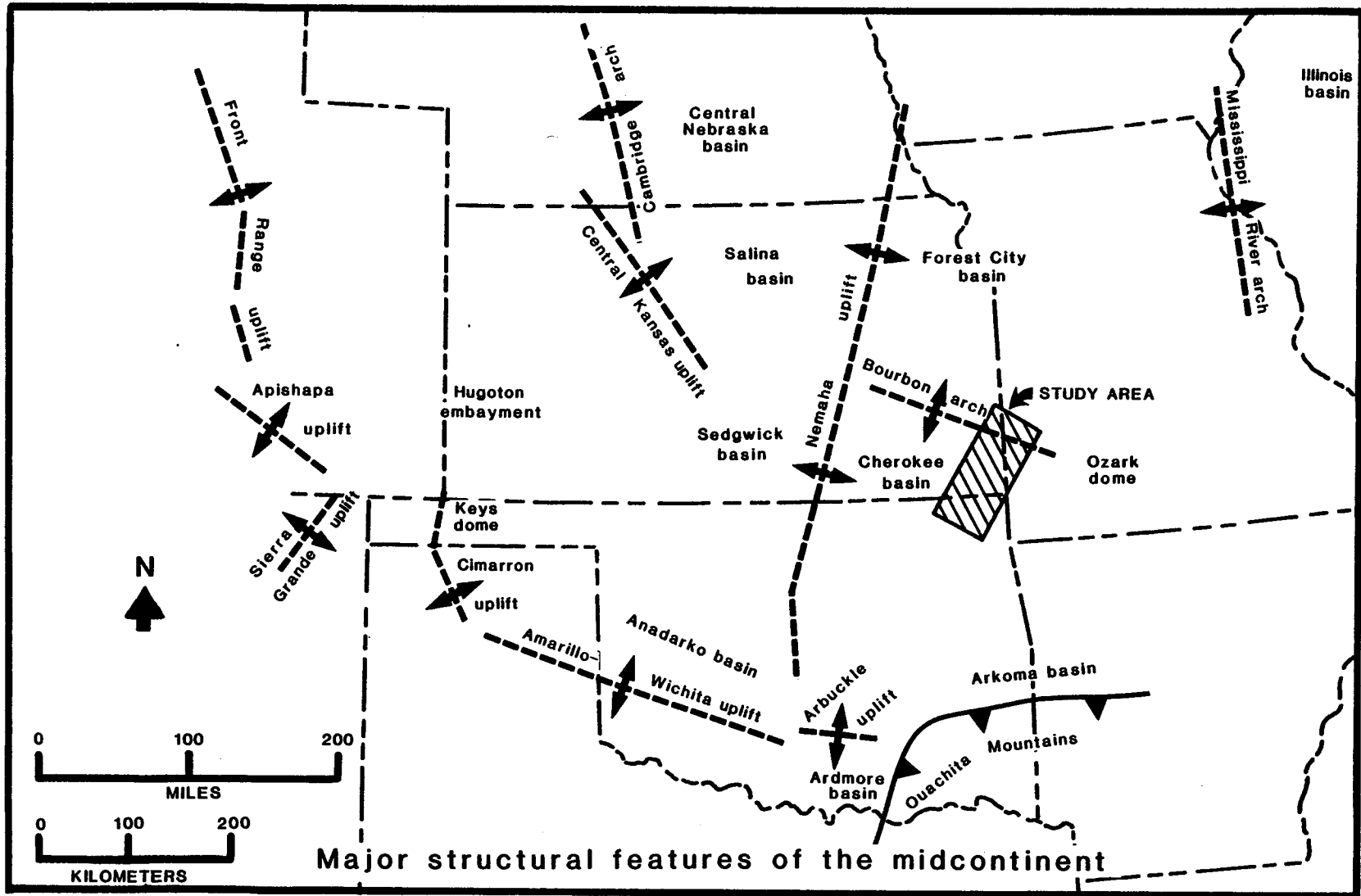


Figure 2

and subsidence characteristic of Pennsylvanian sediments in the midcontinent.

Several plate-tectonic models have been applied to the Ouachita orogeny, but a continent-continent or a continent-arc-continent collisional model seems best to fit the available data (Wickham, Roeder, and Briggs, 1976). Deformation in the Ouachita region extended from the early Morrowan to the middle Virgilian, but the major pulse of deformation seems to have occurred in the early to middle Desmoinesian (Ham and Wilson, 1967; Frezon and Dixon, 1975).

Orogenic activity in the Ouachita region resulted in a variety of uplifts and high-angle faulting in the midcontinent, forming the Arbuckle-Wichita uplift, Ancestral Rockies, Nemaha ridge, Ozark dome, and the Bourbon arch. Rapid subsidence occurred adjacent to the Ouachita Mountains, resulting in formation of the Arkoma basin. Rapid subsidence parallel to the transverse Wichita-Arbuckle trend produced the Anadarko basin. Less rapid subsidence on the stable platform area to the north produced shallow structural basins such as the Cherokee and Forest City basins. It has been postulated that a southward projecting peninsula of the North American plate may have taken the brunt of collisional forces from the

Ouachita orogeny, causing buckling of the craton and producing the observed basins and uplifts of the midcontinent (Kluth and Coney, 1981).

Stratigraphy

Rocks of Desmoinesian age are widely distributed in the central United States west and north of the Appalachian, Ouachita, and Marathon orogenic belts (Wanless, 1969) (Fig. 3). The maximum thickness of Desmoinesian strata occurs in the Anadarko, Ardmore, and Marietta basins of south-central Oklahoma, where 7,000 to 9,000 feet (2,100 to 2,750 m) of conglomerate, sandstone, shale, coal, and limestone are preserved (Ham and Wilson, 1967; Wanless, 1969; Frezon and Dixon, 1975). In the Arkoma basin, near the type area of the Krebs Formation (town of Krebs, T5N, R15E, Pittsburg Co., Oklahoma), maximum thickness estimates for the Krebs range from 4,900 feet (1,500 m) (Frezon and Dixon, 1975) to over 7,000 feet (2,100 m) (Oakes, 1953; Huffman, 1959; Ham and Wilson, 1967). These rocks thin northward from the Arkoma basin by progressive onlap onto the pre-Pennsylvanian unconformity. The Krebs Formation was not deposited over the Central Kansas uplift, the northern end of the Nemaha ridge, the Ozark dome, or the Mississippi River arch (Wanless, 1969; 1975b; Stewart, 1975). The

Figure 3 - Map of the midcontinent illustrating the thickness and major lithologic components of Desmoinesian strata. The study area is outlined. (modified from Wanless, 1969; Moore, 1979).

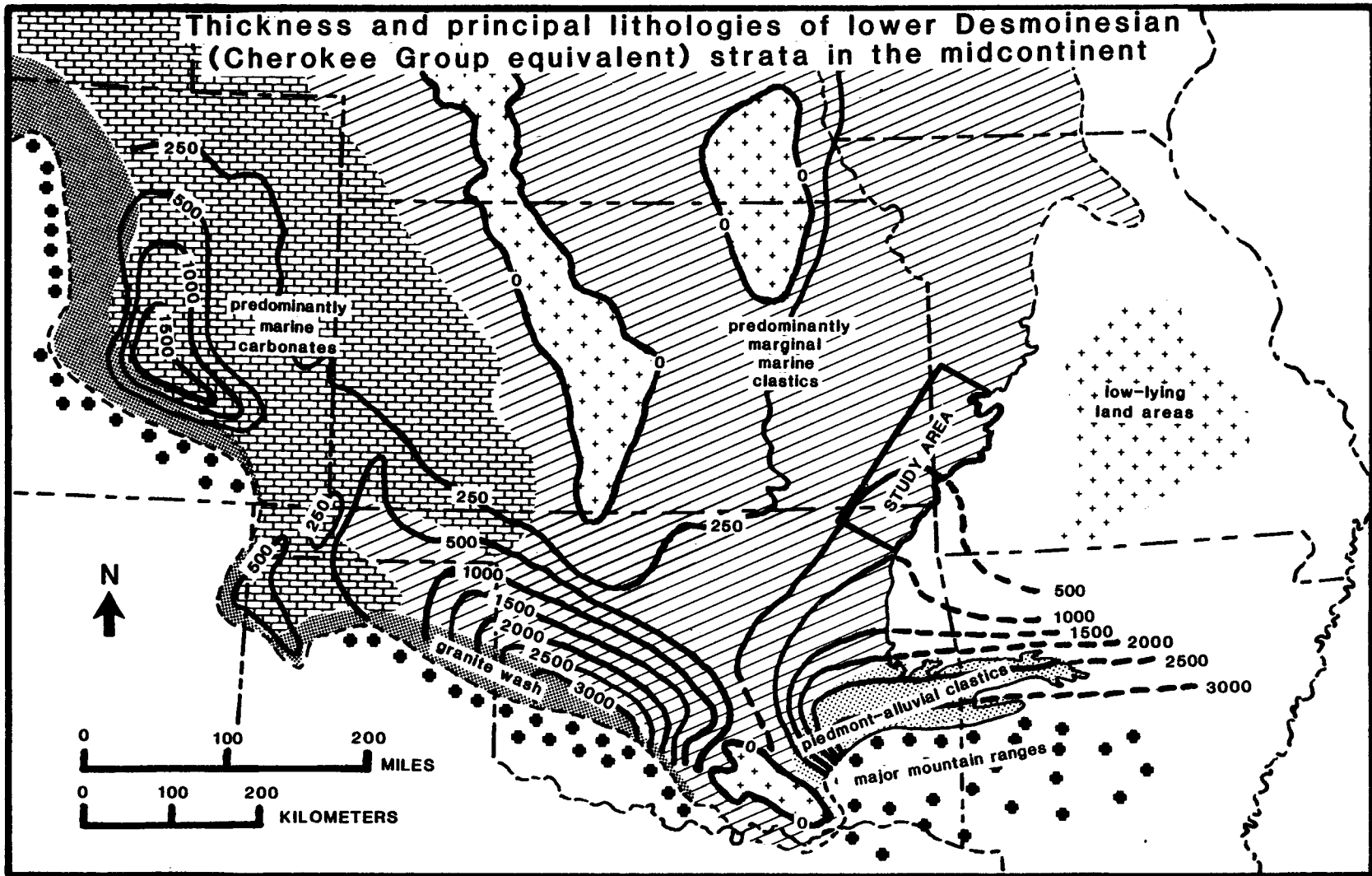


Figure 3

pre-Pennsylvanian unconformity is not recognizable in the Arkoma basin or the Ouachita region, implying that sedimentation was continuous to the south during most of Pennsylvanian time (Ham and Wilson, 1967; Sloss and Speed, 1974; Frezon and Dixon, 1975).

The largely terrigenous strata of the Krebs Formation accumulated during a transgression of the sea that was interrupted by minor progradational pulses of sedimentation. Evidence supporting this interpretation includes (1) lateral continuity and preservation of thin marine and nonmarine marker beds, (2) successive onlap of Desmoinesian and younger Pennsylvanian strata onto positive structural elements, and (3) transition from predominately terrigenous rocks at the base of the Desmoinesian to carbonates at the top (Weirich, 1953; Ham and Wilson, 1967; Visher and others, 1971; Morris, 1974; Frezon and Dixon, 1975; Rascoe and Adler, 1983). Since no interregional unconformities and no marker beds can be traced throughout the United States, regional stratigraphic correlations are best accomplished by paleontological studies, namely fusilinid zonation, floral compression zones, and palynology (Moore, 1929; Wanless, 1969). The current stratigraphic correlations for the Krebs Formation of Kansas, Missouri, and Oklahoma are summarized in Fig. 4. Figure 5 is a

Figure 4 - Stratigraphic correlation chart showing the formal stratigraphic nomenclature for lower Desmoinesian strata in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma (modified from Searight and Howe, 1961; Branson, Huffman and Strong, 1965; Jewett, O'Connor and Zeller, 1968; and Ebanks, 1979).

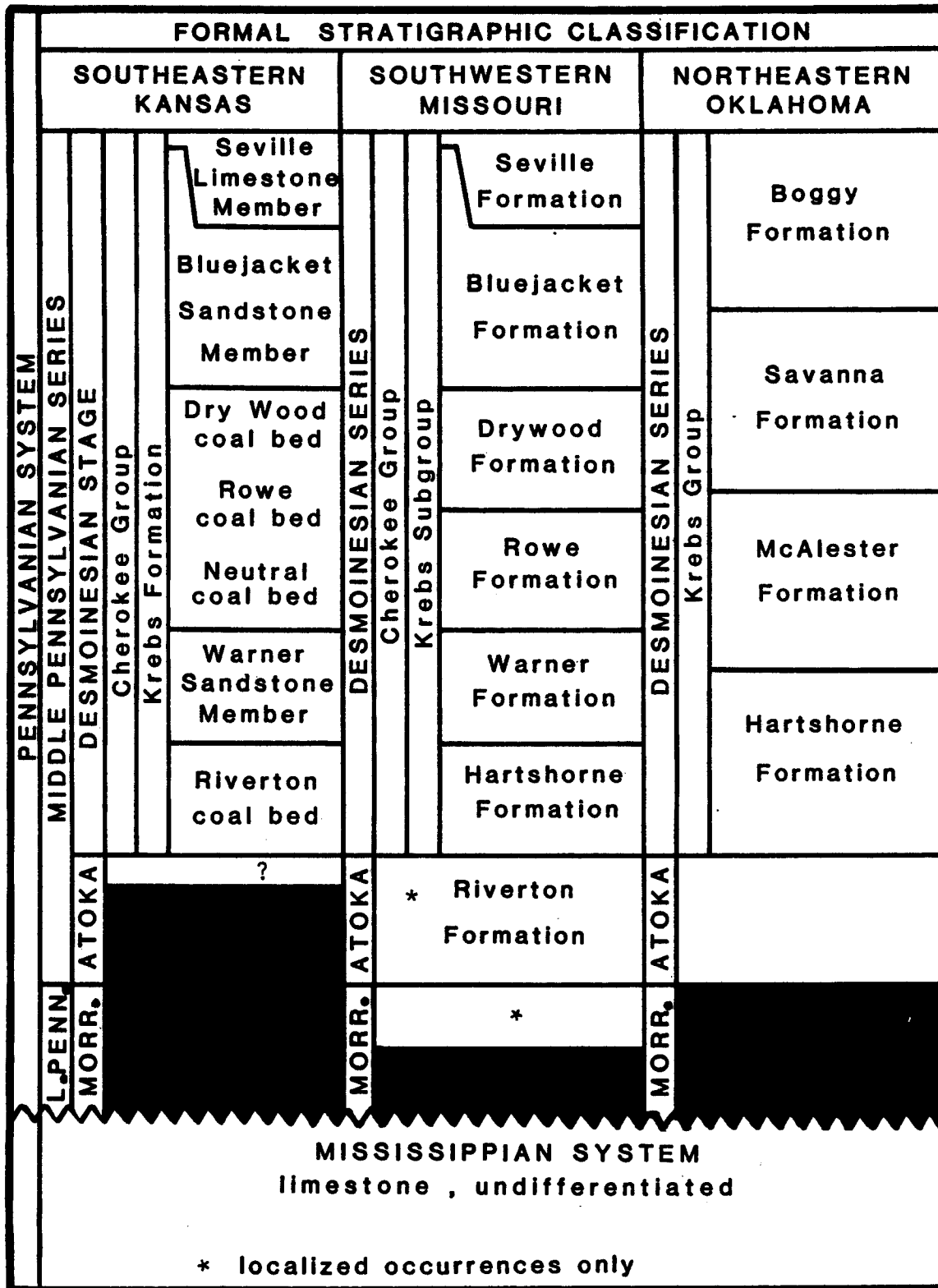


Figure 4

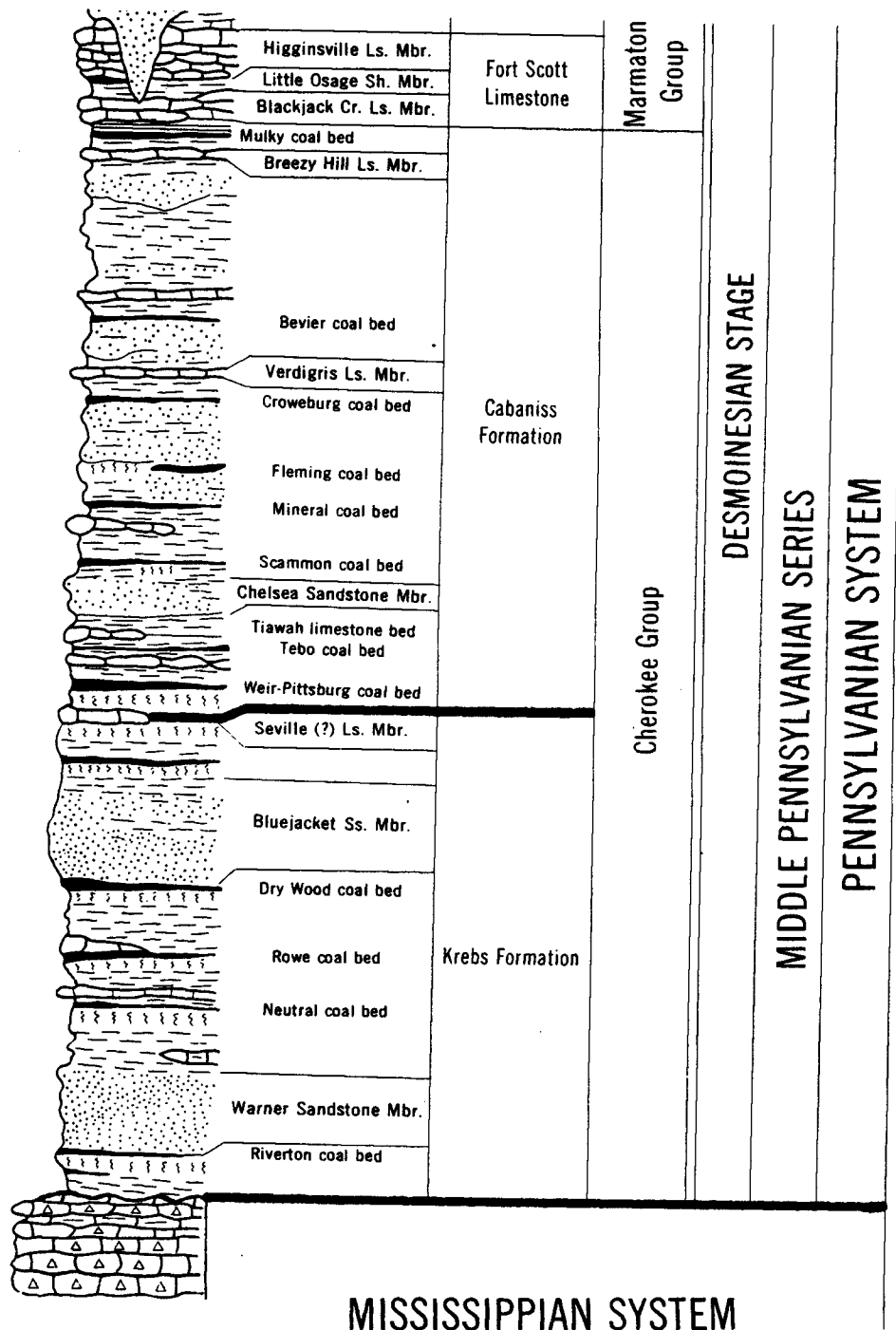


Figure 5 - Detailed stratigraphic column of the Krebs Formation in southeastern Kansas illustrating the formal stratigraphic classification system currently used by the Kansas Geological Survey (from Jewett, O'Connor and Zeller, 1968).

composite stratigraphic section of the Krebs Formation showing nomenclature currently used by the Kansas Geological Survey.

STRATIGRAPHY

In eastern Kansas the Krebs Formation consists of all rocks from the top of the Mississippian limestone up to the top of the Seville Limestone Member, a thin, argillaceous limestone unit (Fig. 5). Thickness of the Krebs Formation ranges from over 220 feet (70 m) in northern Craig County, Oklahoma, to less than 120 feet (36 m) in southern Bourbon County, Kansas. In Cherokee and Crawford counties, Kansas, where the best core control is available, the Krebs Formation consists of an estimated 78 percent shale and mudstone, 18 percent sandstone and siltstone, 3 percent coal, and 1 percent argillaceous limestone. More detailed lithofacies descriptions are included in a later section.

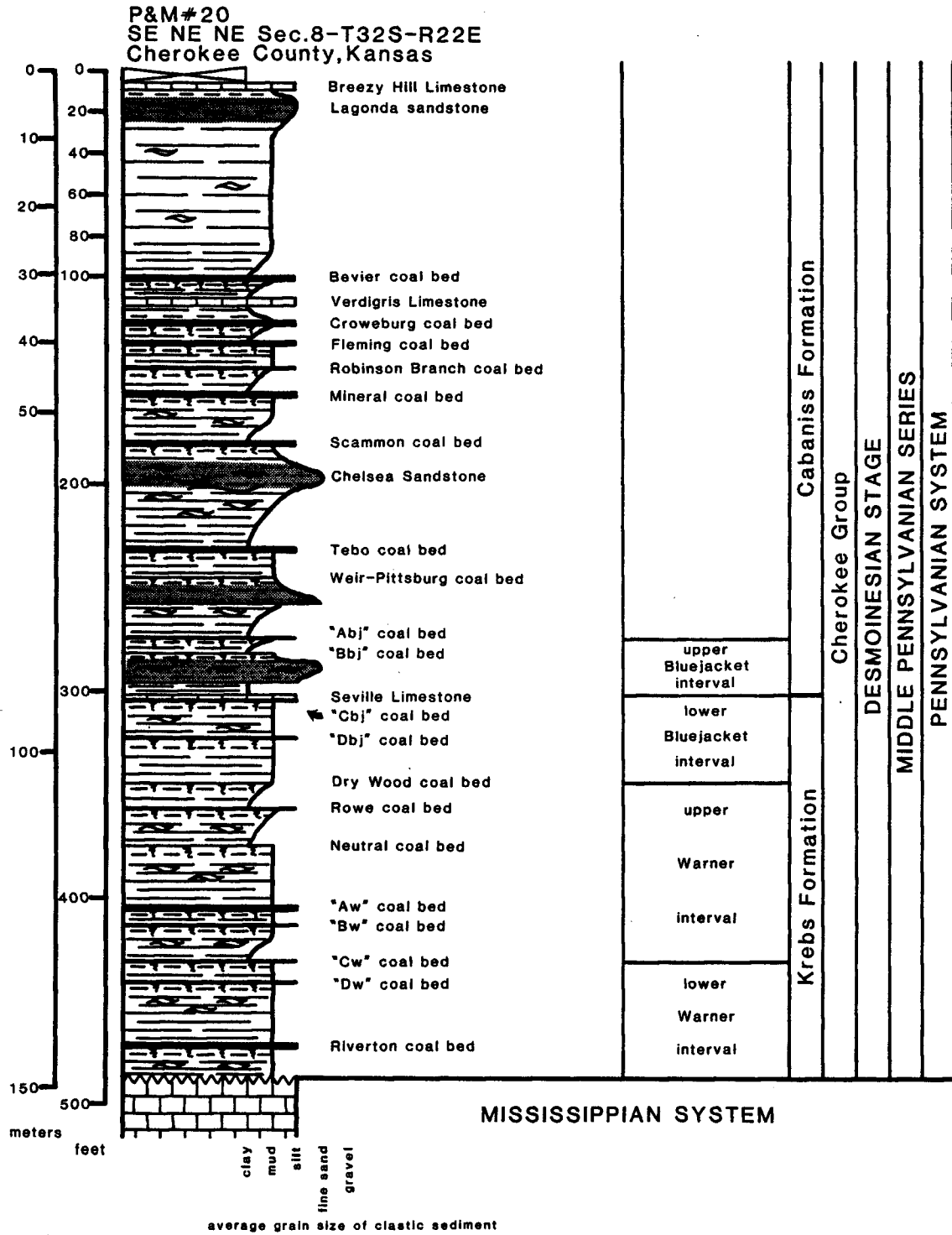
Coal beds, associated seatrock units, dark gray shales, and thin argillaceous limestones of the Krebs Formation are the most laterally persistent units in areas with low net sandstone deposition and are used as stratigraphic markers in this study. Coal beds less than one foot (30 cm) thick extend along strike for more than 30 miles (48 km) and may have an areal distribution of hundreds of square miles (Howe, 1956; Wanless, Baroffio, and Trescott, 1975; Wright, 1975). Coal beds are identified by their low density on neutron or density geophysical logs. Where coal beds are absent

due to nondeposition or erosion, their stratigraphic position may be traced by the presence of an underclay or seatrock unit in sharp contact with the overlying dark gray shale or argillaceous limestone. Dark gray shales with a high organic content are often radioactive and may be identified on gamma-ray geophysical logs. In areas having large amounts of sandstone, these stratigraphic markers are generally not present and must be projected between wells.

Correlations between coal beds, seatrock units, dark gray shales, and argillaceous limestones observed in cores define the subsurface stratigraphy of the Krebs Formation. The Pittsburg and Midway Coal Mining Company core number 20 (SE NE NE Sec. 8-T32S-R22E, Cherokee County, Kansas) provides a nearly complete section of the Cherokee Group and illustrates those units used for stratigraphic correlation within the Krebs Formation (Fig. 6). A composite section of the Cherokee Group is shown in Fig. 7. This composite section is the result of observations made on 24 continuous cores examined during the course of this study. Detailed subsurface stratigraphic relationships between cores from Cherokee and Crawford counties, Kansas, are illustrated by stratigraphic cross section A-A' (Plate 1). Extension of these correlations to the entire study area was

Figure 6 - Cored section of the Cherokee Group showing units used for stratigraphic correlation in this study (Pittsburg and Midway #20, SE NE NE Sec. 8-T32S-R22E, Cherokee County, Kansas).

CORED SECTION ILLUSTRATING STRATIGRAPHIC NOMENCLATURE USED IN THIS REPORT



COMPOSITE SECTION OF THE CHEROKEE GROUP, SOUTHEASTERN KANSAS

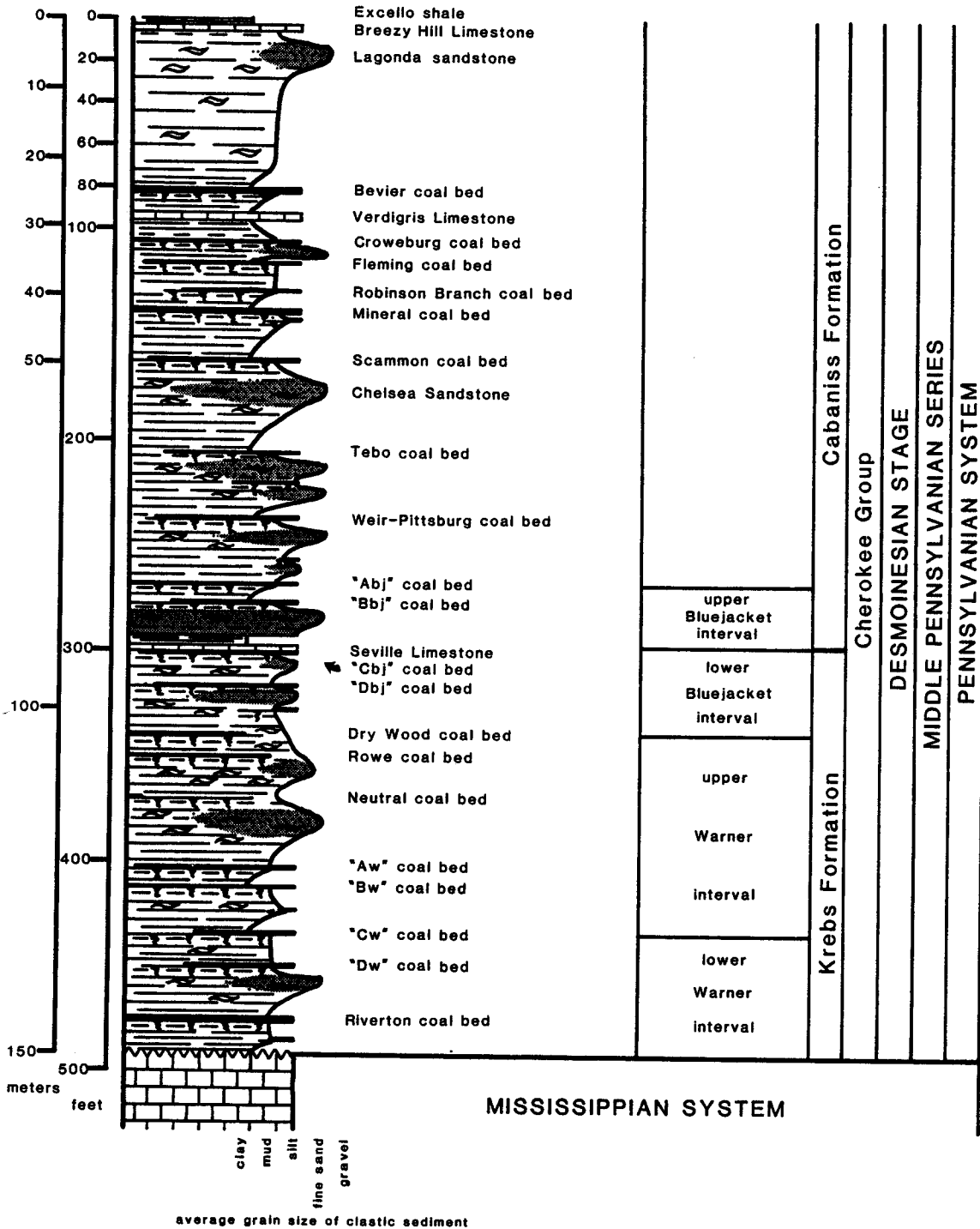


Figure 7 - Composite section of the Cherokee Group resulting from description of 24 continuous cores from Cherokee and Crawford Counties, Kansas.

accomplished through comparison with published core descriptions, geophysical logs, and drillers logs. These correlations are summarized by stratigraphic cross section B-B' (Plate 2).

Krebs Formation

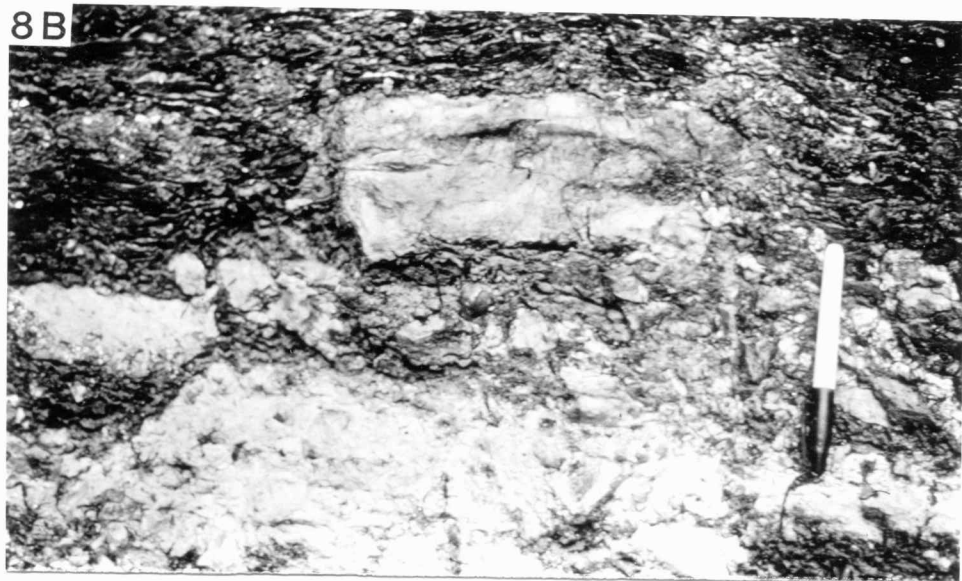
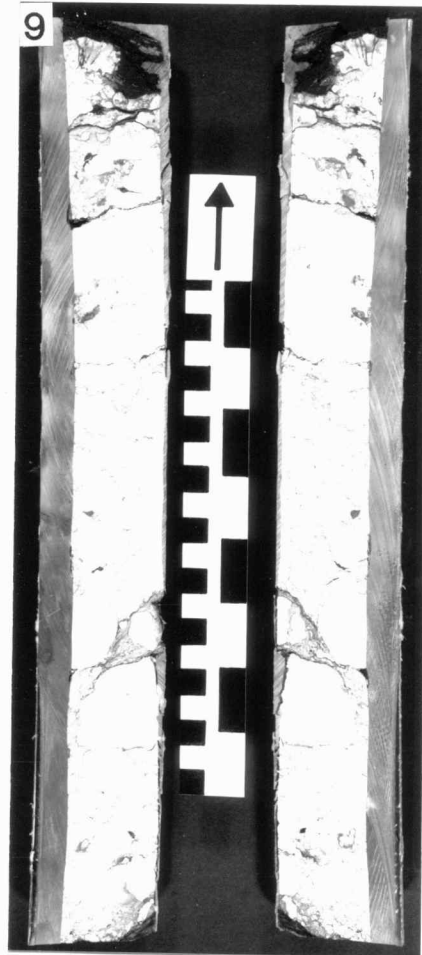
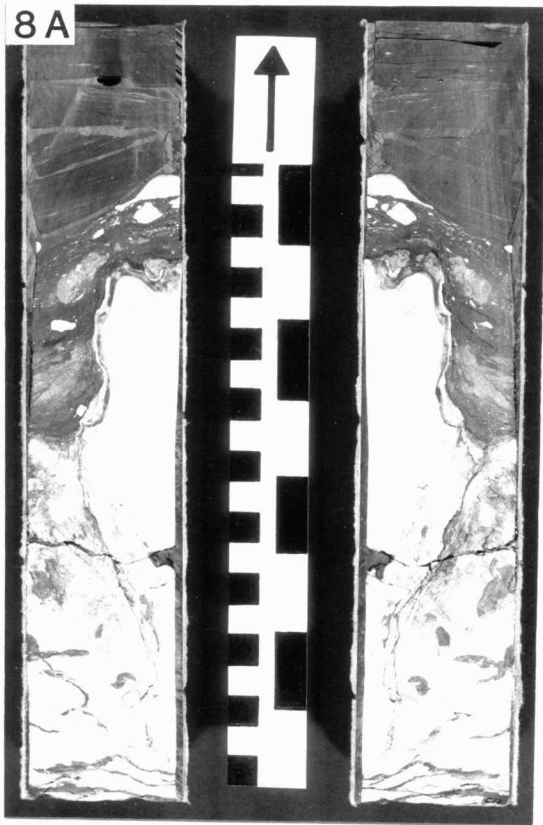
The unconformable basal contact of the Krebs Formation with the underlying Mississippian limestone is generally sharp but irregular (Figs. 8A and 8B). The contact of the Krebs Formation with Mississippian rocks in the subsurface is usually placed at the first appearance of chert nodules or brecciated limestone. The presence of angular chert and limestone boulders within a gray to greenish matrix represents solution and collapse due to minor karst development in the upper part of the Mississippian limestone prior to deposition of the Krebs Formation (Fig. 9).

Riverton interval — Dark gray shale with abundant pyrite usually forms the basal unit of the Krebs Formation, and sandstone at the base is thin and present only locally. The interval from the top of the Mississippian limestone to the base of the Riverton coal bed ranges from 1 to 28 feet (0.3 to 8.5 m) in thickness and consists mainly of dark gray shale, lenticular-bedded shale, and mudstone. A thin, lenticular, unnamed coal bed and seatrock unit is also

Figure 8-A - Photograph of outcrop exposed in a natural sinkhole (SW NW NE Sec. 9-T32S-R25E, Cherokee County, Kansas) illustrating the sharp but irregular nature of the unconformable contact between the Mississippian limestone and basal dark gray shale of the Krebs Formation.

Figure 8-B - Photograph of slabbed core showing the sharp but irregular nature of the unconformable contact between a chert nodule at the top of the Mississippian limestone and the basal dark gray shale of the Krebs Formation. (Sample from Office of Surface Mining - Job Service Center #7, NE SE NE, Sec. 30-T30S-R25E, Crawford County, Kansas, 237.6' - 238.5'.)

Figure 9 - Subareal karst collapse breccia resulting from solution and collapse of the underlying Mississippian limestone followed by infilling of the subsequent depression. (Sample from Pittsburg and Midway #7, SW SW SE Sec. 6-T32S-R22E, Cherokee County, Kansas, 450.0' - 451.2'.)



found in this part of the section. The Riverton coal bed is the first laterally persistent coal bed above the Mississippian limestone surface and ranges in thickness from 0.5 to 2.7 feet (15 to 82 cm). At its type area near Riverton, Kansas, in southeastern Cherokee County, the Riverton coal bed is only 0.4 feet (12 cm) thick. Observation of cores reveals a laterally persistent claystone parting near the base of the coal that is a distinguishing feature of the Riverton coal bed.

Lower Warner interval — Four unnamed but laterally persistent coal beds occur in the section above the Riverton coal bed and below the Neutral coal bed. These coal beds are useful for correlation, and for identification purposes in this study will be referred to informally in ascending stratigraphic order as the Dw, Cw, Bw, and Aw coal beds.

The Dw coal bed is separated from the Riverton coal bed by 1.5 to 40 feet (0.45 to 12 m) of dark gray shale, lenticular-bedded shale, mudstone, siltstone, and sandstone. The Dw coal bed ranges from 0.1 to 1.7 feet (3 to 51 cm) in thickness in the study area. Stratigraphically above the Dw coal bed is another laterally persistent but unnamed coal bed, the Cw coal bed. The interval between the Dw and Cw coal beds consists of 5 to 30 feet (1.5 to 9 m) of dark gray shale and lenticular-bedded shale and mudstone with minor

amounts of siltstone and sandstone. Thickness of the Cw coal bed ranges from 0.1 to 1.2 feet (3 to 36 cm) within the study area. A map of the distribution of the Cw coal bed is shown in Fig. 10.

Due to its lateral persistence, the Cw coal bed is used in this study to separate the lower Warner interval from the upper Warner interval (Ebanks, James, and Livingston, 1977). All sandstones between the Riverton and Cw coal beds are mapped as lower Warner sandstones. As used here, the lower Warner interval is consistent with the correlations of Ebanks, James, and Livingston (1977). Like most sandstone bodies of the Cherokee Group, sandstones in the lower Warner interval are lenticular in three dimensions and erratic in distribution. Individual sandstones of the lower Warner interval range in thickness from 1.5 to 30 feet (0.45 to 9 m) and exhibit both coarsening and fining upwards vertical profiles, suggesting deposition in a variety of environments.

Stratigraphic interval thicknesses between the Mississippian limestone, Riverton, Dw, and Cw coal beds are quite variable. Stratigraphic intervals between higher coal beds in the Krebs Formation have more uniform thicknesses. Since coal beds were essentially horizontal at the time of deposition, these lateral variations in thickness are interpreted to have

DISTRIBUTION MAP - Cw' COAL BED

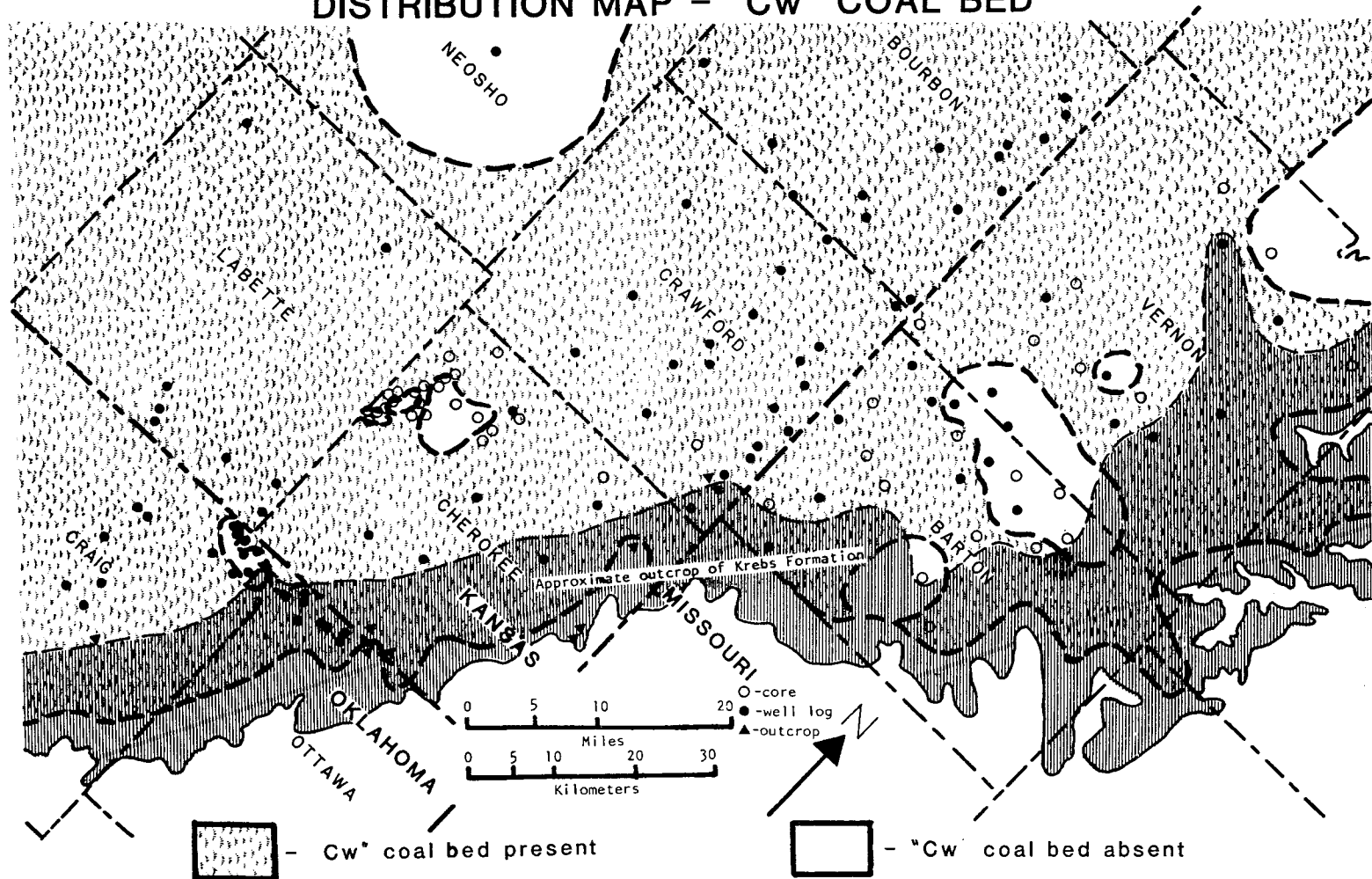


Figure 10 - Map of the study area showing the geographic distribution of the Cw coal bed. Crosshatched pattern shows the approximate outcrop of the Krebs Formation.

resulted from localized solution and subsidence of the underlying Mississippian limestone as well as differential compaction of the thicker shale sections, during deposition of the lower Krebs units. This interpretation is supported by the presence of Desmoinesian sink holes in Sec. 27-T29S-R25E, Crawford County, Kansas (KGS Well G), NE Sec. 9-T32S-R25E Cherokee County, Kansas, (Pierce and Courtier, 1937, p.58; Howe, 1956, p.30), and SE Sec. 23-T29N-R33W, Jasper County, Missouri (Searight, 1955, p.12). These Desmoinesian sinkholes all affect strata below the top of the lower Warner interval (Sauraker, 1966).

A third unnamed coal bed in the Krebs Formation, the Bw coal bed, is among the most laterally persistent units encountered in study of the cores. Separating the Bw coal bed from the underlying Cw coal bed is 16 to 24 feet (4.8 to 7.3 m) of dark gray shale, lenticular-bedded shale and mudstone, with a very minor amount of siltstone or sandstone. Thickness of the Bw coal bed ranges from 0.3 to 1.3 feet (10 to 39 cm) in the cores and outcrops examined.

Stratigraphically above the Bw coal bed is 4 to 10 feet (1.2 to 3 m) of dark-gray to lenticular-bedded shale and mudstone, followed by a fourth unnamed coal bed designated the Aw coal bed. Thickness of the Aw coal bed ranges from 0.25 to 1.5

feet (7.5 to 45 cm). The Aw coal bed is the lowermost coal bed of the Krebs Formation that has been mined commercially on a large scale in southeastern Kansas (SW Sec. 17 and NW Sec. 20-T32S-R25E, Cherokee County).

Neutral interval — Thickness of the interval between the Aw coal bed and the overlying Neutral coal bed ranges from 16 to 45 feet (4.8 to 13.7 m) and includes a variety of lithologies such as dark and medium gray shale, lenticular-bedded shale, mudstone, and abundant sandstone and siltstone. Near its type area (town of Neutral, NE Sec. 8-T34S-R24E Cherokee County, Kansas), the Neutral coal bed has a thickness of one foot (30 cm). More commonly, thickness of the Neutral coal ranges from a feather edge to 0.7 feet (21 cm). In some areas, the Neutral coal bed is not present due to nondeposition or erosion, but its stratigraphic position is often represented by a light gray mudstone or seatrock unit that is sharply overlain by a dark gray shale or argillaceous limestone (Fig. 11). This sharp contact suggests a definite break in sedimentation.

Rowe interval — Where present, the Rowe coal bed is located 17 to 37 feet (5 to 11 m) above the Neutral coal. Lithologies separating the two coal beds include dark gray shale, lenticular-bedded shale, mudstone, and minor amounts of sandstone or siltstone.

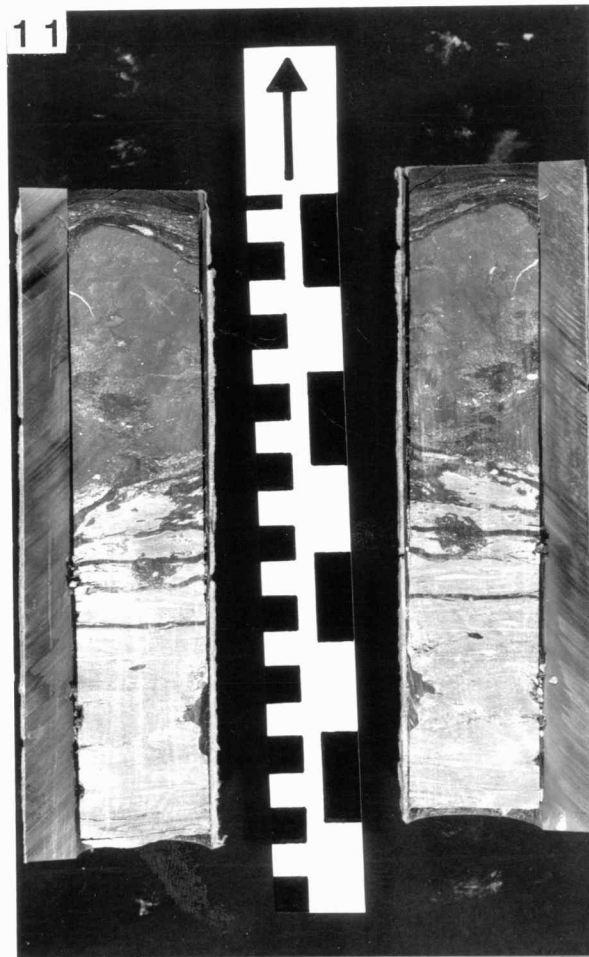


Figure 11 - Photograph of slabbled core showing the sharp contact between a seatrock unit and the overlying dark gray shale. Note the pyrite nodule at the stratigraphic position of the coal bed, probably due to concentration of organic material along this horizon. (Sample from Pittsburg and Midway #18, SW SW SW Sec. 28-T32S-R22E, Cherokee County, Kansas, 361.7' - 362.6'.)

Core studies indicate that the Rowe coal bed is more widespread than the Neutral or Dry Wood coal beds, and thickness of the Rowe coal bed ranges from 0.1 to 1.5 feet (3 to 45 cm). At its type locality near Rowe School (NE Sec. 34-T30S-R25E, Crawford County, Kansas), the Rowe coal bed occurs 7.1 feet (2.1 m) below the Dry Wood coal bed (Plate 3).

Dry Wood interval — Sections between the Rowe coal bed and the overlying Dry Wood (spelled Drywood by the Missouri Geological Survey and Water Resources; Searight and Howe, 1961) coal bed consist of 7 to 16 feet (2.1 to 4.8 m) of dark-to medium-gray shale, lenticular-bedded shale, mudstone, siltstone, and sandstone. Thickness of the Dry Wood coal bed in Kansas ranges from 0.3 to 1.5 feet (9 to 45 cm). At the type section of the Drywood along Dry Wood Creek, NE Sec. 4-T32N-R33W, Barton County, Missouri, the Drywood coal bed is less than one inch (2.5 cm) thick. Correlation of cores from Kansas and Missouri with surface mine exposures suggests that the bed currently recognized as the Dry Wood coal bed in Kansas is stratigraphically lower than the Drywood coal at its type section in Missouri (Plate 3).

Upper Warner interval — The upper Warner interval (Ebanks, James, and Livingston, 1977) includes all sandstones between the Cw coal bed and the Dry Wood

coal bed. Ebanks, James and Livingston (1977) chose the Rowe coal bed as the upper boundary of the upper Warner interval. The Dry Wood coal bed, however, is used as the upper boundary in this study. Individual sandstones of the upper Warner interval are the thickest in the Krebs Formation, ranging from less than three to over 70 feet (1 to 21 m) thick in the study area. Where thick sandstone accumulations occur in this part of the section, the Bw, Aw, Neutral, Rowe, and Dry Wood coal beds are commonly absent due to nondeposition or erosion.

Lower Bluejacket interval — An unnamed coal bed informally referred to in this study as the Dbj coal bed is located 6 to 33 feet (1.8 to 10 m) above the coal bed currently recognized as the Dry Wood in southeastern Kansas and southwestern Missouri. This coal bed correlates with the originally described Dry Wood bed (Plate 3).

Principal lithologies separating the Dry Wood coal bed from the Dbj coal bed include dark-to medium-gray shale, lenticular-bedded shale, mudstone, siltstone, sandstone, and an occasional locally developed coal bed. Although the Dbj coal bed has a maximum thickness of only 0.4 feet (12 cm), it has remarkable lateral persistence over much of the study area.

A section composed of dark-gray shale, lenticular-bedded shale, siltstone, and sandstone ranging in thickness from 9 to 18 feet (3 to 6 m) separates the Dbj coal bed from another unnamed coal bed referred to in this study as the Cbj coal bed. Although only 0.4 feet (12 cm) thick at its maximum measured thickness, the Cbj coal bed is also laterally persistent throughout the study area. The Cbj coal bed is called the Rowe coal bed in Oklahoma, but it is approximately 50 to 60 feet (15 to 18 m) feet above the Rowe coal bed of Kansas and Missouri (L. A. Hemish, personal communication, 1984) (Plate 3).

The discontinuous lower Bluejacket Sandstone of Ebanks, James, and Livingston (1977) occurs in the stratigraphic interval between the Dry Wood coal bed and the Cbj coal bed. Thickness of the lower Bluejacket sandstone ranges from three to 35 feet (1 to 11 m), and both fining and coarsening upwards sequences were encountered in cores and outcrops. Pre-mining cross sections by Ebanks and Brady (Heckel and others, 1979) show that the lower Bluejacket Sandstone occurs below the Dbj coal bed. Examination of outcrops (SW Sec. 35-T30S-R25E, Crawford County, Kansas) reveals that the lower Bluejacket Sandstone was deposited in channels that scoured into the Dry Wood coal bed. Although Ebanks, James, and Livingston (1977) chose the Rowe coal

bed as the base of the lower Bluejacket interval, in this study, only sandstones between the Dry Wood coal bed and the Cbj coal bed were mapped as lower Bluejacket Sandstone. This sandstone interval is formally recognized as the Bluejacket Sandstone by Kansas and Missouri.

Seville Limestone — Immediately above and usually in sharp contact with the Cbj coal bed is a dense, dark-gray, argillaceous limestone unit that is believed to correlate with the Seville Limestone Member recognized in Missouri, Iowa and Illinois. This correlation is based on its lithologic character and its relative stratigraphic position. The Seville Limestone Member has been tentatively identified previously from only one locality in Kansas (abandoned clay pit, SW Sec. 28-T30S-R25E, Crawford County, Kansas) (Howe, 1956). The Seville Limestone in this study, however, was found to be one of the most continuous units in the cores that were examined. An excellent exposure of the limestone referred to in this study as the Seville Limestone may be found in the highwall of an abandoned coal strip mine (SW Sec. 34-T30S-R25E, Crawford County, Kansas). Where present, the Seville Limestone ranges from 0.5 to 1.5 feet (15 to 45 cm) in thickness. Distribution of the Seville Limestone Member, where discernable from cores, well logs, and drillers logs, is illustrated in Fig. 12.

DISTRIBUTION MAP - SEVILLE LIMESTONE

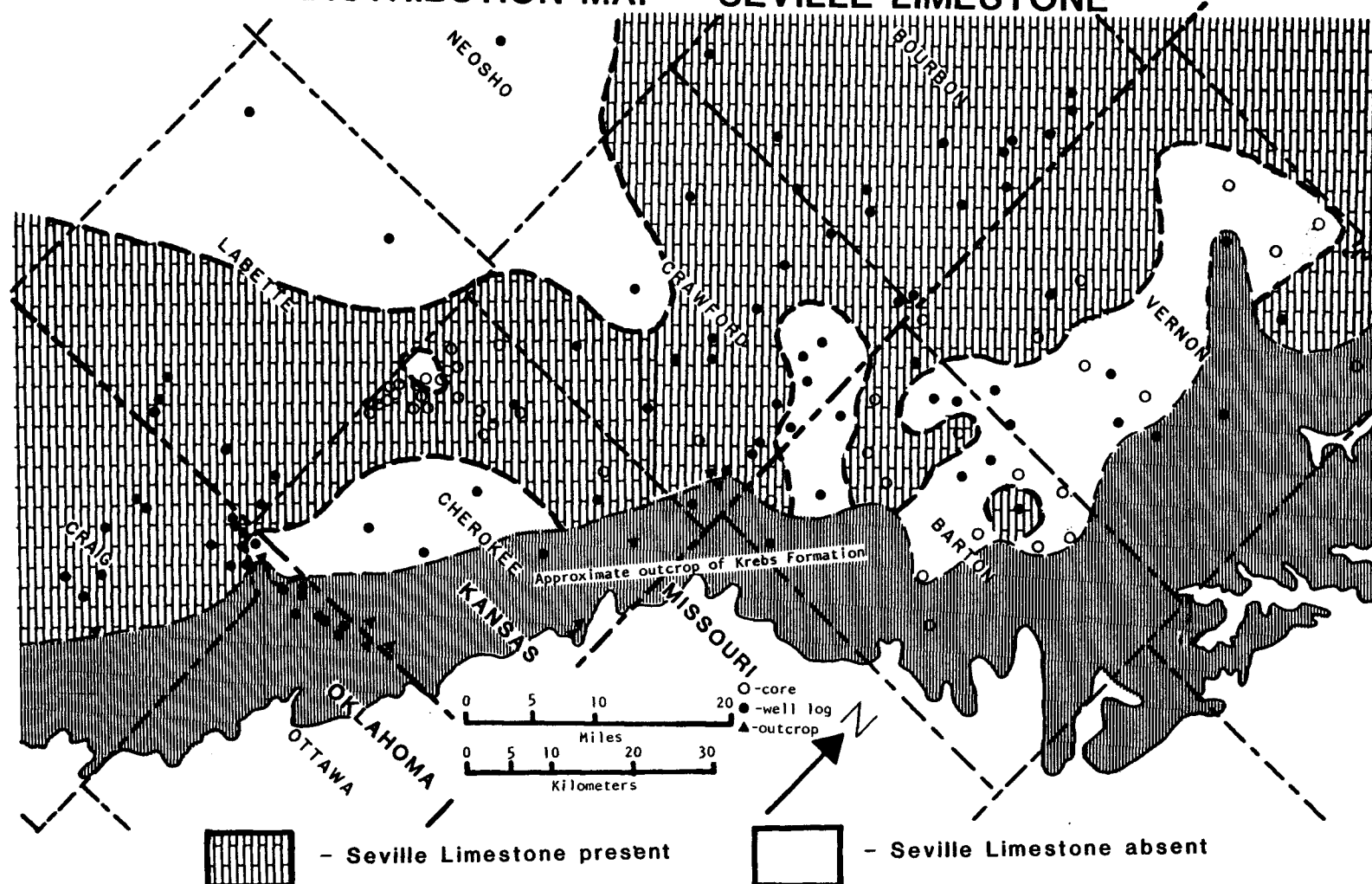


Figure 12 - Map of the study area showing the geographic distribution of the Seville Limestone Member. Crosshatched pattern shows the approximate outcrop of the Krebs Formation.

The Seville Limestone Member is important because of its stratigraphic position as the uppermost member of the Krebs Formation. Results of this study indicate that the Seville Limestone of Kansas and Missouri correlates with the Doneley Limestone of northeastern Oklahoma rather than the Inola Limestone as proposed by Howe (1956) (Plate 3).

Cabaniss Formation

The Cabaniss Formation of Kansas includes all strata between the top of the Seville Limestone Member of the Krebs Formation and the base of the Fort Scott Limestone Formation of the Marmaton Group. Strata of the Cabaniss Formation range in thickness from more than 350 feet (106 m) in northern Craig County, Oklahoma, to 220 feet (67 m) in southern Bourbon County, Kansas. Stratigraphic units of the Cabaniss Formation have been described in more detail than those of the Krebs Formation due to numerous surface and underground coal mine exposures and coal exploration drillers logs (Moore, 1929; Abernathy, 1936; Pierce and Courtier, 1937; Howe, 1956; Jewett, O'Connor and Zeller, 1968; Brady, Livingston, and Adams, 1977). Since emphasis of this study is on the Krebs Formation, only the stratigraphy of the lower part of the Cabaniss Formation below the Weir-Pittsburg coal bed will be discussed.

Graphic core descriptions that include additional units of the Cabaniss Formation are presented in Appendix A.

Upper Bluejacket interval — The lowermost unit of the Cabaniss Formation consists of 2 to 12 feet (0.6 to 3.6 m) of dark-gray shale. Overlying the basal shale unit usually with a sharp, nonscoured lower contact is a thin but widespread sandstone and siltstone unit that correlates with the upper Bluejacket Sandstone of Ebanks, James, and Livingston (1977). The upper Bluejacket Sandstone ranges from 9 to 20 feet (3 to 7 m) in thickness and is the most widespread sandstone unit observed, being traceable in the cores for over 50 miles (80 km) along strike. This sandstone interval is characterized by numerous lateral facies changes, and both coarsening-upwards and fining-upwards sequences are present, with the coarsening-upwards sequences being the most commonly observed vertical transition of lithofacies. The upper Bluejacket Sandstone of Kansas is thought to correlate with the Dickson Sandstone of the Savanna Formation in northeastern Oklahoma (Branson, Huffman, and Strong, 1965; L. A. Hemish, personal communication, 1984) (Plate 3).

Weir-Pittsburg interval — Overlying the upper Bluejacket interval is one to 11 feet (0.3 to 3.3 m) of siltstone, shale, and mudstone, followed by another unnamed coal bed, here referred to as the Bbj

coal bed. The Bbj coal bed ranges in thickness from a featheredge to 0.9 feet (27 cm) in the study area.

Dark-gray shale and mudstone ranging from 3 to 13 feet (1 to 4 m) in thickness separates the Bbj coal bed from another unnamed coal bed referred to here as the Abj coal bed. Basal dark-gray shale units overlying the Bbj coal bed are often highly radioactive and provide convenient markers on gamma-ray geophysical logs. The Abj coal bed has a maximum thickness of one foot (30cm) in the cores examined, but up to 1.5 feet (45 cm) of coal has been reported on drillers logs. The Abj coal bed of Kansas is stratigraphically below the Bluejacket coal bed of Oklahoma, and the Abj coal bed has been called the Dry Wood coal bed in northeastern Oklahoma (L. A. Hemish, personal communication, 1984) (Plate 3).

The Weir-Pittsburg coal bed is present 20 to 36 feet (6 to 11 m) stratigraphically above the Abj coal bed. Lithologies in the intervening interval include shale, lenticular-bedded shale, mudstone, and minor lenticular sandstone and siltstone deposits. Thickness of the Weir-Pittsburg coal bed in the study area ranges from 0.1 to more than 4 feet (0.03 to 1.2 m). Although the Weir-Pittsburg coal bed thins dramatically away from its type area in Crawford and Cherokee counties, Kansas, the stratigraphic position of the Weir-Pittsburg

is well established since two of the cores examined in this study (Office of Surface Mining CH-1, SW Sec. 27-T31S-R24E, Cherokee County, Kansas; and Office of Surface Mining JSC#7, NE Sec.30-T30S-R25E, Crawford County, Kansas) penetrate voids created by the underground mining of this coal at a depth of about 30 feet (10 m).

The Weir-Pittsburg coal bed of Kansas correlates with the Bluejacket coal bed in northeastern Oklahoma, and the Bluejacket Sandstone of northeast Oklahoma is present only locally in southeastern Kansas (L. A. Hemish, personal communication; 1984). Correlations from northeastern Oklahoma to southeastern Kansas indicate that the Bluejacket Sandstone at its type section (NE Sec.25-T27N-R20E, Craig County, Oklahoma) is about 75 feet (22.5 m) stratigraphically above the lower Bluejacket Sandstone and about 30 feet (10 m) above the upper Bluejacket Sandstone of southeastern Kansas (Howe, 1951; Ebanks, James, and Livingston, 1977). Thus, it seems that the Bluejacket Sandstone at its type locality (Howe, 1951) and the upper Bluejacket Sandstone of Kansas (Ebanks, James, and Livingston, 1977) would fall within the Cabaniss Formation, since both lie above the Seville Limestone of Kansas. This probably results from mistakes in correlation of the Dry Wood coal bed and the Seville

Limestone of Kansas into Oklahoma (Plate 3).

Additional details of the stratigraphy of the Cabaniss Formation may be found in Figures 6 and 7, cross sections A-A' and B-B' (Plates 1 and 2), and in the core descriptions in Appendix A.

LITHOFACIES DESCRIPTIONS

Mudrocks

Dark-gray shale — Shales that range from very-dark gray (N2) to medium-dark gray (N4) on the color chart (Goddard and others, 1963) are the most abundant lithofacies in the Cherokee Group in southeastern Kansas, making up 31 percent of the total footage of core and outcrops examined (Fig. 13). Individual shale units range in thickness from less than one foot (30 cm) to more than 25 feet (7.6 m). Dark-gray shales are generally hard and break with a hackly or splintery fracture. Very few shales in the Krebs Formation exhibit platy fracture. Both clayshale and mudshale with minor amounts of quartz silt are common. Fossils observed in dark-gray shales include brachiopods, echinoderms, bivalves, gastropods, ostracodes, fish scales, and abundant terrestrial plant fragments (Dr. Doris Zeller, personal communication; 1982). A few horizontal burrows less than 1 cm in diameter were present in some units. Diagenetic features include calcareous cement, calcareous cone-in-cone structures, and calcareous, clay ironstone, and pyrite concretions. Dark-gray shale units most commonly overlie coal beds, seatrock units, argillaceous limestones, or thin sandstones and conglomerates. Basal

contacts are usually sharp, while upper contacts are usually gradational into light-gray or lenticular-bedded shales. Many dark-gray shale units in the Cherokee Group exhibit high gamma-ray values, providing convenient marker beds. No gamma-ray logs were available for the cored wells, however; so shales with high gamma-ray values are undifferentiated from those with lower or average values. Previous studies have shown that the radioactivity of shales is directly correlatable with the total organic carbon content (Ibach-Johnson, 1982).

The fine grain size of dark-gray shales suggests that they were deposited by clay and silt settling from suspension under extremely low-energy flow conditions. The diversity of faunal remains, the concentration of organic material, and the preservation and pyritization of organic material indicate that these shales were deposited in a shallow, low-energy marine environment with disaerobic or anoxic bottom conditions. Dark-gray shale units are thought to represent the slowest rates of terrigenous sedimentation.

Medium-to light-gray shales — Shales ranging from medium gray (N5) to very light gray (N8) on the color chart (Goddard and others, 1963) are also common in the Cherokee Group and constitute approximately 15 percent of the total thickness of the Cherokee Group

(Fig. 14). Thickness of individual medium-to light-gray shale units ranges up to 75 feet (25 m). Medium-to light-gray shales generally are moderately hard and exhibit a hackly fracture. Mudshales are the most common, consisting of clay with minor amounts of dispersed quartz silt and mica. Large leaves and other plant fossils are the most common fossil type, while molluscs, brachiopods, crinoid columnals, and other marine fauna are present but not as abundant as in the dark-gray shales. A few small vertical and horizontal burrows may be present. Clay ironstone and pyrite concretions, as well as calcareous cement are common diagenetic features. Medium-to light-gray shales often overlie dark-gray shale units with a gradational lower contact and grade upwards into lenticular-bedded shale or mudstone.

Medium-to light-gray shale units also were deposited from suspension under extremely low-flow conditions. The slightly coarser grain size, sparsity of marine fauna and burrows, presence of only larger plant fragments, and the lighter color suggest that medium-to light-gray shales were deposited in a shallow-marine environment having higher terrigenous sedimentation rates than dark-gray shales. The preservation of plant remains and the abundance of pyrite suggest disaerobic bottom conditions, and higher

sedimentation rates resulted in dilution of the concentration of organic debris, producing the lighter color (Ibach-Johnson, 1982).

Lenticular-bedded shales — Lenticular-bedded shales (Reinick and Wunderlich, 1968) consist of dark-to medium-gray (N3 - N5) mudshale interlaminated with thin (less than 1 cm) light gray (N7) lenses of silt to fine-grained quartz sand (Fig. 15). Isolated ripples of sandstone and siltstone and convolute bedding are common sedimentary structures. Individual lenticular-bedded shale units are generally less than 30 feet (10 m) thick, and make up approximately 16 percent of the total rock thickness of the Cherokee Group. Lenticular-bedded shale units contain plant fossils and vertical and horizontal burrows, but marine body fossils such as brachiopods, bivalves, and echinoids are rare. Calcareous cement, pyrite, and clay ironstone concretions are common diagenetic features. Lower contacts of lenticular-bedded shale units are usually gradational with dark-or medium-gray shales, and the abundance of silty lenses commonly increases upwards within each unit. Upper contacts are usually gradational with sandstone, siltstone, shale, or mudstone. Lenticular-bedded shale units grade vertically and laterally into sandstones of the Krebs Formation.

The interlamination of mud and sand implies depositional environments conducive to deposition of both mud and sand. Periods of extremely low current velocities allowing deposition of mud layers from suspension must have alternated with periods of relatively high current velocities required for transportation of sand. Lenticular-bedded shales form when isolated sand ripples form and migrate along a muddy substrate until they are buried by the next influx of mud. This mechanism implies more favorable conditions for the deposition of mud than for sand (Reineck and Singh, 1980; Hawley, 1981). The presence of isolated wave and current-formed ripples indicates shallow-water reworking of the bottom by currents and waves, suggesting that lenticular-bedded shale units represent higher rates of deposition than other types of shale. The abundance of burrows and the presence of a few marine fossils indicates that lenticular-bedded shale units formed in a shallow-water marine environment adjacent to a source of both sand and mud.

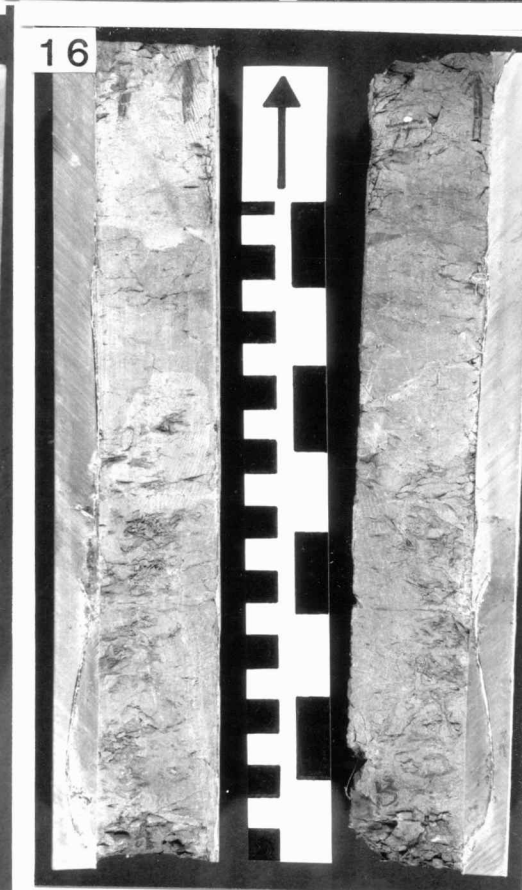
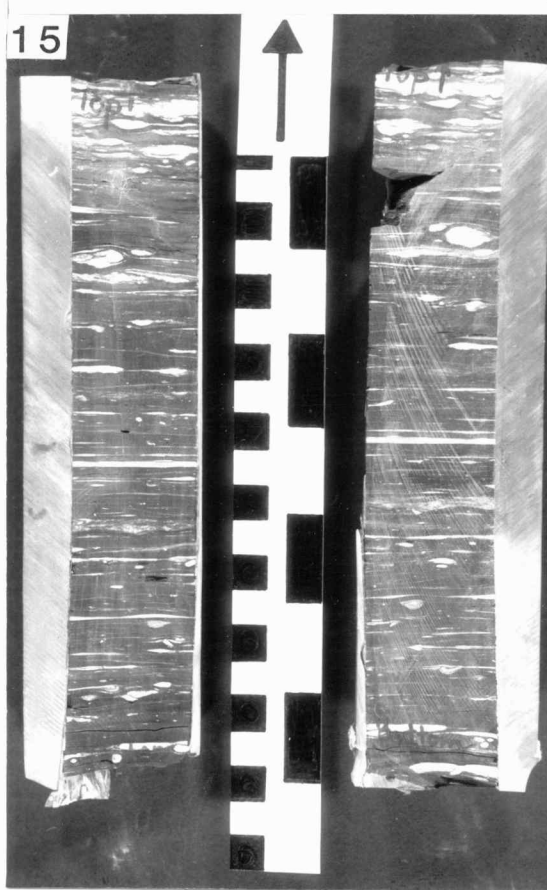
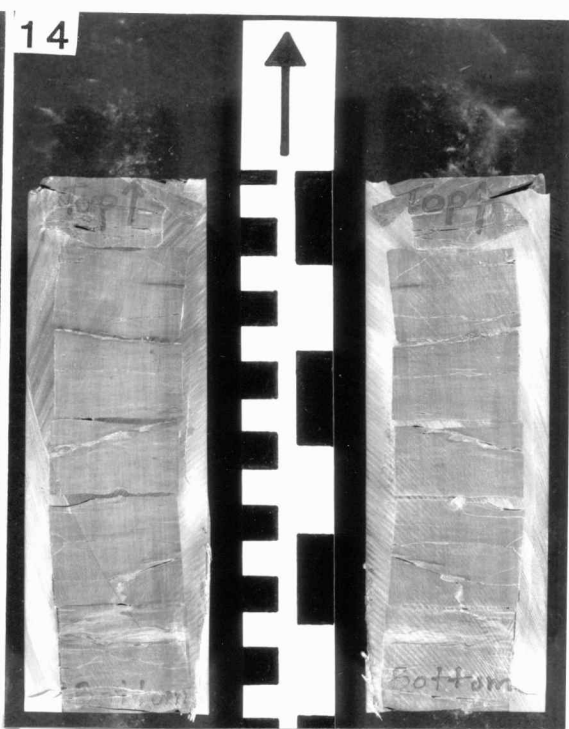
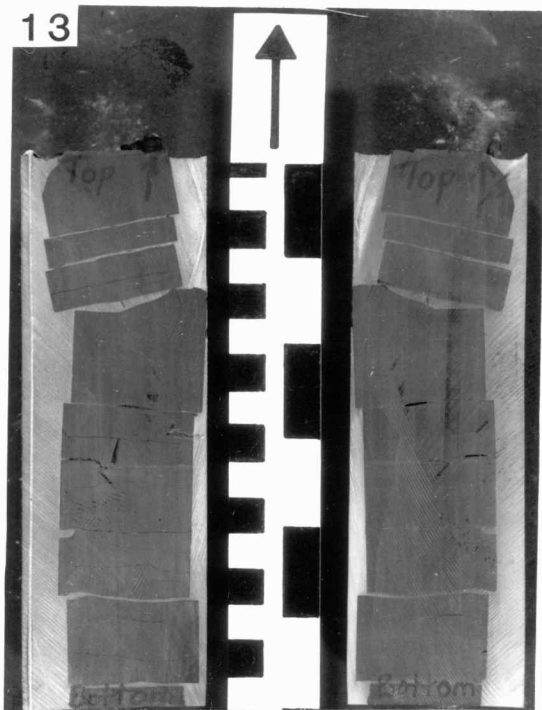
Mudstone and claystone — Mudstones and claystones of the Cherokee Group lack fissility, are soft, and break with a blocky or occasionally conchoidal fracture. Colors range from dark gray (N3) to very light gray (N8) (Goddard and others, 1963) (Fig. 16). One massive mudstone unit in the Dry Wood interval,

Figure 13 - Photograph of slabbed core showing a representative example of a dark-gray shale unit. (Sample from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 162.3' - 163.0'.)

Figure 14 - Photograph of slabbed core showing a representative example of a medium-gray shale unit. (Sample from Pittsburg and Midway #4, NW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 72.4' - 72.9'.)

Figure 15 - Photograph of a slabbed core showing a representative example of a lenticular-bedded shale unit with small, horizontal burrows. (Sample from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 395.1' - 395.8'.)

Figure 16 - Photograph of a slabbed core showing a representative example of a mudstone unit. (Sample from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 372.2' - 372.9'.)



observed in cores from Cherokee County, Kansas, was more than 15 feet (4.5 m) thick, but individual units are usually less than 5 feet (1.5 m) thick. Claystone and mudstone account for approximately 15 percent of the total thickness observed in cores and outcrops of the Cherokee Group. Mudstones and claystones commonly contain abundant quartz silt. Plant fossils and root marks are abundant, but marine fossils are rare. Gradational lower contacts are common, and most mudstone units are overlain by coal beds with a sharp contact.

Structureless mudstones and claystones can form by rapid sedimentation from suspension, or by bioturbation of previously laminated deposits (Hulse, 1978; Potter, Maynard, and Pryor, 1980). The gradational lower contacts of most mudstone units with other types of laminated shales and lenticular-bedded shales suggests that they were formed by bioturbation and homogeneous mixing of previously laminated sediments. Bioturbation may result from growth of plant roots or by burrowing marine infauna. The fact that most mudstones and claystones of the Cherokee Group contain abundant plant fossils, often vertically oriented, makes bioturbation by plant roots a likely explanation for the lack of sedimentary structures.

Sandstones and siltstones

Wavy-bedded sandstone and siltstone _____

Wavy-bedded sandstones and siltstones (Reineck and Wunderlich, 1968) contain approximately equal amounts of interlaminated or interbedded, light-gray (N7) sandstone or siltstone and medium-to dark-gray (N5 to N3) mudshale (Fig. 17A-C). Wavy-bedded sandstone units range in thickness from less than one foot (30 cm) to more than 30 feet (10 m), and wavy-bedded sandstones constitute approximately nine percent of the total thickness of the Cherokee Group. Small-scale unidirectional current and low-angle wave ripples (less than 3 cm high) and convolute bedding from soft-sediment deformation are the most common sedimentary structures. Interbedding of sand and shale occurs on a scale of one to several centimeters. Plant fossils, occasional marine fossils, and burrows of various types are present in wavy-bedded sandstones and siltstones. Diagenetic features include clay ironstone nodules, siderite spherulites, and zones of calcareous cement. Wavy-bedded siltstones and sandstones usually have gradational or intercalating lower contacts with the underlying lithology. In places, a sharp, nonscoured lower contact is present over a large area, indicating rapid lateral progradation of a sedimentary environment and enhancement by compaction (R. L. Brenner, personal communication;

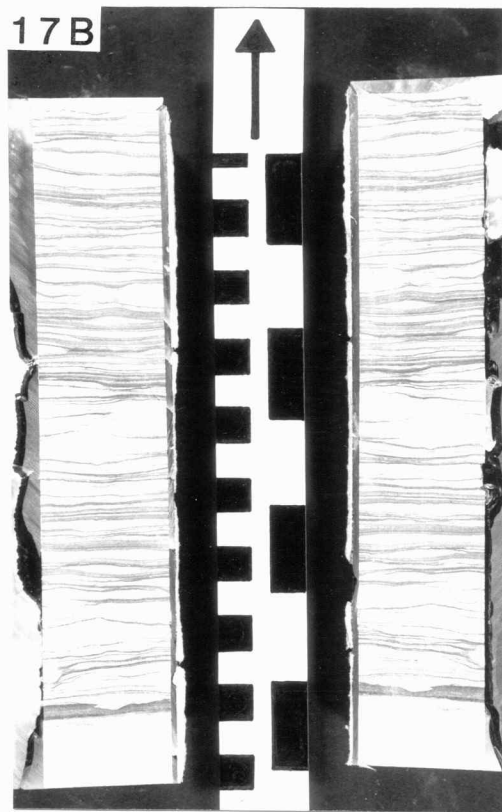
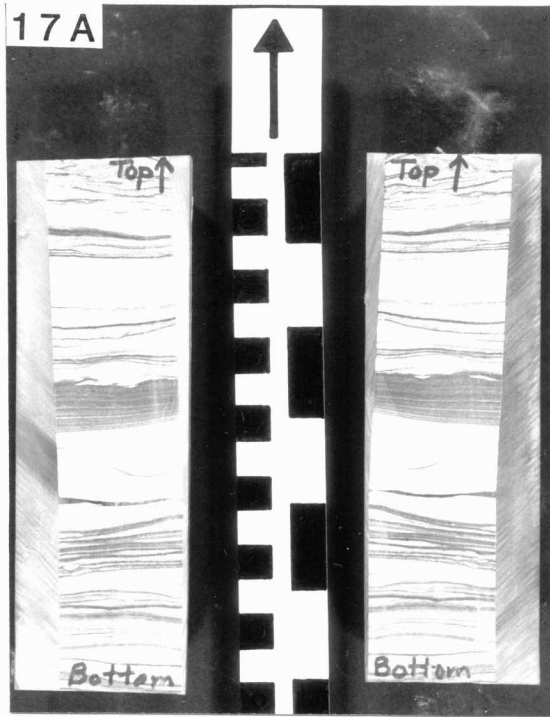
1982). Wavy-bedded siltstone or sandstone units often grade upwards into flaser-bedded to rippled siltstones and sandstones.

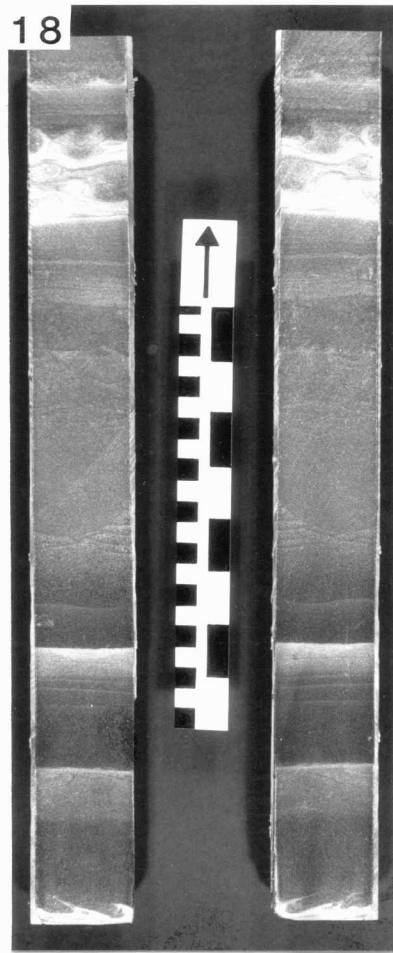
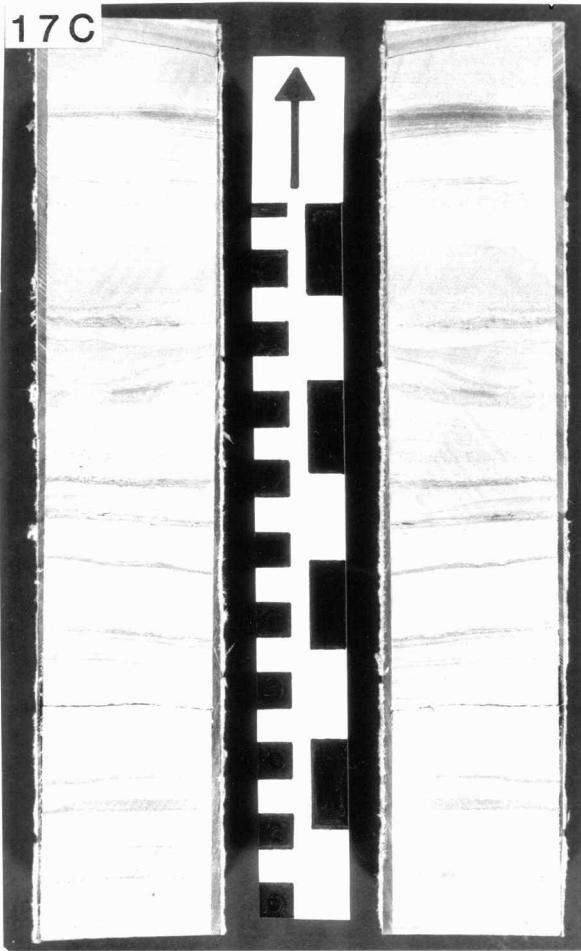
Wavy-bedded siltstones and sandstones, like lenticular-bedded shales, require an alternation of current or wave energy for sand and mud deposition. Preservation of wavy-bedding requires that a continuous, rippled sand bed be covered by a continuous layer of mud, and that the next influx of sand or silt does not erode the mud layer. This indicates that hydraulic conditions are equally favorable for the deposition of sand by traction and mud from suspension (Reineck and Singh, 1980; Hawley, 1981). Early compaction plays a significant role in the preservation of thin mud layers (Hawley, 1981). The presence of burrows and sparse marine fauna suggest that wavy-bedded sandstone and siltstone units were deposited in a marine environment close to a source of both sand and mud.

Sequences of thin, graded beds are commonly associated with the wavy-bedded sandstone facies (Fig. 18). These graded beds are volumetrically insignificant, and individual graded beds are generally less than one foot (30 cm) thick. Graded beds consist of a sharp, scoured basal contact overlain by rippled sandstone and grading upwards into siltstone or shale. Graded beds may be deposited by turbidity currents produced by

Figure 17 - Photographs of slabbed cores showing representative examples of wavy-bedded siltstone and sandstone units. (Sample locations: A - Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 102.4' - 102.9'; B - Pittsburg and Midway #8, NE NE NE Sec. 5-T32S-R23E, Cherokee County, Kansas, 203.1'- 203.7'; C - Office of Surface Mining - Job Service Center #7; NE SE NE Sec. 30-T30S-R25E, Crawford County, Kansas, 162.9' - 163.8'.)

Figure 18 - Photograph of slabbed core showing the graded-bed facies often associated with wavy-bedded sandstones. (Sample from Office of Surface Mining - Job Service Center #7, NE SE NE Sec. 30-T30S-R25E, Crawford County, Kansas, 150.1' - 151.4'.)





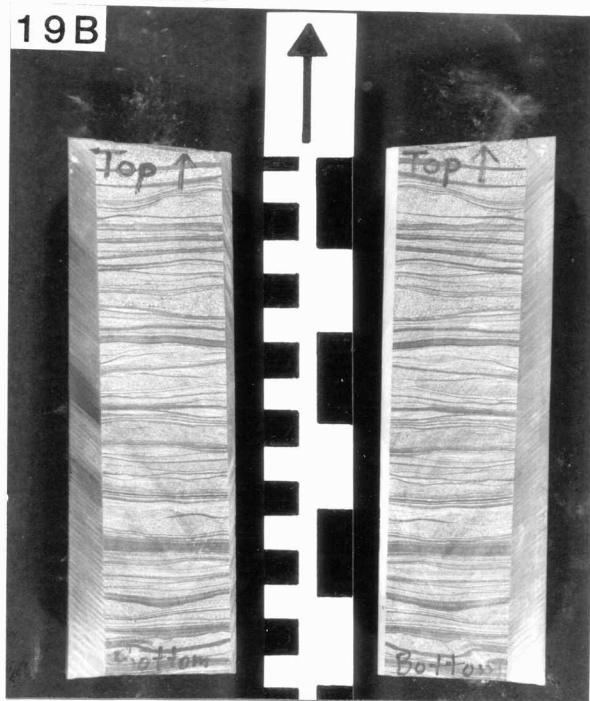
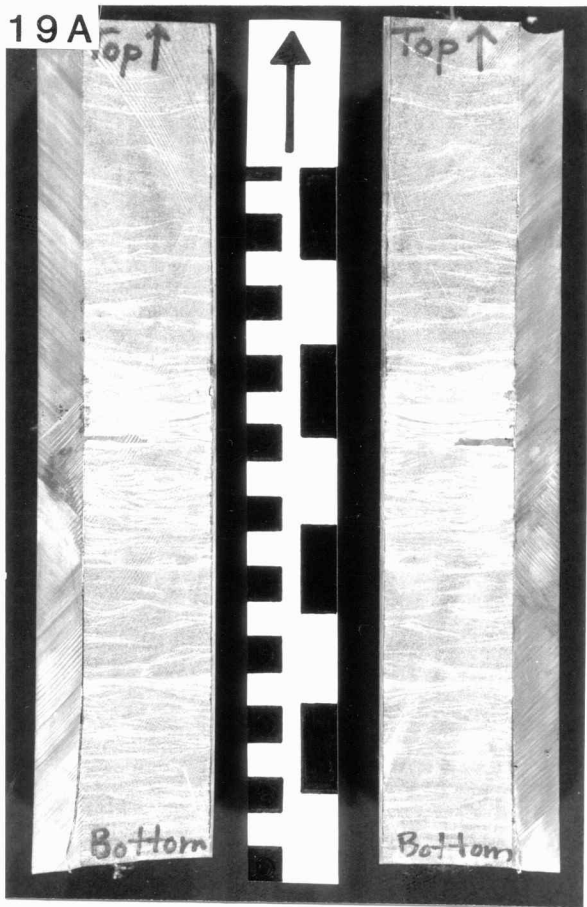
periodic influxes of sediment-laden water, by reworking of the bottom by storm waves, or by combinations of both wave and unidirectional currents (Reading, 1981, p. 127; Swift and others, 1983).

Flaser-bedded sandstones and siltstones —

Flaser-bedded sandstones and siltstones (Reineck and Wunderlich, 1968) are characterized by light-to medium-gray (N7 to N5), rippled, fine-grained sandstone to siltstone, with thin (less than 1 cm) laminae of dark-to medium-gray (N3 to N5) mudstone (Fig. 19). Individual flaser-bedded units may be up to 18 feet (5.4 m) thick and account for about three percent of the total thickness of section measured. Ripples less than one inch (2.5 cm) high are the most common bedforms, and mud flasers are commonly preserved in the ripple troughs. Convolute bedding is also a common secondary sedimentary structure. Plant fossils and both vertical and horizontal burrows are common, but marine body fossils are rare. Flaser-bedded sandstones and siltstones most commonly have gradational or intercalating lower contacts, but a few exhibit sharp or sharply scoured lower contacts.

Formation of flaser-bedded sediments requires the deposition of a rippled sand bed by waves or currents in the lower part of the lower flow regime, followed by periods of extremely low-flow velocities so

Figure 19 - Photographs of slabbed core showing representative examples of flaser-bedded sandstone units. (Sample locations: A - Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 220.9' - 221-8'; B - 317.2' - 317.7'.)

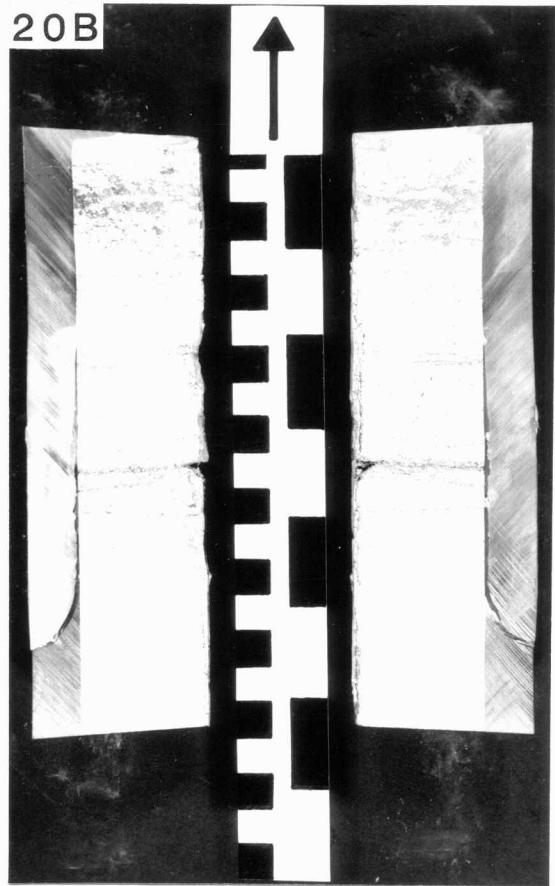
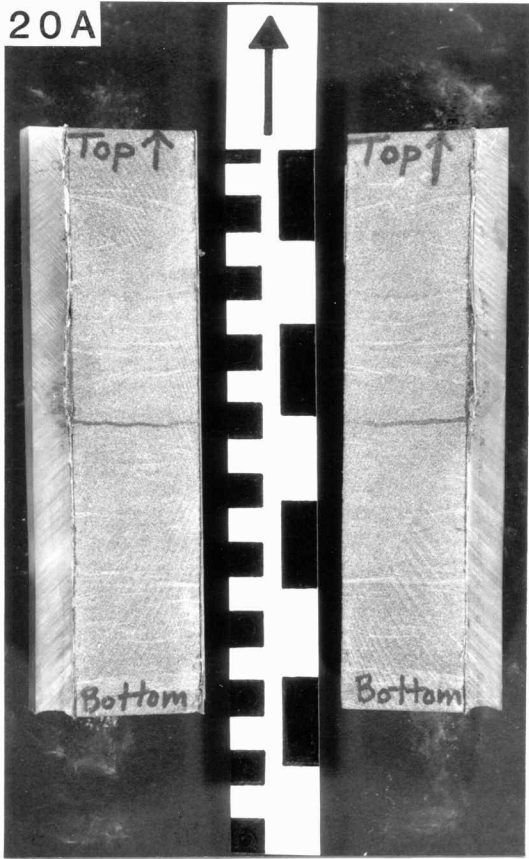


that a layer of mud may be deposited from suspension over the sand ripple troughs and crests. During the next episode of increasing current or wave energy, mud on the ripple crest is eroded, allowing migration of sand from the ripple crest into the adjacent trough, covering and preserving the mud flasers. Flaser-bedding is formed in areas that are more favorable for the transportation and deposition of sand and silt than of mud (Hawley, 1981).

Rippled sandstones and siltstones — Rippled sandstone and siltstone units range in color from medium gray (N5) to very light gray (N8) and are composed of quartz-rich, fine grained sand to silt (Fig. 20). Rippled sandstone or siltstone units range up to 15 feet (4.5 m) thick, and make up approximately 3 percent of the total thickness of all cores and outcrops examined. Unidirectional current ripples less than two inches (5 cm) high are the most common primary sedimentary structure. Occasional wave-formed ripples (Fig. 21) characterized by low-angle dips, bundled offshoots, and chevron upbuilding indicate minor reworking of the bottom by wave energy (De Raaf, Boersma, and Van Gelder, 1977). Plant fossils are abundant; vertical and horizontal burrows are common; but marine body fossils are rare. Rippled sandstone and siltstone units may have either sharp or gradational upper and lower

Figure 20 - Photograph of a slabbed core showing a representative example of a rippled sandstone unit. (Samples from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 218.6' - 219.1'.)

Figure 21 - Photograph from outcrop showing an excellent example of wave-formed ripples. (Sample from outcrop in north end of abandoned strip mine, NW NW NW Sec. 2-T28S-R25E, Crawford County, Kansas.)



contacts.

Rippled sandstones and siltstones were deposited by waves or currents in the middle to lower part of the lower flow regime (Harms and others, 1982).

Large-scale cross-bedded sandstones _____

Large-scale cross-stratified sandstones are normally light gray (N7) to medium gray (N5) and are composed of medium-to very fine-grained, quartz-rich sand (Fig. 22). Individual cross-bedded units range up to 30 feet (9 m) in thickness, and large-scale, cross-bedded sandstones compose approximately 0.8 percent of the cores and sections measured in Cherokee and Crawford counties, Kansas. Low- and high-angle sets of unidirectional cross beds ranging from one foot (30 cm) to over 3 feet (1 m) thick are the most common primary sedimentary structure. Both planar and trough-shaped sets were observed in outcrops, but the type of cross-bedding could not be determined from examination of the cores.

Plant fossils are common, and logs up to 0.75 feet (22 cm) in diameter and more than 5 feet (1.5 m) long have been found in some outcrops. Thin veins of allochthonous coal deposits are commonly associated with the large-scale, cross-bedded facies. No marine fossils have been observed in large-scale, cross-bedded sandstones, which usually have sharp, scoured basal contacts and often overlie mud-clast conglomerates.

Upper contacts may be either sharp or gradational.

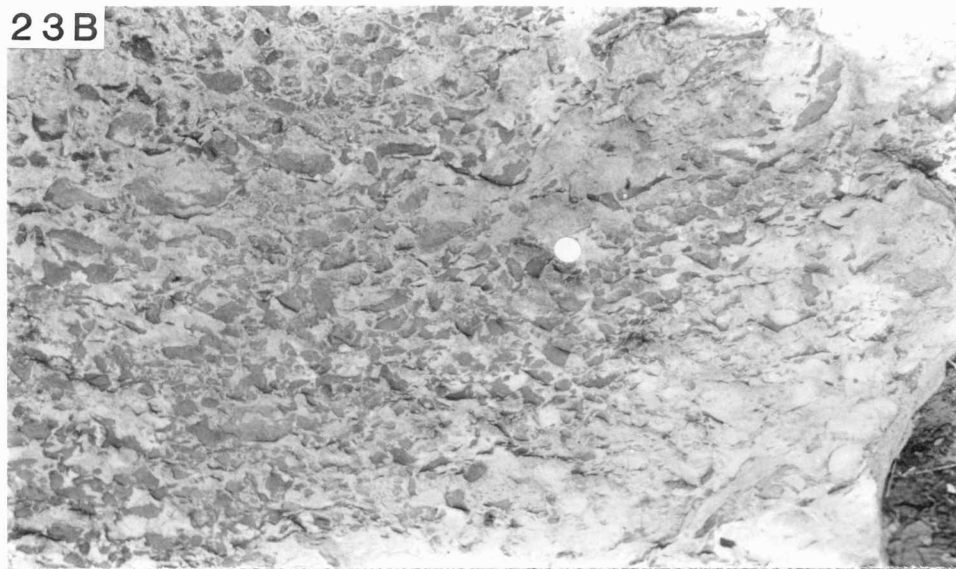
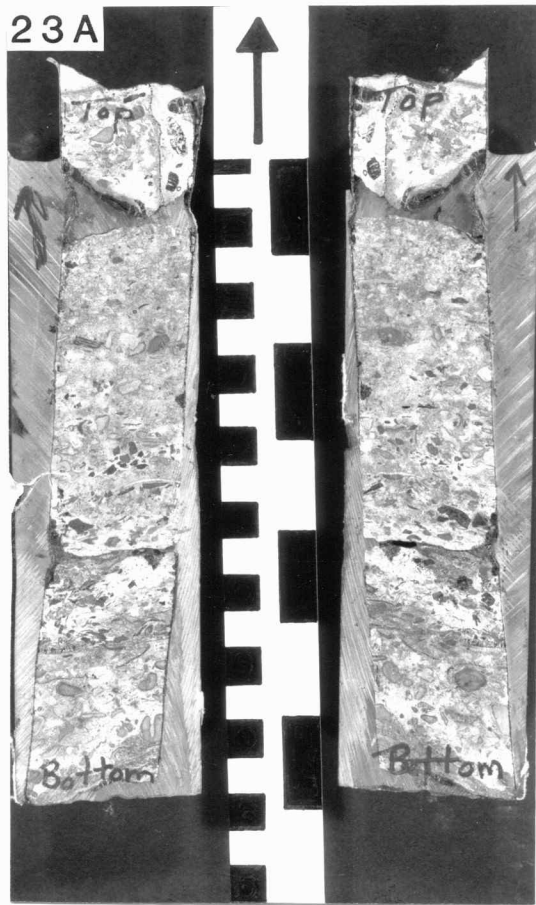
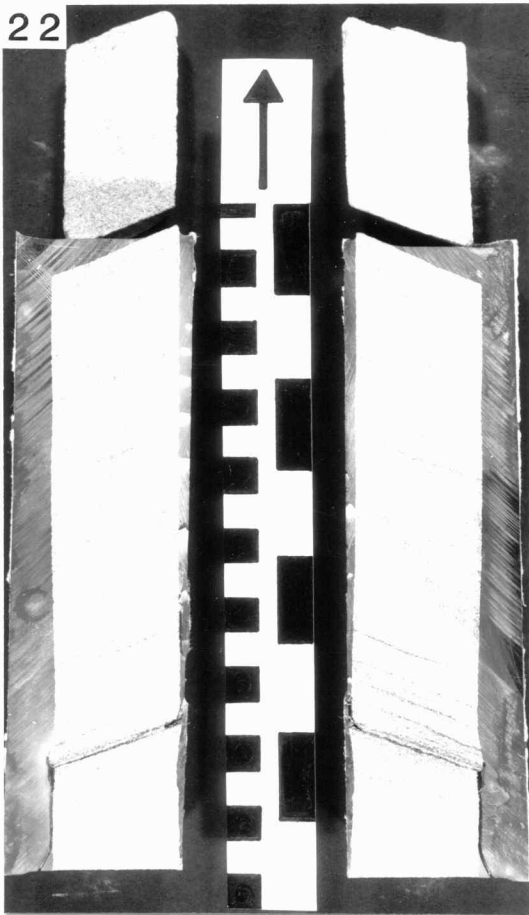
Large-scale cross stratification forms by migration of sand waves or dunes. Sand waves and dunes are commonly formed by currents in the upper part of the lower flow regime (Harms and others, 1975).

Mud-clast conglomerates ——— Mud-clast conglomerates consist of locally derived mud clasts, coal clasts, lime-mud clasts, and plant fossils within a matrix of fine-to very fine-grained sandstone (Fig. 23). Clasts range up to 2 inches (5 cm) in diameter and are often flattened parallel to the bedding. Individual mud-clast conglomerate units range up to 5 feet (1.5 m) in thickness, but most are less than one foot (30 cm) in thickness. Although important to interpretations, mud-clast conglomerate units are volumetrically insignificant, constituting only approximately 0.3 percent of the total thickness of Cherokee sampled. Mud-clast conglomerates are usually structureless. A sharp, scoured lower contact is common in these units, and upper contacts are usually gradational with cross-stratified or rippled sandstone.

The sharp, scoured, basal contacts, presence of unlithified clasts, and the size and angularity of some clasts indicate local erosion and deposition of partially cohesive mud clasts. The lack of primary sedimentary structures probably results from very rapid

Figure 22 - Photograph of slabbed core showing a representative example of a large-scale cross-bedded unit. (Sample from Pittsburg and Midway #7, SW SW SE Sec. 6-T32S-R22E, Cherokee County, Kansas, 136.9' - 138.0'.)

Figure 23 - Photographs of a slabbed core and an outcrop bedding surface showing representative examples of mud-clast conglomerate units. (Sample locations: A - Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas 46.9' - 47.6'; B - outcrop on west side of Neosho River just below Chetopa City dam, SW NE SW Sec. 35-T34S-R21E, Labette County, Kansas.)



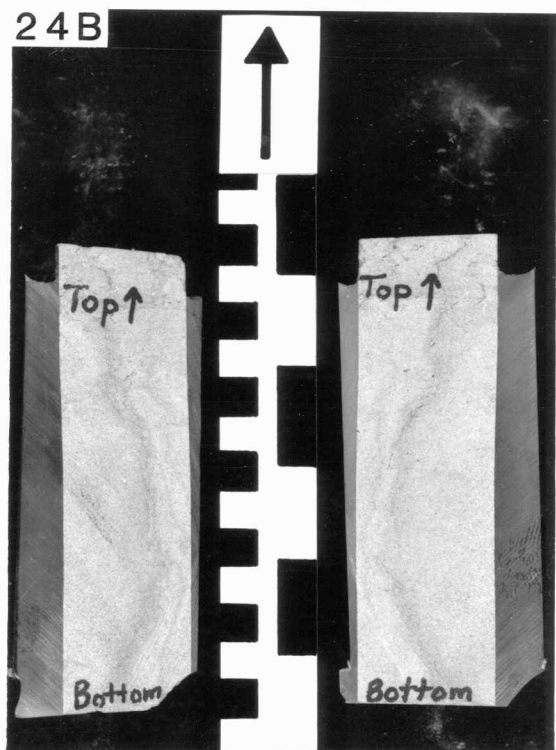
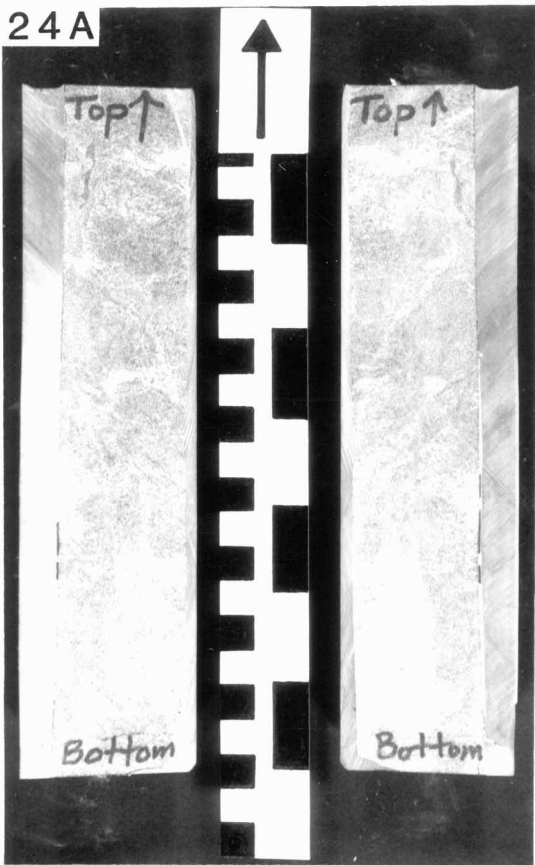
deposition from suspension or from deposition from a sediment-rich slurry (Blatt, Middleton, and Murray, 1979, p. 136). Mud-clast conglomerates represent the highest-energy deposits observed in the Krebs Formation, and overlying sedimentary structures suggest deposition by unidirectional currents in the upper part of the lower flow regime.

Structureless sandstones and siltstones —

Structureless sandstones and siltstones range from medium gray (N5) to light gray (N7) and are composed of fine-to very fine-grained, quartz-rich sandstone or siltstone with varying amounts of mud matrix (Fig. 24). Individual units range up to 16 feet (4.8 m) in thickness, but are usually less than 5 feet (1.5 m) thick. Structureless sandstones and siltstones constitute about 2.8 percent of the total rock volume of the Cherokee Group. No primary sedimentary structures are present, plant fossils and burrows are common, but no marine body fossils were observed. Structureless sandstone or siltstone units usually exhibit gradational lower and upper contacts with other lithofacies except where overlain by a coal bed, resulting in a sharp upper contact.

Massive or structureless sandstone or siltstone beds can result from rapid deposition from suspension, deposition from a sediment-enriched slurry,

Figure 24 - Photographs of slabbed cores showing representative examples of structureless sandstone and siltstone units. (Sample locations: A - Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 144.2' - 144.7'; B - 214.2' - 215.0'.)



or by bioturbation of previously laminated deposits. The presence of abundant burrows and the vertical and lateral gradation into laminated sandstones or siltstones suggest that many massive sandstones result from extensive bioturbation that has destroyed primary sedimentary structures. The source of bioturbation could be either burrowing infauna or growth of plant roots downward into the sediment. Hulse (1978) found that many seemingly structureless beds often had the same internal sedimentary structures as surrounding beds when x-radiographs were taken of slabbed cores. This apparent lack of sedimentary structures results from no contrast of grain size between individual laminae.

Other Lithologies

Argillaceous limestone ——— Carbonaceous argillaceous lime wackestones to packstones are commonly found within dark gray shale units or as a cap-rock overlying coal beds (Fig. 25). These limestones range from dark gray (N3) to medium gray (N5), and may be up to three feet (1 m) thick, although more commonly they are less than one foot (30 cm) thick. Argillaceous limestones form a cap-rock overlying about 46 percent of the coal beds in the Cherokee Group but are volumetrically unimportant and form only 0.8 percent of the total footage of core and outcrops examined.

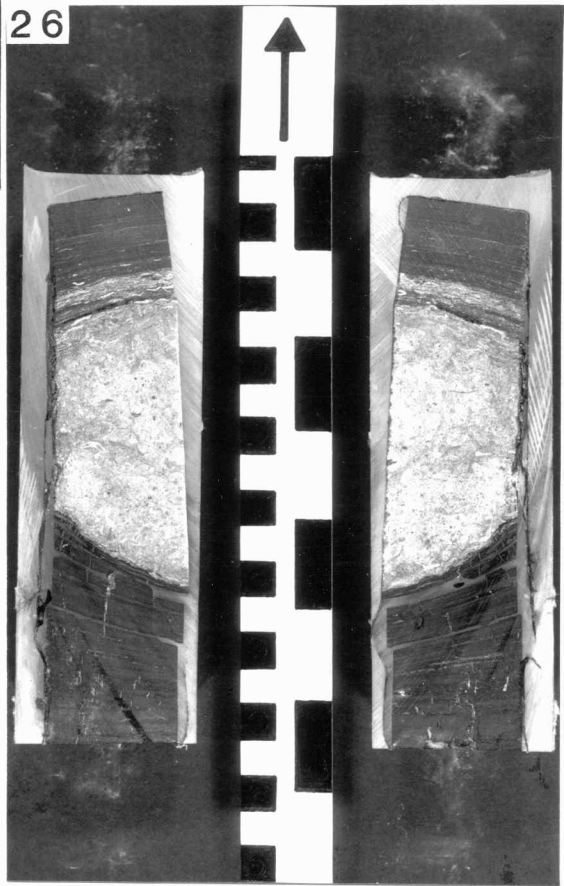
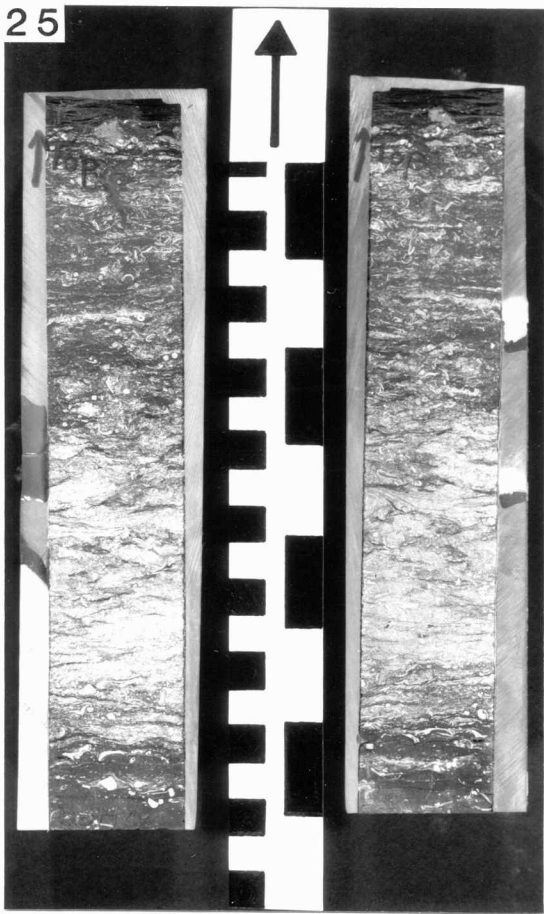
Fossils include brachiopods, bivalves, gastropods, bryozoans, and crinoid columnals, as well as finely macerated plant debris. A few ooids are also present. Insoluble residue tests reveal an average clay content of 47 percent for similar types of limestone in the Cherokee Group (Murphy, 1978). Coal-balls or pyrite-rimmed calcareous concretions are also common in argillaceous limestone units (Fig. 26). Vague, low angle cross-stratification may also be present in argillaceous limestones. Reddish-brown iron oxide staining is commonly observed in outcrop. Basal contacts of argillaceous limestones are usually sharp or sharp and scoured, while upper contacts may be either sharp or gradational.

The abundance of argillaceous material and organic material, the diversity of marine organisms, the presence of abundant broken and abraded fossil fragments, and the presence of low-angle cross-stratification suggest that these argillaceous limestones were deposited or reworked by waves.

Coal — Coal beds encountered in cores and outcrops range from a featheredge to more than 2.5 feet (0.75 m) thick, with coal constituting about 2.6 percent of the total rock thickness of the Cherokee Group. Coal beds in the study area are high volatile bituminous in rank (Hva and Hvb); are black, banded, and moderately

Figure 25 - Photograph of slabbed core showing a representative example of an argillaceous limestone unit. (Sample from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 227.3' - 228.0'.)

Figure 26 - Photograph of a slabbed core showing a coal-ball or a pyrite-rimmed calcareous concretion associated with an argillaceous limestone unit immediately overlying a coal bed. (Sample from Pittsburg and Midway #5, NW NE NW Sec. 30-T32S-R22E, Cherokee County, Kansas, 60.1'- 60.7'.)



bright; and break with a blocky fracture (Brady, Livingston, and Adams, 1976) (Fig. 27). Calcite, pyrite, and sulfate minerals are common in cleats, joints, and fractures, and pyrite concretions are abundant. Coal beds usually possess sharp or intercalating lower and upper contacts. Determination of ash, sulfur, and BTU values on a moisture-free basis for 13 samples reveals that coals of the Krebs Formation are comparable to other coals in the Cherokee Group. Ash contents range from 13.1 to 22.5 percent (average 17.4 percent), sulfur from 3.4 to 12.6 percent (average 6.5 percent), and BTU values from 11,230 to 12,820 BTU/lb. (average 11,977 BTU/lb.). (Unpublished proximate analyses on file at Kansas Geological Survey).

Most coal beds of the Cherokee Group are interpreted to be autochthonous because they are banded and associated with widespread seatrock or underclay units. Conditions required for the accumulation and preservation of autochthonous coal deposits include (1) submergence under water to provide anaerobic conditions, (2) lack of terrigenous sedimentation, (3) high organic productivity in a humid, temperate environment to facilitate accumulation of land plants, and (4) subsidence or slow, continuous rise in the groundwater table to allow deposition and preservation of peat (Wanless, Baroffio, and Trescott,

1969; Horne and Ferm, 1978; Beaumont, 1979; Blatt, 1982). Occasional allochthonous coal deposits do occur, but these are extremely limited in areal extent and are usually found interbedded with sandstone (Fig. 28).

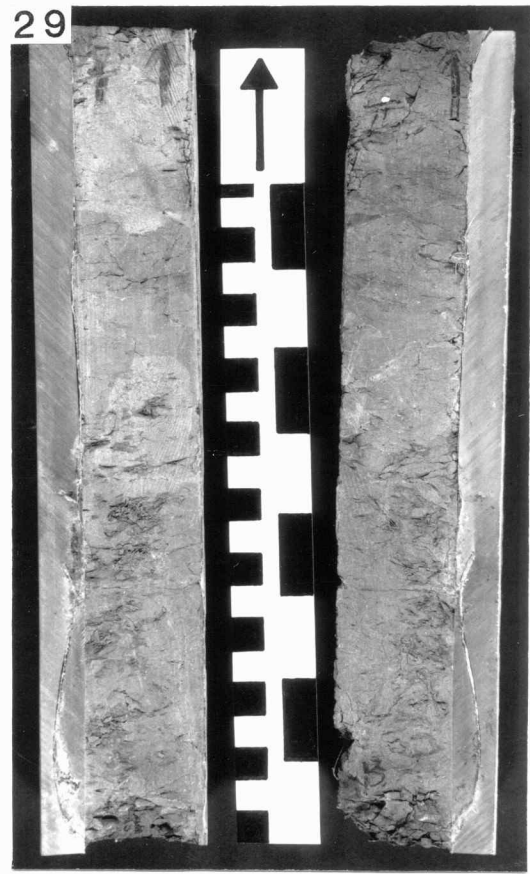
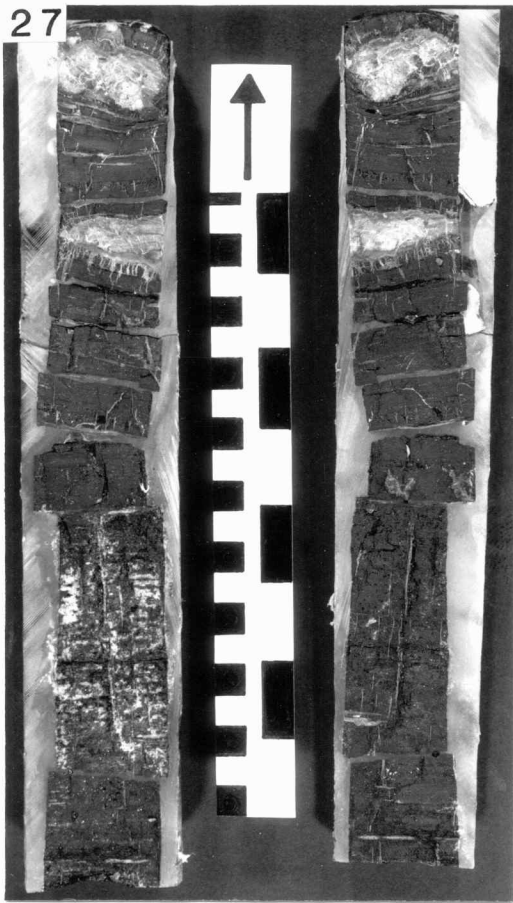
Seatrock — Seatrock, also known as underclay, fireclay and seatearth, commonly occurs below coal beds but may be found where no coal is present (Fig. 29). Seatrock units may be composed of claystone, mudstone, siltstone, sandstone, or argillaceous limestone, and nearly all contain abundant plant or root fossils. Seatrock zones are structureless, bleached, lighter gray than surrounding units, and break with a blocky fracture. Some claystone or mudstone seatrock units contain abundant slickensides. Ironstone and pyrite concretions are common and often concentrated in bands within the seatrock units. The lower contacts of seatrock units are gradational with a variety of lithologies, while the upper contacts are usually sharp.

Due to the variety of lithologies underlying coal beds, the gradational lower contacts, structureless, bleached appearance, and the abundance of plant and root fragments, seatrock units are thought to be paleosols or gley horizons over which peat beds accumulated (Moore, 1947; Huddle and Patterson, 1961; Hulse, 1978).

Figure 27 - Photograph of a slabbed core showing a representative example of a coal bed. Note pyrite concretions near the top. (Sample from Pittsburg and Midway #5, NW NE NW Sec. 30-T32S-R22E, Cherokee County, Kansas, 60.8'-61.9'.)

Figure 28 - Photograph of an outcrop showing an allochthonous coal bed associated with large-scale, cross-bedded sandstone. (Sample from outcrop on west side of Neosho River just below Chetopa City dam, SW NE SW Sec. 35-T34S-R21E, Labette County, Kansas.)

Figure 29 - Photograph of slabbed core showing a representative example of a seatrock unit. (Sample location - same as Figure 16.)



LITHOFACIES RELATIONSHIPS AND ENVIRONMENTAL INTERPRETATIONS

Mud-dominated sequences

The most common vertical succession of lithofacies observed in cores and outcrops of the Krebs Formation in the study area consists of (from bottom to top)--dark-gray shale or argillaceous limestone, medium-gray shale, lenticular-bedded shale, mudstone or seatrock, and coal. Detailed vertical and lateral lithofacies relationships of mud-dominated sequences are illustrated by the interval from the Cw coal bed to the Aw coal bed (Fig. 30). Dark-gray shale units commonly overlie a coal bed or seatrock unit with a sharp basal contact and grade upwards into medium-to light-gray shale or lenticular-bedded shale. The fine grain size, concentration of humic organic debris, presence of marine fauna, and the stratigraphic association with coal beds suggest that dark-gray shale units were deposited in nearshore marine bays. Dark-gray shale units represent extremely slow rates of terrigenous sedimentation, and the environments of deposition of these units were somehow isolated from areas actively receiving terrigenous sediment.

Similar lithologies from other Pennsylvanian

Figure 30 - Idealized facies diagram from cores illustrating the lithofacies relationships of mud-dominated sequences between the Cw and the Aw coal beds. Sandstones and siltstones are shaded. Line to the right of each section indicates the relative grain size of clastic sediment.

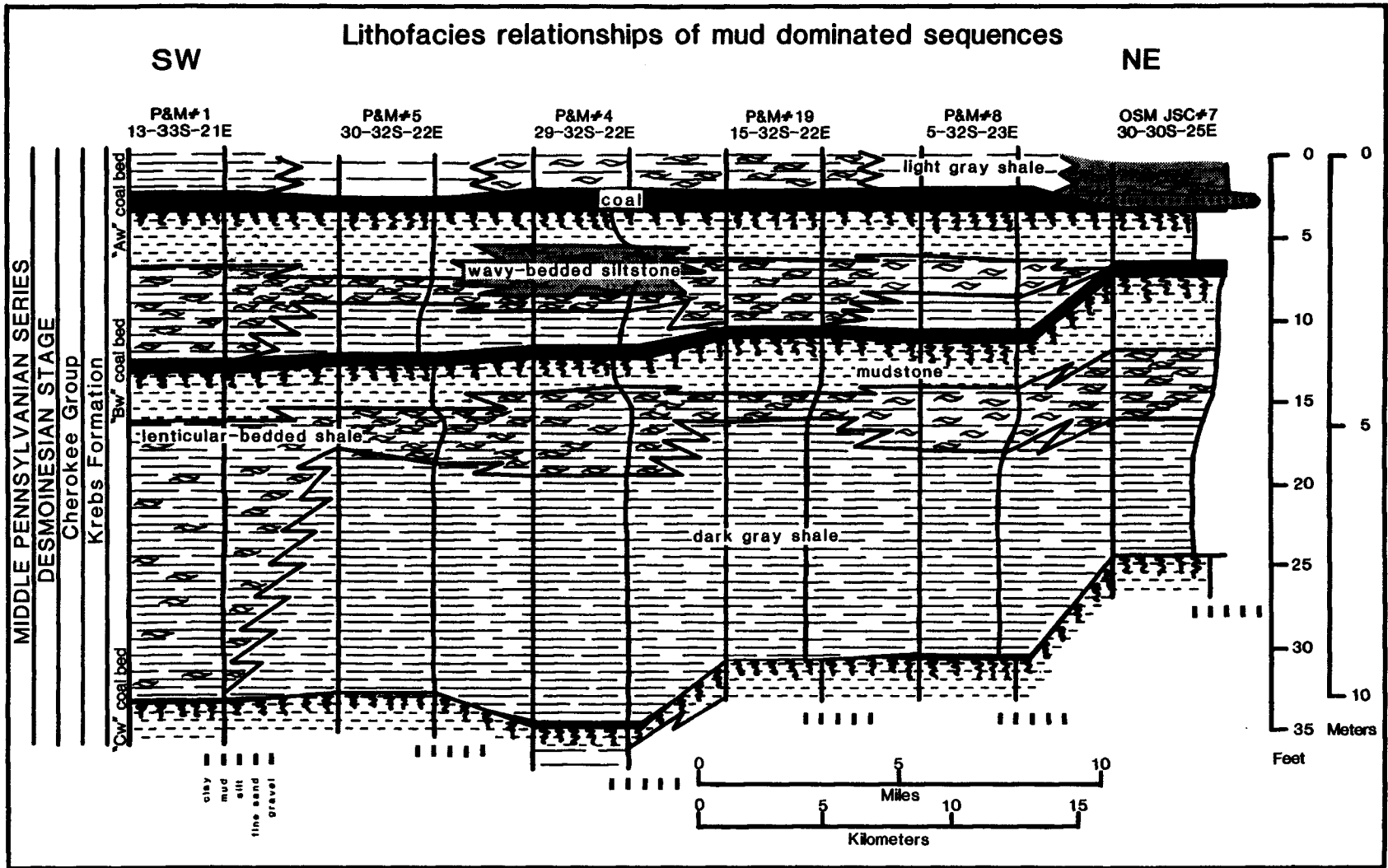


Figure 30.

sediments of the midcontinent have been described and interpreted as shallow-water, restricted, marine-bay deposits (Howe, 1956; Zangerl and Richardson, 1963; Wanless and others, 1971; Brown, 1979). Dark-gray to black, organic-rich muds are presently being deposited in shallow bays, bayous, and coastal swamps of the highly irregular coastline adjacent to the Mississippi River delta (Zangerl and Richardson, 1963; Coleman and Gagliano, 1965; Frazier and Osanik, 1969). Similar shallow-water deposits are found along the New Jersey coastline and in the Baltic Sea (Merrill and Martin, 1976; Heckel, 1977).

Heckel (1977) proposed a deep-water origin for many dark gray or black shale units of the midcontinent. The silty nature, the presence of largely humic organic material, the lack of phosphatic nodules, and the stratigraphic association of dark-shale units with coal beds led Heckel (1977) to postulate a shallow-water origin for most dark-gray shale units in the Cherokee Group.

Dark-gray shale units often contain beds of argillaceous limestone, forming a cap-rock immediately overlying a coal bed. Argillaceous limestone units contain abundant macerated plant debris, echinoid fragments, brachiopods, gastropods, bivalves, and fenestrate bryozoans, with an average of 47 percent clay

(Murphy, 1978). Some argillaceous limestone units are interpreted as representing transportation and mixing during storms of marine fossils, ooids, macerated humic plant debris, and mud. Similar deposits from Pennsylvanian sediments of the midcontinent have been interpreted to be storm berm or transgressive lag deposits of low-energy, muddy shorelines (Wanless and others, 1971; Visher and others, 1971; Murphy, 1978; Brown, 1979). Lithologically similar units have also been reported in delta destructional units of the Wilcox Group (Eocene) of the Texas Gulf Coast (Fisher and McGowen, 1969). Concentrations of shelly debris, organic material, and mud are presently being deposited as storm berms along low-energy, muddy shorelines of the Holocene Guadalupe and Colorado River deltas off the Texas Gulf Coast (Kanes, 1970; Donaldson and others, 1970).

Shelly lags are also reported in interdistributary bays with low sedimentation rates in the Mississippi River deltaic complex (Coleman and Gagliano, 1965), where occasional reworking of the bottom by waves results in a shelly lag. These bay deposits may be the best modern analog to the widespread argillaceous limestone units observed in the Krebs Formation.

Dark-gray shale and argillaceous-limestone

units grade vertically and laterally into medium-to light-gray or lenticular-bedded shales. The lighter color, presence of marine fauna, and preservation of only larger plant fossils in medium-to light-gray shales suggest an increase in the rate of sedimentation, water circulation, and oxygenation to explain the paucity of preserved organic matter (Ibach, 1982). Medium-to light-gray shales are intermediate between dark-gray shales and lenticular-bedded shales, representing deposition in a shallow-marine environment adjacent to areas with rapid terrigenous sedimentation rates.

Lenticular-bedded shales consist of dark-to medium-gray mudshale containing laminae of light-gray siltstone or very-fine grained sandstone. Lenticular-bedded shale units grade laterally into dark-gray shales or sandstone units. The presence of sparsely distributed burrows and marine fauna and the interlamination of sand and shale suggest deposition in a shallow, low-energy marine environment that was periodically subjected to wave or current energy. Soft-sediment deformation is common, suggesting rapid sedimentation rates. Although lenticular-bedded shales presently form in a variety of depositional environments, lenticular-bedded shale units of the Krebs Formation are interpreted as prodeltaic or interdeltic deposits.

Similar lithologies in Pennsylvanian rocks of the midcontinent have been previously interpreted as prodeltaic deposits (Wanless and others, 1970; Horne and Ferm, 1978). Brown and others (1973) and Brown (1979) suggested that silty or sandy shales may result from transport of fine-grained sediment along depositional strike into interdistributary areas. Modern analogies of lenticular-bedded shales may be found in the prodeltaic facies of the Mississippi, Colorado, and Guadalupe River deltas (Coleman and Gagliano, 1965; Kanes, 1970; Donaldson and others, 1970).

Lenticular-bedded shales commonly grade upwards into mudstones that form seatrocks underlying coal beds. Mudstones of the Krebs Formation are characterized by a light-gray color, lack of sedimentary structures, and an abundance of plant debris. Since mudstones have gradational contacts with lenticular-bedded shales as well as other types of shale, the structureless nature is interpreted to have resulted from extensive bioturbation of previously laminated mudrocks. The presence of plant roots or fossils and the common association with coal beds suggests that plant roots are responsible for the bioturbation and destruction of original laminae in mudstones. Most mudstones of the Krebs Formation are interpreted as seatrocks or ancient, poorly-drained soil

profiles over which coal swamps developed. This interpretation has been applied to similar Pennsylvanian mudstones by Moore (1947), Huddle and Patterson (1961), Wanless and others (1971), Hulse (1978), and Blatt (1982). Extensively bioturbated, light-gray mudstones are presently found in fresh-to brackish-water transition zones on the Mississippi River delta and in the Everglades swamp of southern Florida, where plant growth and rooting occurs but no peat is actually accumulating (Coleman and Gagliano, 1965; Frazier and Osanik, 1969; Spackman and others, 1969).

Mudstones and claystones are commonly overlain by coal beds with a sharp, basal contact. The association of coal beds with well-developed seatrock zones that are also traceable over large areas supports the autochthonous origin of most coal beds of the Krebs Formation. Coal and peat deposits typically form in fresh or brackish-water swamps in a variety of depositional systems. The specific environment or subenvironment of coal deposition must be interpreted from the lithofacies relationships of associated strata and will be discussed in a later section.

The upwards-coarsening, mud-dominated sequences of the Krebs Formation, consisting of dark-gray shale, argillaceous limestone, medium-gray shale, lenticular-bedded shale, mudstone, and coal, are

interpreted as the result of repeated infilling of interdistributary areas (Horne and Ferm, 1978; Brown, 1973; Elliott, 1974). Murphy (1978), in a study of the middle Cherokee Group (Tebo coal bed to Verdigris Limestone interval), described similar vertical sequences and interpreted them as strand plain or low-energy, mud-dominated shoreline deposits.

Upwards-coarsening sandstone sequences

Gradational lower contact — The most common type of sandstone body observed in cores and outcrops of the Krebs Formation exhibits a gradational lower contact with a general upwards-coarsening sequence and a decrease in the amount of interlaminated mud. Examples of the vertical and lateral lithofacies relationships of coarsening-upwards sandstone sequences are illustrated by the lower Warner interval (Fig. 31) and the upper Warner interval (Fig. 32). Most individual upwards-coarsening sequences are less than 25 feet (7.6 m) thick, and consist of lenticular-bedded shale grading upwards into wavy-bedded sandstone or siltstone. This sequence then grades upwards into flaser-bedded or rippled sandstone with occasional mud-clast conglomerate or large-scale cross-bedded sandstone.

Wavy-bedded sandstones and siltstones contain

Figure 31 - Idealized facies diagram from cores illustrating the lithofacies relationships of the lower Warner interval. Sandstones and siltstones are shaded. Line to the right of each section indicates the relative grain size of clastic sediment.

Figure 32 - Idealized facies diagram from cores illustrating the lithofacies relationships of the upper Warner and lower Bluejacket intervals. Sandstones and siltstones are shaded. Line to the right of each section indicates the relative grain size of clastic sediment.

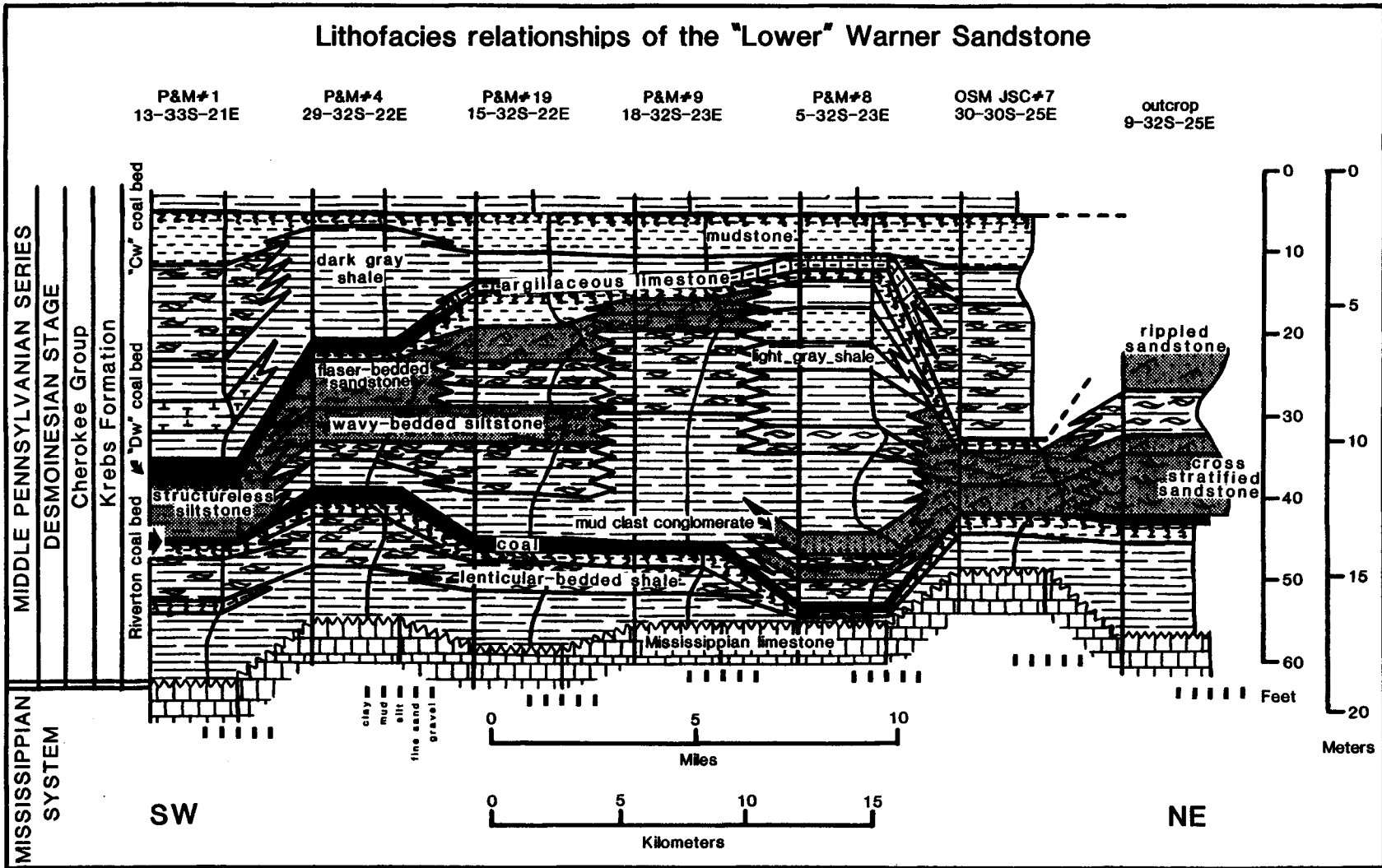


Figure 31

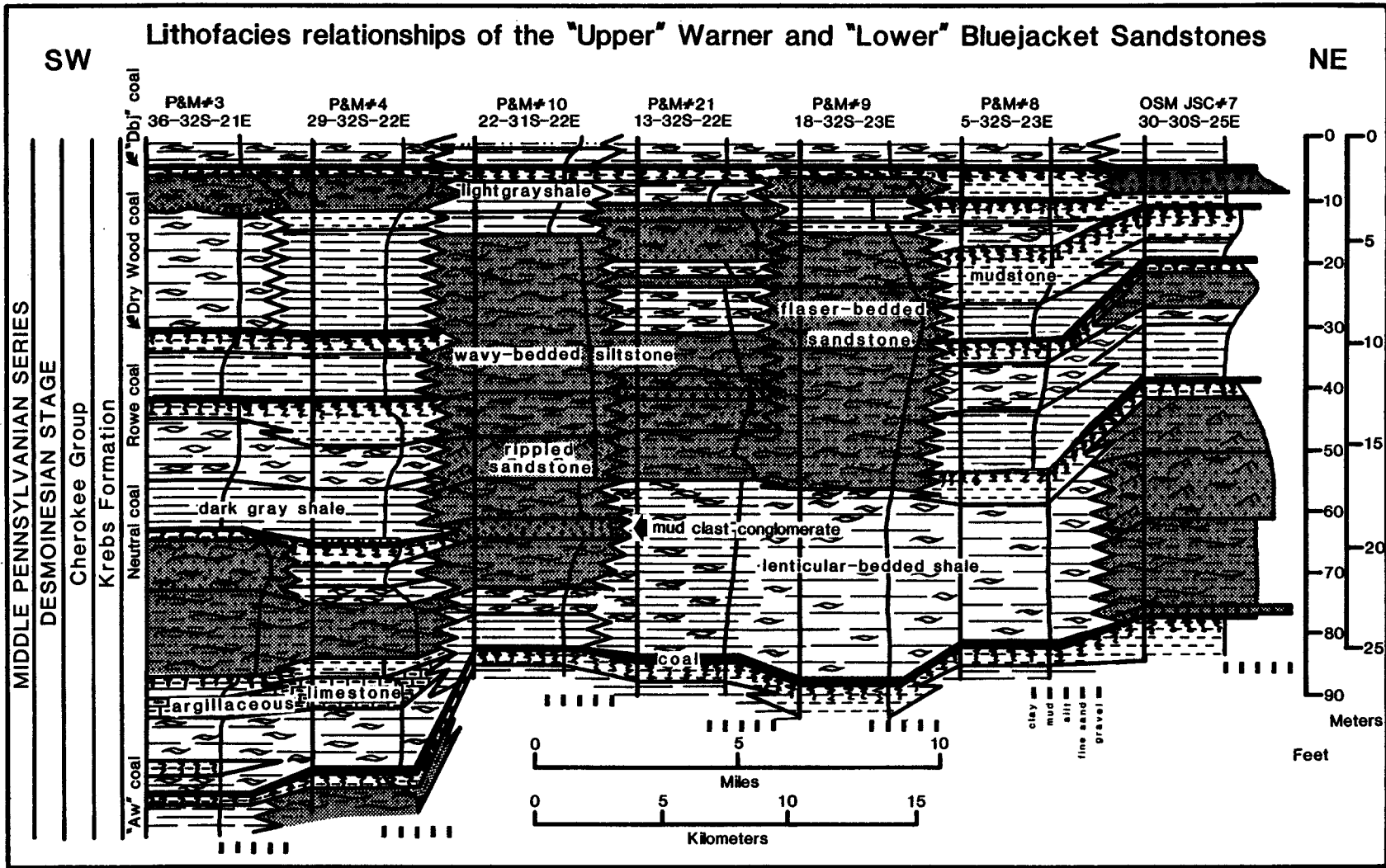


Figure 32

approximately equal amounts of rippled sand or silt interstratified with mudstone or shale. The presence of abundant convolute bedding formed from soft-sediment deformation under loading, the presence of burrows, and the abundance of macerated organic matter support a delta-front origin for wavy-bedded sandstones. Sequences of thin, graded beds often associated with the wavy-bedded sandstone facies represent deposition from turbidity currents resulting from periodic discharges of sediment-laden water onto the delta front or reworking of delta front deposits by waves.

Similar lithologies from Pennsylvanian rocks of the midcontinent and the Appalachian basin have also been interpreted as delta-front deposits (Wanless and others, 1971; Horne and Ferm, 1978; Brown and others, 1973; Brown, 1979). Wavy-bedded sandstones are currently being deposited on the delta front of the modern Mississippi River delta (Coleman and Gagliano, 1965) as well as the delta fronts of the modern Colorado and Guadalupe River deltas of the Texas Gulf coast (Kanes, 1970; Donaldson and others, 1970).

Wavy-bedded sandstones and siltstones commonly grade upwards or laterally into flaser-bedded and rippled sandstones. Flaser-bedded sandstones indicate a fluctuating current velocity with deposition of sand and mud. Rippled sandstones were deposited by

relatively steady currents with little mud deposition. The presence of a few oscillatory, wave-formed ripples suggests deposition of some sandstones by waves. Burrows of various types are common in flaser-bedded or rippled sandstones, but marine fossils are rare. Flaser-bedded and rippled sandstones are interpreted to be proximal delta-front or distributary-mouth-bar deposits.

Similar environmental interpretations for flaser-bedded to rippled-sandstone sequences have been reached by Brown, Cleaves, and Erxleben (1973) and Brown (1979) for Desmoinesian age sandstones in north-central Texas and by Horne and Ferm (1978) for Pennsylvanian sandstone sequences in eastern Kentucky. Flaser-bedded to rippled sandstones have also been observed in delta-front and distributary-mouth-bar deposits of the modern Mississippi, Colorado, and Guadalupe River deltas (Coleman and Gagliano, 1965; Kaner, 1970; Donaldson and others, 1970).

The vertical lithofacies transition from lenticular-bedded shale into wavy-bedded sandstone and then into flaser-bedded and rippled sandstone, is interpreted as the result of lateral progradation or migration of distributary-mouth-bar facies over delta-front and prodeltaic facies. The resulting upwards-coarsening sandstone sequences observed in the

Krebs Formation closely resemble models for deltaic sedimentation proposed by Selley (1970), Walker (1975), and Reading (1980). Similar lithofacies sequences and deltaic models have been derived from Pennsylvanian sediments of the Appalachian basin and from north-central Texas (Brown and others, 1973; Horne and Ferm, 1978; Brown, 1979). The lack of marine fauna, the absence of a distinctive trace-fossil assemblage, and the lack of any high-energy, wave-formed sedimentary structures serve to distinguish these deltaic sequences from other types of upwards-coarsening sequences such as shoreline or marine-bar deposits.

Sandstone bodies exhibiting coarsening-upwards vertical profiles grade vertically and laterally into interbedded dark-gray shales and coal beds (Fig. 32). Sandstones of the upper Warner interval (Fig. 32; cores P&M #10, P&M #9, P&M #21) show an upward transition from lenticular-bedded shale into wavy or flaser-bedded sandstones with occasional mud-clast conglomerate units. Two or three coarsening-upwards sequences may be present in a vertical section, and individual sandstone bodies appear to be offset. These deposits are confined to a belt 3 to 5 miles (5 to 8 km) wide and 6 to 8 miles (10 to 13 km) long that has a southeast to northwest trend, from which the Dry Wood, Rowe, and Neutral coal beds as well as their associated seatrock zones are absent.

The sandstones, siltstones, and shales that are laterally equivalent to three coal beds in this example (Fig. 32) are interpreted to have been deposited as distributary mouth bars and minor channels of a small, elongate delta.

The coarsening upwards of grain size, the abundance of convolute bedding, and the presence of some bioturbation support a distributary-mouth-bar origin for these sandstones. Other possibilities, such as fluvial deposition, were dismissed due to a lack of fining-upwards sequences, scour surfaces, mud-clast conglomerates, and large-scale cross stratification. The lack of a basal scour surface, fining-upwards sequences, and marine body fossils, as well as the sparsity of bioturbation, precluded an estuarine origin for these deposits.

The facies relationships of the coal beds and sandstones in the Krebs Formation suggest that coal swamps developed in response to progradational pulses of deltaic or interdeltatic sedimentation. The thin, sheetlike geometry of sandstones and the dominance of mud in units associated with coal beds suggest that coal-bearing strata were deposited by progradation of a series of small subdeltas or crevasse splays into large interdeltatic embayments. Similar models and environments of deposition for thin, repetitive

sandstone, shale, and coal sequences in the midcontinent and the Appalachian basin have been proposed by Elliot (1974), Wanless and Wright (1978), Horne and Ferm (1978), and Brown (1979).

Sharp, nonscoured lower contact — A somewhat problematic type of sandstone body with an upwards-coarsening sequence is characterized by a sharp, nonscoured lower contact. Exemplifying this type of sandstone is the upper Bluejacket interval (Fig. 33), in which dark-gray clayshales are sharply overlain by wavy or flaser-bedded sandstones that grade upwards into rippled or large-scale cross-stratified sandstones (Fig. 34). The upper Bluejacket Sandstone consists of less than 20 feet (6 m)), widespread sandstone and siltstone with numerous abrupt lateral facies changes (Figs. 33 and 35). The sharp, nonscoured lower contact typical of the upper Bluejacket is interpreted as the result of rapid lateral progradation of a subdelta into shallow water, interdistributary areas following avulsion or abandonment of a distributary channel. Rapid lateral progradation produces a relatively sharp lower contact that is further enhanced by differential compaction.

An excellent modern example of this type of rapid progradation is provided by the small-scale Colorado and Guadalupe River deltas of the Texas gulf

Figure 33 - Idealized facies diagram from cores illustrating the lithofacies relationships of the upper Bluejacket interval. Sandstones and siltstones are shaded.

Figure 34 - Photograph of a slabbed core showing the sharp, non-scoured lower contact commonly observed in the upper Bluejacket sandstone. (Sample from Pittsburg and Midway #4, SW NW SW Sec. 29-T32S-R22E, Cherokee County, Kansas, 224.5' - 225.0'.)

Figure 35 - Photograph of an outcrop showing the thin, laterally continuous nature and numerous facies changes typical of the upper Bluejacket sandstone. (Outcrop location - abandoned strip-mine highwall, W $\frac{1}{2}$ SW $\frac{1}{4}$ Sec. 34-T30S-R25E, Crawford County, Kansas.)

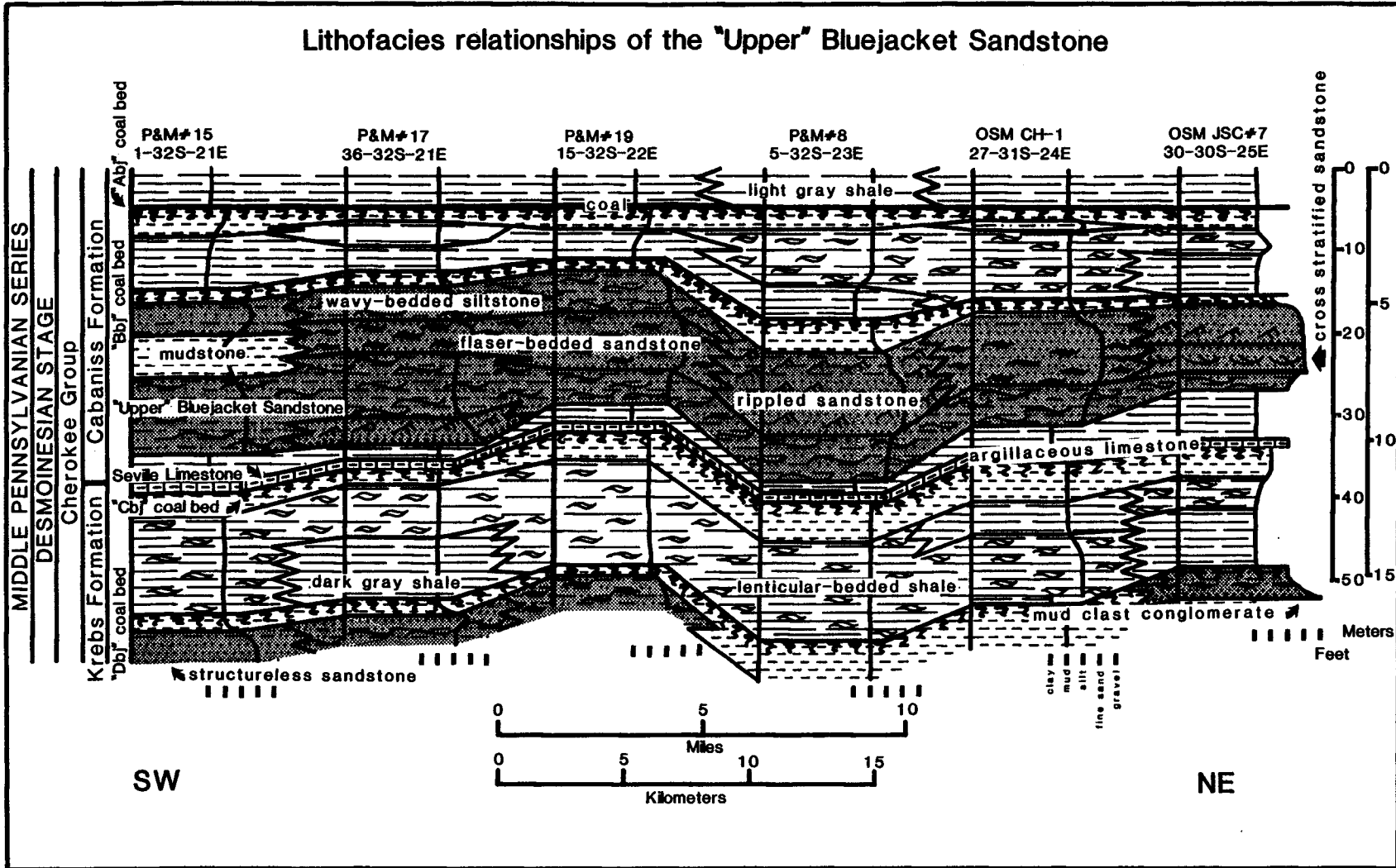
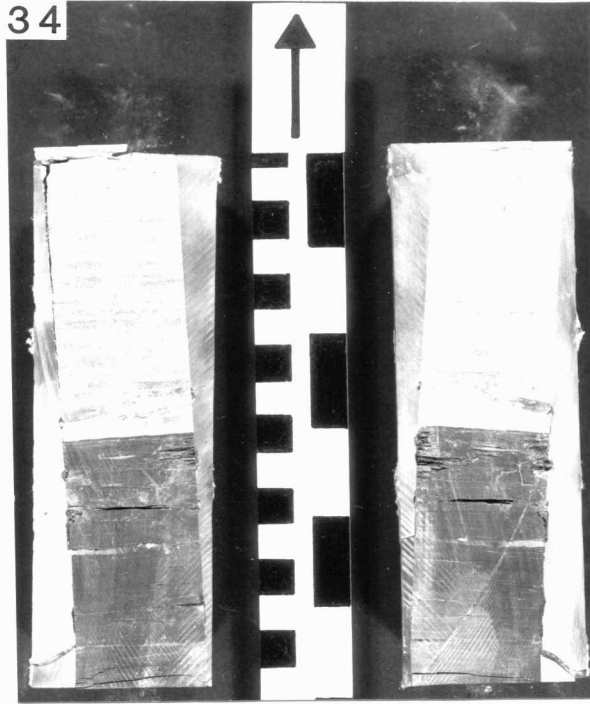
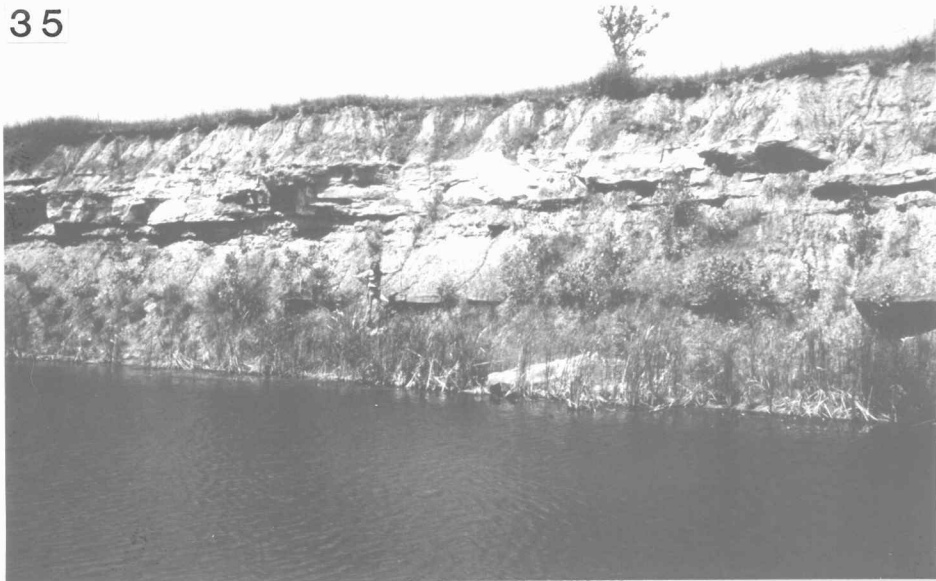


Figure 33

34



35



coast. Here, small, lobate subdeltas prograde laterally into interdistributary areas that have been made extremely shallow by previous deltaic sedimentation. Shallow water depths allow much more rapid lateral progradation of the subdeltas than of the original deltaic complex. Distributary channels decrease in size but increase in numbers and the amount of bifurcation. The increased bifurcation of distributary channels allows the coalescing of distributary mouth bars on the delta front, resulting in deposition of a sheetlike sand body with a sharp, nonscoured lower contact and numerous lateral facies changes (Kanes, 1970; Donaldson and others, 1970).

Fining-upwards sandstone sequences

Fining-upwards sandstone sequences consist of a sharp, scoured basal contact overlain by mud-clast conglomerate or large-scale cross-bedded sandstone and grade upwards into rippled and flaser-bedded sandstone. These units are commonly found stratigraphically adjacent to or superimposed upon coarsening-upwards sandstone sequences. The fining-upwards nature of these sandstones is demonstrated in Figs. 36 and 37. Mud-clast conglomerates at the base of these sequences contain a variety of locally derived clasts including mudstone, shale, coal, siltstone, and lime mudstone.

Figure 36 - Photograph of an outcrop showing a fining-upwards sandstone sequence with large-scale cross-bedding in the lower Warner interval that has scoured down onto the Riverton coal bed. (Outcrop location - natural sinkhole, SW NW NE Sec. 9-T32S-R25E, Cherokee County, Kansas.)

Figure 37 - Photograph of an outcrop showing a fining-upwards sandstone body in the lower Bluejacket interval that has scoured down onto the Drywood coal bed. (Outcrop location - abandoned strip-mine highwall, N $\frac{1}{2}$ SW $\frac{1}{4}$ Sec. 30-T30S-R25E, Crawford County, Kansas.)



Several mud-clast conglomerate units, known as amalgamation surfaces, may be present within an overall fining-upwards sequence. These mud-clast conglomerates are interpreted as channel-lag deposits, probably representing deposition under maximum flow conditions at or near the thalweg of a channel. The abundance of mud clasts suggests that channel banks were composed mainly of mud (Jackson, 1981).

Large-scale cross-bedded sandstones often overlie mud-clast conglomerate units. Cross-stratification is nearly always unidirectional, and large-scale, cross-bedded sandstones often contain plant debris and allochthonous horsetails of coal. Most large-scale, cross-bedded sandstones grade upwards into rippled and flaser-bedded sandstones. No marine fossils have been observed, and these fining-upwards sequences are interpreted to be channel-fill or point-bar deposits.

Wanless and others (1970), Wanless and Wright (1978), Horne and Ferm (1978), and Brown (1979) all described similar sequences from Pennsylvanian sediments in the United States and interpreted them as channel deposits. Modern analogs of these fining-upwards sequences are presently forming in distributary and upper delta-plain channels of the Mississippi, Colorado, and Guadalupe River deltas (Coleman and Gagliano, 1965;

Kanes, 1970; Donaldson, Martin, and Kaner, 1970). Fining-upwards sandstones of the Krebs Formation show some similarities to depositional models for meandering streams described by Harms and others (1975), Walker (1980), Reading (1981), and Jackson (1981).

Lithofacies relationships of distributary channels are very similar to those of fluvial channels, although distributary channels have low width-to-depth ratios and tend to meander less than fluvial channels (Wanless and others, 1965; Wanless and others, 1971; Wanless and Wright, 1978; Reading, 1980). Vertical and lateral lithofacies relationships of fining-upwards sandstone sequences in the Krebs Formation suggest that both distributary and fluvial channels may be present. For example, the scour surface, mud-clast conglomerate, and rippled sandstone associated with the coarsening-upwards sequence of the upper Warner interval in P&M #21 (Fig. 32) possibly represent the progradation and scouring of a small distributary channel through its own delta front or mouth bar deposits. The fining-upwards sequences that overlie dark-gray shale, coal beds, or seatrock units, such as in the lower Warner interval (outcrop and JSC #7, Fig. 31) and the lower Bluejacket interval (JSC #7, Fig. 32; outcrop, Fig. 37), could be interpreted as being of upper delta-plain or fluvial origin, since they are not

associated with delta-front deposits. Channels often scour into or occasionally completely erode coal beds and associated strata. For example, a fining-upwards sandstone in the lower Bluejacket interval (Fig. 37; Secs. 34 and 35-T30S-R25E, Crawford County, Kansas) rests upon the Dry Wood coal bed.

Occasionally mud-clast conglomerate units may be found near the top of a sandstone sequence, and are overlain by shale, mudstone, or coal, representing abandonment and infilling of a previously existing channel by mud or peat (Woody, 1982). Thin mud-clast conglomerate units, usually less than one foot (30 cm) thick, are common and are isolated within dark-to medium-gray or lenticular-bedded shale units. These thin conglomerates have sharp, scoured basal contacts, are often graded, and contain ooids, marine fossil fragments, mud clasts, plant fragments, and sand or silt. Such isolated mud-clast conglomerates probably represent transgressive lag deposits or deposition by waning storm currents.

DISTRIBUTION OF SANDSTONES

Structural contour, isopach, and net sandstone isolith maps for various stratigraphic intervals were constructed to evaluate the distribution of sandstones of the Krebs Formation. A structural contour map of the

top of the Mississippian limestone (C.I. = 50 feet; 15 m) is shown in Fig. 38. Structural dip on the Mississippian limestone surface is about 20 feet per mile (4 m/km) to the northwest. Several broad, northwest-to-southeast trending anticlines, synclines, and associated faults are the major structural features of the study area. Displacement along these faults is generally less than 50 feet (15 m). A pre-Pennsylvanian sink hole in Crawford County, Kansas (KGS G, Sec. 27-T29S-R25E) was identified by the presence of approximately 45 feet (14 m) of additional shale below the Riverton coal bed and overlying units (Sauraker, 1966).

The structural contour map of the top of the Krebs Formation (Fig. 39) shows many of the same northwest-to-southeast trending anticlines, synclines, and faults. The coincidence of major structural features for both the top of the Mississippian limestone and the top of the Krebs Formation, as well as the lack of any thickness or lithologic changes in the Krebs Formation associated with these structures, indicates that most structural features of the study area are postdepositional.

The net isopach map (Fig. 40) shows that the maximum thickness of the Krebs Formation occurs in southern Labette County, Kansas, and in northeastern

Figure 38 - Structural contour map - top of the Mississippian limestone; contour interval = 50 feet.

Figure 39 - Structural contour map - top of the Krebs Formation; contour interval = 50 feet. Where the Seville Limestone was not present, the top of the Krebs Formation was determined by projection from the nearest well where present.

Figure 40 - Net isopach map of the Krebs Formation; contour interval = 20 feet. Hatchures outline areas with lower thicknesses.

STRUCTURAL CONTOUR MAP - TOP OF MISSISSIPPIAN LIMESTONE

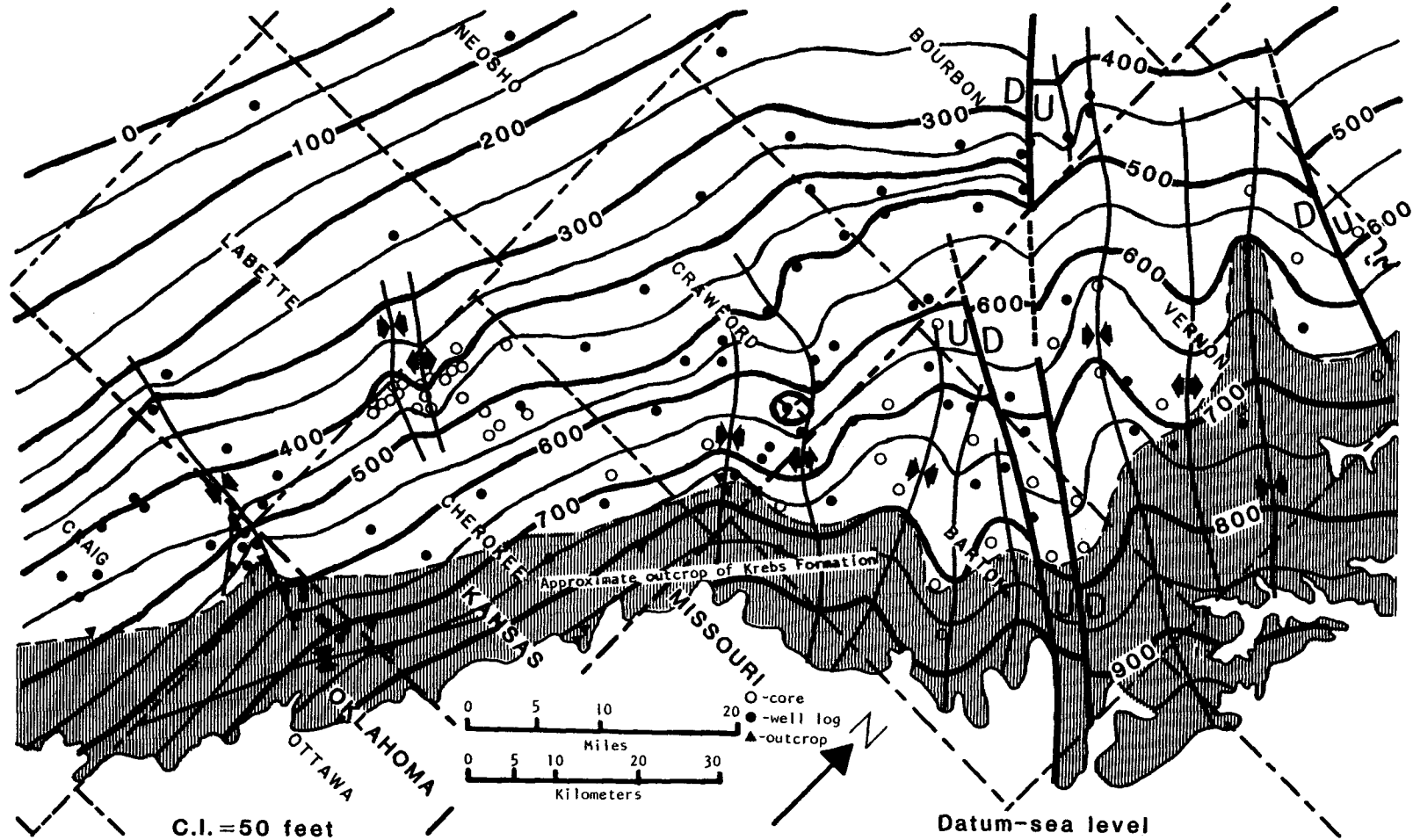
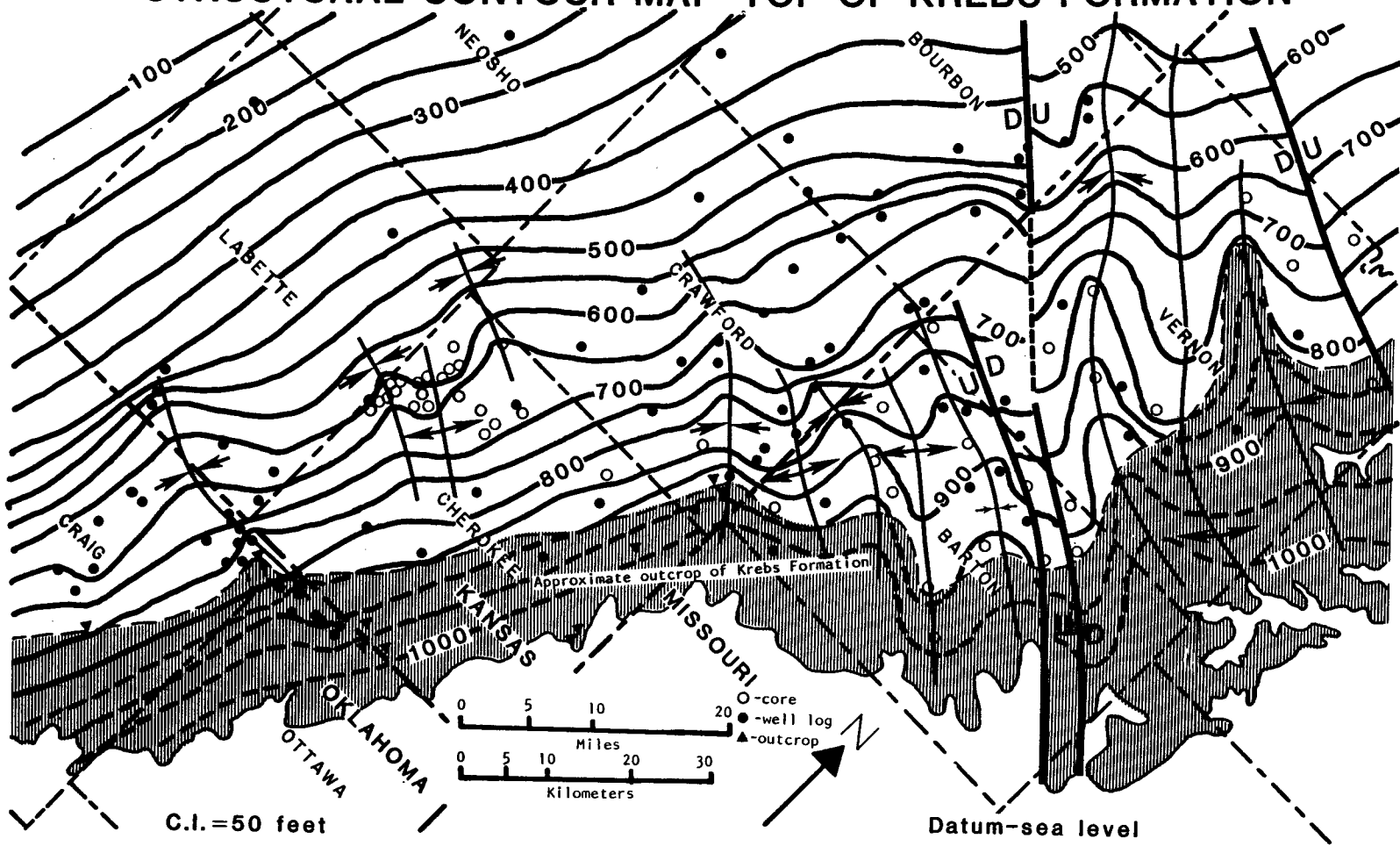


Figure 38

STRUCTURAL CONTOUR MAP-TOP OF KREBS FORMATION



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Figure 39.

NET ISOPACH MAP-KREBS FORMATION

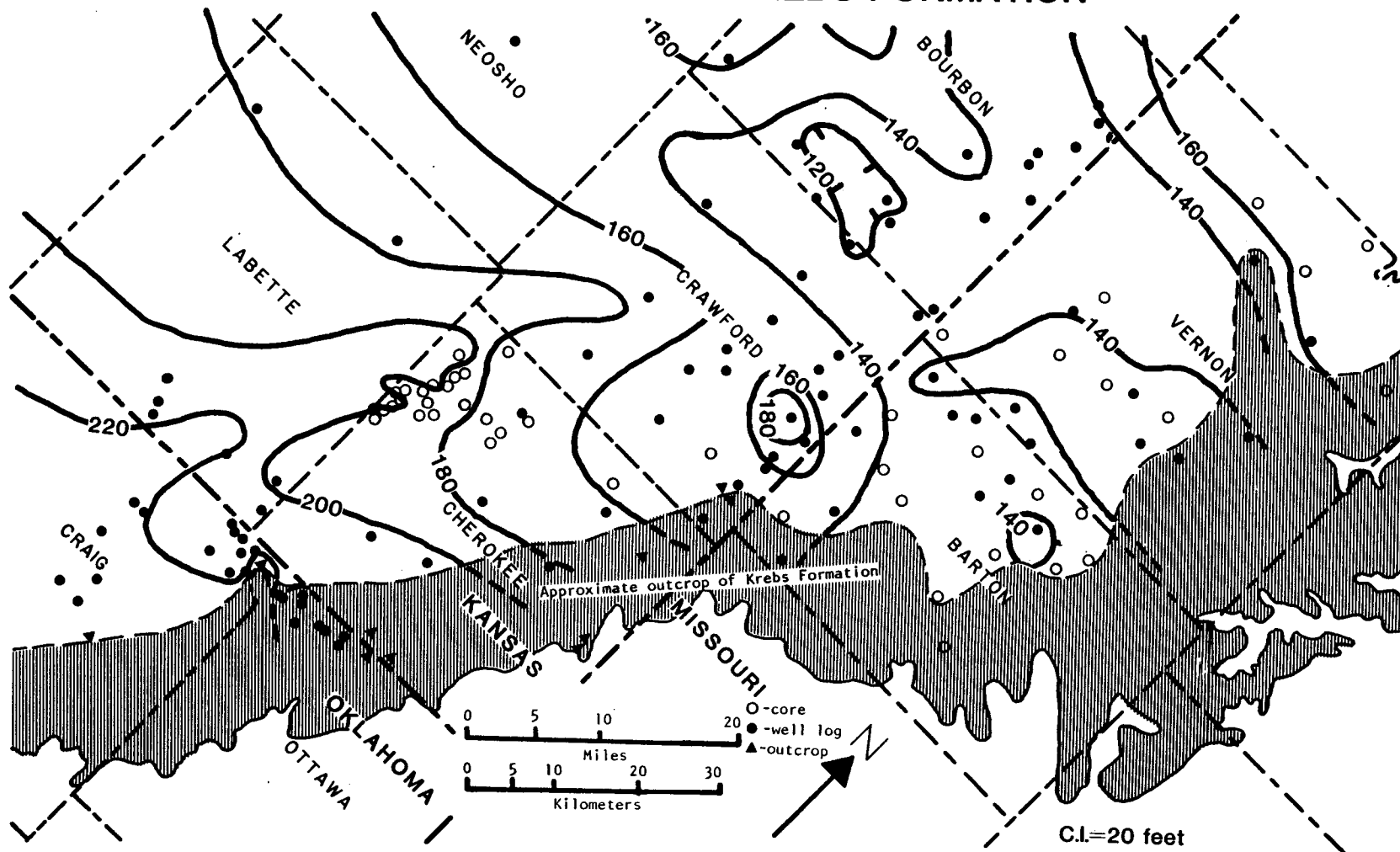


Figure 40

Oklahoma. Pronounced thinning along a 25 to 30 mile (40 to 48 km) wide, northwest-to-southeast trending band, parallel and superjacent to the Bourbon arch, may indicate less subsidence along the arch than in the surrounding basinal areas. Thickening occurs to the south-southwest and to the north away from the Bourbon arch at a rate of approximately two feet per mile.

The net sandstone and siltstone isolith map for the Krebs Formation (Fig. 41) shows that much of the sandstone is concentrated in the northeastern one-half of the study area. The area of maximum sandstone deposition coincides with the area of thinning on top of the Bourbon arch, and the thickest sections of the Krebs Formation are often composed mainly of shale. This inverse relationship between the total isopach map and the net sandstone isolith maps cannot be due to differential compaction of sandstone and shale sections. Thus, structural subsidence and sedimentation rates must have been greater in areas to the southwest and north of the Bourbon arch.

Net sandstone isolith maps were constructed for the sandstone intervals of the Krebs Formation illustrated in Fig. 6. The net sandstone isolith map for basal Pennsylvanian sandstones shows an apparently random sandstone distribution pattern (Fig. 42). Sinkholes identified in this study and by Sauraker

Figure 41 - Net sandstone and siltstone isolith map for the Krebs Formation; contour interval = 20 feet. Hatchures indicate areas with the lowest net sandstone and siltstone accumulations.

Figure 42 - Net sandstone and siltstone distribution map for basal sandstone units of the Krebs Formation. Shading indicates areas where sandstone is thought to be present and numbers indicate the recorded thickness in feet.

NET SANDSTONE ISOLITH MAP-KREBS FORMATION

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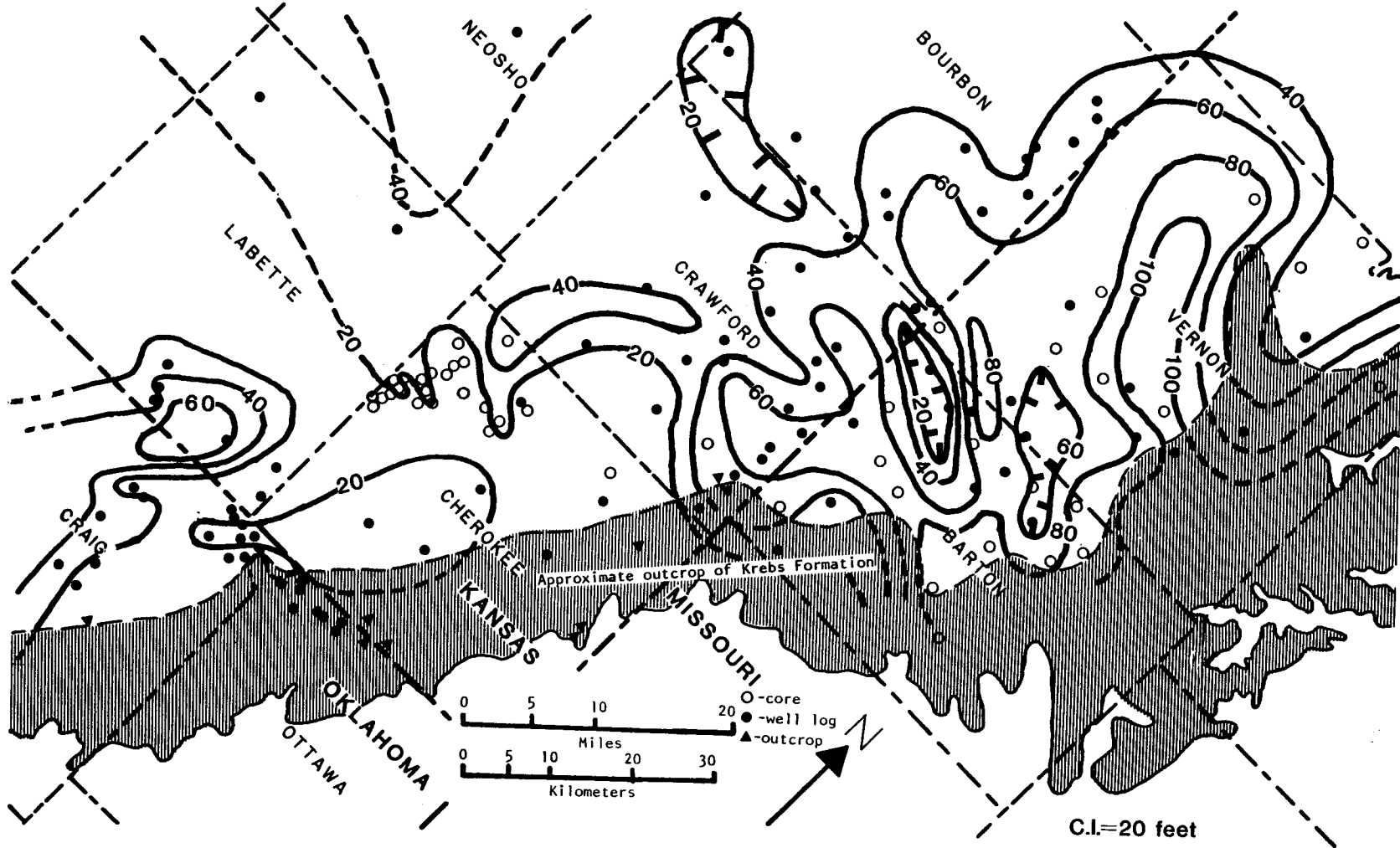


Figure 41

SANDSTONE DISTRIBUTION MAP-BASAL PENNSYLVANIAN SANDSTONE

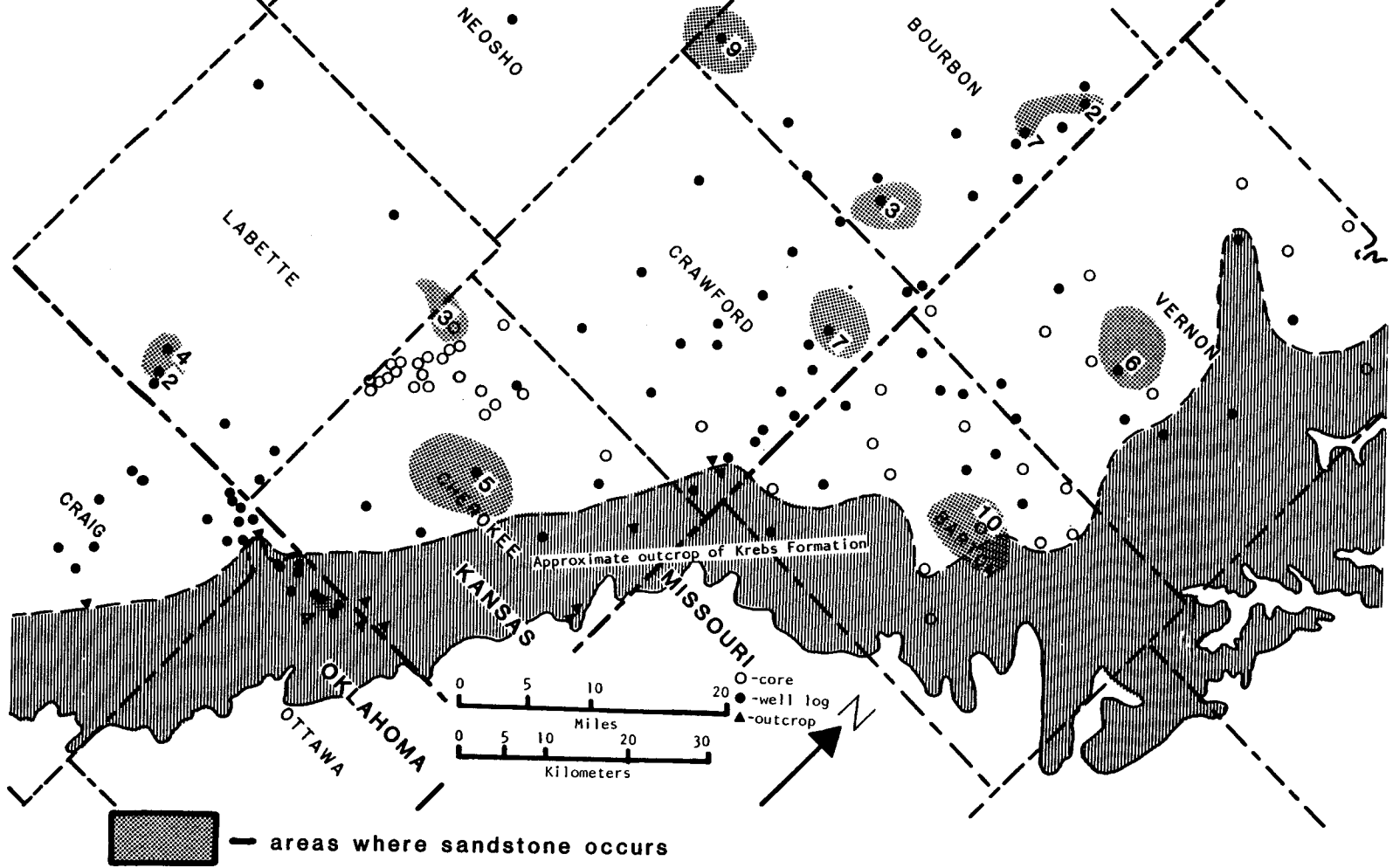


Figure 42

(1966) are filled mainly by shale. The fact that sandstones show no relationship to any structural or topographic feature on the top of the Mississippian limestone suggests that the pre-Pennsylvanian topography had little effect on sandstone distribution within the study area. This contrasts with the findings of Busch (1959), who concluded that shoestring sand bodies were strike-valley sandstones, forming in valleys between cuestas on the pre-Pennsylvanian unconformity.

Net sandstone isolith maps for the lower and upper Warner and the lower Bluejacket intervals (Figs. 43, 44, 45) reveal the presence of several stacked, elongate to lobate sandstone deposits located in northern Barton and south-central Vernon counties, Missouri. The upper Warner interval (Fig. 44) represents the most significant influx of sandstone in the Krebs Formation, with more than 70 feet (21 m) of composite sandstone being present in the northeastern one-half of the study area. Sandstones of the lower Warner interval (Fig. 43) and the lower Bluejacket interval (Fig. 45) also reach their maximum thicknesses in the northeastern portion of the study area. Sandstones of the lower Warner interval are up to 36 feet (9.7 m) thick, and sandstones of the lower Bluejacket interval are in excess of 45 feet (13.7 m) thick.

Figure 43 - Net sandstone and siltstone isolith map for the lower Warner interval; contour interval = 10 feet. Hatchures indicate areas with the lowest net sandstone and siltstone accumulations.

Figure 44 - Net sandstone and siltstone isolith map for the upper Warner interval; contour interval = 10 feet. Hatchures indicate areas with the lowest net sandstone and siltstone accumulations.

Figure 45 - Net sandstone and siltstone isolith map of the lower Bluejacket interval; contour interval = 10 feet. Hatchures indicate areas with the lowest net sandstone and siltstone accumulations.

NET SANDSTONE ISOLITH MAP—LOWER WARNER INTERVAL

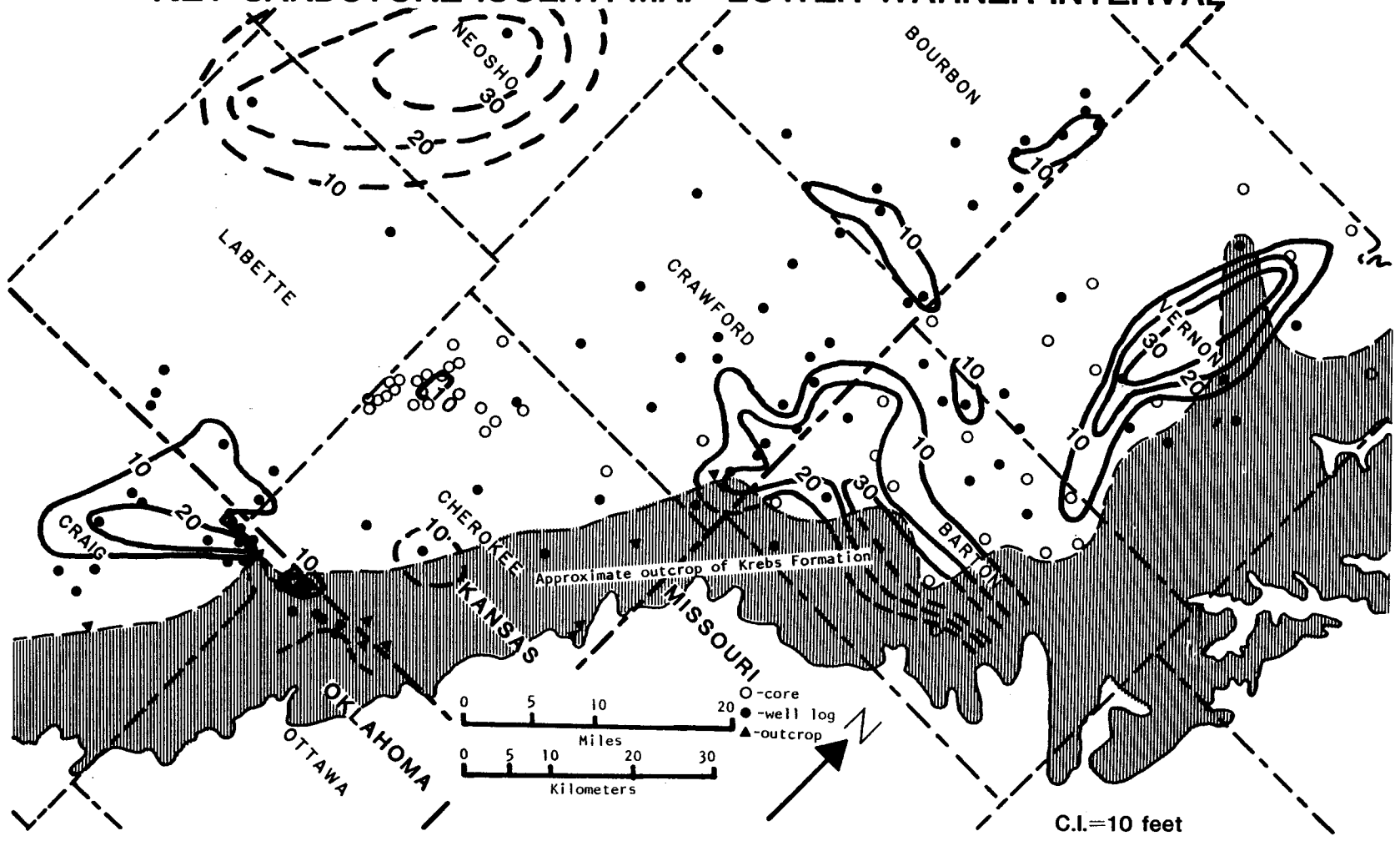


Figure 43

NET SANDSTONE ISOLITH MAP-UPPER WARNER INTERVAL

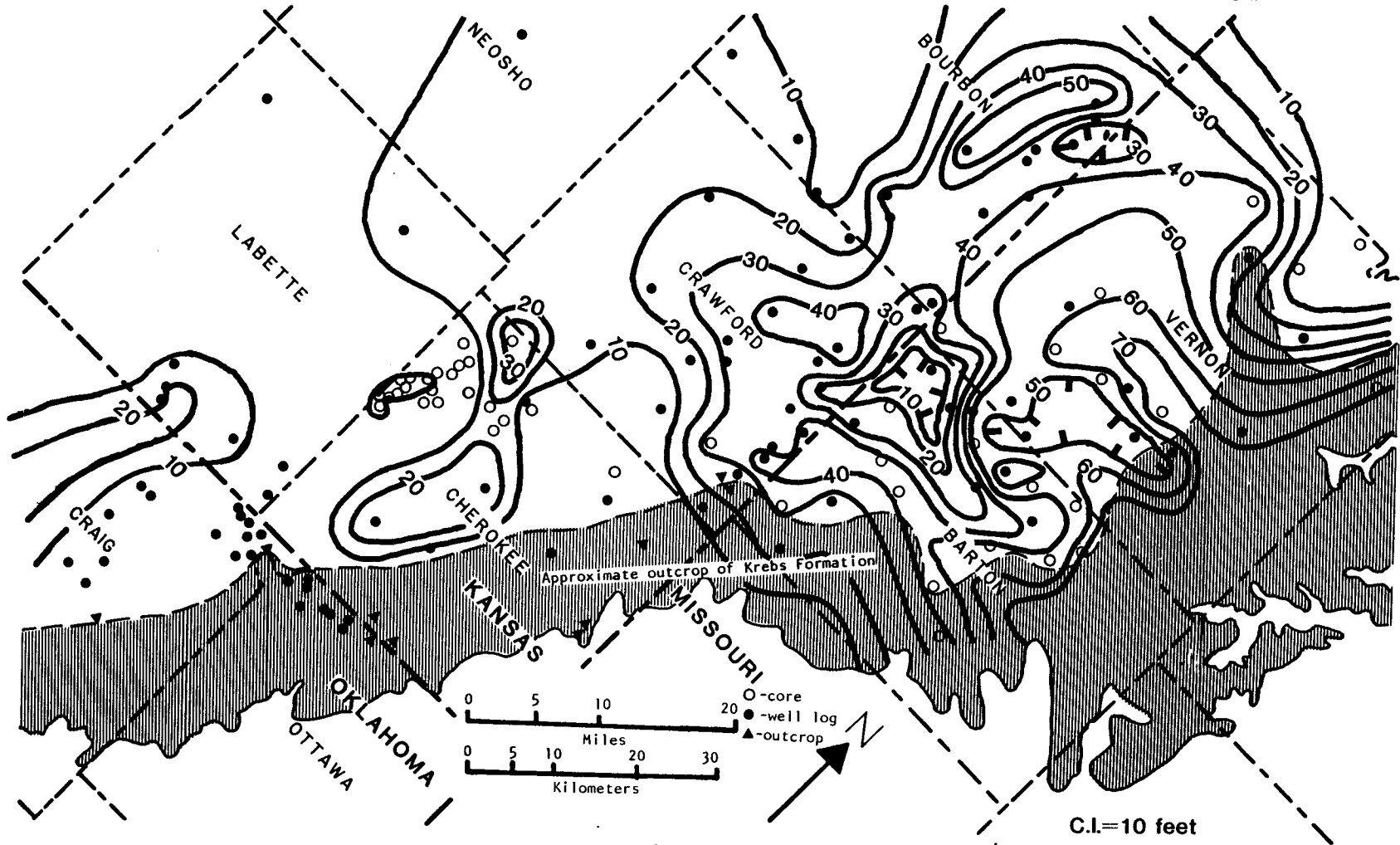


Figure 44

NET SANDSTONE ISOLITH MAP—LOWER BLUEJACKET INTERVAL

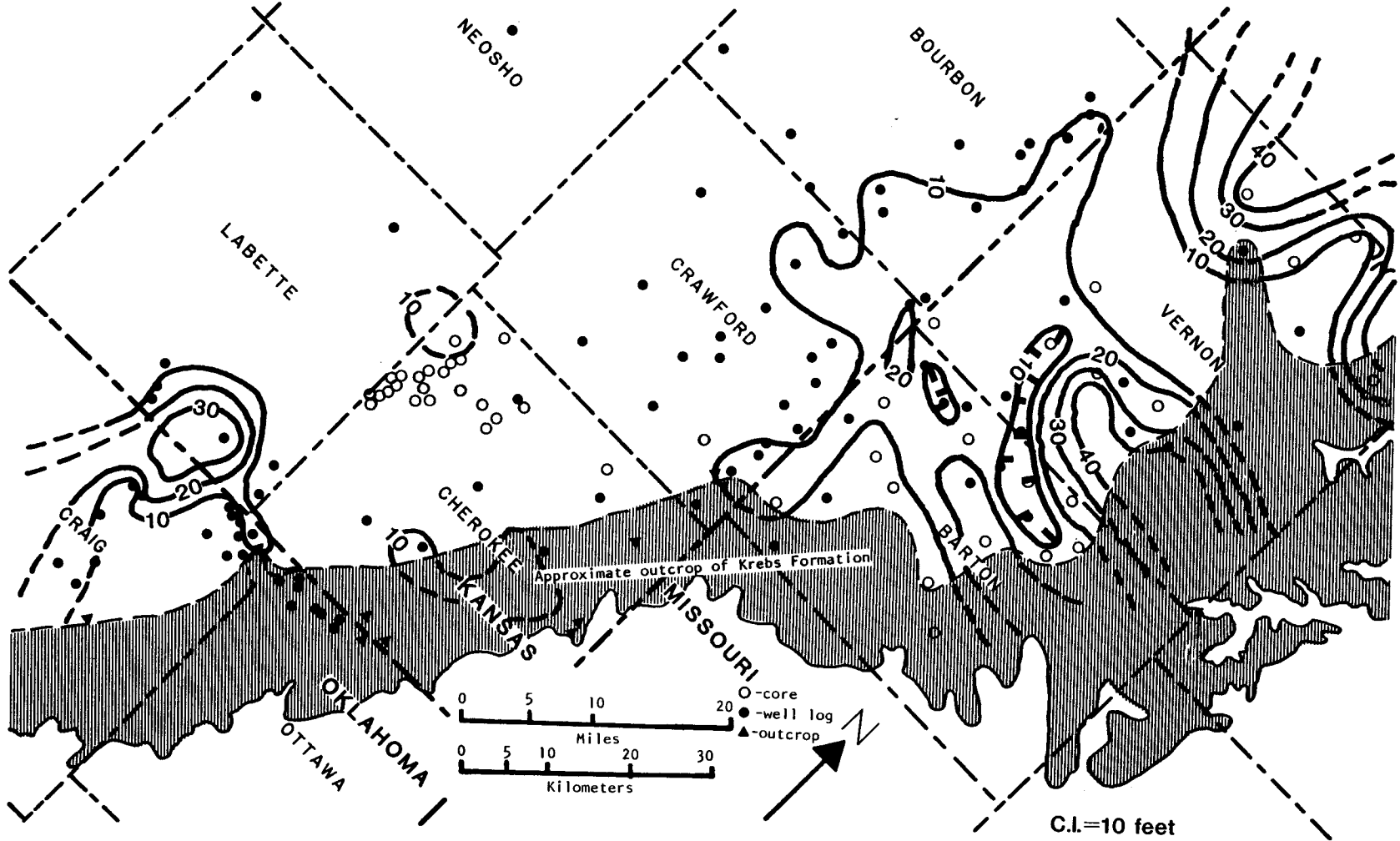


Figure 45

SUMMARY

Net sandstone isolith maps and lithofacies relationships of the Krebs Formation suggest the presence of a major deltaic complex in the northeastern one-half of the study area. Thick sandstone sequences of Vernon and Barton counties, Missouri, commonly contain several scour surfaces overlain by mud-clast conglomerates and large-scale, cross-bedded, rippled and flaser-bedded sandstones. An example of this type of vertical sequence may be seen in the upper Warner to lower Bluejacket interval (core DOE-TS-#26; Plate 2), where a composite sandstone over 100 feet (30 m) thick consists of at least eight mud-clast conglomerate units interbedded with cross-stratified, rippled, and flaser-bedded sandstone. The abundance of scour surfaces, mud-clast conglomerates, and large-scale cross-bedding common in channel sandstones suggest that these thick sandstone deposits are amalgamated or stacked channel sandstones.

Composite channel sandstones of southwestern Missouri grade laterally into upwards-coarsening sandstone sequences, each generally less than 30 feet (9.1m) thick. In the OSM-JSC #7 core (Plate 2), a coarsening-upwards sequence in the upper Warner interval consists of a basal mud-clast conglomerate (transgressive lag deposit) overlain by 13.5 feet

(4.1 m) of wavy-bedded siltstone, 10.5 feet (3.2 m) of graded sandstone beds, each less than 2 feet (60c m) thick, followed by 8.8 feet (2.6 m) of rippled sandstone and siltstone. The overall coarsening-upwards profile, the abundance of convolute bedding, and the presence of plant debris and a few burrows support a distributary-mouth-bar origin for this sandstone. Similar coarsening-upwards sequences are present in the lower Warner, upper Warner, and lower Bluejacket intervals of DOE-TS-#13 (Plate 2).

Channels and distributary mouth bars grade laterally into thin, interbedded sandstones, shales, coals and argillaceous limestone units that are interpreted as progradational interdeltatic or bay-fill deposits, resulting from repeated infilling of interdistributary bays by crevasse splays or smaller subdeltas. An example of these mud-dominated sequences may be seen in P&M #8, P&M #20, and P&M #1 cores (Plate 2). Coal swamps developed in response to progradational pulses of fine-grained sediment during times when sedimentation rates exceeded subsidence or transgression of the sea. The great areal extent of some of the thin coal, limestone, and shale units (approximately 3,600 square miles (6,400 sq. km) for the Cw coal bed, Fig. 10) resulted from deposition in large, interdeltatic embayments. The nondeposition or erosion of these thin

beds results from either penecontemporaneous deposition of deltaic sediments or by shifting of deltaic depocenters and scour during later progradational events.

Cross section B-B' (Plate 2) approximately parallels depositional strike and represents the lateral facies transition from the proximal sandstones of a large deltaic complex in the northeast to the distal shales, coals, and limestones in the southwestern portion of the study area. This deltaic complex exhibits stacking or multistorying of distributary channels and distributary mouth bars, as well as persistence of interdeltic embayments. Similar stacking of both distributary channels, mouth bars, and interdistributary areas has been documented from Pennsylvanian sequences of north-central Texas (Brown, 1979) and from the Wilcox Group (Eocene) of the Texas Gulf coastal region (Fisher and McGowen, 1969).

Individual delta lobes of the deltaic complex in Vernon and Barton counties, Missouri, apparently entered the study area from an easterly or east-southeasterly direction. This is indicated by the fact that sandstone thicknesses are greatest near the outcrop belt and thin into the subsurface. Net sandstone isolith maps and facies trends suggest that sandstones were dispersed in a northwesterly, westerly,

and southwesterly direction. Depositional strike of the system was in a north-northwesterly direction, while depositional dip of the deltaic complex was in a west-southwesterly direction, forming an oblique angle with the present day strike and dip of the Krebs Formation.

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APPENDIX A

Graphic Descriptions of Cores from
Cherokee and Crawford Counties, Kansas

Described by John W. Harris

(Original verbal descriptions at a scale
of 1 inch = 1 foot are on file with the
Mineral Resources section at the Kansas
Geological Survey.)

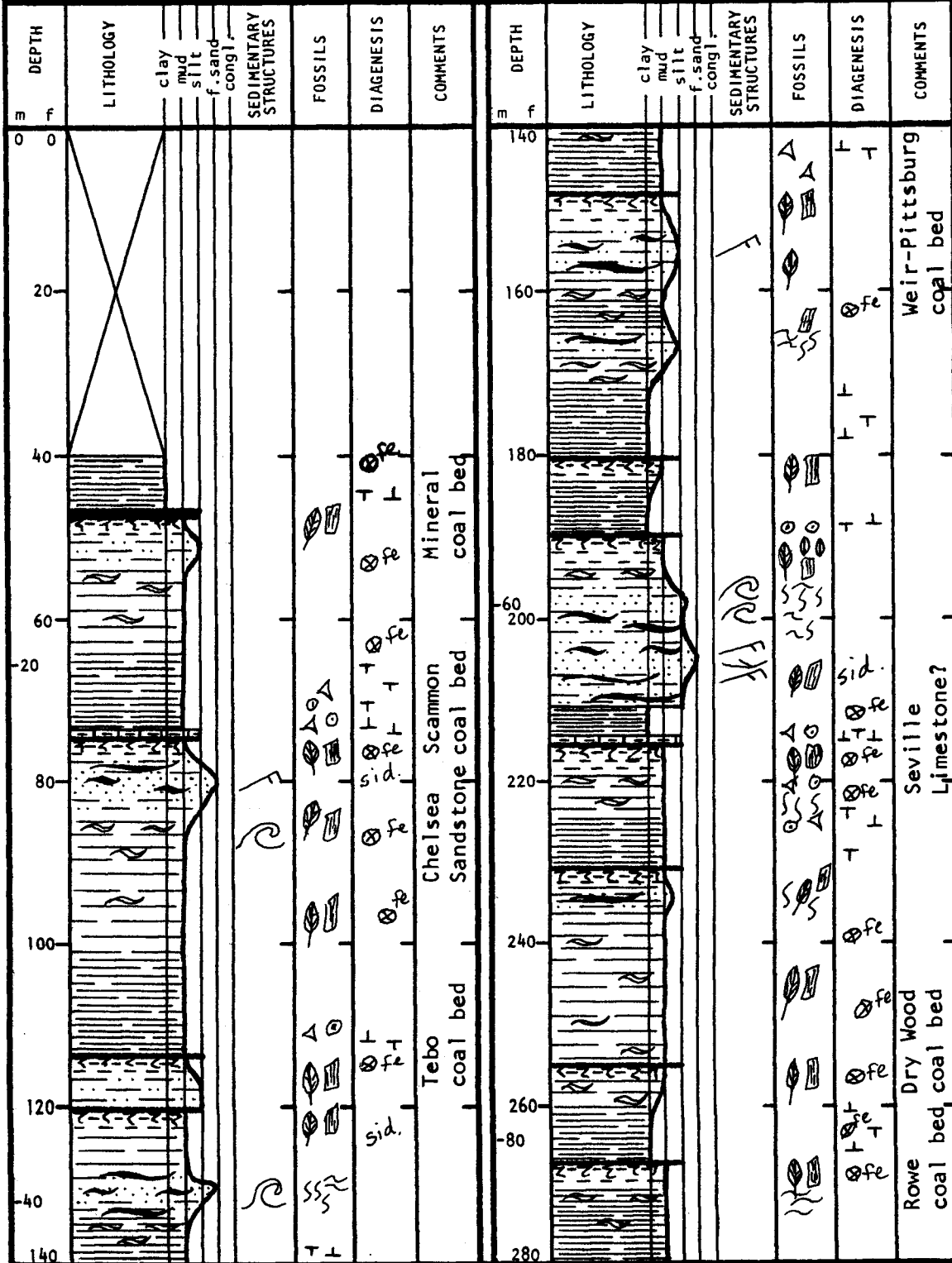
EXPLANATION OF SYMBOLS

dark gray shale		scour surface	
light gray shale		graded beds	
mudstone		unconformity	
siltstone		convolute bedding	
sandstone		plant fragments	
mud-clast conglomerate		brachiopods	
coal		bivalves	
argillaceous limestone		crinoids	
limestone		bryozoans	
lenticular bedding		burrows	
wavy bedding		rootlets	
flaser bedding		pyrite concretions	
no core recovery		clay ironstone concretions	
asymmetric ripples		calcareous cement	
symmetric ripples		siderite spherulites	
large-scale cross beds		cone in cone structures	

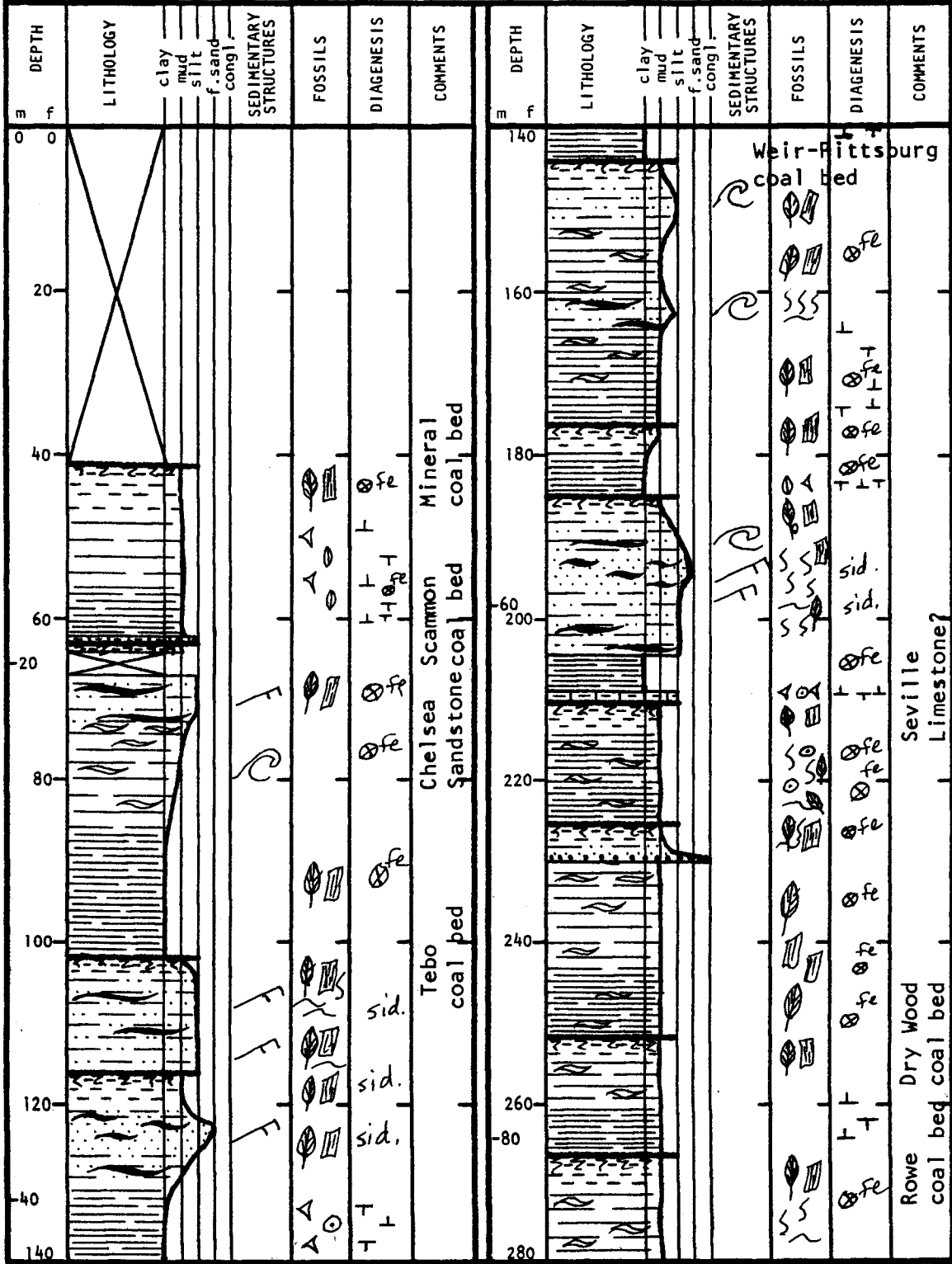
OSM CH-1
 SW SE SW Sec.27 T31S R24E
 Cherokee County, Kansas
 Surface Elevation-922

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS		
m	f							m	f								
0	0							140									
	20					⊕ PY	Weir-Pittsburg coal bed mined out							⊕ fe			
	40					⊕											
	60					LT											
	80					LT											
-20							Seville Limestone										
	100					T L											
	120					⊕ PY		Rowe Dry Wood coal bed									
	140					⊕ PY											
	160					⊕ fe											
	180					⊕ fe											
	200																
	220																
	240																
	260																
	280																

P&M # 1
 NW NE NW Sec.13 T33S R21E
 Cherokee County, Kansas
 Surface Elevation -815



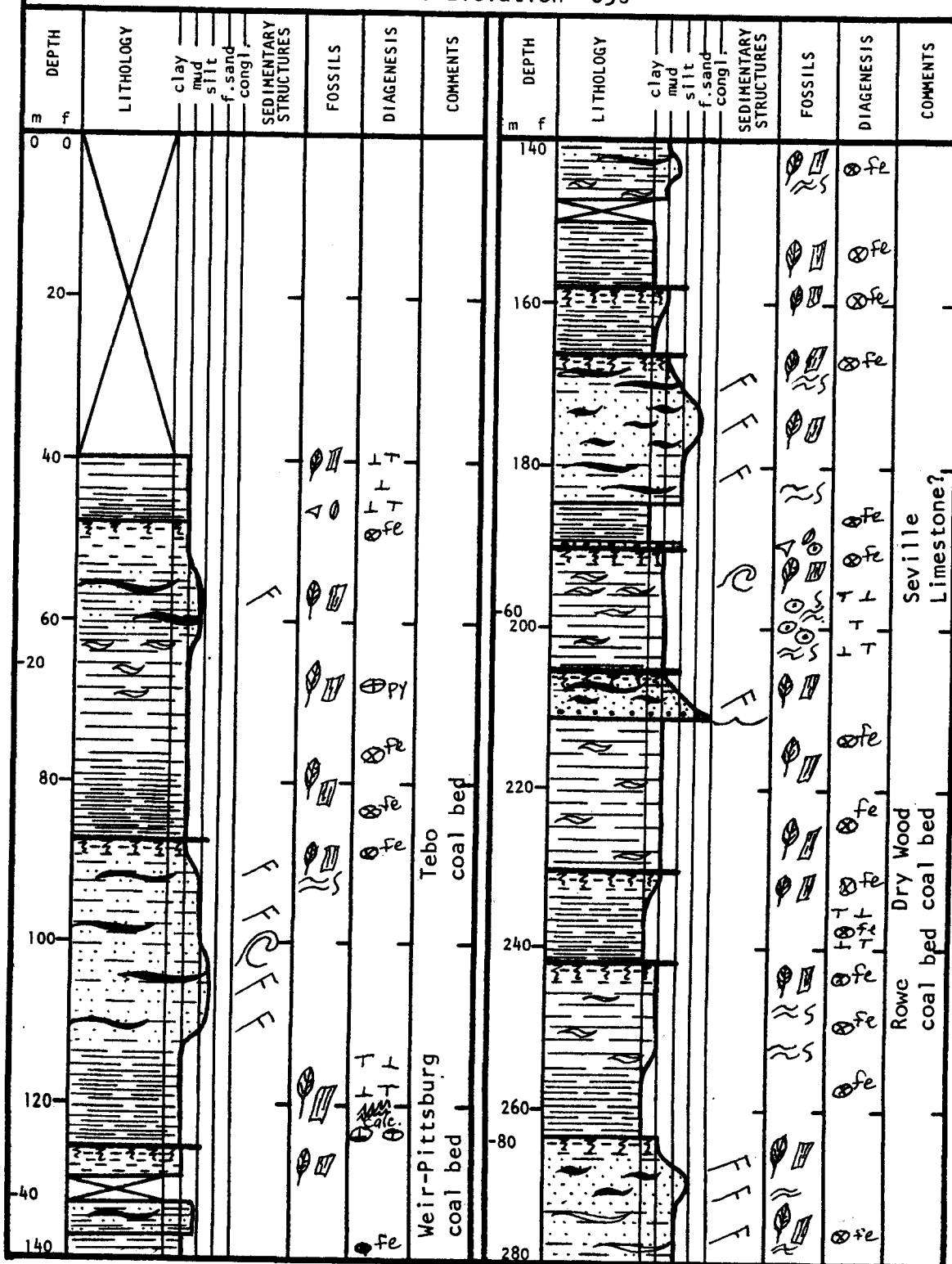
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 SE NW Sec.12 T33S R21E
 Cherokee County, Kansas
 Surface Elevation -815



P&M #2
 SE NW NW Sec.12 T33S R21E
 Cherokee County, Kansas
 Surface Elevation -815

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	
m	f							m	f							
280								420								
300									440							
320									460							
									480							
340																
									500							
360																
									520							
380																
									540							
400								Riverton coal bed								
									560							
420								Mississippian Limestone								

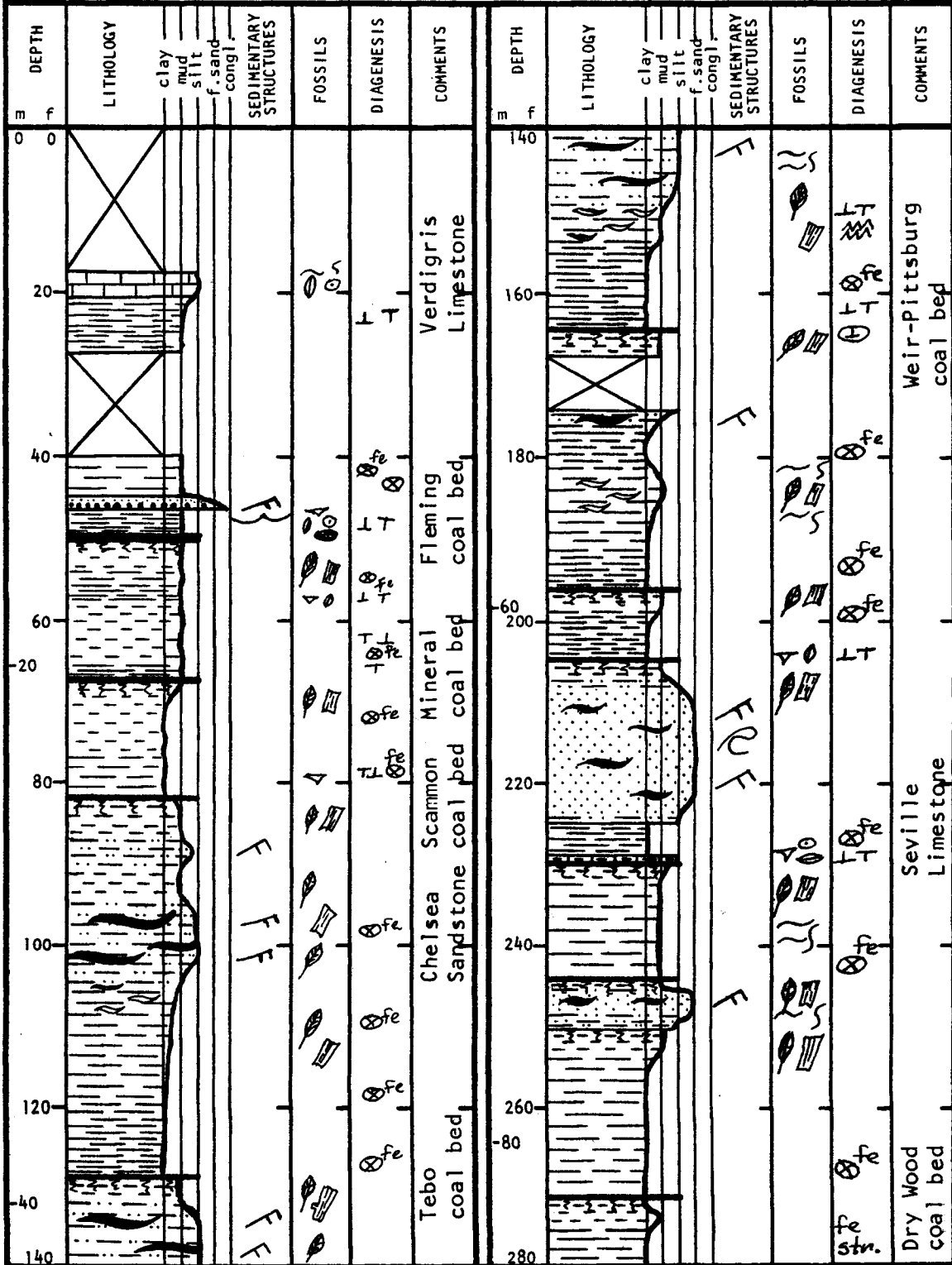
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 Cherokee County, Kansas
 Surface Elevation -830



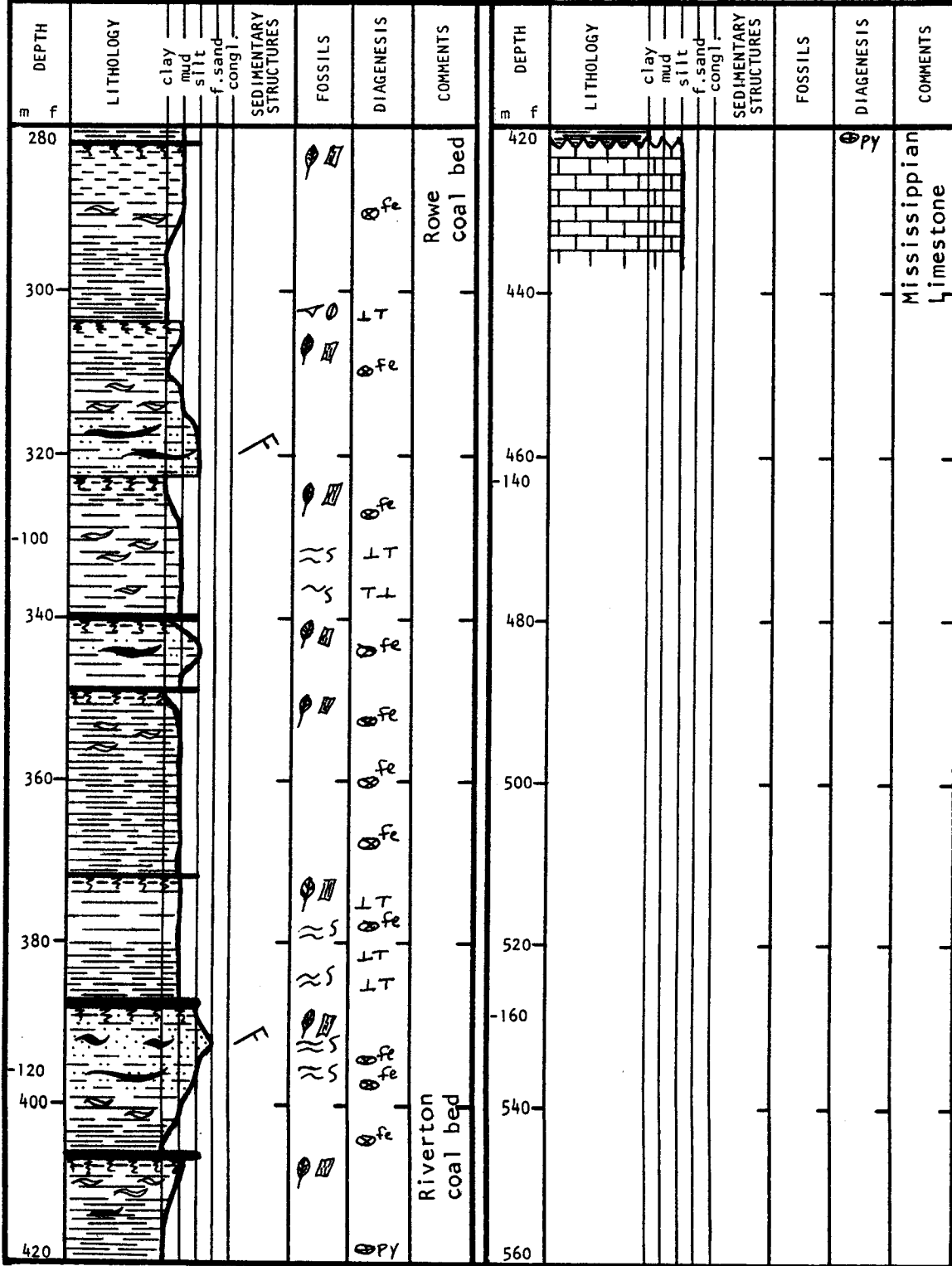
P&M #3
 SE SE SE Sec.36 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -830

DEPTH		LITHOLOGY	clay mud silt	f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt	f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	
m	f								m	f								
280									420									
300									440									
320									460									
									480									
-100									500									
340									520									
									540									
360									560									
380																		
-120																		
400								Mississippian Limestone										
420																		

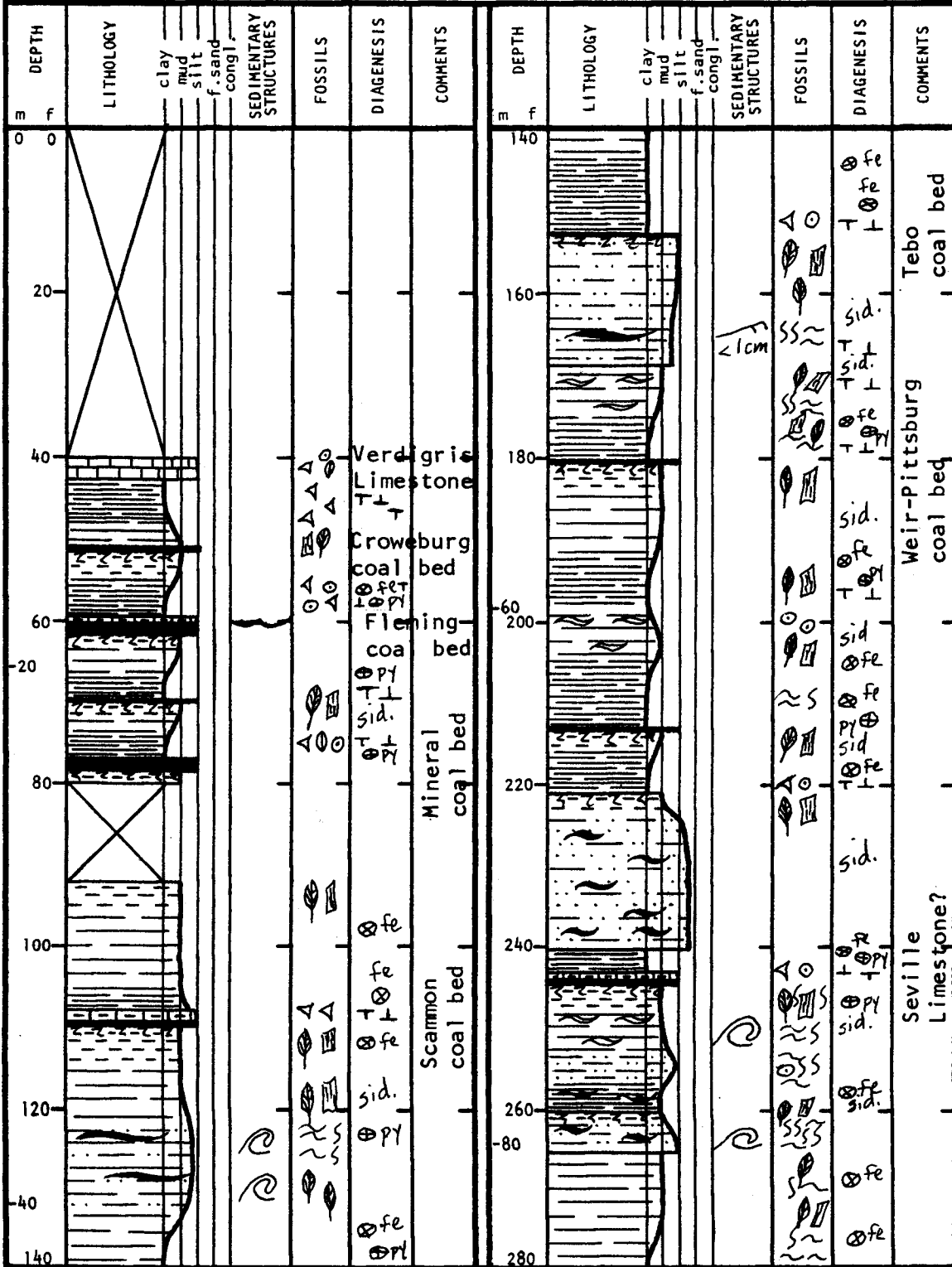
SW NW SW Sec.29 T32S R22E
 Cherokee County, Kansas
 Surface Elevation-830



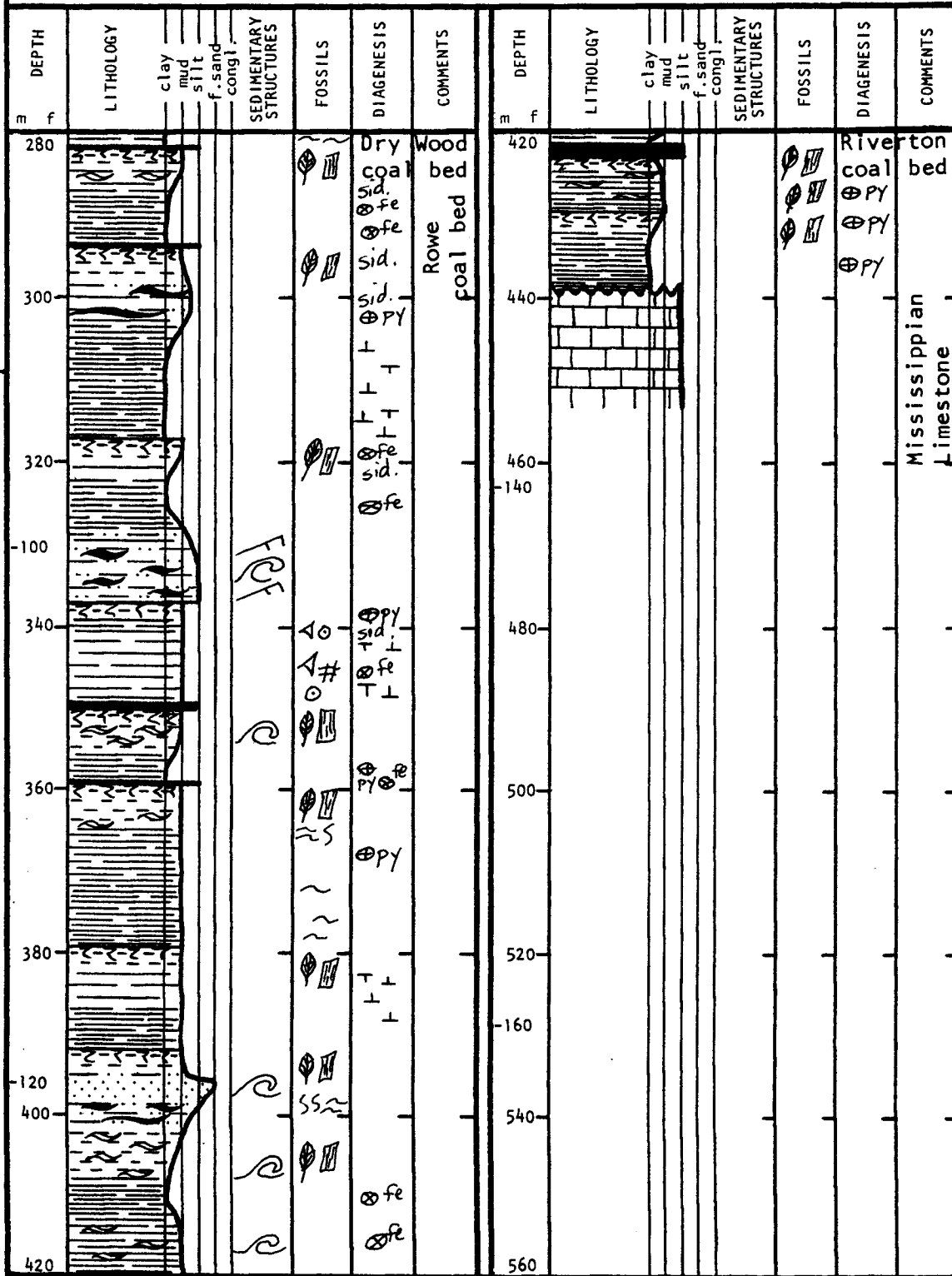
P&M #4
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 Cherokee County, Kansas
 Surface Elevation-830



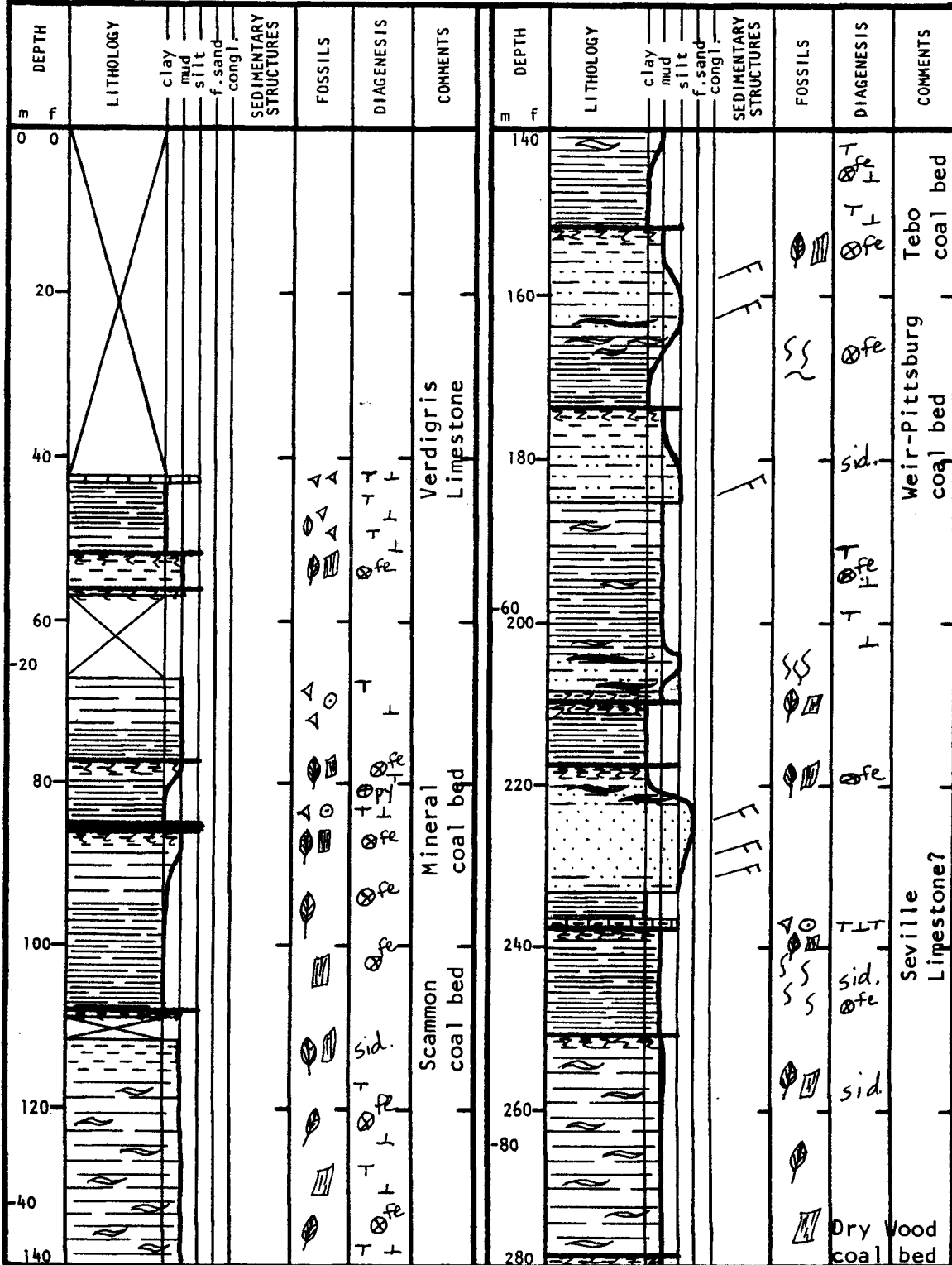
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 Cherokee County, Kansas
 Surface Elevation -830



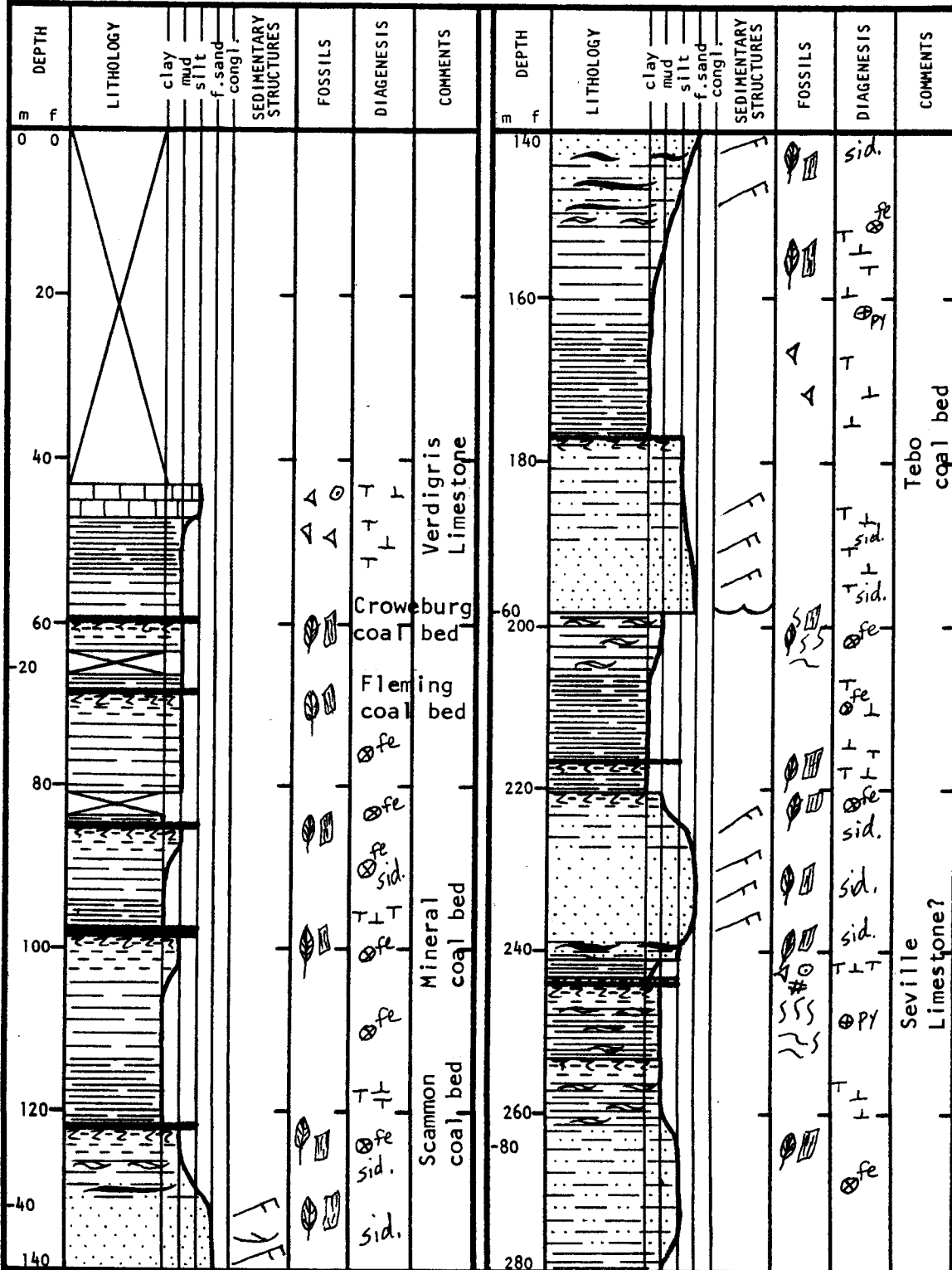
P&M #5
 NW NE NW Sec.30 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -830



P&M #6
 SE SW SE Sec.8 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -835



P&M #7
 SW SW SE Sec.6 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -840

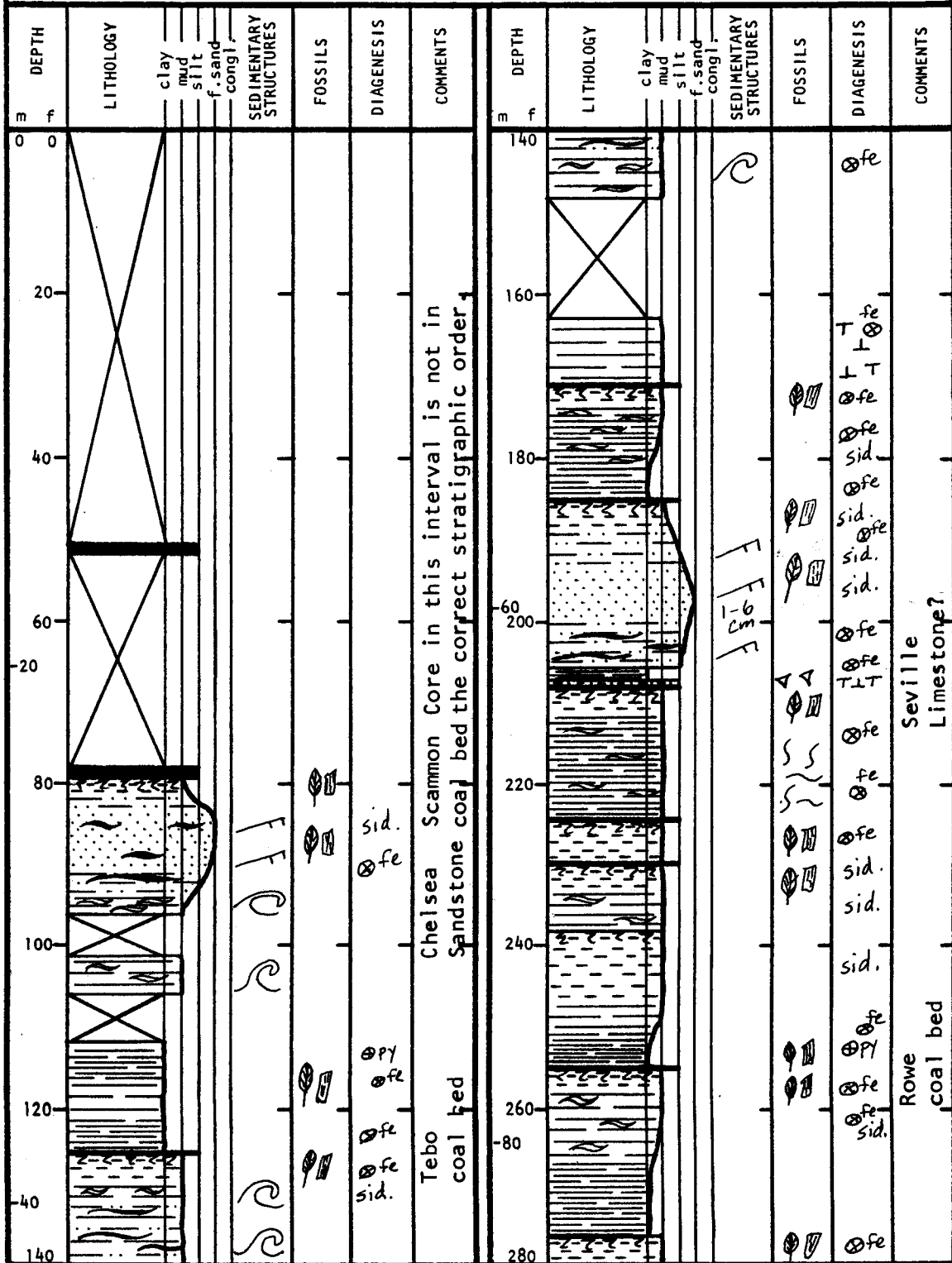


P&M #7
 SW SW SE Sec. 6 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -840

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS
m	f							m	f						
280							Wood bed	420							Riverton coal bed
					☉	Dry coal	Rowe coal bed						☉	⊕PY	
300					☉	☉fe		440						T L	
					☉	sid. ☉fe							☉	⊕PY	
					☉	sid. ☉fe								T L	
320					☉	☉fe		460							
					☉	☉fe		-140							
-100					☉	☉fe									
340					☉	☉fe		480							
					☉	T									
					☉	T									
					☉	L T									
360					☉	☉fe		500							
					☉	sid.									
					☉	T									
					☉	fe L									
					☉	T L									
380					☉	T		520							
					☉	⊕PY									
					☉	L T		-160							
					☉	☉fe									
-120					☉	sid.									
400					☉	☉fe		540							
					☉	☉fe									
420					☉	☉fe		560							

Mississippian Limestone

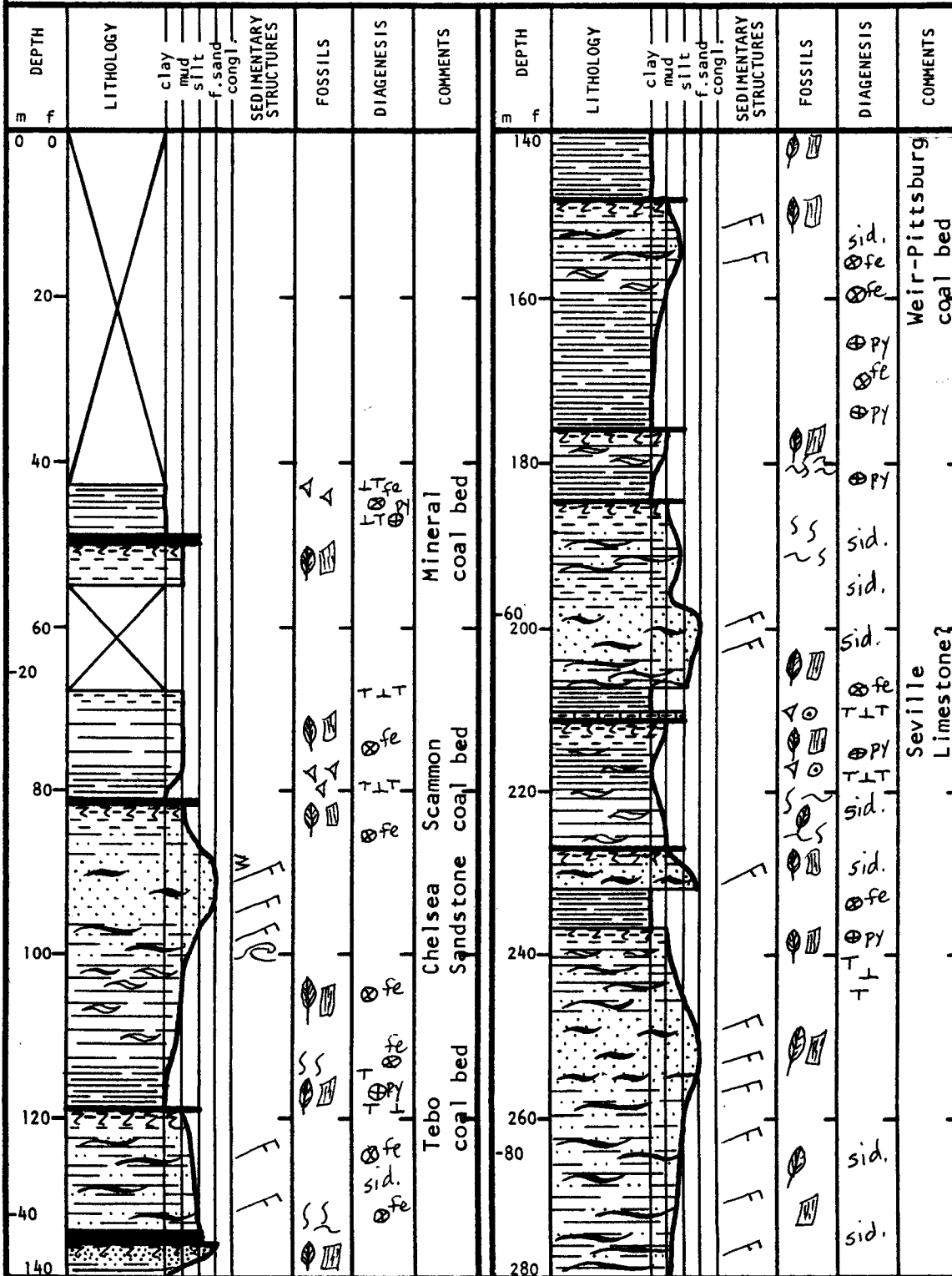
P&M #8
 NE NE NE Sec.5 T32S R23E
 Cherokee County, Kansas
 Surface Elevation -905



P&M #8
 NE NE NE Sec.5 T32S R23E
 Cherokee County, Kansas
 Surface Elevation -905

DEPTH		LITHOLOGY	clay mud silt f.sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f.sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	
m	f							m	f							
280						⊗ Fe		420								
						⊗ Fe										
300						⊗ Fe		440								
						⊗ Fe sid.										
						sid. ⊗ Fe		460								
320						⊗ Fe		140								
						⊗ Fe										
-100						⊗ Fe sid.		480								
						TLT LT										
340						⊗ Fe										
						⊗ Fe										
						⊗ Fe		500								
360						⊗ Fe										
						TLT ⊗ Fe										
						⊗ Fe		520								
380						⊗ Fe										
							Mississippian Limestone Riverton cpal bed	-160								
-120								540								
400								560								
420																

P&M #9
 NW NE NE Sec.18 T32S R23E
 Cherokee County, Kansas
 Surface Elevation -900



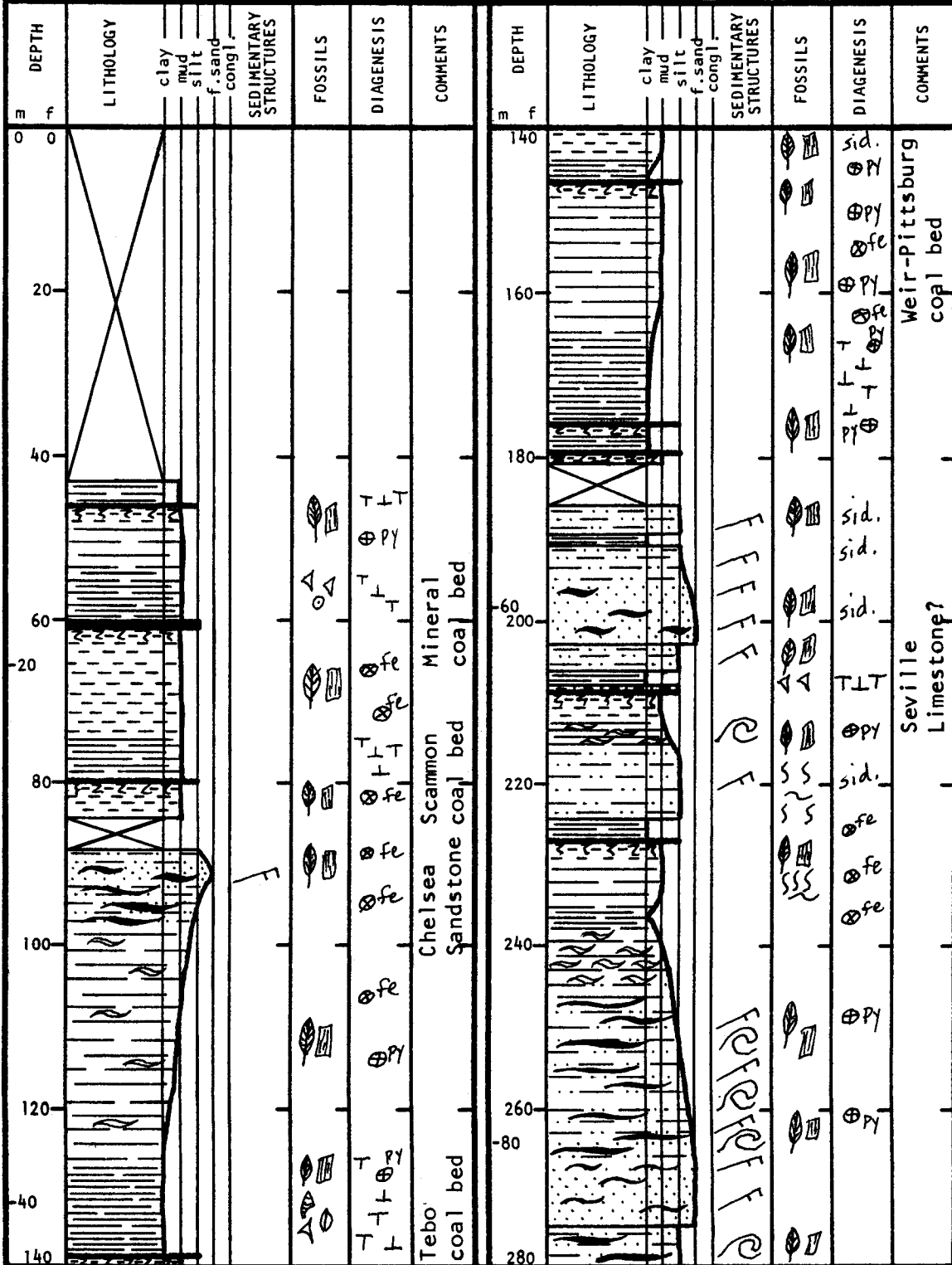
NW NE NE Sec.18 T32S R23E

Cherokee County, Kansas

Surface Elevation -900

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	
m	f							m	f							
280					⊙ ⊙	⊗ Fe sid.		420								
					⊙ ⊙	⊗ Fe sid.		440								
300					⊙ ⊙	⊗ Fe sid.		460								
					⊙ ⊙	⊗ Fe sid.		480								
320					⊙ ⊙	T LT T Fe		500								
					⊙ ⊙	T T		520								
-100					⊙ ⊙	⊗ PY ⊗ PY		540								
340					⊙ ⊙	T LT sid.		560								
					⊙ ⊙	⊗ Fe ⊗ Fe										
360					⊙ ⊙	⊗ PY ⊗ PY										
					⊙ ⊙	⊗ PY ⊗ Fe ⊗ PY										
380					⊙ ⊙	⊗ PY ⊗ PY										
					⊙ ⊙	⊗ PY ⊗ PY										
-120							Mississippian Limestone									
400							Riverton coal bed									
420																

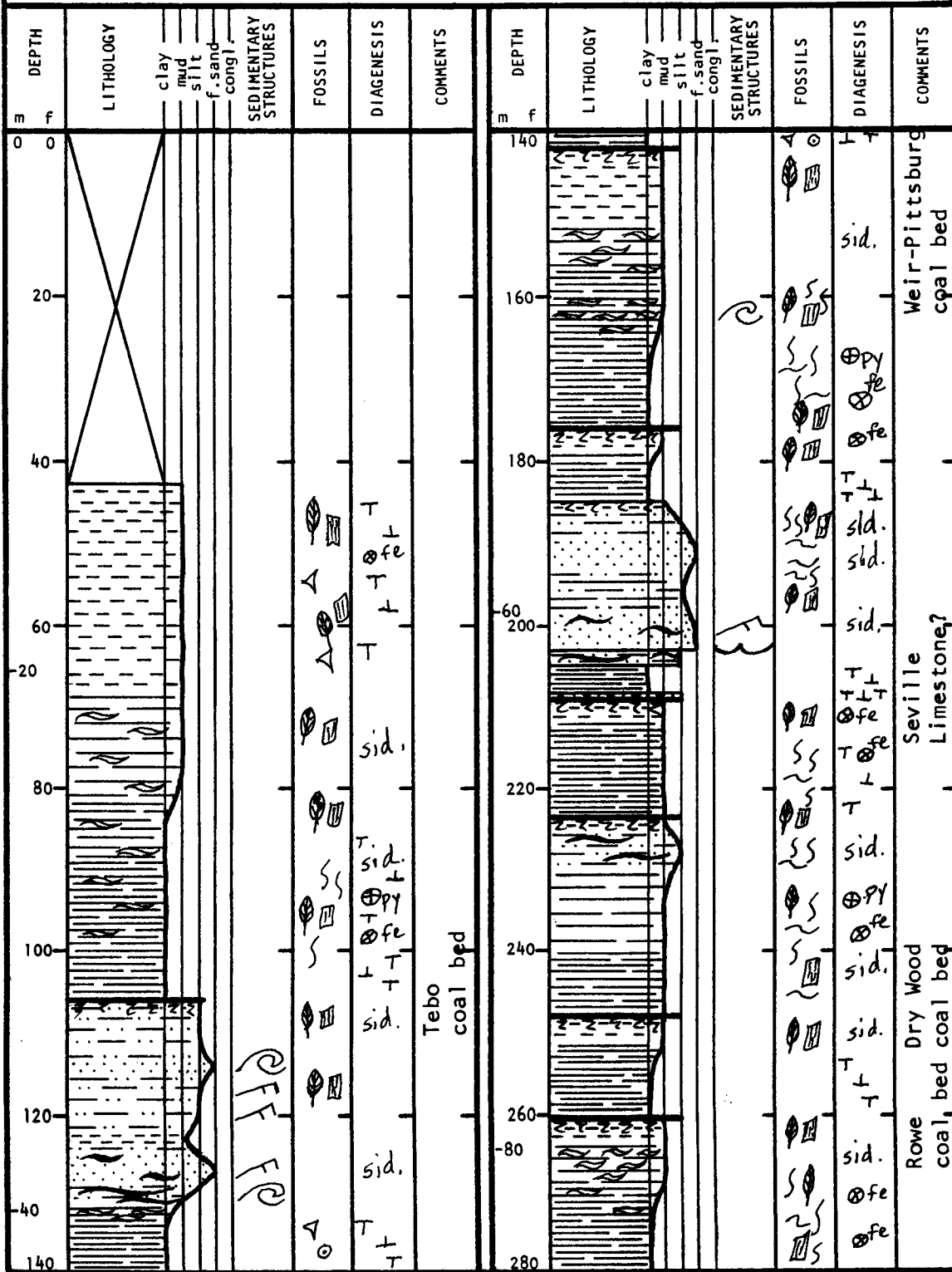
P&M #10
 NW NW SW Sec.22 T31S R22E
 Cherokee County, Kansas
 Surface Elevation -863



P&M #10
 NW NW SW Sec.22 T31S R22E
 Cherokee County, Kansas
 Surface Elevation -863

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	
m	f							m	f							
280						sid.		420								
						⊗fe										
						⊗fe										
300						⊗fe		440								
						sid.										
						⊗py										
						⊗fe										
320								460								
								140								
100						⊗fe										
						T										
340						T		480								
						T										
						⊗py										
						sid.										
360						⊗py	Riverton coal bed	500								
						⊗py										
						py⊗										
						⊗py	Mississippian Limestone	520								
380								160								
120								540								
400																
420								560								

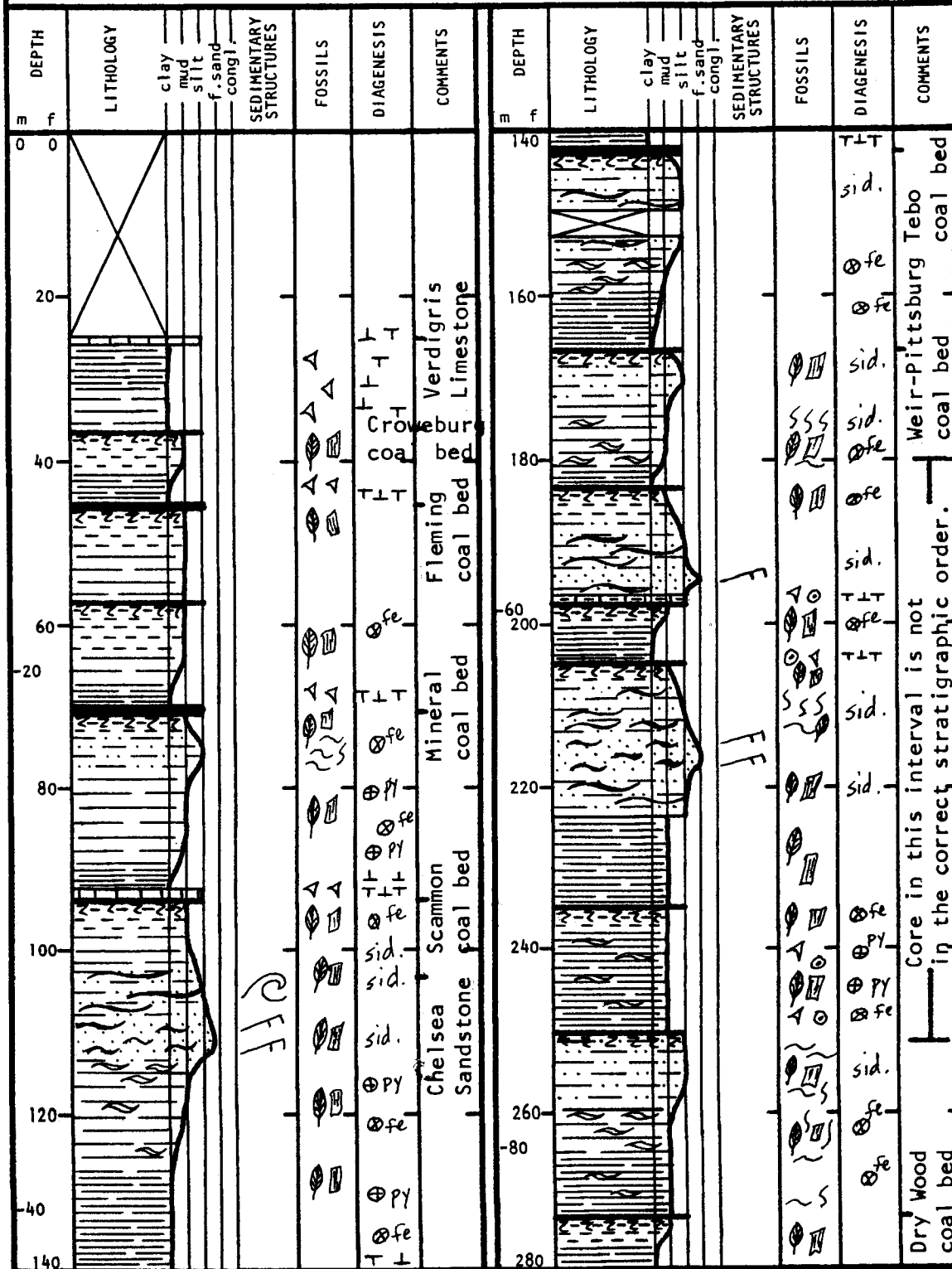
P&M #11
 NE NE NE Sec. 12 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -825



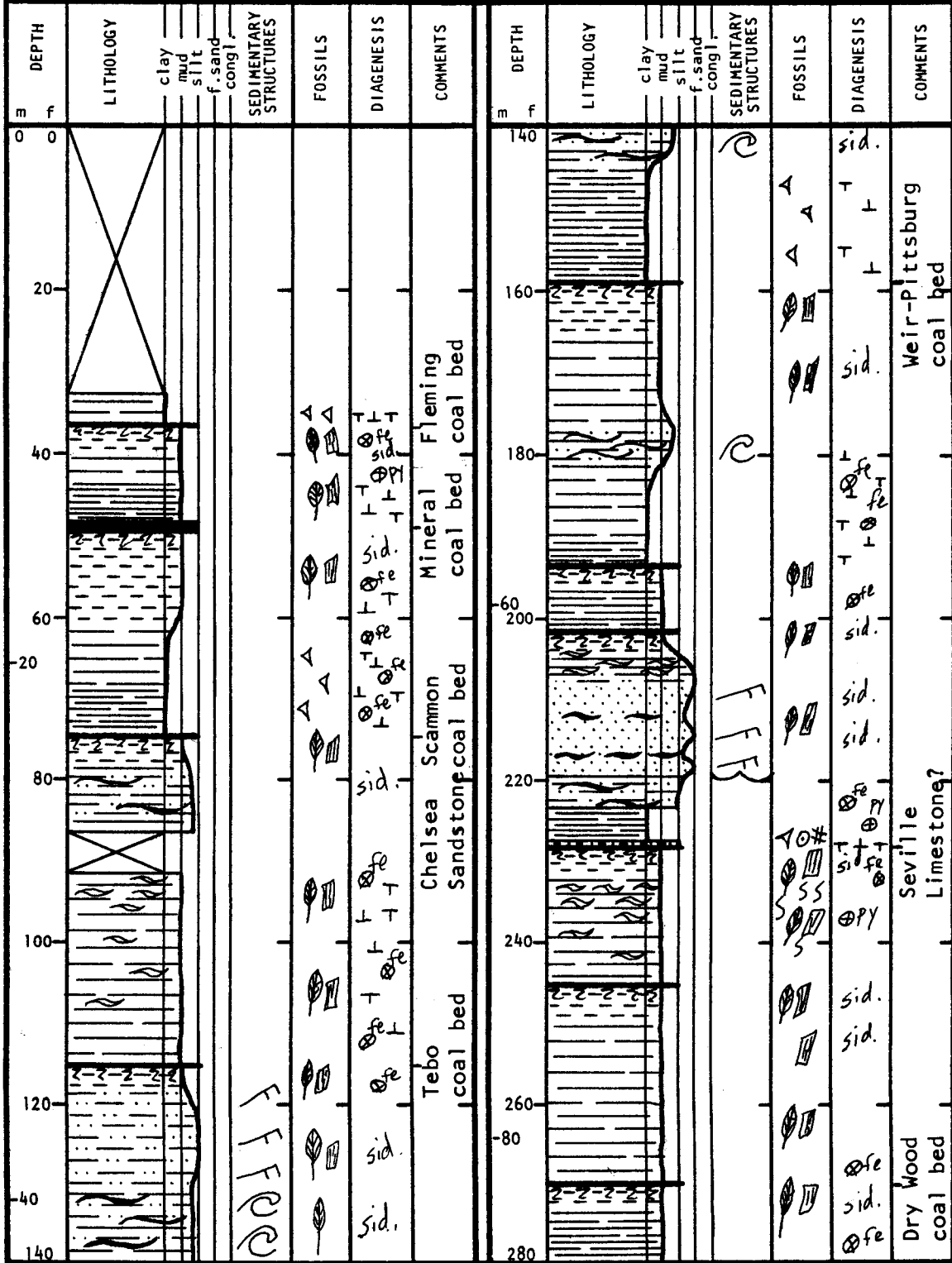
P&M #11
 NE NE NE Sec. 12 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -825

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS
m	f							m	f						
280				FOF FO		⊗ fe sid. ⊕ PY ⊗ fe T ⊕ PY T T ⊕ PY ⊗ fe ⊗ fe T ⊗ fe T ⊗ fe L sid ⊗ fe T T ⊗ fe sid. ⊕ PY ⊗ fe ⊕ PY ⊕ PY	Mississippian Limestone	420							
300															
320															
340															
360															
380															
400															
420															
440															
460															
480															
500															
520															
540															
560															

P&M #12
 NW SW NE Sec.19 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -830



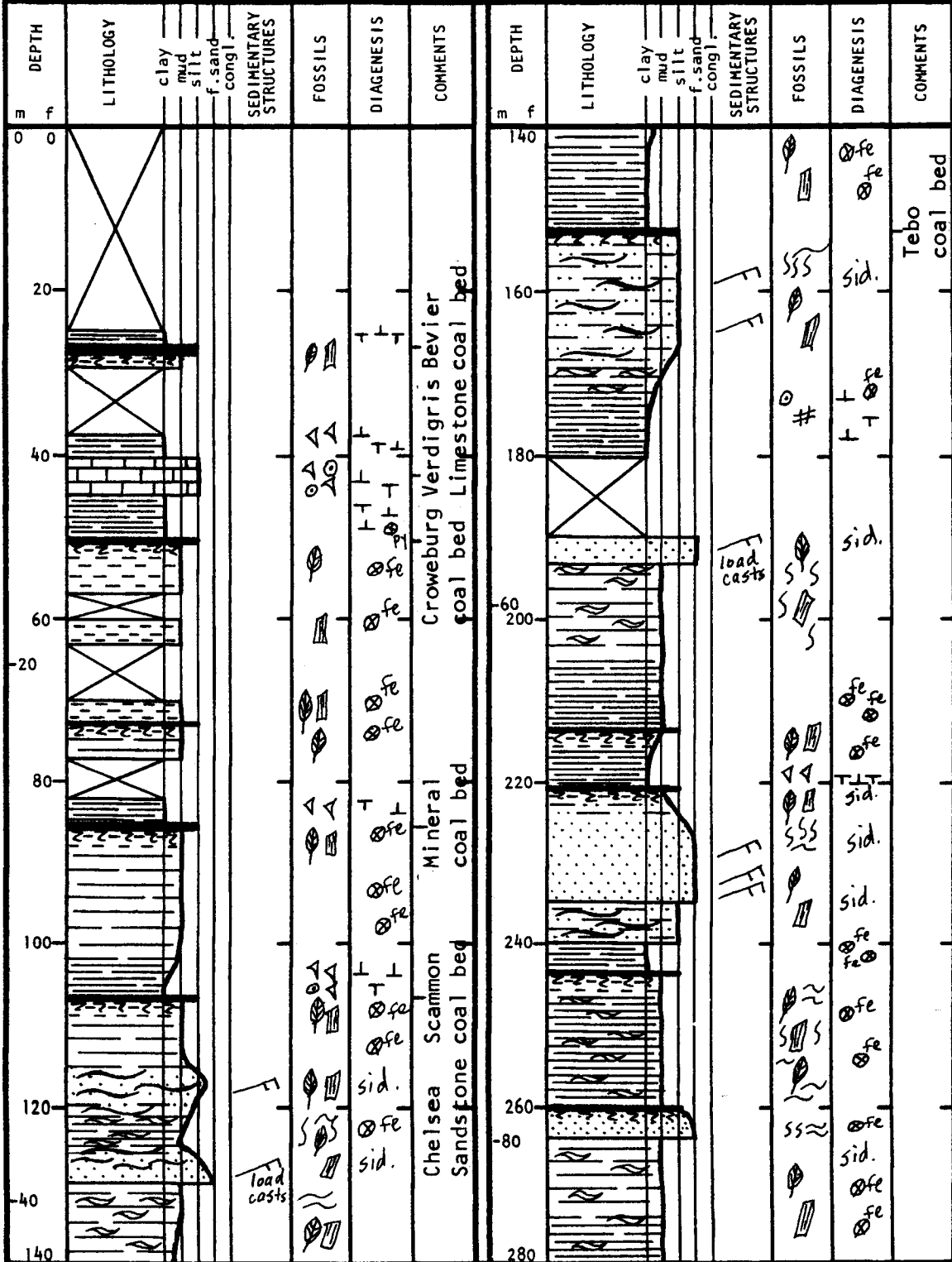
P&M #13
 SW NW SW Sec.12 T33S R21E
 Cherokee County, Kansas
 Surface Elevation -810



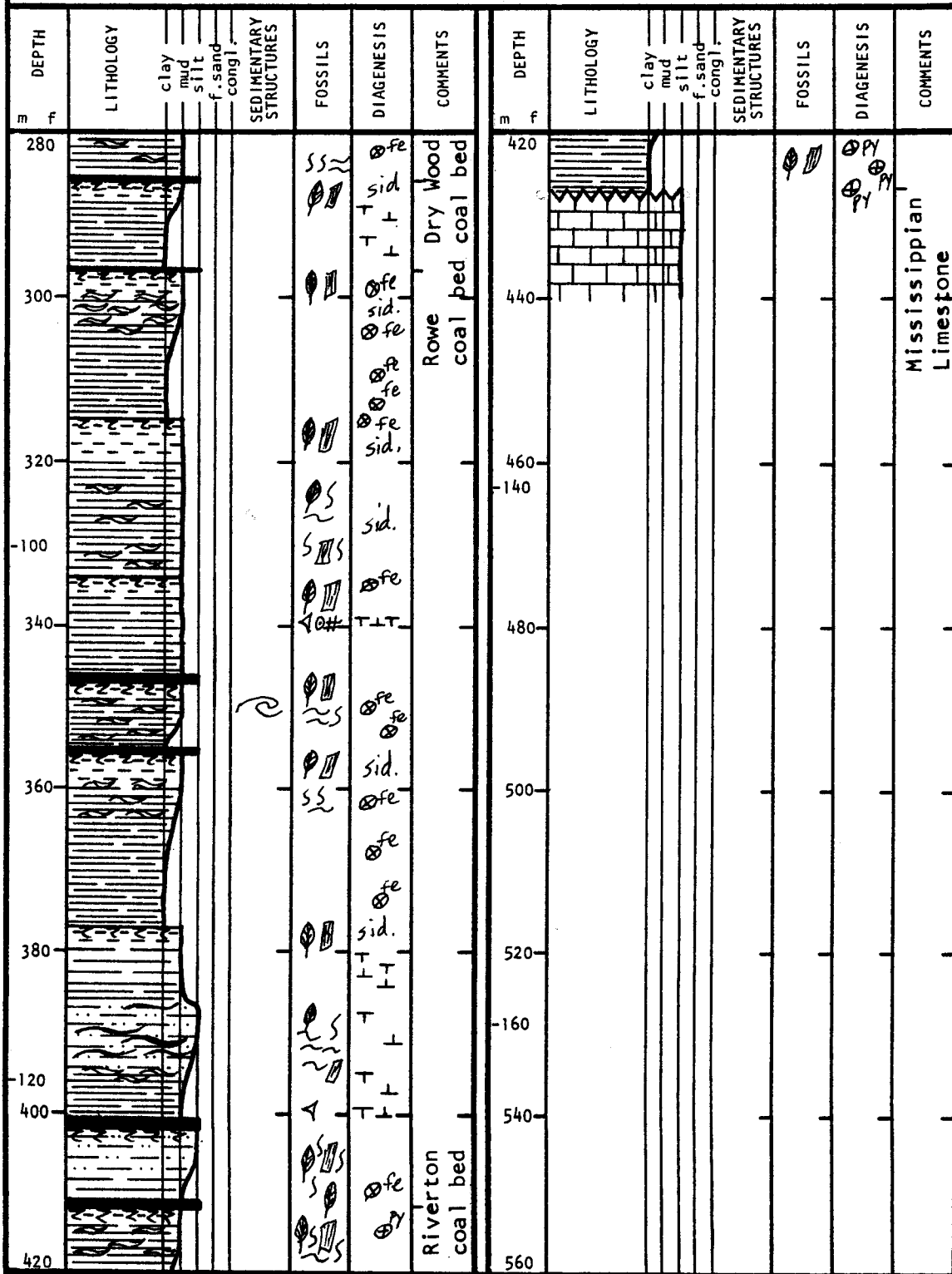
P&M #13
 SW NW SW Sec.12 T33S R21E
 Cherokee County, Kansas
 Surface Elevation -810

DEPTH m f	LITHOLOGY	clay mud silt f.sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH m f	LITHOLOGY	clay mud silt f.sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS
280					⊙ fe ⊙ fe	Rowe coal bed	420				⊙ PL ⊙ PY PY ⊙		
300					⊙ fe		440						
320			FCF		⊙ fe PY ⊙ ⊙ fe ⊙ fe		460						
340					⊙ fe T T ⊙ PY		480						
360					⊙ fe sid. T T ⊙ fe T T sid.		500						
380					⊙ PY ⊙ fe ⊙ fe		520						
400					SS SS		540						
420					⊙ PY ⊙ fe ⊙ PY ⊙ fe T T ⊙ PY	Riverton coal bed	560						
													Mississippian Limestone

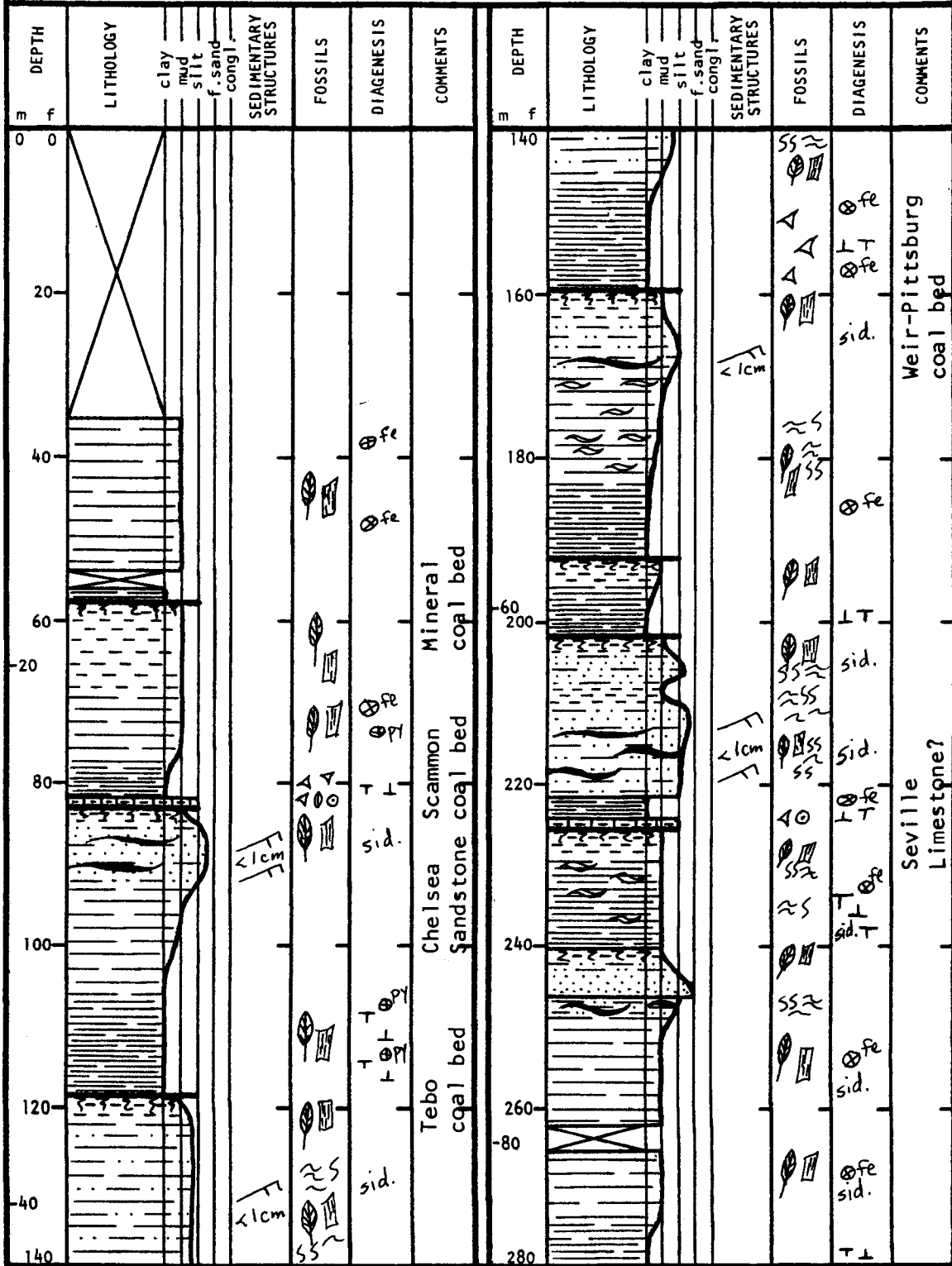
P&M #14
 SW SW NE Sec.17 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -835



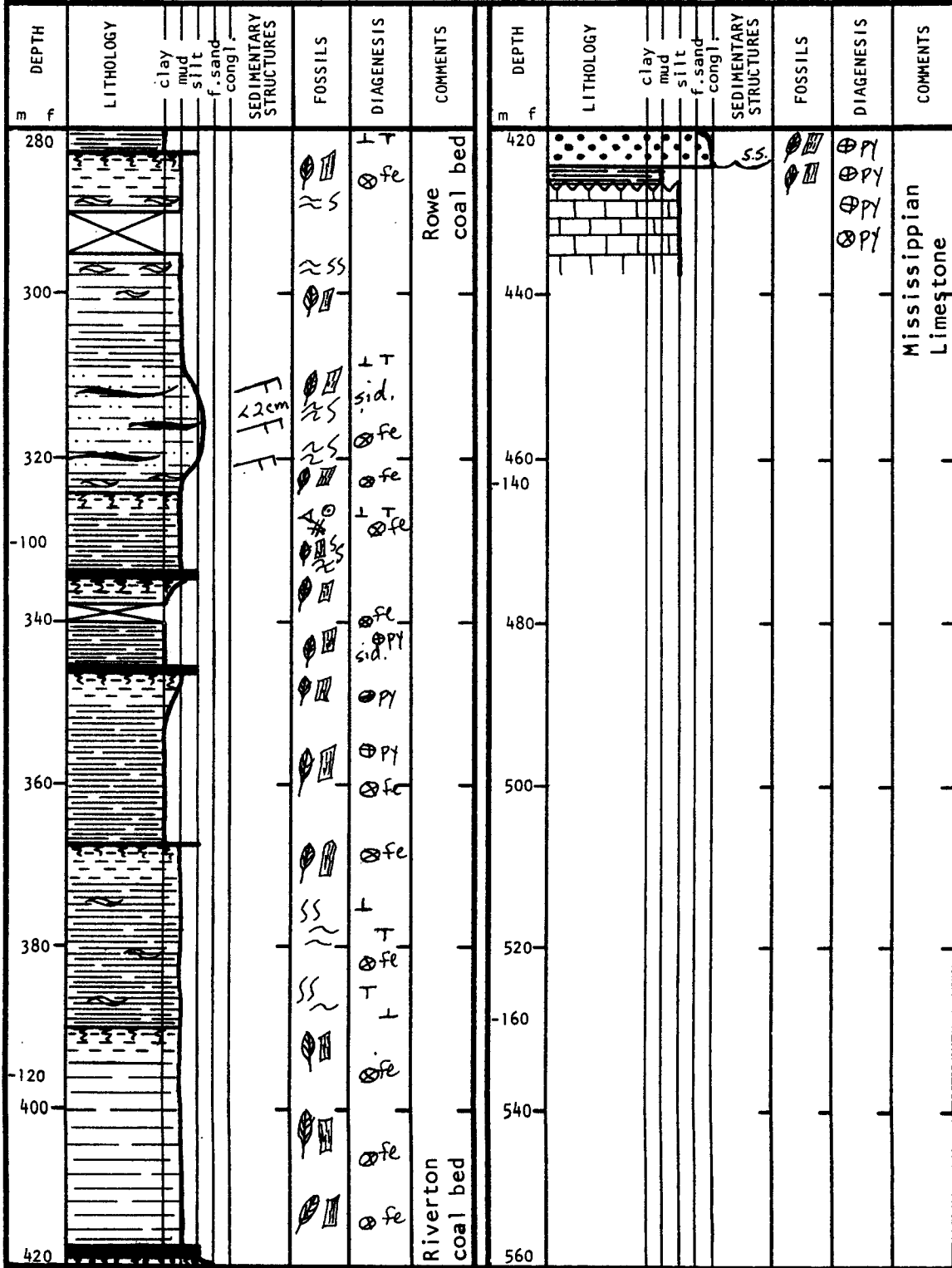
P&M #14
 SW SW NE Sec. 17 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -835



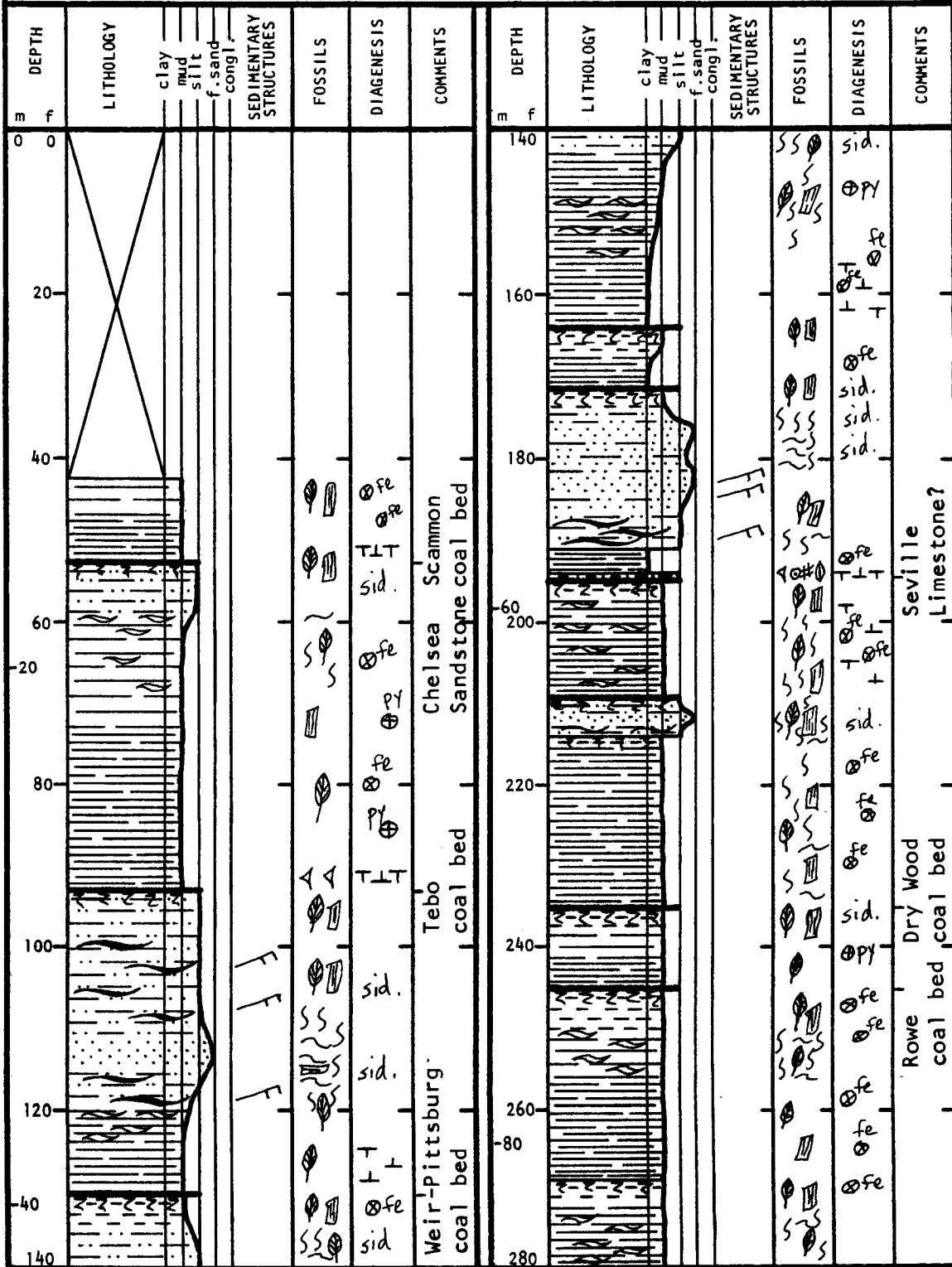
P&M #15
 SE SE SE Sec. 1 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -830



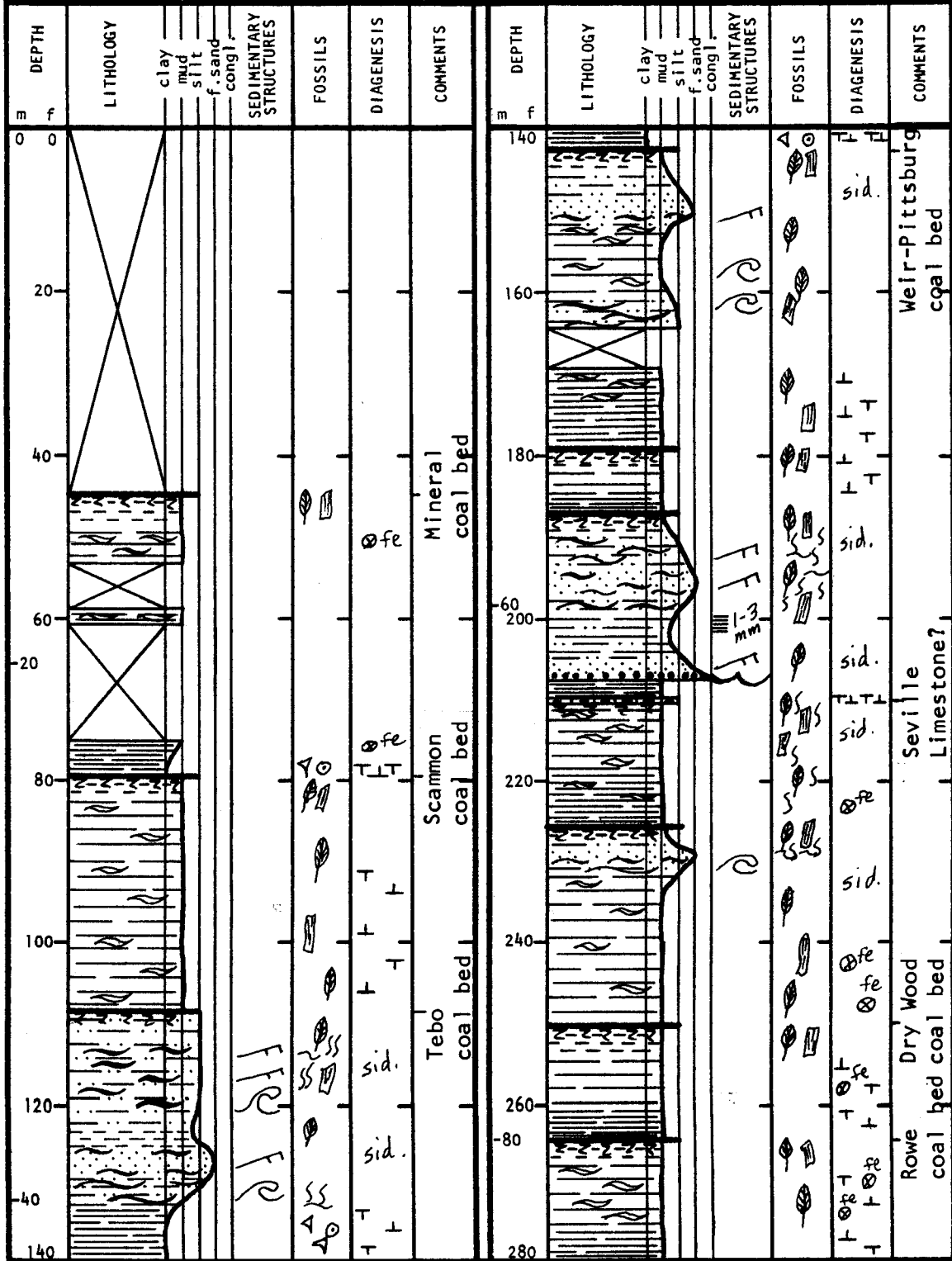
P&M #15
 SE SE SE Sec.1 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -830



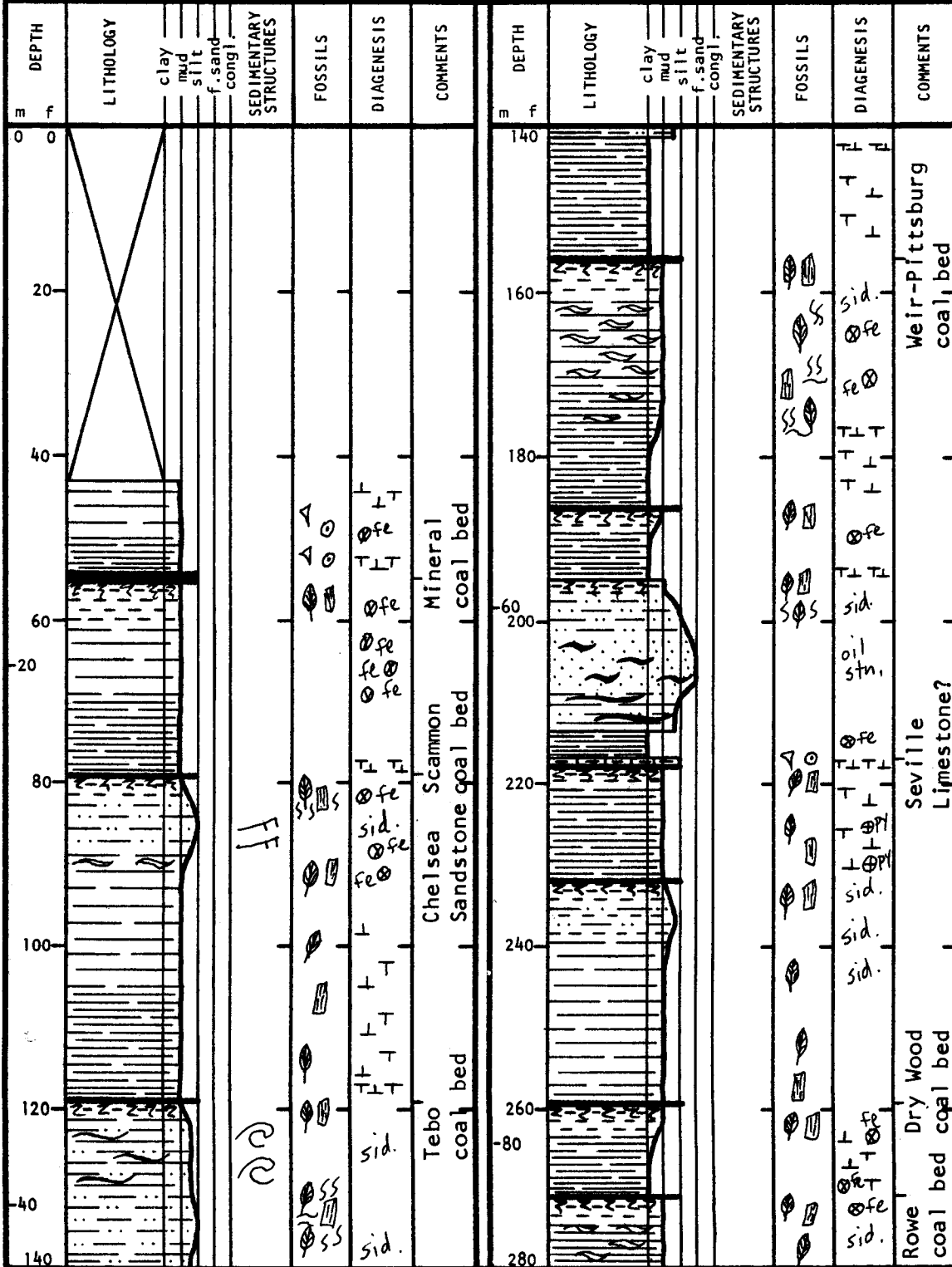
P&M #16
 SW SW SE Sec. 32 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -835



P&M #17
 SW NW SE Sec.36 T32S R21E
 Cherokee County, Kansas
 Surface Elevation -830



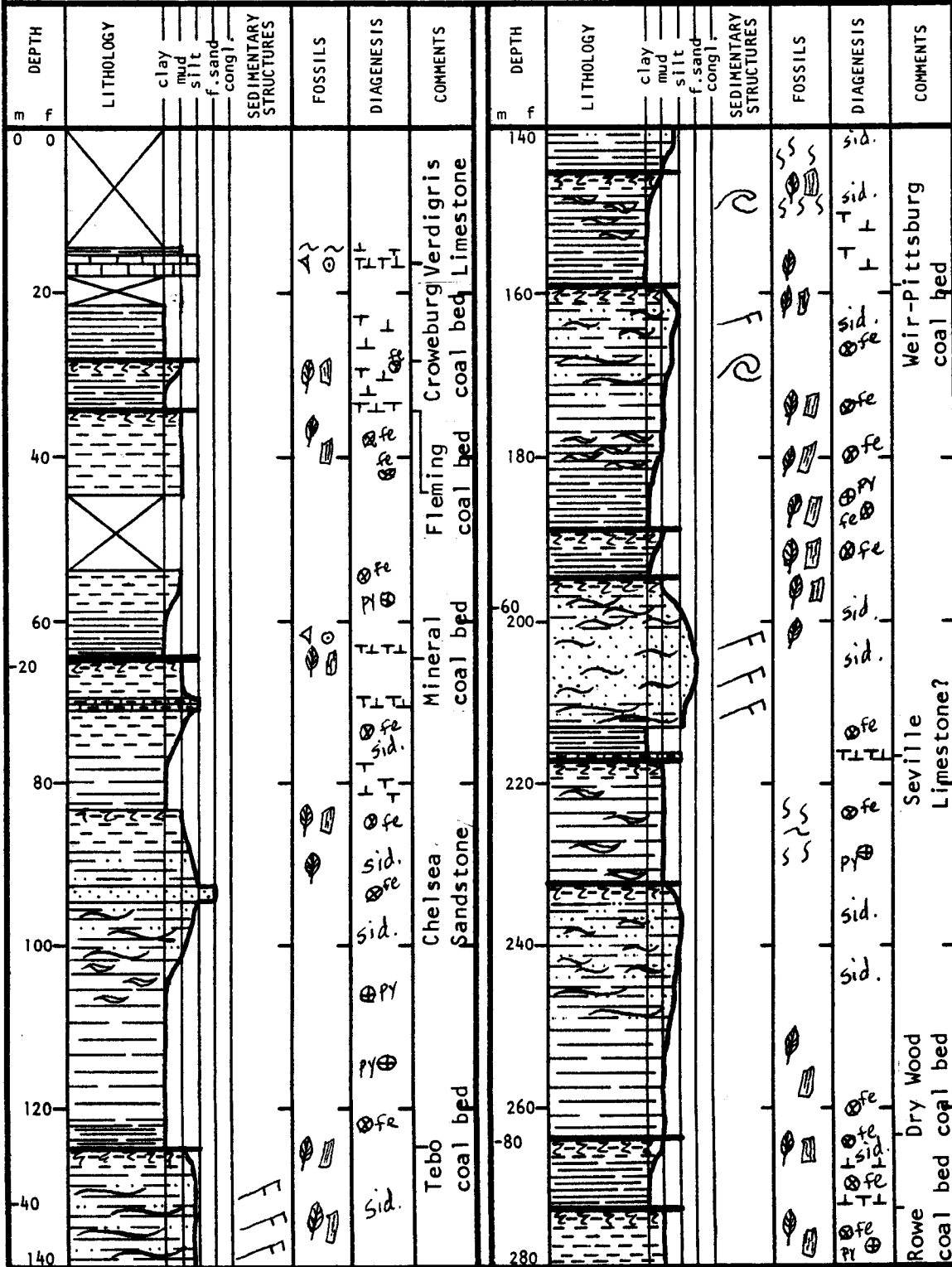
P&M #18
 SW SW SW Sec.28 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -850



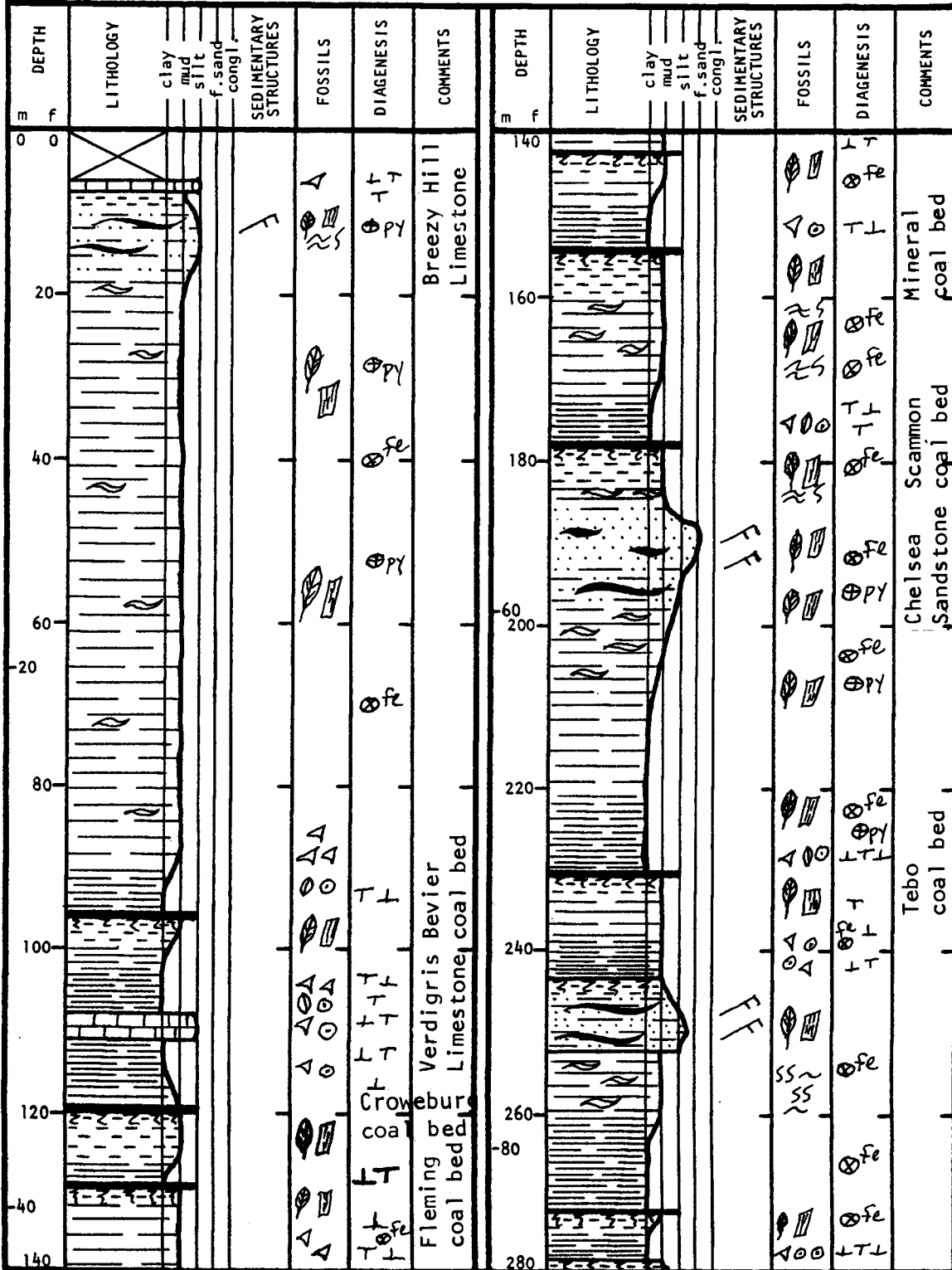
P&M #18
 SW SW SW Sec.28 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -850

DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay mud silt f. sand congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS
m	f							m	f						
280						⊗ fe fe ⊗		420							
						fe ⊗ sid.		440							
300						T ⊗ fe Fe str.									
						⊗ PY ⊗ fe T LT		460							
320						⊗ PY ⊗ fe sid.		480							
100						T ⊗ fe T ⊗ fe		500							
340						sid. ⊗ fe		520							
						T LT ⊗ fe		540							
360						T ⊗ fe T ⊗ fe		560							
						T ⊗ fe									
380						T ⊗ fe									
						⊗ fe	Riverton coal bed	160							
120						⊗ PY		540							
400						PY ⊗ ⊗ PY									
						Mississippian Limestone		560							

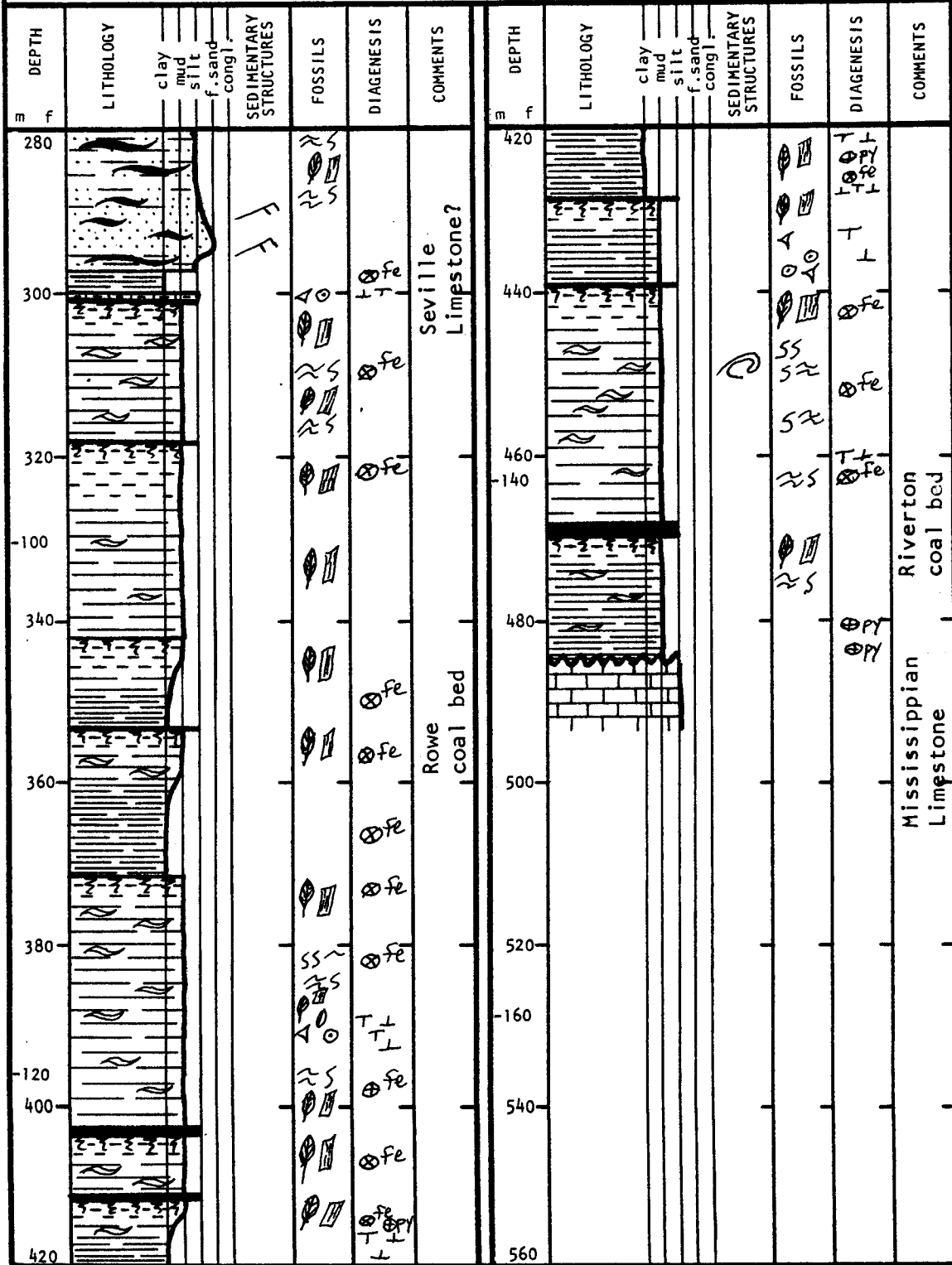
P&M #19
 SE SE SE Sec. 15 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -895

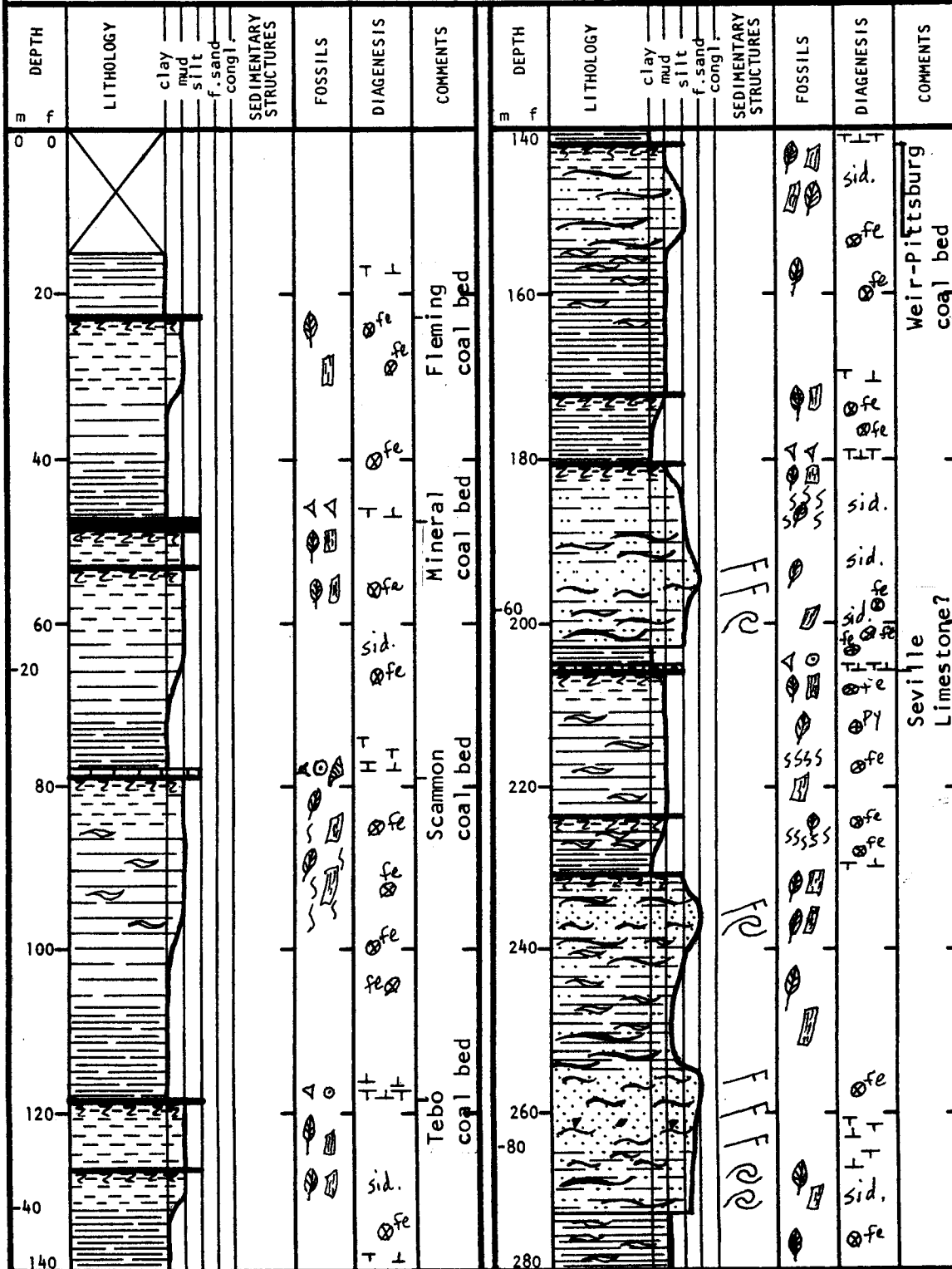


P&M #20
 SE NE NE Sec.8 T32S R22E
 Cherokee County, Kansas
 Surface Elevation -895

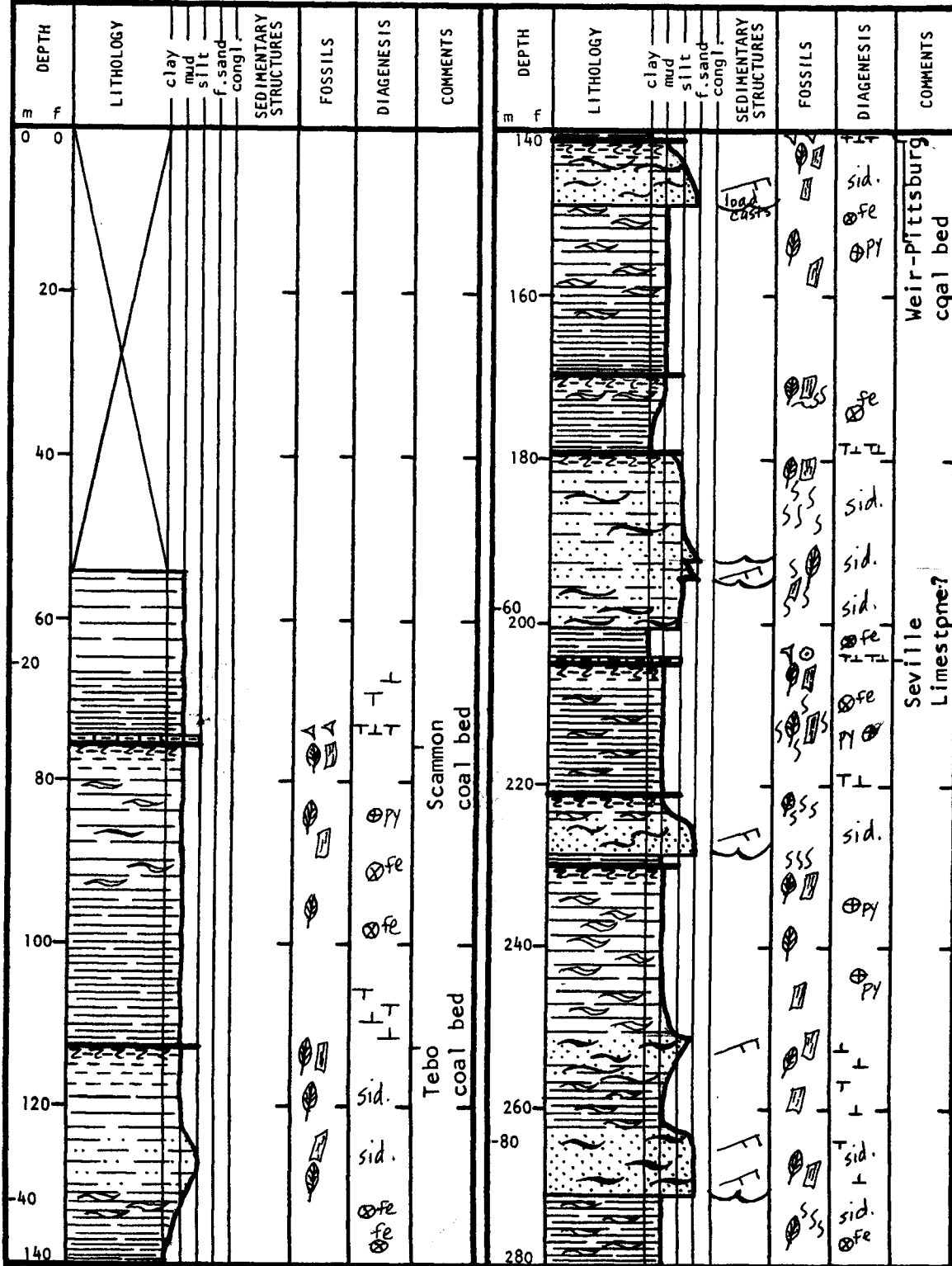


P&M #20
 SE NE NE Sec.8 T32S R22E
 Cherokee County, Kansas
 Surface Elevation-895





P&M #22
 NW NW NE Sec. 19 T32S R23E
 Cherokee County, Kansas
 Surface Elevation -890



P&M #22
 NW NW NE Sec.19 T32S R23E
 Cherokee County, Kansas
 Surface Elevation -890

DEPTH		LITHOLOGY	clay	mud	silt	f.sand	congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS	DEPTH		LITHOLOGY	clay	mud	silt	f.sand	congl.	SEDIMENTARY STRUCTURES	FOSSILS	DIAGENESIS	COMMENTS
m	f											m	f										
280									SS	sid.		420											
									SS	fe													
300									SS	fe		440											
									SS	fe													
320									SS	sid.		460											
									SS	fe		480											
100									SS	fe		500											
									SS	fe		520											
340									SS	fe		540											
									SS	fe		560											
360									SS	fe													
									SS	fe													
380									SS	py													
									SS	py													
400																							
420																							

APPENDIX B

List of control points used in this report

Name of organization or company;
well name or number; location;
county; state; type of log; source.

Abbreviations

KGS - Kansas Geological Survey
OGS - Oklahoma Geological Survey
MDNRDGLS - Missouri Department of Natural
Resources, Division of Geology
and Land Survey
OSM - Office of Surface Mining
GMRC - Gulf Mineral Resources Company
P&M - Pittsburg and Midway
GR - gamma ray
N - neutron
DL - drillers log
D - density
R - resistivity
SP - spontaneous potential
C - conductivity
S - sonic

CONTINUOUS CORES

(Graphic Descriptions of Cores from Kansas
are in Appendix A)

KANSAS --

(Described by John W. Harris)

OSM; Pittsburg Job Service Center #7; NE SE NE Sec.
30-T30S-R25E; Crawford County, Kansas; KGS.

GMRC; P&M No. 10; NW NW SW Sec. 22-T31S-R22E, Cherokee
County, Kansas; KGS.

OSM; CH-1; SW SE SW Sec. 27-T31S-R24E; Cherokee County,
Kansas, KGS.

GMRC; P&M No. 11; NE NE NE Sec. 12-T32S-R21E, Cherokee
County, Kansas; KGS.

GMRC; P&M No. 17; SW NW SE Sec. 36-T32S-R21E; Cherokee
County, Kansas; KGS.

GMRC; P&M No. 3; SE SE SE Sec. 36-T32S-R21E; Cherokee
County, Kansas; KGS.

GMRC; P&M No. 7; SW SW SE Sec. 6-T32S-R22E; Cherokee
County, Kansas; KGS.

GMRC; P&M No. 20; SE NE NE Sec. 8-T32S-R22E; Cherokee
County, Kansas; KGS.

GMRC; P&M No. 6; SE SW SE Sec. 8-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 21; NW NE NW Sec. 13-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 19; SE SE SE Sec. 15-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 14; SW SW NE Sec. 17-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 12; NW SW NE Sec. 19-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 18; SW SW SW Sec. 28-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 4; SW NW SW Sec. 29-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 5; NW NE NW Sec. 30-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 16; SW SW SE Sec. 32-T32S-R22E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 8; NE NE NE Sec. 5-T32S-R23E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 9; NW NE NE Sec. 18-T32S-R23E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 22; NW NW NE Sec. 19-T32S-R23E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 15; SE SE SE Sec. 1-T33S-R21E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 2; SE NW NW Sec. 12-T33S-R21E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 13; SW NW SW Sec. 12-T33S-R21E; Cherokee County, Kansas; KGS.

GMRC; P&M No. 1; NW NE NW Sec. 13-T33S-R21E; Cherokee County, Kansas; KGS.

MISSOURI --

(Cores described by Richard J. Gentile)

MDNRDGLS; DOE-TS-No. 26; SE SW SE Sec. 11-T37N-R32W; Vernon County, Missouri; Wells, 1979; p. 122-128.

MDNRDGLS; DOE-TS-No. 24; SW SW SE Sec. 14-T37N-R31W; Vernon County, Missouri; Wells, 1979; p. 112-117.

MDNRDGLS, DOE-TS-No. 23; NE NE NE Sec. 29-T37N-R29W; Vernon County, Missouri; Wells, 1979.

MDNRDGLS; DOE-TS-No. 21; SE SE SE Sec. 8-T35N-R32W;
Vernon County, Missouri; Wells, 1979; p. 98-101.

MDNRDGLS; DOE-TS-No. 18; NW NW NW Sec. 36-T35N-R31W;
Vernon County, Missouri; Wells, 1979; p. 86-89.

MDNRDGLS; DOE-TS-No. 20; NW SW SW Sec. 5-T34N-R32W;
Vernon County, Missouri; Wells, 1979, p. 92-97.

MDNRDGLS; DOE-TS-No. 19; NE NE SE Sec. 1-T34N-R32W;
Vernon County, Missouri; Wells, 1979; p. 89-91.

MDNRDGLS; DOE-TS-No. 38; NW NW SE Sec. 6-T33N-R33W;
Barton County, Missouri; Wells, 1979; p. 173-179.

MDNRDGLS; DOE-TS-No. 13; NW SW SW Sec. 33-T33N-R33W;
Barton County, Missouri; Wells, 1979; p. 66-71.

MDNRDGLS; DOE-TS-No. 37; SW SW SW Sec. 16-T33N-R32W;
Barton County, Missouri; Wells, 1979; p. 168-172.

MDNRDGLS; DOE-TS-No. 17; NW NW NE Sec. 2-T33N-R31W;
Barton County, Missouri; Wells, 1979; p. 83-85.

MDNRDGLS; DOE-TS-No. 36; SE SE SW Sec. 8-T33N-R31W;
Barton County, Missouri; Wells, 1979; p. 163-167.

MDNRDGLS; DOE-TS-No. 27; NW NW NW Sec. 17-T33N-R30W;
Barton County, Missouri; Wells, 1979; p. 129-132.

MDNRDGLS; DOE-TS-No. 28; SW SW SW Sec. 30-T33N-R30W;
Barton County, Missouri; Wells, 1979; p. 133-137.

MDNRDGLS; DOE-TS-No. 39; SW SW SW Sec. 14-T32N-R33W;
Barton County, Missouri; Wells, 1979; p. 180-184.

MDNRDGLS; DOE-TS-No. 14; NE NE NE Sec. 19-T32N-R32W;
Barton County, Missouri; Wells, 1979; p. 72-75.

MDNRDGLS; DOE-TS-No. 16; NE NW NW Sec. 9-T32N-R31W;
Barton County, Missouri; Wells, 1979; p. 79-82.

MDNRDGLS; DOE-TS-No. 40; NW NE NE Sec. 28-T31N-R33W;
Barton County, Missouri; Wells, 1979; p. 185-191.

MDNRDGLS; DOE-TS-No. 15; NE NE NE Sec. 5-T31N-R31W;
Barton County, Missouri; Wells, 1979; p. 76-78.

MDNRDGLS; DOE-TS-No. 22; NE NE NE Sec. 14-T31N-R31W;
Barton County, Missouri; Wells, 1979; p. 102-104.

WELL LOGS -- KANSAS

Baker and Williams; C. M. Blevins #1; SW SW NW Sec.
15-T24S-R25E; Bourbon County, Kansas; GR-N; KGS.

KGS; Test Hole O; NE NE NE Sec. 22-T24S-R25E; Bourbon
County, Kansas; DL-GR-D-R; Ebanks, James and Livingston,
1977; p. 62.

KGS; Test Hole A; SE SW SE Sec. 35-T24S-R25E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 49.

City of Fort Scott; Deep Well No. 2; NE Sec. 35-T25S-R24E; Bourbon County, Kansas; GR-N; KGS.

KGS; Test Hole B; SE SE SW Sec. 9-T25S-R25E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 50.

Dr. W. E. Walsh; Everett Wrotchford #1; SE SE SW Sec. 16-T25S-R25E; Bourbon County, Kansas; GR-N; KGS.

KGS; Test Hole Q; NE SE SW Sec. 26-T25S-R25E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 64.

KGS; Test Hole C; SW SW SW Sec. 10-T26S-R25E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 51.

Mitidete, Inc.; Johnson No. 1; NW NW NE Sec. 12-T27S-R21E; Bourbon County, Kansas; GR-N; KGS.

KGS; Test Hole KK; SW SE SW Sec. 8-T27S-R23E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 81.

KGS; Test Hole S; SW SW SE Sec. 24-T27S-R23E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 66.

KGS; Test Hole P; NW NW NW Sec. 3-T27S-R24E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 63.

Jeep Johnson; Coonrod No. 3; C N NW Sec. 14-T27S-R24E; Bourbon County, Kansas; GR-N; KGS.

KGS; Test Hole R; NE NE NE Sec. 27-T27S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 65.

KGS; Test Hole D; NW NW NW Sec. 24-T27S-R25E; Bourbon County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 52.

KGS; Test Hole 2, NE NE SE Sec. 26-T27S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 72.

Independence Energy Incorporated; Swanson #1; Sec. 36-T28S-R19E; Neosho County, Kansas; GR-N; KGS.

KGS; Test Hole II; SE SE NE Sec. 24-T28S-R22E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 79.

KGS; Test Hole Y; NE NE NE Sec. 16-T28S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 71.

KGS; Test Hole F; SW SE SE Sec. 28-T28S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 53.

KGS; Test Hole HH; SE SE SE Sec. 32-T29S-R23E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 78.

KGS; Test Hole X; NW NW NW Sec. 3-T29S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 70.

Shell Oil Company; Core Hole (Fisher) Kansas #9; NW SE NW Sec. 28-T29S-R24E; Crawford County, Kansas; SP-R; KGS.

KGS; Test Hole N; NW NE NW Sec. 34-T29S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 61.

Shell Oil Company; Test Hole (Burnick) No. 130-C; NW SE NW Sec. 4-T29S-R25E; Crawford County, Kansas; SP-R; KGS.

Shell Oil Company; Test Hole (Clemens Coal Company) No. 134-T; SW NE SW Sec. 11-T29S-R25E; Crawford County, Kansas; SP-R; KGS.

KGS; Test Hole G; NW NE NE Sec. 27-T29S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 54.

Shell Oil Company; Test Hole (L. F. Setina) No. 136-B; NW NW SE Sec. 26-T29S-R25E; Crawford County, Kansas; SP-R; KGS.

KGS; Test Hole GG; SW SW SW Sec. 32-T30S-R23E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 77.

KGS; Test Hole V; NW NW NW Sec. 8-T30S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 69.

KGS; Test Hole I; NE NE NW Sec. 33-T30S-R24E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 57.

KGS; Test Hole H; SW NW NW Sec. 11-T30S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977, p. 56.

KGS; Test Hole JJ; SE NE NW Sec. 14-T30S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 80.

KGS; Test Hole T; SW SW SW Sec. 26-T30S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 67.

Reese Ringard; Myers No. 1; C SW NE Sec. 29-T31S-R18E; Labette County, Kansas; GR-N; KGS.

USGS and KGS; Kansas Ordinance No. 1; C SW Sec. 22-T31S-R20E; Labette County, Kansas; GR-D-N; KGS.

KGS; Test Hole U; NE NE SE Sec. 15-T31S-R25E; Crawford County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 68.

KGS; Test Hole M; NW NW NE Sec. 5-T32S-R23E; Cherokee County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 60.

KGS; Test Hole AA; NW SW SW Sec. 2-T32S-R24E; Cherokee County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 73.

KGS; Test Hole L; SW SW SW Sec. 3-T33S-R23E; Cherokee County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977, p. 59.

KGS; Test Hole BB; NW SW SW Sec. 2-T33S-R24E; Cherokee County, Kansas; DL-GR-D-R; Ebanks, James and Livingston, 1977; p. 74.

Lightning Oil Company; R. M. Stewart No. 1; SE SE Sec.
26-T34S-R19E; Labette County, Kansas; GR-N; KGS.

B.R.B. Energy Resources Group; Marie Wackerle Disposal #1;
NE SE SW Sec. 36-T34S-R20E; Labette County, Kansas; GR-N;
KGS.

Overby Drilling Company; Roemiller No. 1; NE NE SW Sec.
27-T34S-R21E; Labette County, Kansas; SP-C-S; KGS.

KGS; Test Hole DD; NW NW NW Sec. 13-T34S-R22E; Cherokee
County, Kansas; DL-GR-D-R; Ebanks, James and Livingston,
1977; p. 76.

KGS; Test Hole CC; SE SE SW Sec. 3-T34S-R23E; Cherokee
County, Kansas; DL-GR-D-R; Ebanks, James and Livingston,
1977; p. 75.

Petrovest; Wackerle No. 1; NE SW NW Sec. 1-T35S-R19E;
Labette County, Kansas; GR-N; KGS.

Valentine Energy; Royse #2; NW SW NE Sec. 12-T35S-R19E;
Labette County, Kansas; GR-N; KGS.

Tenneco Oil Company; #3 Robert Swanwick; SE SW SW Sec.
2-T35S-R21E; Labette County, Kansas; GR-N; Ebanks, 1979;
Figs. 8 and 9, log #12; p. 304-305.

MISSOURI --

MDNRDGLS; DOE-TS-No. 30; SW SE SE Sec. 29-T37N-R31W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 143-145.

MDNRDGLS; DOE-TS-No. 29; SE SW SW Sec. 33-T37N-R30W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 138-142.

MDNRDGLS; DOE-TS-No. 6; SE SE SE Sec. 30-T35N-R32W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 50-52.

MDNRDGLS; DOE-TS-No. 8; SW NW SW Sec. 32-T35N-R31W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 53-54.

MDNRDGLS; DOE-TS-No. 1; NE NE SW Sec. 11-T35N-R30W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 35-36.

MDNRDGLS; DOE-TS-No. 5; SE NE SE Sec. 29-T34N-R32W;
Vernon County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 46-50.

MDNRDGLS; DOE-TS-No. 4; SW SW SW Sec. 35-T34N-R32W; Vernon
County, Missouri; DL-GR-SP-R; Wells, 1979; p. 43-45.

MDNRDGLS; DOE-TS-No. 3; NW NW SW Sec. 2-T34N-R31W; Vernon County, Missouri; DL-GR-SP-R; Wells, 1979; p. 40-42.

MDNRDGLS; DOE-TS-No. 2; SE SE NE Sec. 6-T34N-R30W; Vernon County, Missouri; DL-GR-SP-R; Wells, 1979; p. 37-39.

MDNRDGLS; DOE-TS-No. 10; NW NW NW Sec. 20-T33N-R33W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 58-61.

MDNRDGLS; DOE-TS-No. 9; NE NW NW Sec. 25-T33N-R33W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 55-57.

MDNRDGLS; DOE-TS-No. 33; NW NW NW Sec. 7-T33N-R32W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 153-155.

MDNRDGLS; DOE-TS-No. 11; SW SW NW Sec. 13-T33N-R32W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 61-63.

MDNRDGLS; DOE-TS-No. 12; NE NE NW Sec. 35-T33N-R32W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 64-66.

MDNRDGLS; DOE-TS-No. 34; SW SW SW Sec. 22-T33N R31W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 156-158.

MDNRDGLS; DOE-TS-No. 35; NW SE NW Sec. 17-T32N-R33W; Barton County, Missouri; DL-GR-SP-R; Wells, 1979; p. 159-162.

MDNRDGLS; DOE-TS-No. 32; SW SE SE Sec. 11-T31N-R33W;
Barton County, Missouri; DL-GR-SP-R; Wells, 1979;
p. 149-152.

MDNRDGLS; DOE-TS-No. 31; NE NE SE Sec. 3-T30N-R33W; Barton
County, Missouri; DL-GR-SP-R; Wells, 1979; p. 146-148.

OKLAHOMA --

OGS; Stratigraphic Test Hole 1 (OGS, Don Stewart No. 1);
C NW SW NW Sec. 13-T29N-R20E; Craig County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 32.

OGS; Stratigraphic Test Hole 2 (OGS, Charles Rickman
No. 1); SE NE SW SW SE Sec. 13-T29N-R20E; Craig County,
Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 33.

OGS; Stratigraphic Test Hole 17, (OGS, Dale Tullis No. 1);
SE SW NE NW Sec. 36-T29N-R20E; Craig County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 45.

OGS; Stratigraphic Test Hole 5; (OGS, Richard Boyd No. 1);
NW NW SW SW Sec. 13-T29N-R21E; Ottawa County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 36.

OGS; Stratigraphic Test Hole 4; (OGS, Walter Gray No. 1);
SW NE SE SW Sec. 16-T29N-R21E; Craig County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 35.

OGS; Stratigraphic Test Hole 3; (OGS, Walter Goddard No. 1); SE SE NE SE Sec. 18-T29N-R21E; Craig County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 34.

OGS; Stratigraphic Test Hole; (OGS, Gale Bachman No. 1); SE SE SW NW Sec. 23-T29N-R21E; Ottawa County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 42.

OGS; Stratigraphic Test Hole 13; (OGS, John Sullivan No. 1); NE SE SE SE Sec. 24-T29N-R21E; Ottawa County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 41.

OGS; Stratigraphic Test Hole 15; (OGS, Willard Lester No. 1); NE NW NE NW Sec. 28-T29N-R21E; Craig County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 43.

OGS; Stratigraphic Test Hole 16; (OGS, Calvin Brady No. 1); NE SW NW NW Sec. 29-T29N-R21E; Craig County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 44.

OGS; Stratigraphic Test Hole 18; (OGS, Carl Kelsey No. 1); SW SE SE NE Sec. 32-T29N-R21E; Craig County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 46.

OGS; Stratigraphic Test Hole 10; (OGS, Berl Garrett No. 1); NW SE SW SW Sec. 13-T29N-R22E; Ottawa County, Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 39.

OGS; Stratigraphic Test Hole 7; (OGS, Leo Alsbaugh No. 1);
SE SE SE SE Sec. 18-T29N-R22E; Ottawa County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 38.

OGS; Stratigraphic Test Hole 6; (OGS, Leo Alsbaugh
No. 1-A); SE SE SE SE Sec. 18-T29N-R22E; Ottawa County,
Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 37.

OGS; Stratigraphic Test Hole 11; (OGS, Berl Garrett
No. 2); NW NW NW SW Sec. 24-T29N-R22E; Ottawa County,
Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 40.

OGS; Stratigraphic Test Hole 9; (OGS, Paul Darnell No. 1);
NE NE NE NE Sec. 22-T29N-R22E; Ottawa County, Oklahoma;
DL-GR-N; Harrison and Roberts, 1979; p. 39.

OGS; Stratigraphic Test Hole 8; (OGS, M. B. Darnell
No. 1); NW NW NW NW Sec. 22-T29N-R22E; Ottawa County,
Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 38.

OGS; Stratigraphic Test Hole 12; (OGS, Clyde Bachman
No. 1); NE NE NE NE Sec. 29-T29N-R22E; Ottawa County,
Oklahoma; DL-GR-N; Harrison and Roberts, 1979; p. 40.

R. H. Operating Company; Cherokee coal #32; Sec.
5-T28N-R20E; Craig County, Oklahoma; GR-N; KGS.

R. H. Operating Company; Cherokee coal #31; C NW SW Sec.
5-T28N-R20E; Craig County, Oklahoma; GR-N; KGS.

R. H. Operating Company; Cherokee coal #27, SE SW NE Sec.
6-T28N-R20E; Craig County, Oklahoma; GR-N; KGS.

Mingo Oil and Gas Company, Incorporated; Hood No. 6;
C NW SE Sec. 19-T28N-R20E; Craig County, Oklahoma; GR-N;
KGS.

Welch Gas Copmany, Incorporated; S. R. Bradshaw #4;
SE NW SE Sec. 4-T27N-R20E; Craig County, Oklahoma; GR-D;
KGS.

Welch Gas Company, Incorporated; Winton #1; C SE SE
Sec. 16-T27N-R20E; Craig County, Oklahoma; GR-D; KGS.

Welch Gas Company, Incorporated; Collins #1,
C SE Sec. 18-T27N-R20E; Craig County, Oklahoma; GR-D; KGS.