STATE GEOLOGICAL SURVEY OF KANSAS

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Chancellor of the University, and ex officio Director of the Survey

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BULLETIN 123

STRATIGRAPHY OF PRE-MARMATON DESMOINESIAN (CHEROKEE) ROCKS IN SOUTHEASTERN KANSAS

By

WALLACE B. HOWE

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STRATIGRAPHY OF PRE-MARMATON DESMOINESIAN (CHEROKEE) ROCKS IN SOUTHEASTERN KANSAS

By Wallace B. Howe

ABSTRACT

This report presents a detailed stratigraphic study of the pre-Marmaton Desmoinesian (Cherokee) beds exposed in southeastern Kansas. The classification applied is that adopted by northern Midcontinent state geological surveys in 1953. Lithologic successions extending from the top of a given coal bed to the top of the next higher coal bed are classed as formations, the formational name given being that of the most prominent unit included. Certain portions of the Cherokee section are not amenable to such division and have received different treatment. The widespread black shale above the Mulky coal and below the basal Marmaton Blackjack Creek limestone has been termed Excello, and by itself constitutes the Excello formation. Altogether, 17 formations, aggregating 450 to 500 feet in thickness, are recognized in the pre-Marmaton Desmoinesian succession in the area. The Krebs subgroup comprises 6 of these formations, and 11 are included in the overlying Cabaniss subgroup. Establishment of the Krebs and Cabaniss subgroups, which together form the Cherokee group, follows recognition of a time-stratigraphic boundary within the succession. The Venteran Substage (including the Krebs subgroup) and the Cygnian Substage (including the Cabaniss subgroup and Marmaton group) are recognized time-stratigraphic subdivisions of the Desmoinesian Series, (Middle) Pennsylvanian System.

Rocks of five persistent lithologic types compose the typical formation within the Cherokee in southeastern Kansas. These are, in upward order: dark shale and dark, irregular limestone; gray shale; underlimestone and sandstone; underclay; and coal. Minor variations of these principal lithologies are useful in identification of individual formations. Especially important are persistent facies of the lower dark shale and irregular limestone division. Underlimestones occur principally in formations classed within the Cabaniss subgroup; they grade laterally from thin, impure, irregular to nodular-bedded limestone to evenly bedded, typically marine limestone. The horizon in each formation at which underlimestone occurs seems to be the position at which additional, possibly nonpersistent cycles of sedimentation may be found in adjacent areas.

INTRODUCTION

Rocks of Desmoinesian age occurring below the Marmaton group in southeastern Kansas are those originally included within the Cherokee group of Haworth and Kirk (1894) and are classed as early and middle Desmoinesian in age. At an interstate conference held at Nevada, Missouri, March 31 and April 1, 1953, substage divisions were adopted for the Desmoinesian Series (Middle Pennsylvanian), and two group terms were introduced to replace the term Cherokee. Cherokee is retained, however, as an informal term for designating the generally clastic succession below the Marmaton group and above the Mississippian rocks in the northern Midcontinent. This inclusive term is useful in subsurface work where differentiation of beds is not sufficiently clear to allow identification of key beds in the succession, and was re-adopted for Kansas at a meeting in Lawrence on October 17, 1955, the Krebs and Cabaniss being relegated to subgroup status.

In southeastern Kansas the Cherokee includes a maximum of approximately 500 feet of sedimentary rocks characterized principally by the presence of numerous coal beds, thin limestone beds, relatively prominent sandstone and shale beds, and mostly inconspicuous underclays.

Economic resources associated with this succession include bituminous coal, raw materials for ceramic products, and petroleum. Knowledge of the stratigraphy is important, for it serves to guide production of these economic materials and study of their reserves.

The area of exposure of the pre-Marmaton Desmoinesian rocks in southeastern Kansas is about 1,000 square miles, and includes parts of Labette, Cherokee, Crawford, and Bourbon Counties. This, however, constitutes only a small portion of the area of continuous outcrop of strata of this age in the whole northern Midcontinent region (Fig. 1).

Purpose and scope of investigation.—The present investigation has as its prime purpose the detailed description of strata below the Marmaton group and above the Mississippian System in their outcrop area in southeastern Kansas, presenting this material in orderly succession according to a classification that seems most applicable to the included strata. The system of

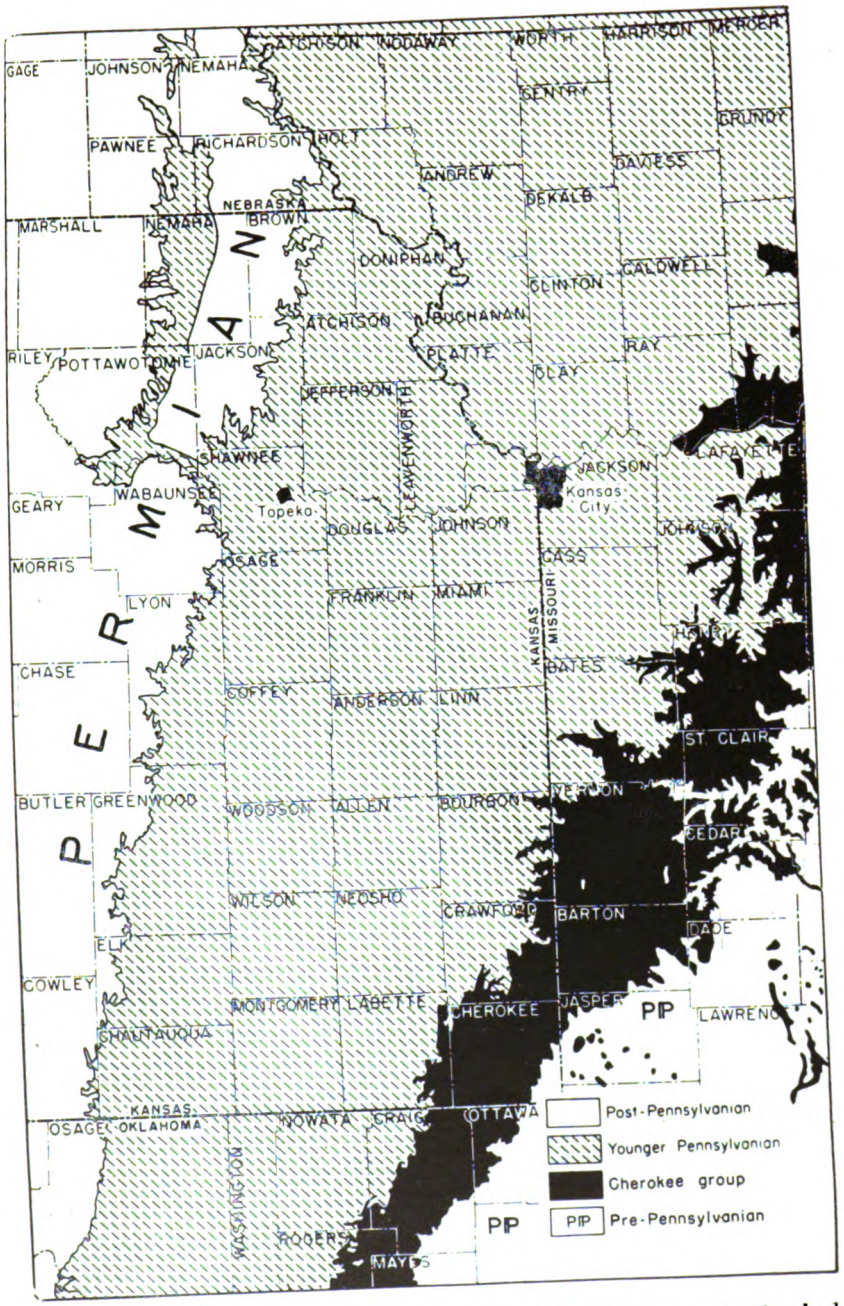


FIG. 1.—Area of outcrop (in black) of pre-Marmaton Desmoinesian beds in southeastern Kansas and adjacent areas in the northern Midcontinent region (from Moore, 1949).

classification recently adopted for these beds by several state geological surveys (Searight and others, 1953) is followed with minor modification in this report.

Area and method of study.—Information included in this report was derived principally from detailed study of exposures in the outcrop belt in southeastern Kansas. Cursory examination of portions of the succession in Missouri and in northern Oklahoma permitted determination of the lateral extent and variation of individual beds and regional correlation of major units. Secondary sources of information include numerous drill-hole records and early descriptions of outcrops that now are poorly exposed or inaccessible. Logs of coal prospect holes supply the most detailed subsurface information. Natural exposures of Cherokee strata are not abundant in the area, because of its generally low relief and presence of a widespread mantle of "gumbo clay" of Pleistocene age. They occur only along major streams and in areas of local relief, such as the Timbered Hills region in southern Cherokee County. Most stratigraphic sections used in preparing this report were described from artificial exposures made in strip-mining operations. Most of these open pits expose 20 to 30 feet, but a few reveal as much as 60 feet of strata. They are ideal for detailed study even though only parts of the succession in which strippable coals occur can be seen in the walls of the pits. Principally exposed are the Weir-Pittsburg coal and overlying beds, constituting approximately the upper one-half of the complete succession. Several sinkholes in the southeastern part of the area permit study of the basal Desmoinesian strata and show the contact with underlying Mississippian rocks.

Correlation charts (Pl. 1 and Fig. 2, 3, and 4), compiled from described sections in the area, illustrate lateral variation in lithology and thickness of the succession. An appendix contains representative stratigraphic sections. Plate 2 illustrates the stratigraphic distribution of common fossils in Krebs and Cabaniss subgroups of the Cherokee group.

Acknowledgments.—The present report was begun and completed under the auspices of the State Geological Survey of Kansas, and is a slightly modified form of a dissertation submitted as a partial requirement for the degree of Doctor of Phil-

osophy at the University of Kansas. Field work was done in the summer field seasons of 1948, 1949, and 1950.

I am much indebted to officials of the Missouri Geological Survey for aid and consultation on geologic problems and for arrangements making it possible to complete writing of this report while in the employ of that organization.

Various members of the Oklahoma Geological Survey have given assistance in the solution of geologic problems in which both Kansas and Oklahoma areas are involved.

It is a pleasure to acknowledge the cooperation of mine operators and landowners within the area. In no case have they refused entry to mines or other property, and have given freely any information requested.

PREVIOUS WORK

Reports that are judged to be of major importance in connection with study of the pre-Marmaton Desmoinesian beds (Cherokee) in southeastern Kansas and adjacent areas are briefly noted in the following paragraphs.

The work of Broadhead (1873-74) in western Missouri counties adjacent to the southeastern Kansas area seemingly contains the first detailed descriptions of the Cherokee succession in the western Missouri—eastern Kansas area. Although Broadhead's work was done in Missouri, his geologic sections in Vernon, Bates, and Barton Counties were very useful for later work on strata of equivalent age in southeastern Kansas.

Descriptions of pre-Marmaton Pennsylvanian beds in western Missouri are given also by Winslow (1891).

Earliest specific reference to the southeastern Kansas beds now called the Cherokee group was made by Haworth and Kirk (1894, p. 104-115), who first named and defined the succession as the "Cherokee shales".

Two years later, Haworth and others (1896) published additional information relative to the stratigraphy of these deposits. This included several geologic cross sections (by Bennett, Adams, Kirk, and Haworth) transverse to the outcrop belt, as well as a résumé of the stratigraphy of the "Cherokee shales" (by Haworth), and a preliminary catalog of Kansas Carboniferous fossils (by Bennett).

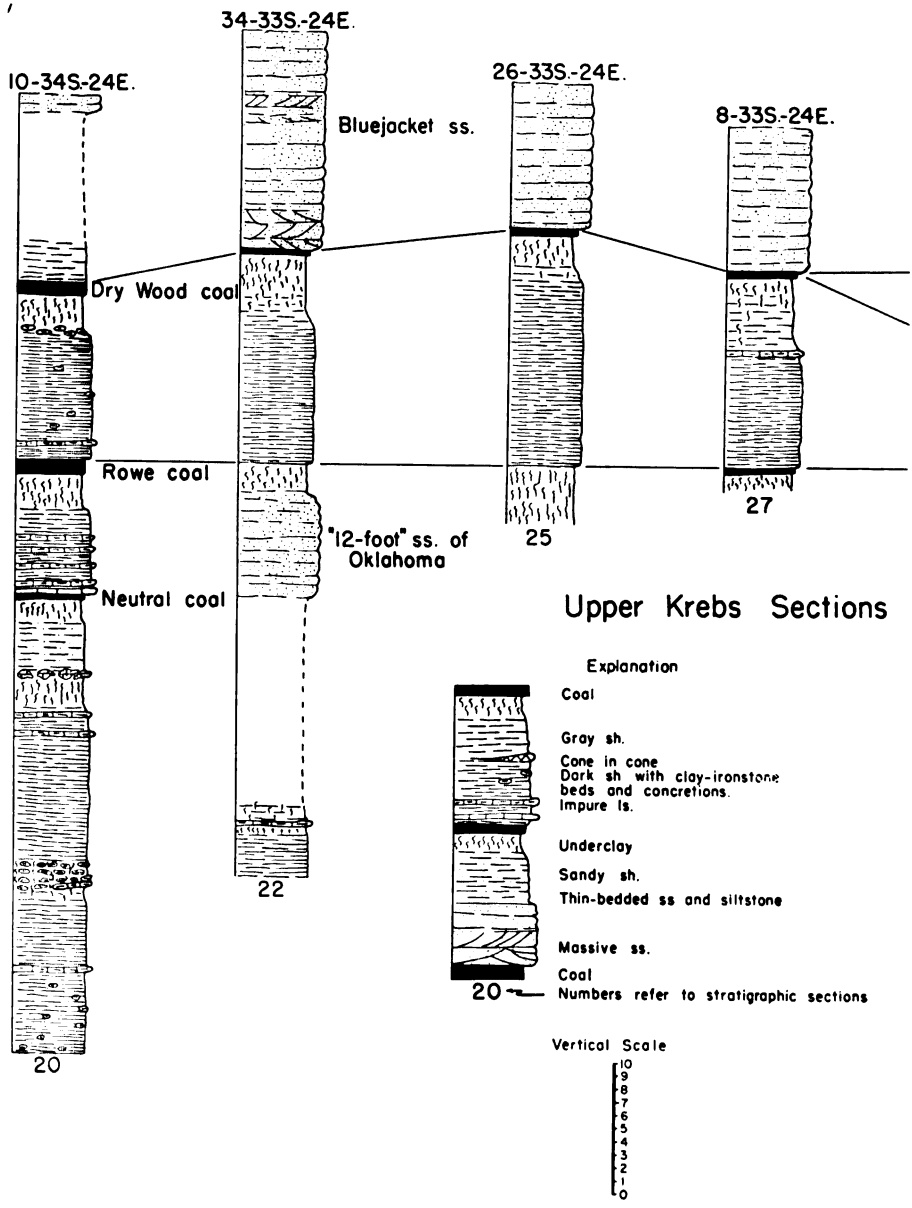
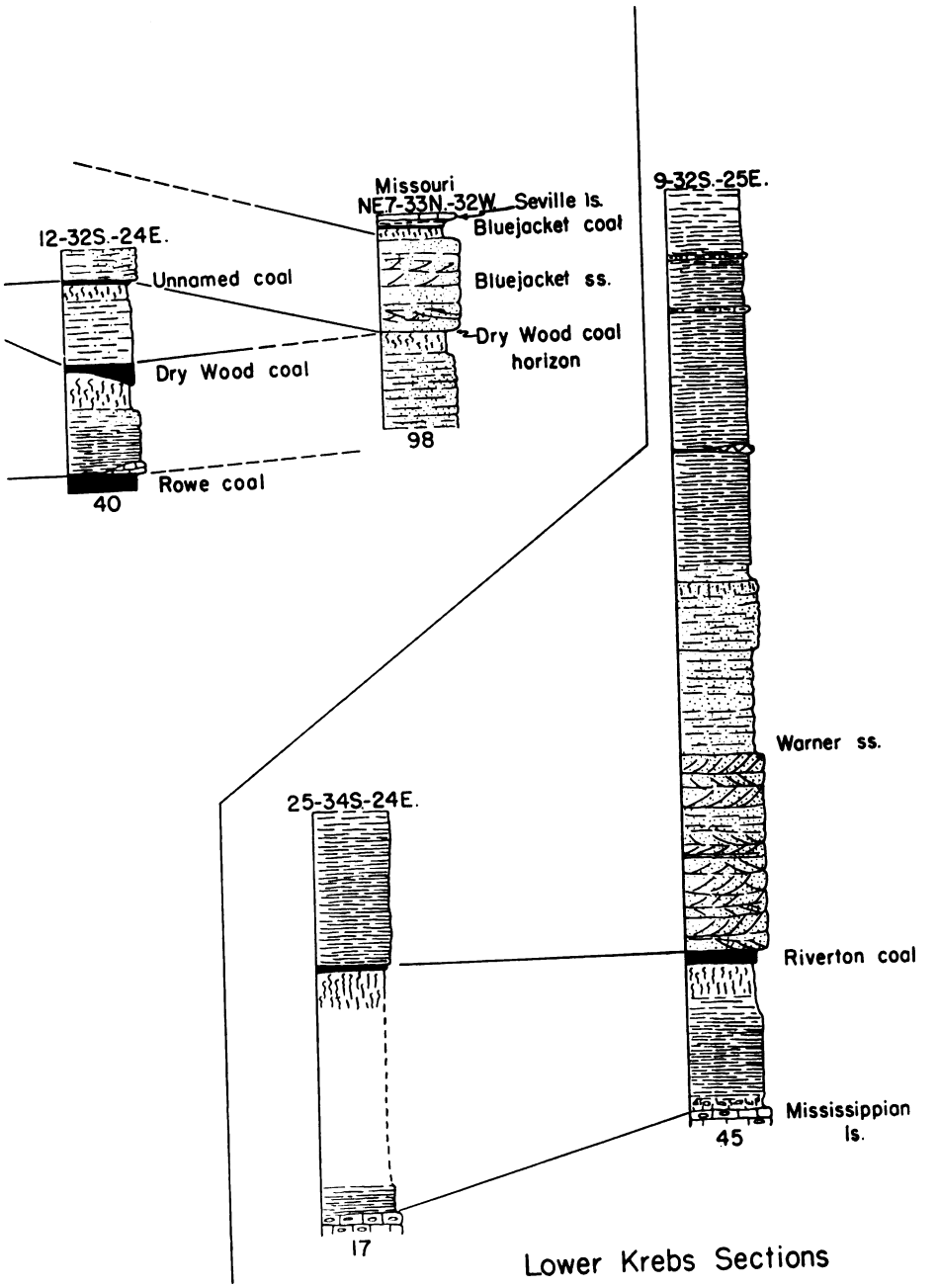


FIG. 2.—Detailed sections of Krebs beds



in southeastern Kansas and western Missouri.

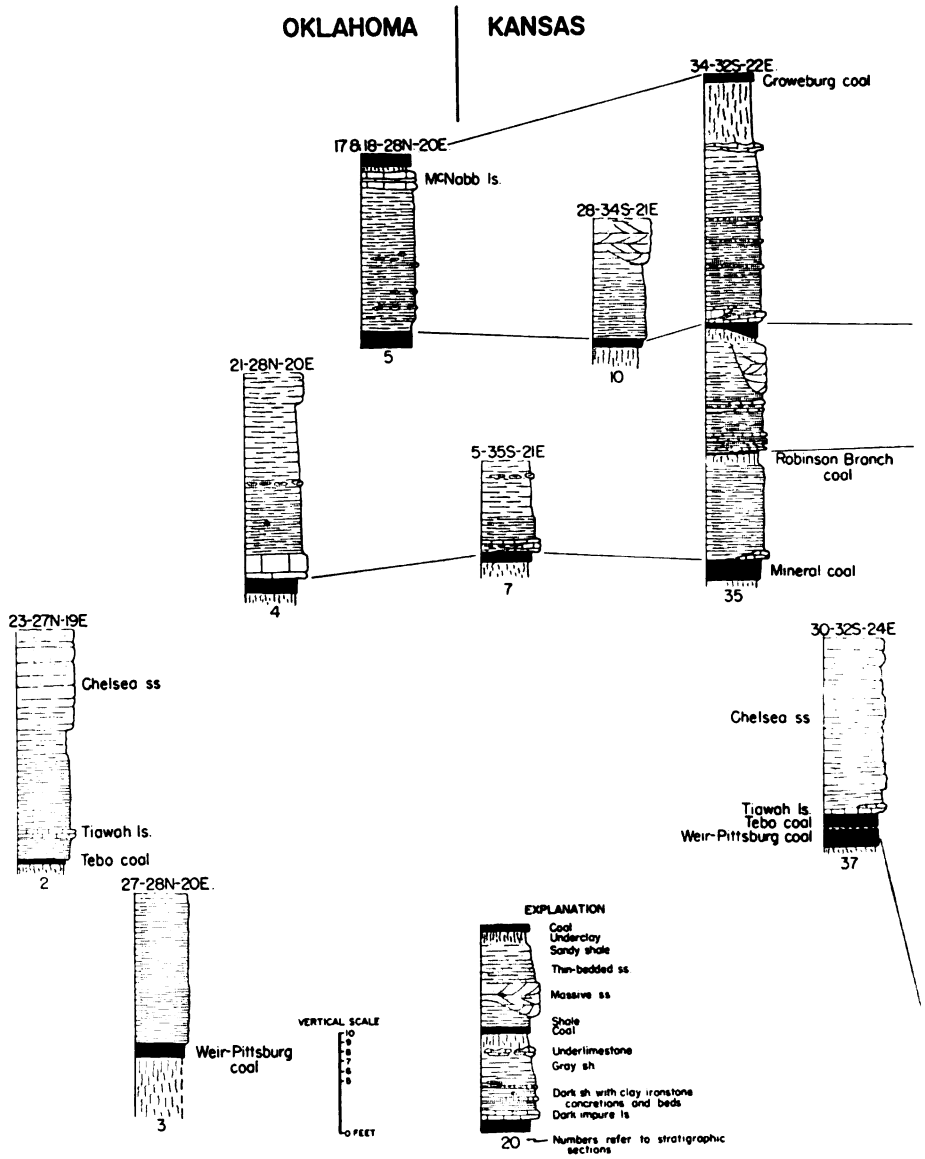
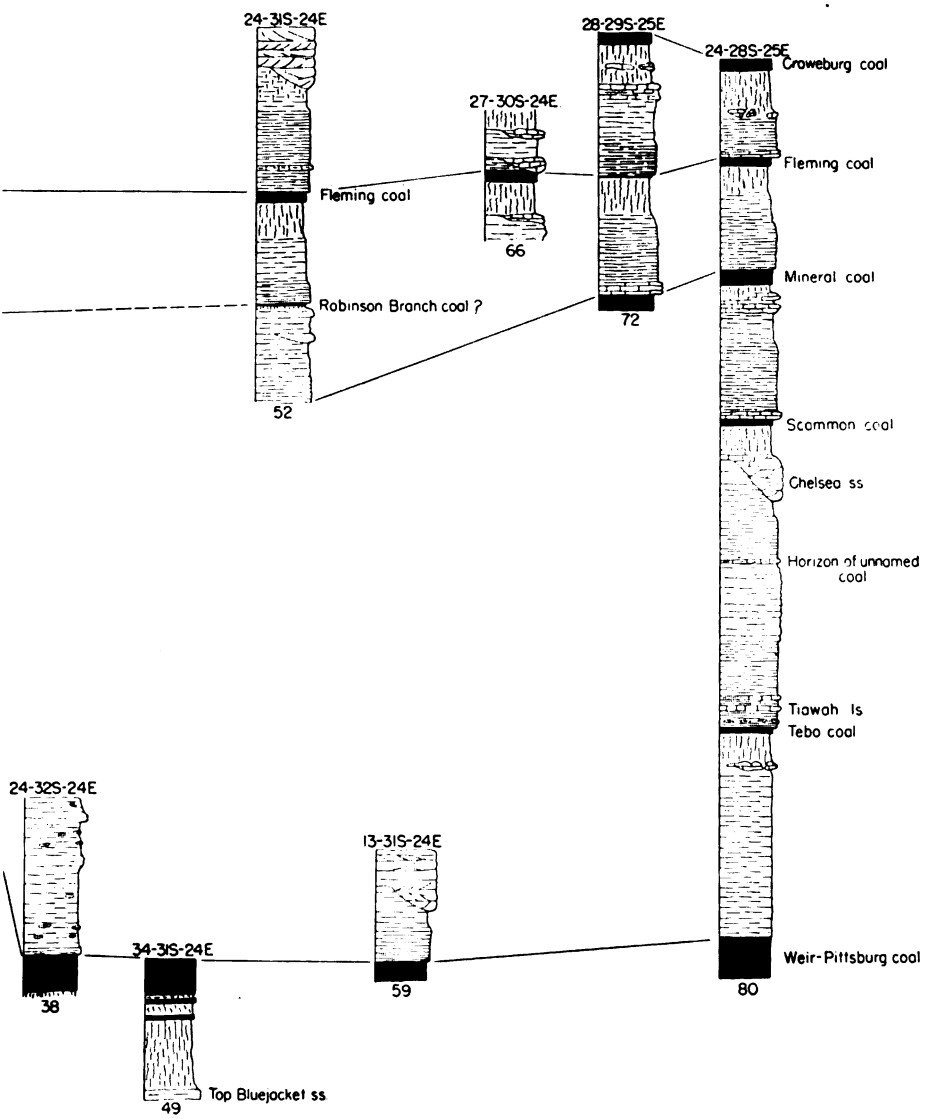


FIG. 3.—Detailed sections of Lower Cabaniss beds



in northern Oklahoma and southeastern Kansas.

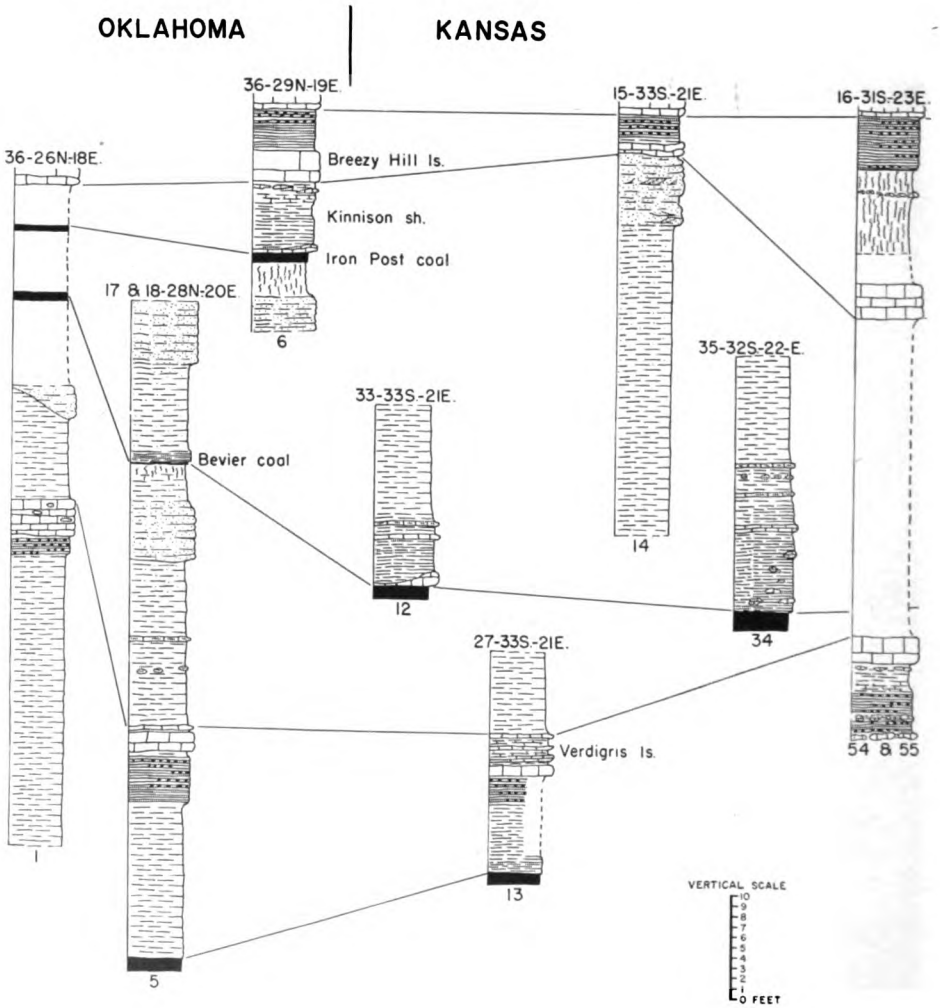
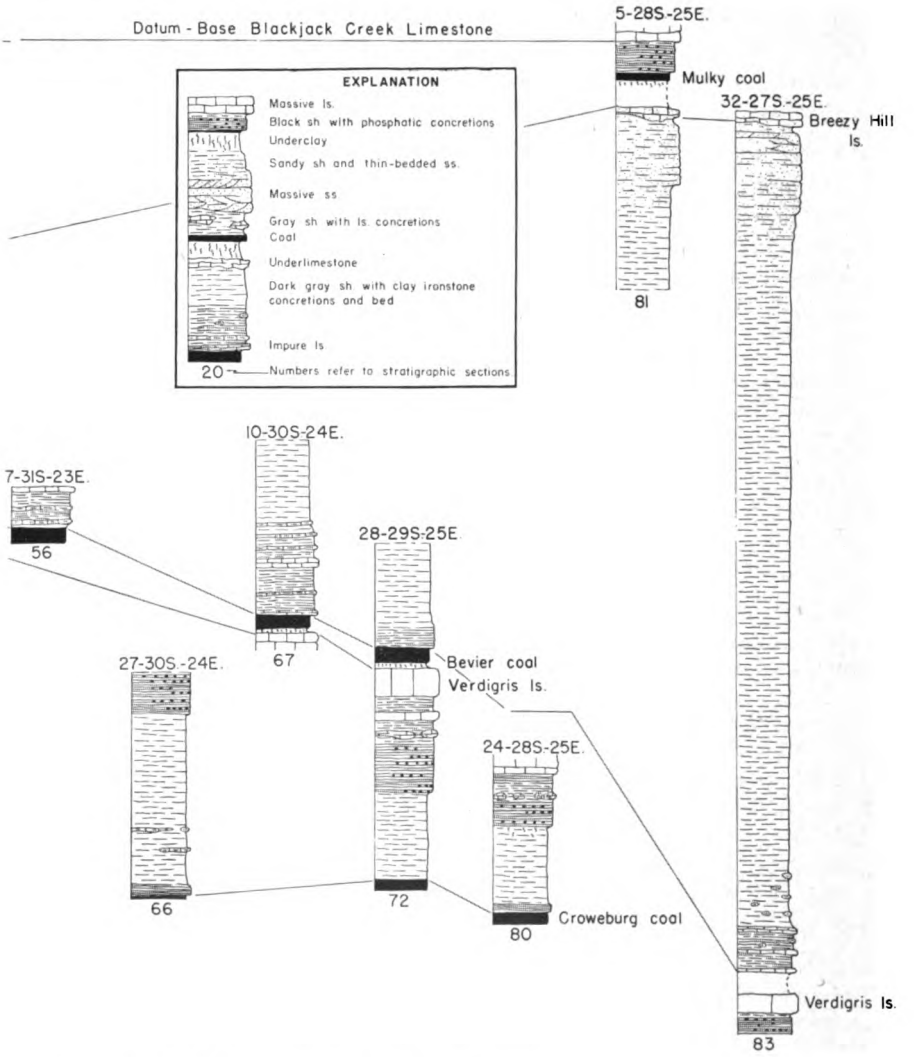


FIG. 4.—Detailed sections of Upper Cabiness beds



in northern Oklahoma and southeastern Kansas.

The first comprehensive report on the stratigraphy of these beds in southeastern Kansas was presented by Haworth and Crane (1898, p. 21-30).

A second report on Carboniferous fossils in Kansas was prepared by Beede (1900), who described and illustrated many invertebrates characteristic of these strata, but gave few definite records of their occurrence.

Haworth and others (1908) again summarized the stratigraphy of the Cherokee beds. Included in this report are chapters on Coal-Measures faunas (Beede and Rogers) and floras (Sellards). Animal remains of Cherokee age listed were collected from relatively few localities and beds. The fossil plants came principally from deep mines at Lansing, Leavenworth County, Kansas.

Hinds (1912) published a comprehensive county-by-county study of coal beds of Missouri, including information on stratigraphic and geographic occurrence, and statement of computed reserves of Missouri coal. Numerous detailed sections of the coals and associated strata are included. This report was followed by Hinds and Greene's comprehensive report (1915) on the Pennsylvanian stratigraphy of Missouri; these two reports have constituted standard references for detailed information on Missouri Pennsylvanian deposits.

Ohern (1914) made an important contribution to the general knowledge of the Midcontinent Cherokee in issuing one of the first reports of detailed studies of these strata to be made in northeastern Oklahoma. He named several early Desmoinesian rock units and was the first to note the marked southward thickening of these strata. He was the first to correlate the limestone later called Verdigris in Oklahoma with its equivalent in Kansas and Missouri.

A report on Vernon County, Missouri, by Greene and Pond (1926) is a detailed study of the geology of an area adjacent to that of the present investigation.

Young (1925) outlined the general stratigraphic occurrence of the principal coal beds mined from this succession in southeastern Kansas, and discussed coal-mining practices in the area at the time, with special attention to strip-mining, as his report was primarily economic.

Cooper (1927) summarized information on strata equivalent to the Cherokee lying north and south of Arkansas River in northeastern Oklahoma, discussed correlation with rocks described in Kansas, and called attention to the north-south facies variation developed within the succession.

Weidman (1932) studied the southward extent of the Little Cabin (Warner) sandstone in Oklahoma and described a thin limestone found below the Bluejacket sandstone.

Abernathy (1936), in a doctoral dissertation prepared under direction of the Department of Geology and Geological Survey of the University of Kansas, reviewed the Cherokee successsion in southeastern Kansas and developed a classification based on concepts of cyclical sedimentation as developed by Weller (1930a, 1930b), Wanless and Weller (1932), and Moore (1936).

The most important report on the sub-Marmaton Pennsylvanian section of southeastern Kansas is that of Pierce and Courtier (1937). Their study included description of the stratigraphy of the succession in the area of outcrop in Kansas. An excellent geologic map accompanies the report. Numerous collections of invertebrates from the Pennsylvanian in southeastern Kansas are recorded in a separate section prepared by James S. Williams.

Newell (in Wilson and Newell, 1937), in a report on the geology of the Muskogee-Porum district of east-central Oklahoma, discussed southward equivalents of the lower portion of the succession, and more importantly, the northward overlap of Morrowan rocks by Desmoinesian beds.

Information organized by Oakes (1944) in a study of the Broken Arrow coal in northeastern Oklahoma is of importance inasmuch as it describes the succession from the Chelsea sandstone to the base of the Fort Scott formation, basal Marmaton, in Rogers, Wagoner, and Tulsa Counties. In this report Oakes correlated the Broken Arrow coal of Oklahoma with the Croweburg coal of Kansas.

The work of Renfro (1947) is a northward extension of that by Wilson and Newell (1937) and covers the Vinita-Wagoner district in eastern Oklahoma.

Howe (1951) redefined the Bluejacket sandstone and noted correlation of several southeastern Kansas coals with equivalents in northeastern Oklahoma; also he described the

section between the "Squirrel" sandstone and Breezy Hill limestone in northeastern Oklahoma, proposing names for the included coal and shale units.

Officials of the Kansas, Missouri, Oklahoma, Nebraska, and Iowa Geological Surveys held a conference at Nevada, Missouri, on March 31 and April 1, 1953, for the purpose of discussing problems of classifying the pre-Marmaton Desmoinesian rocks in the northern Midcontinent. A short report by Searight and others (1953) outlined conclusions reached at this meeting. Recently published guidebooks for field trips in western Missouri (Searight, 1955) and northeastern Oklahoma (Branson, 1954) Desmoinesian strata utilize this classification and contain much detailed information on the stratigraphy of the Cherokee rocks.

CLASSIFICATION

Major Divisions

The beds extending from the Mississippian System to the base of the Fort Scott formation (basal Marmaton group) in southeastern Kansas were originally designated the "Cherokee shales" by Haworth and Kirk (1894, p. 105-106). Since the definition of this succession, later called the Cherokee group (Moore, 1949), its original boundaries have been accepted consistently in geologic literature. Various beds have been widely traced, and stratigraphic boundaries corresponding to those of the Cherokee as originally defined have been established for many years in areas to the south where these strata rest on older Pennsylvanian beds rather than rocks of Mississippian age. Extensive study of pre-Marmaton beds of Desmoinesian age in the northern Midcontinent by Walter V. Searight, of the Missouri Geological Survey, has led to recognition of a significant time-stratigraphic break within the Cherokee. The Seville limestone and lower beds contain the brachiopods *Marginifera missouriensis, Spirifer rockymontanus, S. occidentalis,* and striated forms of *Mesolobus*, whereas stratigraphically higher Desmoinesian strata are characterized by the presence of *Marginifera muricatina* and smooth forms of *Mesolobus.* In addition, recent work in east-central Oklahoma (Oakes, 1953) indicates that important diastrophism is approximately contemporaneous with the faunal change noted in areas to the north. At the Nevada

conference (Searight and others, 1953) the Venteran and Cygnian Substages were adopted as time-stratigraphic divisions of the Desmoinesian Series (upper Middle Pennsylvanian). The Venteran Substage includes rocks extending from the top of the Atoka formation upward to the top of the Seville limestone. The Cygnian Substage extends from the top of the Seville limestone to the base of the Missourian Series (base of Pleasanton group). Two new group names, Krebs and Cabaniss (Oakes, 1953), were adopted to replace the term Cherokee. In view of the undesirability of discarding the extremely useful and convenient term Cherokee, it was re-adopted and the Krebs and Cabaniss were relegated to subgroup status at a meeting in Lawrence on October 17, 1955. The Krebs subgroup includes all rocks of the Venteran Substage, and the term Cabaniss is applied to post-Venteran Cherokee strata. The Cabaniss subgroup and Marmaton group together constitute the Cygnian Substage.

At the Nevada conference, Searight also proposed division of the Krebs and Cabaniss subgroups into formations, each of which is composed of the deposits extending from the top of a specified coal bed to the top of the next higher coal bed, except in a few special cases. This proposal was accepted for the northern Midcontinent region but not for the area of thick basin-type sediments in southeastern Oklahoma, where such division was judged undesirable. Formations are named after the unit judged to be most prominent in the formation, regardless of lithology.

The classification, as adopted at the Nevada conference and later modified, is illustrated by Figure 5. Stratigraphic divisions of less than formation rank are informally regarded as members, and are described individually.

Subdivisions of Formations

The formations extending from the top of a given coal bed to the top of the next higher coal bed are judged to be cyclic successions. Each is made up of several lithologic units. Five of these are common to most Cherokee formations, and include, from the base upward: dark shale and dark irregular limestone, gray shale, underlimestone and sandstone, underclay, and coal. Each of these types of rock, although subject to minor variation, oc-

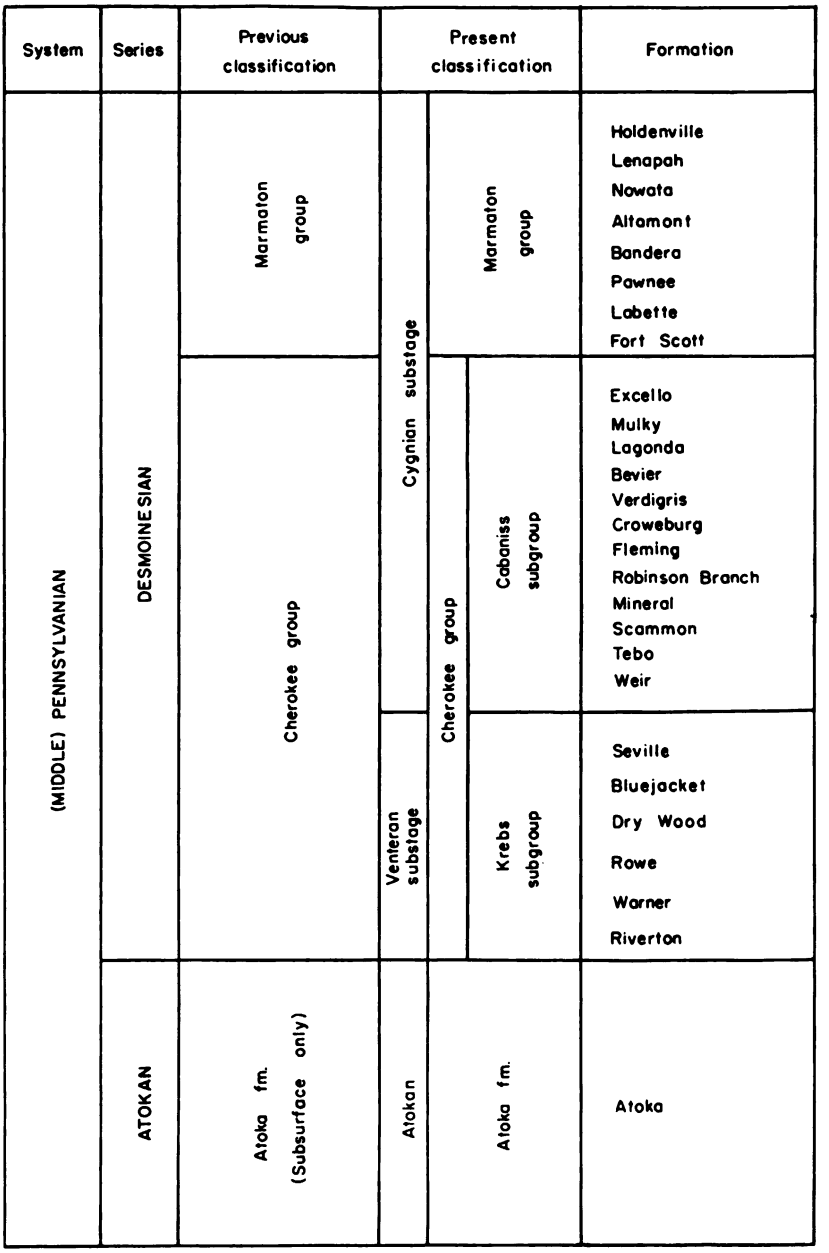


FIG. 5.—Classification of Middle Pennsylvanian beds in the northern Midcontinent.

curs constantly in the same relative position in the several successive formations, and is informally regarded as of member rank. Field evidence indicates that nearly all other sorts of rock encountered are products of facies variation of those regarded as basic. The descriptions of lithology apply fully only to beds included in the Cabaniss subgroup. Specific differences or complete absence of some of these in the underlying Krebs subgroup are noted in the following brief discussion of the five major lithologic subdivisions of coal-measure formations.

Dark shale and dark, irregular limestone.—Coal beds in the Krebs and Cabaniss subgroups are characteristically overlain by dark shale or limestone or both. In the Krebs subgroup, although dark shale lies on the coal beds, it is associated with beds of clay-ironstone more commonly than with limestone, such as occurs generally at this position in the overlying Cabaniss subgroup. Phosphatic nodules in platy black fissile shale, common in the Cabaniss subgroup, are not known in the Krebs subgroup. Evidence of a minimum of water circulation is the abundance of the iron sulfide minerals, pyrite and marcasite, and the presence of soft to fissile, thinly laminated, dark-gray to black, carbonaceous, calcareous, or phosphatic shales. Marine fossils of several kinds are common in the lower part of most Cherokee formations (Pl. 2). It is apparent that the presence of different kinds of fossils is controlled chiefly by slight variations in environment. Dark calcareous shale may be seen to grade laterally into dark impure limestone. Spirifers, productids, chonetids, and simple corals are normally the most abundant forms in the dark calcareous shales and limestones. Orbiculoids are the most common forms in phosphatic shales. At some places the dark shales overlying coal beds contain so much finely disseminated carbonaceous material that they are best described as carbonaceous shales. The three major types of dark shale (calcareous shale grading to limestone, carbonaceous shale, and phosphatic shale) suggest appreciable differences in depth and probably circulation of water by currents, but all seem to be variants of a lagoonal or near-shore environment, differing from that of coal only by presence of sea water having moderate depth. Clay-ironstone in layers and concretions is exceedingly common in this lithologic subdivision and also occurs in the lighter-col-

ored superjacent shales. It is more prominently developed in the Krebs than in the Cabaniss subgroup.

Gray shale.—Generally unfossiliferous, evenly bedded gray shale, which overlies dark shale and impure limestone, commonly forms the thickest lithologic unit in the formations. This shale seemingly would result from relatively rapid subsidence and concurrent deposition of silty muds in shallow marine water.

Underlimestones and sandstones.—Either sandstone or impure nodular limestone characteristically overlies the evenly bedded, relatively thick shales just described, and lies below underclay associated with the coal above. The underlimestones, seemingly formed in very shallow lagoonal waters, are rare in Missouri, but become relatively common, especially in the Cabaniss subgroup, in Kansas and northern Oklahoma. They are regarded as marine because some have been found to contain marine fossils.

Sandstone at this position ranges from massive to shaly or thin bedded; most of it is fine grained, lenticular, and grades laterally into impure sandy limestone, which is a facies of the impure limestones called underlimestones. Underlimestones are in some places brecciated or conglomeratic, suggesting wave or current action. The good to excellent sorting of sand grains and the presence of marine fossils at a few localities, together are evidence of a marine environment of deposition of the sandstone. Underlimestones and sandstones are the most variable of the lithologic divisions. It is judged that the most likely point of introduction of nonpersistent cycles of deposition is below this unit and above the thick shale unit in a given cycle. It is noted that the Iron Post coal and overlying Kinnison shale, present in northern Oklahoma below the Breezy Hill limestone, are unknown farther north and east in Kansas and Missouri, where the Breezy Hill is much less regular and in general closely resembles underlimestones developed below underclays in other Cabaniss formations. Changes in lithology and stratigraphic relations of the Breezy Hill limestone from Oklahoma northeastward across southeastern Kansas are illustrated by Figure 6. Some, and perhaps all, underlimestones grade laterally from very impure, nodular, seemingly unfossiliferous rock to more even, less impure, abundantly fossiliferous limestone, as does

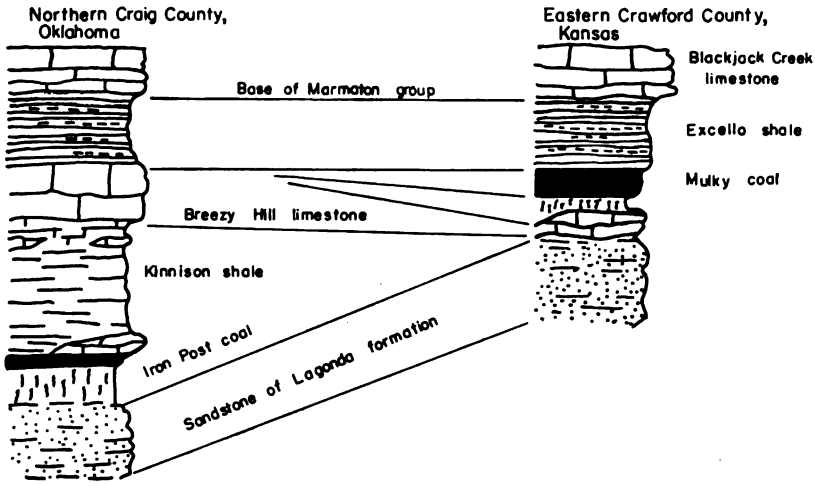


FIG. 6.—Diagram showing southward change in Breezy Hill limestone, and introduction of additional beds between sandstone of Lagonda formation and Breezy Hill limestone in northern Oklahoma.

the Breezy Hill. A second example of lateral gradation of this sort is found in the underlimestone of the Croweburg coal, which is represented in northern Oklahoma by the McNabb limestone.

Underclay.—Underclay is a characteristic associate of coal, and is one of the least variable lithologic types. This material, which is relatively even in thickness, commonly is somewhat silty and may be slightly calcareous. Carbonized plant material and fossil root impressions are present in most exposures. Slickensides are very common. Underclays in this region locally contain portions of fossil root systems, including stigmaria and attached rootlets, but whether or not underclays represent a true soil in which the plants form an entire coal bed is unknown. Nearly all such clays express the lithology of the underlying bed to a greater or lesser degree. Most beds of underclay next above sandstones are sandy or silty, and the upper surface of the subjacent sand may be unevenly leached and contain root markings in vertical position. Few, if any, of the underclays of this region are of fire-clay quality.

Coal.—Coal is economically the most important rock in these strata. Lateral extent, thickness, and quality are variable. Many

coal beds in this region are remarkably persistent throughout the area of this report.

The Croweburg-Verdigris relationship.—An outstanding exception to the generalization in the preceding paragraphs is the Verdigris formation, which includes beds from the top of the Croweburg coal to the top of the Wheeler coal, where the succession is fully developed. The prominent and extremely widespread Verdigris (Ardmore) limestone, for which the formation was named, is probably not nearly so closely related to the Croweburg coal as the adopted classification implies. The Verdigris limestone and underlying black slaty shale find their closest lithologic counterpart in rocks within the lower part of the Marmaton group. They correspond very closely to the Blackjack Creek limestone and underlying black shale, or to the Myrick Station limestone and subjacent shale. It is here suggested that further study of this succession, possibly in the subsurface, will result in the discovery of an additional coal bed below the black shale associated with the Verdigris, and above the gray clay shale overlying the Croweburg coal.

STRATIGRAPHY

Desmoinesian Series—Cherokee Group

Venteran Substage—Krebs Subgroup

The Krebs subgroup (Oakes, 1953) includes the Hartshorne sandstone and the McAlester, Savanna, and Boggy formations in the type area in southeastern Oklahoma. Thus, the division extends from the base of the Hartshorne sandstone upward to the top of the Seville (Inola) limestone. The above-named units are terms applied to the thick basin deposits of Venteran age by Oklahoma geologists, and their stratigraphic boundaries do not coincide with those of formational rank in areas to the north, which may be regarded as shelf areas. The Hartshorne sandstone is not recognized in northern Oklahoma, southeastern Kansas, or Missouri. The Krebs thins northward to only a fraction of its thickness in the basin, but except for the Hartshorne sandstone is regarded as being completely represented in southeastern Kansas. The southward thickening of Cherokee rocks in Oklahoma is illustrated by Figure 7.

Throughout the region the Krebs subgroup is characteristically much more clastic than the overlying Cabaniss and Marma-

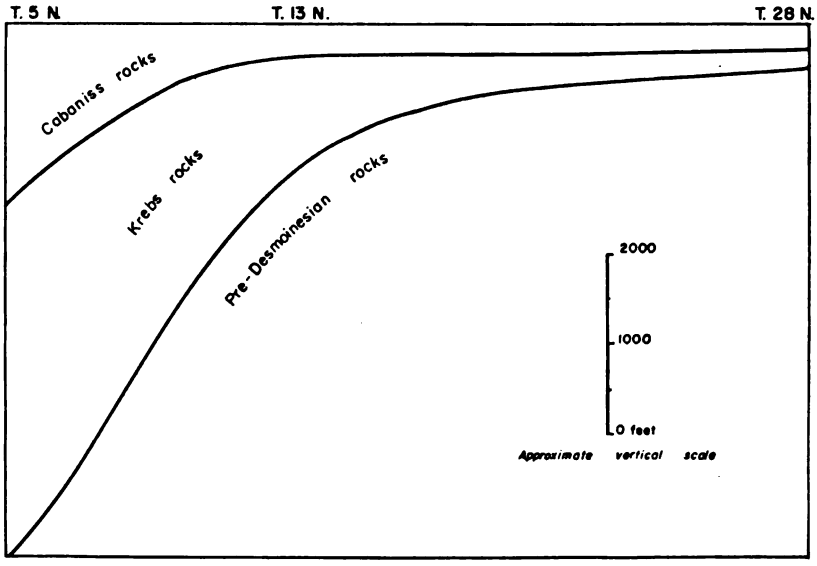


FIG. 7.—Diagram illustrating southward thickening of pre-Marmaton Desmoinesian rocks from shelf area in northern Oklahoma to McAlester basin. (Modified from unpublished chart prepared by R. H. Dott, 1951.)

ton. The Krebs succession includes much less limestone, but in general clay-ironstone is abundant in dark shaly portions.

In the outcrop area in southeastern Kansas, the Krebs includes only three coal beds (Riverton, Rowe, and Dry Wood) that are of minable thickness. Two prominent sandstones are present. The Seville limestone and the underlying thin coal (Bluejacket) are absent in most places; accordingly, for practical purposes, the top of the Bluejacket sandstone may be regarded as the upper boundary of the group (Pl. 1).

Exposures showing the succession between the Bluejacket sandstone and the base of the subgroup are uncommon, except where coals in the upper part of the group have been mined and associated strata are uncovered. The Warner sandstone and lower beds locally may be seen along streams and in sinkholes. Accordingly, it is not possible to describe the Krebs in as much detail as the overlying Cabaniss subgroup.

Searight and others (1953) defined the following Krebs formations: Riverton (beds above rocks of Mississippian or pre-Desmoinesian Pennsylvanian age and below the top of the Riv-

erton coal); Warner (beds above the Riverton coal, including the prominent Warner standstone, and extending upwards to the top of the Neutral coal); Rowe (beds above the Neutral coal and below the top of the Rowe coal); Dry Wood (beds above the Rowe coal and including the Dry Wood coal at the top); Bluejacket (beds above the Dry Wood coal, including the Bluejacket sandstone, and extending upwards to the Seville limestone); and the Seville (including only the Seville limestone).

The Bluejacket formation includes at least one coal bed above the Dry Wood coal and below the Bluejacket sandstone. Coal in this sequence is extremely erratic in its distribution, and no single coal horizon* can be traced in western Missouri or in southeastern Kansas. Accordingly, no name has been applied to such coal or coals, and they are included within the Bluejacket formation. A well-defined coal horizon lies just above the Warner sandstone and probably is to be correlated with an unnamed coal at this position (Wilson and Newell, 1937, p. 37-39) in eastern Oklahoma. The average thickness of the Krebs in the outcrop area in southeastern Kansas is between 200 and 250 feet. The subgroup is somewhat thinner in western Missouri, but thickens southward in northeastern Oklahoma, increasing tremendously south of T. 13 N., toward the McAlester basin. In the vicinity of McAlester, Oklahoma, this succession is reported to be more than 10,000 feet thick (Wilson and Newell, 1937, p. 19). The Krebs comprises about half of the pre-Marmaton Desmoinesian section in southeast Kansas, but it becomes so thick toward the south that it represents about 75 per cent of this section in the McAlester basin (Fig. 7).

Because of the complexity of the stratigraphy and nomenclature of the sub-Bluejacket coal beds in Kansas and Missouri, Walter V. Searight, of the Missouri Geological Survey, and the writer have worked in close cooperation in an attempt to avoid addition of unnecessary names in this succession. The coal beds are exceptionally variable, and many names have been applied to them, both in Kansas and in Missouri. The uppermost of the Krebs coal beds found to be laterally persistent is the Dry Wood,

* The term *coal horizon* is used in this report to indicate the position in stratigraphic sequence at which coal would be expected if the sedimentary cycle were completely represented by sediments. The position may be indicated by a film of carbonaceous matter or unusual concentration of carbonaceous matter in rocks of other lithology.

named from its occurrence in a tributary to Dry Wood Creek in the NW¼ SE¼ NE¼ sec. 4, T. 33 N., R. 33 W., Barton County, Missouri. The Rowe coal (Pierce and Courtier, 1937, p. 65) is the most extensively mined bed between the Warner and Bluejacket sandstones, and occurs below the Dry Wood. It is characterized locally by a fossiliferous cap-rock limestone. In central and southern Cherokee County, an additional coal bed is found below the Rowe coal and above the Warner sandstone. This coal, which is overlain by a thin bed of ferruginous limestone, is not known north and east of central Cherokee County in Kansas, but may be present in Barton County, Missouri. A thin impure limestone or clay-ironstone bed in northeastern Cherokee County probably represents the ferruginous limestone. The coal bed next below the Rowe in central Cherokee County is the Neutral. The formations constituting the Krebs subgroup, as developed in southeastern Kansas, are described in ascending order.

Riverton Formation

Definition and subdivisions.—The Riverton formation (Searight and others, 1953) includes all lower Desmoinesian beds below the top of the uppermost of the Riverton coal beds, from which the formation takes its name. The name Riverton was originally applied (Pierce and Courtier, 1937, p. 62) to the coal bed between the Warner (Little Cabin) sandstone and the underlying Mississippian rocks in southeastern Cherokee County. It is now known that two somewhat irregular coal beds separated by clay occur at this position in southeastern Kansas and adjacent parts of western Missouri. It has not been possible to differentiate these beds with sufficient certainty to allow identification in an exposure where only one coal is present. Accordingly, for the purposes of this report, the Riverton coal is recognized as being composite. The Riverton formation comprises three distinct units; dark fissile shale at the base, underclay, and Riverton coal at the top. In all exposures observed in Cherokee County, the basal dark shale lies on leached chert rubble derived from underlying Mississippian rocks. The latter material is the basal Pennsylvanian "chat" of drillers in southeastern Kansas. The best exposures of the Riverton formation occur along tributaries of Spring River and in sinkholes in eastern Cherokee County. In sinkholes (Pl. 3A), where the strata are commonly

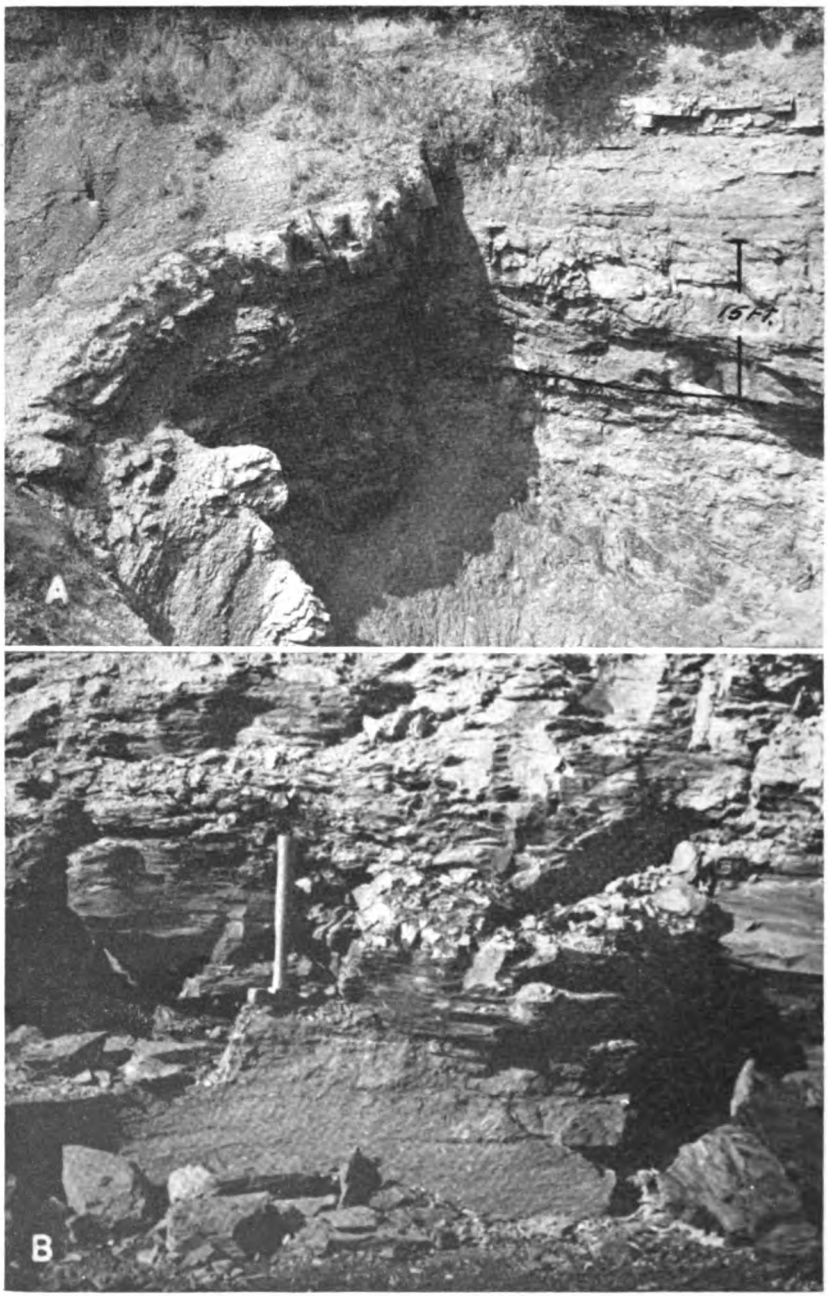


PLATE 3.—**A.** Sinkhole exposure of Riverton and lower part of Warner formation, SW¼ NE¼ sec. 9, T. 32 S., R. 25 E., Cherokee County. Massive bed above line is coarsely cross-bedded Warner sandstone. Riverton coal is just below line. **B.** Caprock limestone of Rowe coal (below hammer head), NE¼ SW¼ sec. 12, T. 32 S., R. 24 E., Cherokee County.

faulted, owing to slumping or collapse, the basal shale and higher exposed beds contain masses of euhedral pyrite and marcasite crystals. These sulfides are most abundant along joints and fault planes, and were probably introduced after collapse of caverns in the underlying Mississippian limestone. It is apparent that the lowermost Pennsylvanian sediments in this area were deposited on a surface of relatively low relief, and that the caverns were formed and collapsed after consolidation of those sediments.

The Riverton formation, as presently defined, is in part equivalent to the McCurtain shale (Wilson, 1935, p. 508) of eastern and southeastern Oklahoma. The coal beds in the formation may be correlated tentatively with the upper Hartshorne coal of Oklahoma.

The thickness of this basal formation of the Krebs subgroup in Kansas ranges from 10 to 20 feet, and averages about 15 feet.

Basal shale.—Dark-gray to black fissile shale ranging in thickness from 4 or 5 feet to an observed maximum of 13 feet forms the lowermost division of the Riverton formation in Kansas. The chert rubble of Mississippian age beneath this shale ranges in thickness from a few inches to several feet. No fossils have been observed in this shale unit. The upper part is commonly leached to medium or light gray.

Underclay.—The Riverton coal is underlain by medium- to light-gray underclay, which is hard and tough. The clay contains fossil root impressions and also disseminated carbonized plant material. Thickness of this unit ranges from 2 to 4 feet.

Riverton coal.—The Riverton coal (Pierce and Courtier, 1937, p. 62) is the uppermost unit of the Riverton formation. At least two coal beds separated by clay are known at this position. For the purposes of this report, and in regional classification (Searight and others, 1953), they are not separately named, because of the difficulty in identifying individual beds where only one is present, and because of their seemingly close genetic relation. The overlying Warner sandstone may rest upon the shale over the upper coal, on the upper coal, on clay over the lower coal, or directly upon the lower coal. The upper coal, slightly more than 1 foot thick, has been mined locally in southeastern Cherokee County. In most outcrops the lower coal is indicated only by a thin streak, but it reaches a thickness of several inches in exposures in Jasper County, Missouri. The ag-

gregate thickness of the Riverton coals, including intervening clay, probably averages about 2 feet in southeastern Kansas. The Riverton coal has never been commercially important in southeastern Kansas.

Warner Formation

Definition and subdivisions.—The Warner formation (Searight and others, 1953) includes the beds above the Riverton coal extending upward to the top of the Neutral coal bed. The succession includes the prominent and widespread Warner (Little Cabin) sandstone (Wilson, 1935, p. 508; Wilson and Newell, 1937, p. 37-39), from which it takes its name. A coal horizon is present above the Warner sandstone, but as its relations are not clear at present, it is included within the Warner formation, and the Neutral coal is defined as the uppermost unit of the formation. An unnamed coal (Wilson and Newell, 1937, p. 37-38), is present just above the Warner sandstone in east-central Oklahoma, and the horizon noted above is probably its northward equivalent. Further detailed study of this succession in northeastern Oklahoma may substantiate this view, and if such correlation can be established, beds above it, extending upward to the top of the Neutral coal in southeastern Kansas, would be called the Neutral formation, following usage adopted at the Nevada conference (Searight and others, 1953). This unnamed coal above the Warner sandstone and below the Neutral coal would then receive the name Warner. Lithologic subdivisions of the Warner formation in southeastern Kansas include: shale above the Riverton coal and below Warner sandstone, Warner sandstone, fissile dark- to medium-gray shale containing clay-ironstone concretions and beds, underclay of the Neutral coal, and the Neutral coal. The Warner formation thickens southward in the outcrop area in southeastern Kansas. It is generally less than 50 feet thick in southwestern Vernon County and northwestern Barton County, Missouri, and is 50 to 100 feet thick in Cherokee County, Kansas. Inadequacy of exposures precludes exact determination of thickness. Available well logs are not sufficiently detailed to show the position of the Neutral coal bed and are likewise of no value for determining exact thickness of the formation as defined. Logs indicate that locally the Warner sandstone rests on the surface of the Mississippian rocks and that the next lower formation (Riverton) is absent.

Shale between the Riverton coal and Warner sandstone.—Dark-gray shale is seen overlying the Riverton coal bed in a few exposures in southeastern Cherokee County. It is generally absent, however, owing to erosion prior to deposition of the Warner sandstone, which commonly rests on the upper surface of the coal. Thickness of the shale ranges from a featheredge to about 2 feet. No fossils have been found in the shale.

Warner sandstone.—The Warner sandstone (Wilson, 1935, p. 508; Wilson and Newell, 1937, p. 37-39) is one of the most prominent lithologic units in the succession assigned to the Krebs subgroup. This sandstone was earlier called Little Cabin by Ohern (1914), but participants at the Nevada conference agreed to use the term Warner because of its wider usage. Studies by Wilson (1935), Renfro (1947), and Weidman (1932) indicate that the Warner is essentially continuous in outcrop from the type locality near Warner, in Muskogee County, Oklahoma, northward to the Oklahoma-Kansas line, thence northeastward across Cherokee County into western Missouri. In part it is probably represented in the Ozark area by the Graydon sandstone and conglomerate. The Warner sandstone is composed of fine- to medium-grained, angular to subrounded quartz sand, and generally abundant muscovite. In the few exposures in southeastern Kansas where the complete succession can be seen (Pl. 3A), the Warner consists of a lower, massive, coarsely cross-bedded portion, 10 to 15 feet thick, overlain by 5 to 10 feet of micaceous siltstone and sandy shale, which is overlain by about 5 feet of massive fine-grained sandstone. The upper portion is locally a stigmarian sandstone, containing roots and root casts, and is overlain by dark-gray to black shale. In one exposure, underclay occurs above the stigmarian sandstone and below dark shale. The upper surface of the Warner sandstone is regarded as a coal horizon, and coal at this position in east-central Oklahoma (Wilson and Newell, 1937, p. 37-38) is tentatively correlated with it. Stratigraphic sections 19 and 45 include detailed descriptions of exposures illustrating this relationship. Continuous-inclined bedding ("torrential bedding") is common in the lower portion of the Warner sandstone, and in general is inclined southward. The basal portion of the Warner very commonly contains fragments or molds of fragments of shale incorporated from underlying beds, forming a "blister" conglom-

erate. No exposures were observed in which the Warner rests upon rocks of Mississippian age. The Warner commonly is asphaltic in southeastern Kansas.

The "Burgess sand" of the subsurface in Kansas is probably equivalent to the Warner. Wilson (1935, p. 505) also correlated the "Booch" sandstone of the subsurface in Oklahoma with the Warner.

The thickness of the Warner sandstone in the outcrop area in southeastern Kansas ranges from 10 to about 25 feet.

Dark shale above the Warner sandstone.—Several isolated exposures in southeastern Kansas indicate that the rocks between the Warner sandstone and Neutral coal consist of dark- to medium-gray fissile shale, containing abundant clay-ironstone, present both as isolated concretions and as well-defined beds or layers. This succession, although much condensed, represents the bulk of the McAlester formation of east-central and southeastern Oklahoma. In the upper part of the succession, well exposed along Brush Creek in the NE¼ SW¼ sec. 10, T. 34 S., R. 24 E., Cherokee County, at least two well-defined clay-ironstone zones are underlain by poorly developed underclays, and may represent coal and limestone beds (Spaniard or ?Sam Creek) present in eastern Oklahoma, where this portion of the Warner formation thickens markedly.

The thickness of the Warner sandstone-Neutral coal sequence ranges from a few feet in northeastern Crawford County (based upon exposures in adjacent Vernon and Barton Counties, Missouri) to an estimated 70 feet in central and southern Cherokee County.

Underclay.—Scattered exposures in the vicinity of Neutral, in central Cherokee County, indicate that the Neutral coal is underlain by underclay having an average thickness of about 2 feet.

Neutral coal.—The name Neutral was originally applied by Abernathy (1936, p. 74-75; 1938, p. 196) to a succession containing two coal beds, which he identified as parts of a cyclothem. These coal beds seemingly are the upper two of three distinct coal beds between the Warner and Bluejacket sandstones in the vicinity of Neutral. The lower of these two is the Rowe coal, and the upper is the Dry Wood coal. The name Neutral is here redefined and restricted so as to apply to the lowermost of the

three coal beds present in that locality. Stratigraphic section 20 describes the exposure designated as typical, located along Brush Creek in the NE¼ SW¼ sec. 10, T. 34 S., R. 24 E., a short distance east of the town of Neutral. In this vicinity the coal attains its maximum known thickness of 6 inches. Its stratigraphic position has been tentatively identified in northeastern Cherokee County (stratigraphic section 44), but the bed itself has not been identified positively in the outcrop area north and east of Neutral either in Kansas or in western Missouri. The Neutral coal is characterized in the type area by an extremely ferruginous cap-rock, which is classed as the lower portion of the overlying Rowe formation and is discussed along with other units in that formation. The Neutral coal is not known to have been mined in southeastern Kansas. It is possibly equivalent to the "Lower Boggy" coal (Wilson and Newell, 1937, pl. 3) of eastern Oklahoma.

Rowe Formation

Definition and subdivisions.—The Rowe formation (Searight and others, 1953) includes beds above the Neutral coal and extends to the top of the Rowe coal (Pierce and Courtier, 1937, p. 65). The formation takes its name from the Rowe coal, which has been the most extensively mined sub-Bluejacket coal in southeastern Kansas and western Missouri.

Because of insufficient exposures it is not possible to describe precisely the complete succession of beds that constitute the Rowe formation. The Rowe coal bed itself is widespread, and its thickness and general character are relatively well known, owing to extensive mining. The lower part of the formation includes the distinctively ferruginous limestone cap-rock of the underlying Neutral coal. Recognized divisions of the Rowe are described in the following paragraphs.

Lowermost limestone.—In the type area of the Neutral coal and elsewhere in Cherokee County, this coal is overlain by a 3- to 6-inch impure limestone or clay-ironstone bed containing coquinoidal layers of detrital shell material. This bed ranges from essentially unfossiliferous clay-ironstone to impure fossiliferous limestone so rich in iron that it weathers to impure hematite and limonite. It is the most persistently fossiliferous bed in the Krebs subgroup in southeastern Kansas. Limestone above

the Rowe coal attains greater thickness, and is less impure, but is characteristically lenticular and very erratic in distribution. Most fossil material in the lower Rowe bed is detrital and associated with fragments of fusain. Locally, however, fossils are abundant in the form of external and internal molds, the shell material having been dissolved, and the matrix altered to limonite and hematite. Insoluble residue from a sample of this bed at a locality where a small quantity of fossil material was observed amounted to only about 5 percent, consisting chiefly of silicified shell fragments and some very fine subangular to rounded quartz sand. This bed is tentatively identified in northeastern Cherokee County (stratigraphic section 44), where it is represented by clay-ironstone. Identification at this place is based upon similarity of lithologic succession. The Neutral coal is absent; underclay regarded as that belonging next below the Neutral coal lies directly under the clay-ironstone. The limestone is present south and east of Columbus, in the vicinity of Neutral (stratigraphic section 20), and is probably represented in northern Oklahoma by the limestone called Elm Creek (Weidman, 1932, p. 25-26) and Doneley (Chrisman, 1951; Branson, 1954, p. 192). It seemingly corresponds to the cap-rock of the Lower Boggy coal of Wilson and Newell (1937, p. 53) in east-central Oklahoma. In the field this bed has been given the name "Red lime" because of its characteristically red or reddish-brown color. It is underlain by the Neutral coal and overlain by dark fissile shale. No formal name has been applied to this persistent bed in Kansas, as it is judged that future work will establish correlation with the Doneley limestone in northern Oklahoma. The term Elm Creek (Weidman, 1932, p. 25-26) has been abandoned (Claxton, 1952, p. 7) because of its older usage for other beds.

Fossils from the cap-rock of the Neutral coal include very abundant *Derbyia crassa, Marginifera* cf. *ingrata* or *nana,* and *Neospirifer cameratus. Composita subtilita* is common; *Aviculopecten?, Astartella, Spirifer occidentalis,* and crinoid elements occur locally. A group of small, possibly depauperate, snails and clams is associated with the other forms. Bone and tooth fragments are locally present.

Beds between the limestone and Rowe coal.—The sequence between the basal limestone of the formation and the Rowe coal

is known from only a few scattered outcrops in southeastern Kansas. The only complete exposure known to me is along Brush Creek, in the NE¼ SW¼ sec. 10, T. 34 S., R. 24 E., Cherokee County (stratigraphic section 20). The available data indicate that the succession includes dark-gray to black fissile shale 5 to 10 feet thick, overlain by 2 or 3 feet of underclay. The dark shale contains several layers of clay-ironstone having a maximum thickness of 4 inches. Slumped and partly covered outcrops in eastern Cherokee County indicate that part of this section, the "12-foot" sandstone (field term used by geologists in Craig County, Oklahoma), seemingly lies either at this position or in the overlying Dry Wood formation.

Rowe coal.—The Rowe coal (Pierce and Courtier, 1937, p. 65), named for its occurrence in the vicinity of Rowe School in eastern Crawford County (sec. 34 and 35, T. 30 S., R. 25 E.), is economically the most important coal bed within the Krebs subgroup in southeastern Kansas and western Missouri. It has been mined extensively by stripping in the area south and east of Pittsburg, in Crawford County; east of Weir City in northeastern Cherokee County; east and south of Columbus, and in the vicinity of Neutral, in central Cherokee County. It is the lower of the two coal beds included in the "Neutral cyclothem" of Abernathy (1936, p. 74-75; 1938, p. 196), and is the bed called "Columbus" and mined near that town. The "Bellamy" coal (Greene and Pond, 1926, p. 46), which actually includes two distinct coal beds, is in part equivalent to the Rowe.

The Rowe coal ranges in thickness from about 10 inches to a maximum of 20 inches, and is commonly 15 to 18 inches thick. It is characteristically blocky, and is reported by users to be of good quality. A thin clay parting in this bed was reported by Pierce and Courtier (1937, p. 65), and regarded by them as characteristic. A clay parting less than 1 inch thick is present in it near Neutral but was not noted in the several mines operating on this bed in northeastern Cherokee County. The Rowe is characterized by a limestone cap-rock, which, in contrast to the relatively persistent one above the Neutral coal, is lenticular and extremely erratic in its distribution. It properly belongs within the Dry Wood formation and is described as a part thereof.

The Rowe coal bed has been a relatively minor source of coal production in southeastern Kansas.

Dry Wood Formation

Definition and subdivisions.—The Dry Wood formation (Searight and others, 1953) includes beds between the top of the Rowe coal and the top of the Dry Wood coal. The formation is somewhat variable in thickness and in lithology. The coal bed (Dry Wood) included in the formation has been mined only locally, and is characteristically irregular. In northeastern Cherokee County the formation includes a lenticular limestone, which lies next above the Rowe coal. The Dry Wood formation includes the following recognized divisions in upward order: basal dark shale containing lenticular limestone, thin irregular silty limestone and clay-ironstone, underclay, and the Dry Wood coal. The formation thickens from 6 or 8 feet in southeastern Crawford County to a maximum of somewhat more than 15 feet in central and southern Cherokee County.

Dark shale.—Dark-gray to black fissile shale composes the lower part of the Dry Wood formation. This unit commonly contains thin beds and small isolated concretions of clay-ironstone, and weathers light gray, forming thin brittle chips. Thickness ranges from 3 or 4 feet in the northern part of the area of outcrop to slightly more than 10 feet in central and southern Cherokee County.

Locally, massive lenticular limestone is found at the base of the unit, lying just above the Rowe coal. This limestone, which, because of its seemingly local occurrence has not been named, is dark gray to black, carbonaceous, and ranges from compact crystalline rock (Pl. 3B) to very impure shaly limestone. Its thickness ranges from a featheredge to about 30 inches. This bed is extremely fossiliferous, and is composed principally of organic debris. Fossils include locally very abundant *Spirifer occidentalis*, *Composita subtilita*, *Derbyia crassa*, *Linoproductus* sp., *Prismopora triangulata*, crinoid plates and columnals, *Orbiculoidea capuliformis*, *Fenestrellina* sp., *Rhombopora* sp., and *Punctospirifer kentuckyensis*. Fish teeth, especially those assigned to the genus *Petalodus*, and bone fragments are locally very abundant. Limestone in the basal part of the Dry Wood formation is known only in a few localities in northeastern Cherokee County. Branson (1954, p. 192) tentatively correlated the Doneley limestone of Oklahoma with this bed, but it seems more likely that the Doneley overlies the Neutral coal.

Silty limestone and clay-ironstone.—Most exposures of the Dry Wood formation, including that at the type locality, in a tributary to Dry Wood Creek in northwestern Barton County, Missouri, reveal the general presence of silty limestone or very impure clay-ironstone above the lower shale and below the underclay division of the formation. This unit is very irregular in lithology, and averages somewhat less than 1 foot in thickness. It occupies the position and has many of the characteristics of the underlimestones commonly associated with the underclays of coal beds in the overlying Cabaniss subgroup. In natural exposures this material weathers to reddish-brown, sintery or porous silt and clay. No fossils, other than worm trails, are known from it in the area of this report.

Underclay.—Underclay associated with the Dry Wood coal ranges in thickness from about 2 feet to an observed maximum of 5 feet. This bed contains fossil plant material and root impressions throughout, even where it is thickest.

Dry Wood coal.—The Dry Wood coal is extremely irregular in thickness and quality, and has not been mined extensively in southeastern Kansas. It is equivalent in part to the "Bellamy" coal of western Missouri (see Rowe coal). This bed seemingly has been mined only locally in southeastern Crawford County and northeastern Cherokee County, and is the uppermost of the two coal beds formerly mined in the vicinity of Neutral. It is directly overlain by the Bluejacket sandstone in many places and is commonly deeply weathered or leached. The Dry Wood is seemingly the uppermost coal bed included in the "Neutral cyclothem" of Abernathy (1936, p. 78-79; 1938, p. 196). Thickness of the Dry Wood coal ranges from a featheredge to 20 inches, but in most places is 3 to 8 inches.

Bluejacket Formation

Definition and subdivisions.—The Bluejacket formation includes beds directly above the Dry Wood coal and extending to the top of the Bluejacket coal (Searight and others, 1953). The succession includes the prominent and well-known Bluejacket sandstone (Ohern, 1914, p. 28-29; Howe, 1951, p. 2088-2091), from which the formation takes its name. The Bluejacket coal has been identified at only one locality in southeastern Kansas

(abandoned clay pit, sec. 28, T. 30 S., R. 25 E., Crawford County). At this place the coal is represented by a thin smut. Elsewhere in southeastern Kansas both this bed and the overlying Seville limestone seem to be absent and the upper unit of the Bluejacket formation is the Bluejacket sandstone, which directly underlies the thin Bluejacket coal or, where the succession is complete, its underclay.

Divisions of the Bluejacket formation in southeastern Kansas include, from the base upward: sandy shale over the Dry Wood coal, Bluejacket sandstone, and Bluejacket coal with its associated underclay. The Bluejacket sandstone is the most widespread of these units in the Oklahoma-Kansas-Missouri area. The thin coal forming the upper member of the formation is of very limited extent in Kansas.

Lower shale and sandy shale.—The Dry Wood is the highest sub-Bluejacket coal bed having appreciable lateral extent in the area of this report. Between it and the base of the Bluejacket sandstone lie shale and sandy shale (Pl. 4A). This shale locally contains a thin, seemingly nonpersistent coal, which is included within the formation because it is judged not to be of sufficient thickness or lateral extent to merit separate description. The thickness of the shale unit is at most only a few feet; commonly the Bluejacket sandstone rests on an erosion surface developed at or about the position of the Dry Wood coal, higher sub-Bluejacket beds being absent.

Bluejacket sandstone.—The Bluejacket is the uppermost sandstone unit in the Krebs subgroup in northern Oklahoma, southeastern Kansas, and Missouri. In southeastern Kansas, the Bluejacket sandstone forms the uppermost unit of the Krebs except in the limited area where the overlying Bluejacket coal and underclay can be identified (see Bluejacket coal).

The Bluejacket was originally described by Ohern (1914, p. 28-29). Howe (1951, p. 2088-2091) revised Ohern's definition, because the locality designated by Ohern as typical included several sandstone beds separated by shale and coal beds, and usage had not been consistent. The original designation of the type locality included conglomeratic sandstone now regarded as Chelsea above the Bluejacket (restricted) and the "12-foot" sandstone (field term of Oklahoma geologists) below it. According to Carl C. Branson, of the University of Oklahoma (quoted

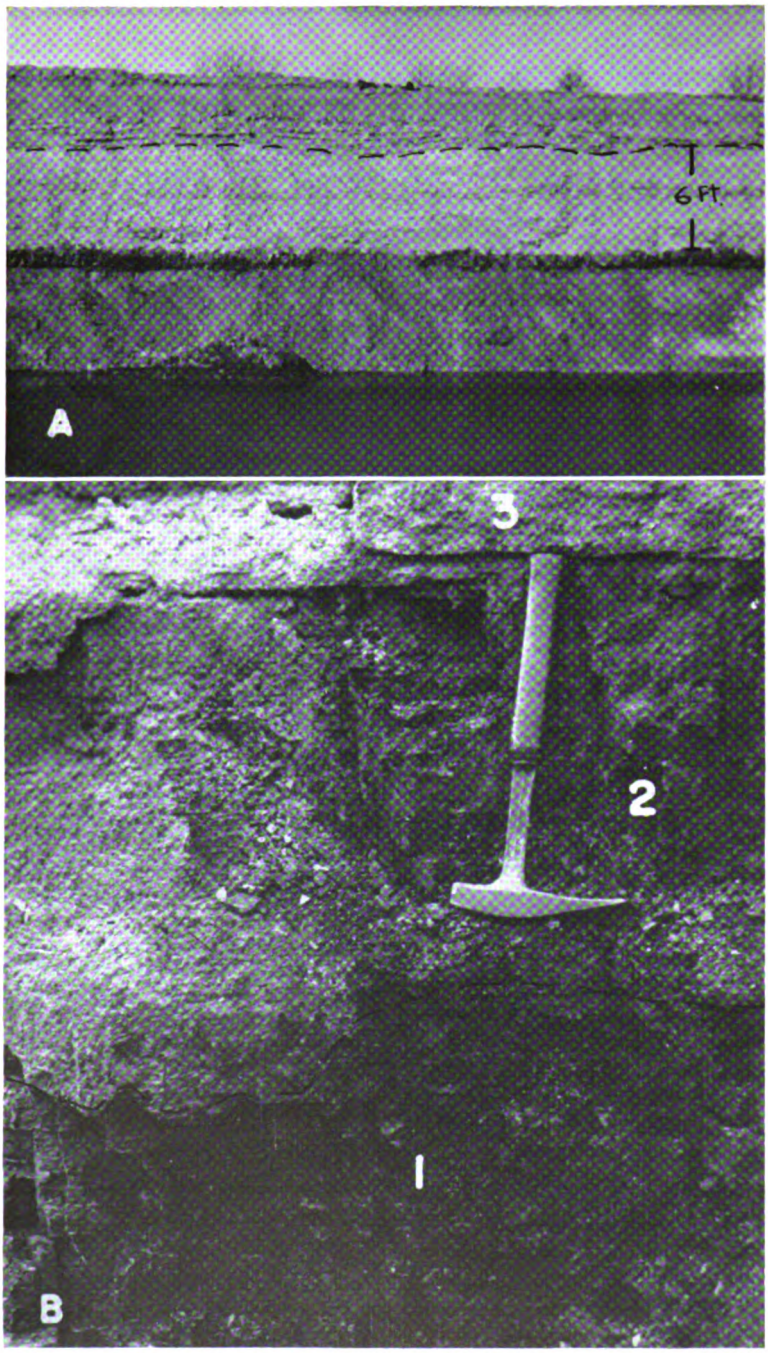


PLATE 4.—**A.** Dry Wood coal and base of Bluejacket sandstone (dashed line), SW¼ sec. 12, T. 32 S., R. 24 E., Cherokee County. Rowe coal was mined here. **B.** Weir-Pittsburg (1) (below hammer head) and Tebo coal (2) beds, NW¼ sec. 25, T. 32 S., R. 23 E., Cherokee County. Light-colored bed (3) above hammer handle is Tiawah limestone. *Photograph by A. L. Hornbaker.*

in Howe, 1951, p. 2090), the "12-foot" sandstone originally was mapped as Bluejacket by Ohern in the vicinity of Bluejacket, Vinita, and Whiteoak, Oklahoma, but in areas farther south the Bluejacket sandstone as now restricted was mapped. The definition and designation of the type section of the Bluejacket was revised so as to include the sandstone regarded by both the Oklahoma and Kansas Geological Surveys as true Bluejacket. This sandstone commonly is regarded as equivalent to the "Bartlesville" sand of the subsurface.

The Bluejacket sandstone can be traced along virtually all of the outcrop in southeastern Kansas, and it is present in western Missouri. It is extensively exposed in the vicinity of Columbus, central Cherokee County, and east to Pittsburg, eastern Crawford County. Topographically, it forms a cuesta, which is variable in prominence, principally owing to variation in thickness. In central and southern Cherokee County, the Bluejacket sandstone caps several outliers and buttes such as the Timbered Hills and prominent Mounds near Treece, just north of the Kansas-Oklahoma line. Pierce and Courtier (1937, pl. 1) indicated the presence of the Bluejacket sandstone in Cherokee County, but did not map it as far northeast as Weir City. There seems no valid reason for not extending recognition of this unit across Cherokee County and southeastern Crawford County, Kansas, into Barton County, Missouri. It is somewhat thinner in the north, possibly because of the development of the Pittsburg anticline, but the succession of coal beds beneath it is similar throughout the region.

The Bluejacket sandstone rests unconformably on lower beds, but the surface of unconformity seemingly has a maximum relief of only 10 or 15 feet in the area of this report. The Dry Wood coal locally is absent, owing to pre-Bluejacket erosion.

The Bluejacket is composed principally of fine- to medium-grained, micaceous, angular to subangular quartz sand, but includes minor amounts of very fine sand and silt. It is a well-sorted deposit, for sieve analyses of samples from several exposures indicate that 50 to 60 percent of the sand passes the 60-mesh and is caught on the 100-mesh (Tyler) screen (fine sand of Wentworth classification), and progressively smaller amounts are included in the finer sizes. A "blister" conglomerate, formed of fragments of clay-ironstone concretions and shale,

commonly is present in the basal part of the member. The conglomeratic material is seemingly all of local origin. Bedding in the Bluejacket member ranges from nearly flat bedding to steeply inclined cross-bedding. Layers of cross-bedded sandstone are set off from similar cross-bedded sandstone both below and above by almost horizontally bedded sandstone. This type of cross-bedding is particularly common where the Bluejacket sandstone is thick, as in exposures along Neosho River near the Kansas-Oklahoma state line. It is also found in the asphaltic sandstone quarry at Iantha, in Barton County, Missouri. Steeply inclined cross-bedding of this type (continuous incline-bedding of Pettijohn, or "torrential bedding") is best developed where the member is 20 feet thick or more. In most of the area of Bluejacket outcrop, cross-bedding is much less pronounced, and the rock is slabby or thin bedded to massive. In southeastern Crawford County, the upper part is locally shaly. In outcrop the Bluejacket weathers tan to brown or reddish brown.

The Bluejacket sandstone increases in thickness to the south in the outcrop area in southeastern Kansas. It is 10 to 15 feet thick in western Barton County, Missouri, and eastern Crawford County and northern Cherokee County, Kansas, but 20 to 30 feet thick in central and southern Cherokee County. It is about 40 feet thick along Neosho River near the Kansas-Oklahoma state line and in northern Craig County, Oklahoma.

The Bluejacket sandstone has been quarried for building stone in Cherokee County, and provides road-surfacing material at Iantha, in Barton County, Missouri, where it is extremely asphaltic. This member is most important economically as an oil reservoir in eastern Kansas.

Bluejacket coal.—The Bluejacket coal (Searight and others, 1953) has been identified only tentatively at a single locality (abandoned clay pit, SW¼ sec. 28, T. 30 S., R. 25 E., Crawford County) in Kansas, where it is represented by a thin smut. The Bluejacket coal is regarded as a correlative of the Rock Island No. 1 coal of western Illinois. It has been mined locally in the vicinity of Clinton, Henry County, Missouri and elsewhere in that state.

Seville Formation

The Seville formation, as defined in this area (Searight and others, 1953), includes only the Seville limestone (Wanless, 1931, p. 804-805). It is found in northern Barton County and southern Vernon County, western Missouri, but has not been recognized in southeastern Kansas except in a single locality near Pittsburg, in eastern Crawford County (abandoned clay pit, SW¼ sec. 28, T. 30 S., R. 25 E.). At this place identification is tentative, being based mainly upon stratigraphic position. The limestone is very impure and has little resemblance to the Seville of western Missouri. Although fossiliferous, the bed does not contain the fauna characteristic of the Seville. It is judged that the bed identified as Seville near Pittsburg represents a unique facies of the Seville.

The Seville lies above the Bluejacket coal and below the underclay of the Weir-Pittsburg coal bed where the complete succession is present. This limestone, which here forms the uppermost unit of the Krebs subgroup, also crops out in Iowa and at various places in Missouri. Probably it is represented in Oklahoma by one of the several limestones called Inola, which are known only south of the latitude of Chelsea (Carl C. Branson, personal communication, May 5, 1953).

In southeastern Kansas, the bed tentatively identified as Seville is argillaceous and weathers to thin, irregular slabs. It is about 6 inches thick. Fossils observed include: *Prismopora* sp., *Fusulinella?* sp., *Tetrataxis* sp., and crinoid columnals. At localities in northwestern Barton County and southwestern Vernon County, Missouri, the limestone is characterized by *Marginifera missouriensis, Mesolobus striatus*, and *Derbyia crassa.*

Cygnian Substage—Cabaniss Subgroup

The Cabaniss subgroup (Oakes, 1953), in the type area situated in the McAlester basin in southeastern Oklahoma, comprises beds referred to the Thurman, Stuart, and Senora formations, which overlie the Krebs subgroup and occur below strata equivalent to the Marmaton group of the northern Midcontinent region. The Thurman and Stuart formations do not extend north of T. 13 N., because of northward overlapping by younger Cabaniss (Senora) deposits. In southeastern Kansas, the Cabaniss

succession extends from the top of the Seville limestone to the base of the Blackjack Creek limestone, which is lower Marmaton.

The Cabaniss subgroup and overlying Marmaton deposits are included in the Cygnian Substage, because of continuity in the nature of the fauna, including particularly *Marginifera muricatina* and smooth forms of *Mesolobus mesolobus;* it is noteworthy also that as a whole this major division is characteristically somewhat less clastic (containing many prominent limestones) than the underlying Venteran Substage. Coal beds of the Cabaniss very commonly are characterized by association of underlimestones with their underclays, whereas such limestones are extremely uncommon in the Krebs.

The average thickness of rocks assigned to the Cabaniss subgroup in southeastern Kansas is about 200 feet. The succession is of comparable thickness in western Missouri and in Craig County, Oklahoma, but farther south in Oklahoma it increases in thickness. Although thickness of the Verdigris-Fort Scott sequence decreases considerably in northern Oklahoma, southward thinning of this portion of the Cabaniss is more than compensated by thickening of the pre-Verdigris Cabaniss beds. Such marked increase in thickness is especially noticeable in the shale between the Croweburg (Broken Arrow) coal and the Verdigris limestone.

In southeastern Kansas, and also in Missouri, the Cabaniss includes most of the minable coal beds, and is thus the most important coal-producing portion of the Pennsylvanian System in the two states.

A single prominent unconformity has been observed within the Cabaniss subgroup, at the base of the Chelsea sandstone; its local relief is about 30 feet in Cherokee and Crawford Counties, but is much greater in northern Oklahoma, where the unconformity seems to be associated with faulting. In southeastern Labette County no beds between the Bluejacket sandstone and the Mineral coal (about 70 feet above the base of the Cabaniss) have been identified positively, and it is possible that the Chelsea and the Bluejacket together form the unusually thick sandstone previously regarded (Pierce and Courtier, pl. 1) as Bluejacket. The area is south of Chetopa, along Neosho River near the Kansas-Oklahoma line, and there erratic dips and faulting of the Pennsylvanian strata are common.

The Cabaniss is described in more detail than the underlying Krebs subgroup, for exposures are better and other sources of information are plentiful.

Weir Formation

Definition and subdivisions.—The Weir formation (Searight and others, 1953) includes beds next above the Seville limestone and extends upward to the top of the Weir-Pittsburg coal (Haworth and Crane, 1898, p. 25-26). The name Weir had previously been applied by Abernathy (1938) to the cyclothem containing the Weir-Pittsburg coal. Searight and others (1953) modified the term by redefinition, and their usage is followed in this report.

The Seville limestone and the underlying Bluejacket coal are extensively exposed in northwestern Barton County and southwestern Vernon County, Missouri, but have not been observed in southeastern Kansas except in a clay pit at the east edge of Pittsburg. At this locality poorly developed limestone and an underlying coal smut above the Bluejacket sandstone and below the Weir-Pittsburg coal are tentatively correlated with the Seville limestone and the Bluejacket coal. These beds probably are lacking in the Cabaniss outcrop area farther south and west in southeastern Kansas, and accordingly the base of the underclay beneath the Weir-Pittsburg coal is regarded as the base of the formation there. The Weir formation, therefore, includes only the Weir-Pittsburg coal and its underclay. The thickness of the formation averages about 12 feet at outcrops in Cherokee and Crawford Counties. The formation has not been observed in eastern Labette County, but is seemingly present at depth in western Labette County.

Underclay.—The underclay of the Weir-Pittsburg coal is exceptionally thick in western Missouri and in Crawford and Cherokee Counties, Kansas. It is characteristically light gray, somewhat silty, and contains fossil root impressions throughout. This clay is used in the manufacture of buff-burning brick by the United Brick and Tile Company at Weir City in northern Cherokee County. The clay is 5 to 7 feet thick at Weir City and about the same at Pittsburg.

Weir-Pittsburg coal.—The Weir-Pittsburg (Haworth and Crane, 1898, p. 25-26) is the thickest coal in the southeastern

Kansas region and has been most important commercially. The bed characteristically includes a thin clay parting 4 to 6 inches above the base. Over most of the area in Cherokee County and southern Crawford County where it has been mined, this coal is underlain by an uneven, plastic, dark-gray clay containing abundant fossil plant impressions and coaly material, and showing profuse slickensides. This type of clay, almost universally called "blackjack" by miners in the region, formed the floor of most of the mines operating on this bed in the area. The clay is not known at outcrops in eastern Crawford County, but it is exposed in southern Crawford County and northern Cherokee County and has been logged in coal prospect drilling in these areas. The plasticity of the "blackjack", according to Crane (in Haworth and Crane, 1898, p. 156-180), has been a source of considerable difficulty in underground mining because the clay absorbed much of the shock of blasts.

A thin coal bed is recorded beneath the "blackjack" in logs of some holes in Cherokee and Crawford Counties, and it is found exposed in the clay pit of the United Brick and Tile Company at the southeastern edge of Weir City, in northern Cherokee County. This bed is logged in few of the drill-holes that penetrate the succession, however, and so its areal extent is unknown. In the single exposure seen it is only 3 to 4 inches thick.

The Weir-Pittsburg coal is locally impure in the upper and lower parts, and large amounts of fusain are common. Fusain in the coal commonly is completely filled or replaced by iron sulfide and presents a problem in coal preparation. In one area (see Tebo coal) the Weir-Pittsburg and Tebo coals are in contact.

Of importance in the mining of this bed are features called horsebacks. These are clay masses and ridges that have been displaced upwards through the coal. If numerous, they are especially detrimental in underground mining, but offer somewhat less difficulty in surface mining. These structures seemingly result from plastic flowage of the "blackjack" and underlying clay along planes and areas of weakness in the overlying coal. They are described in detail by Crane (in Haworth and Crane, 1898, p. 167-213).

The Weir-Pittsburg coal bed, excluding the "blackjack" and lower coal bed, averages about 38 inches in thickness in the

Cherokee-Crawford County area. The lower coal, where present, is about 4 inches thick, and probably never has been mined by itself or in conjunction with the main bed above. The Weir-Pittsburg bed has been mined underground and by very extensive stripping in Cherokee and Crawford Counties, as described by Abernathy (1944). The Weir-Pittsburg coal is not known to be present in the outcrop area in eastern Labette County, but has been strip-mined west of Welch, Craig County, Oklahoma. Numerous logs of prospect holes in western Labette County indicate that the bed is present at depth there, and that its maximum thickness is about 5 feet. The Weir-Pittsburg bed has been mined extensively also in western Barton County, Missouri, both by underground and surface methods.

The thin lower coal described above, although generally regarded as a part of the Weir-Pittsburg, may represent a portion of an additional formation, not heretofore recognized in southeastern Kansas. Lack of information concerning this coal precludes more than mention of its occurrence. It is possible that the "blackjack" layer described above and the thin clay parting within the main mass of the coal simply represent interruptions during a period of coal formation. The presence of locally abundant fusain may indicate periods of partial oxidation of coal-forming materials. The clay partings may consist of residue that results from a relatively long period of almost complete oxidation of coal-forming materials, plus introduced silt and clay. If this is true, the complete succession would be classed properly as the Weir-Pittsburg coal bed.

Other names applied to the Weir-Pittsburg coal in Kansas include: "Weir-Pittsburg lower", "Cherokee", "4-foot", and "Big Lower".

Tebo Formation

Definition and subdivisions.—The Tebo formation (Searight and others, 1953) includes beds from the top of the Weir-Pittsburg coal extending upward to the top of the Tebo coal (Marbut, 1898, p. 123). The formation is well exposed in many strip mines in eastern Crawford County, Kansas, and in western Barton County, Missouri, for the Weir-Pittsburg coal has been strip-mined extensively in that area. The upper part of the succession is not known to be exposed in south-central Crawford

County. In northwestern Cherokee County (NW¼ sec. 25, T. 32 S., R. 22 E., and NE¼ sec. 30, T. 32 S., R. 23 E.), the interval between the Weir-Pittsburg and Tebo coal beds decreases to zero and the two coal beds are in contact (Pl. 4B). In these localities, the composite Weir-Pittsburg–Tebo coal has been mined, but the coal, although 30 to 40 inches thick, is poor in quality and much of the upper part (Tebo) has been discarded. The irregular contact between the two coals is locally marked by a clay parting. The limestone bed (Tiawah) that normally lies above the Tebo coal is present in both localities. Study of spores from this locality by Mart P. Schemel, then with the Missouri Geological Survey, indicates that both the Weir-Pittsburg and Tebo coal beds are present. The results of Schemel's work corroborate earlier identification based upon field relations.

Thickness of the Tebo formation ranges from a few inches (including principally the Tebo coal bed) to about 26 feet in southeastern Kansas. It is 20 to 26 feet except in the area of the abrupt thinning described above.

In southeastern Kansas, the following divisions of the formation are recognized: dark- to light-gray silty to sandy shale at the base, impure limestone, underclay, and the Tebo coal bed at the top.

Shale.—The lowermost division of the Tebo formation constitutes the major portion of the succession, and consists principally of gray silty shale. It is locally dark gray at the base. This unit is commonly sandy or silty, particularly in the upper part. In the large area of Weir-Pittsburg stripping in eastern Crawford County, Kansas, and in western Barton County, Missouri, the lower division ranges from clay shale ("soapstone") to sandy or silty shale; farther south and west, in southern Crawford County and northern Cherokee County, both outcrop descriptions and logs of coal prospect drilling indicate that this part of the formation consists chiefly of micaceous sandy or silty shale (Pl. 5A) and some interbedded fine-grained sandstone. Small isolated clay-ironstone concretions are common in this unit. Dark shale as much as 6 feet thick is present at the base at Weir City, in northern Cherokee County. Dark shale in the lower part of the division at other localities in northern Cherokee County is in general lenticular and has a maximum thickness of about 2 feet. No fossils were observed in the dark basal shale.

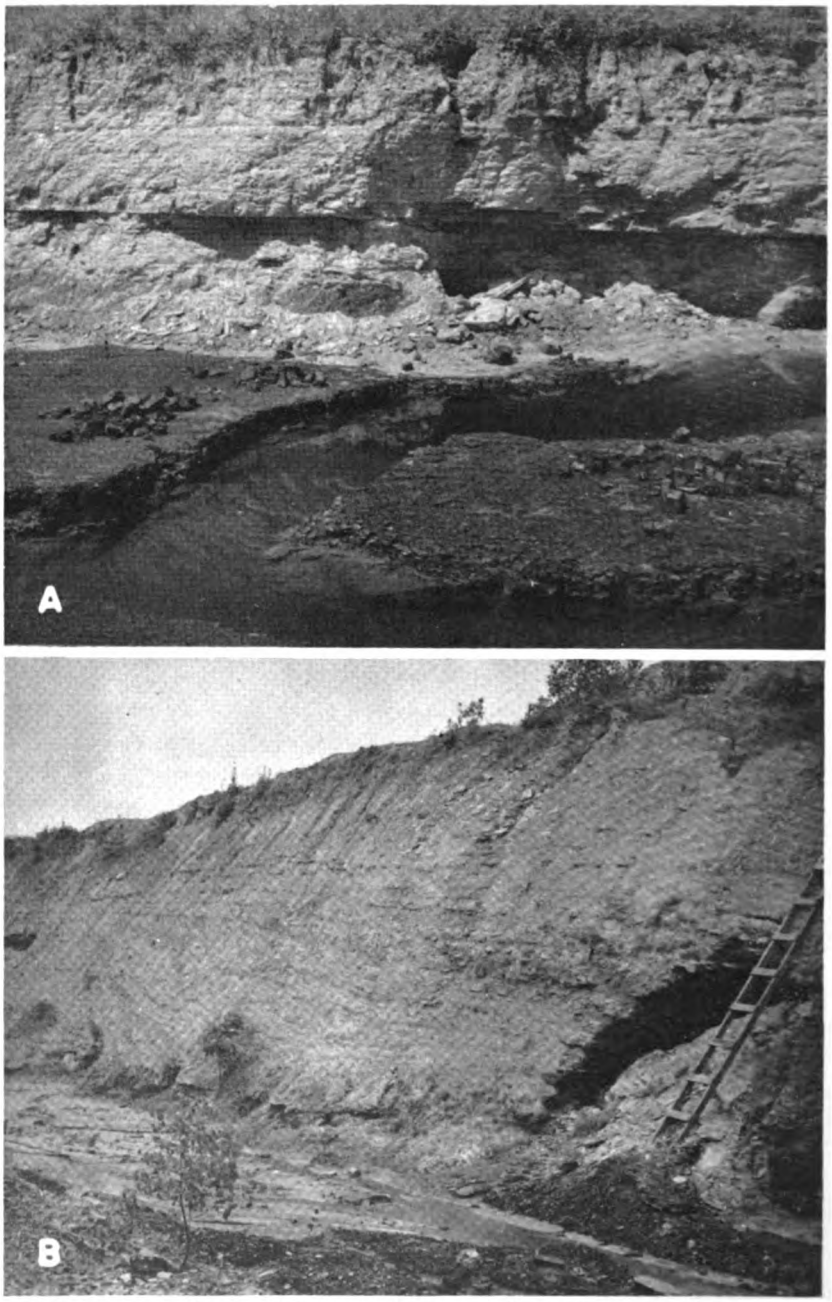


PLATE 5.—**A.** Weir-Pittsburg coal and overlying shale and thin-bedded sandstone of Tebo formation, NE¼ NE¼ sec. 13, T. 31 S., R. 24 E., Crawford County. **B.** Weir-Pittsburg coal and overlying thin-bedded sandy shale of Tebo formation, NE¼ NE¼ sec. 24, T. 32 S., R. 24 E., Cherokee County. Note inclination of bedding planes of shale relative to coal.

In several exposures of the lower shale, lamination is very slightly inclined to the plane of the underlying Weir-Pittsburg coal (Pl. 5B). This relationship of shale to underlying coal is, as far as is known, peculiar to this formation in the pre-Marmaton Pennsylvanian of southeastern Kansas. It is regarded as indicating some type of deltaic environment of deposition of the shale and sandy shale. In exposures where this feature was noted the inclination of the laminae was northerly. At an outcrop illustrated by Pierce and Courtier (1937, pl. 2B) purporting to show this relationship, the distinct unconformity shown is regarded by me as related to local structure and hence different from the generally barely perceptible inclination noted above.

The thickness of the shale forming the lower unit of the Tebo formation ranges from a featheredge, bordering the area where the Weir-Pittsburg and Tebo coal beds are in contact, to about 25 feet. Over most of the area, thickness of the shale ranges from 15 to 20 feet.

Underlimestone.—Impure nodular to massive limestone above the lower shale and below the underclay of the Tebo coal is present in exposures in eastern Crawford County, Kansas, and in western Barton County, Missouri, but has not been noted elsewhere. Limestone at this position grades laterally from a thin zone of nodules in a clayey matrix to a single massive bed having a maximum thickness of about 10 inches. The rock is mottled light and dark gray. The darker portions are irregular fragments of very fine grained limestone scattered at random in the slightly coarser grained and lighter colored matrix. Insoluble material in the rock is about 10 percent of the total, and consists chiefly of fine silt and clay. Thin veinlets of calcite are common. No material of organic nature could be recognized in acetate peel sections of the rock.

Underclay.—The underclay of the Tebo coal is silty and gray and contains root impressions. Its average thickness is about 3 feet.

Tebo coal.—The Tebo coal of Henry County, Missouri (Marbut, 1898, p. 123) is a correlative of the "Pilot" coal (Pierce and Courtier, 1937, p. 68-69) of southeastern Kansas, and the term Tebo is adopted in this report. The coal is not of minable thickness in southeastern Kansas except where it is in contact with the Weir-Pittsburg coal (see discussion in definition and sub-

divisions), and has been mined with it. The Tebo coal is of minable thickness in some areas in Missouri, but seemingly has not been mined in northern Oklahoma. Exposures and logs of coal prospect drilling indicate that the average thickness of this coal bed in Cherokee and Crawford counties is about 6 inches. It has not been observed in the outcrop area in eastern Labette County, Kansas, but is present to the south in Craig County, Oklahoma, and seems to be present at depth in western Labette County.

Popular names applied to this coal are "Pilot" and "Sun bed". Both are miner's terms.

Scammon Formation

Definition and subdivisions.—The Scammon formation (Searight and others, 1953) includes those beds next above the Tebo coal and extends to the top of the Scammon coal. At the type locality of the Scammon coal at exposures along Cherry Creek, northwest of Scammon, in Cherokee County (Abernathy, 1936, p. 83-84; 1938, p. 195) only underclay and coal, overlain by about 3 feet of fossiliferous dark fissile shale and thin limestone beds, are exposed. The fauna of these beds is similar to that present above the Tebo coal, and it is possible that the type Scammon is actually Tebo. Because the name Scammon has had continued usage, and because its nomenclator did specify its stratigraphic position as being between the "Pilot" (Tebo) and Mineral coal beds, the term has been adopted in recent usage (Searight and others, 1953). The complete succession included in this formation is exposed at only one Kansas locality (strip-pit highwall in SE¼ NE¼ sec. 24, T. 28 S., R. 25 E., Crawford County). As the Scammon coal bed is too thin to be mined and lies about 23 feet below the Mineral coal and 55 to 60 feet above the next lower minable coal, the complete succession is unlikely to be exposed in strip-mining operations. The lower part of the formation is exposed in many strip mines operating on the Weir-Pittsburg coal bed. Data from logs of coal prospect drilling provide most of the information on thickness and general character of this formation in the greater part of the area, where the complete succession is not exposed.

The Scammon formation, as defined, may eventually be divided into two formations, as an unnamed coal bed is present

about midway between the Tebo and Scammon coals. The locally very prominent Chelsea sandstone occurs a few feet above this coal, and a generally less well developed sandstone bed is present below it. The coal bed or coal horizon that might properly mark the base of an upper unnamed formation has been identified in strip pits in the area along the Kansas-Missouri state line north of Mulberry, in eastern Crawford County, Kansas, and in western Barton and Vernon Counties, Missouri. A well-defined coal bed at this position has been observed only in a single exposure in southwestern Vernon County, Missouri (Personal communication, W. V. Searight, April 1, 1954). In other outcrop areas in western Missouri and in southeastern Kansas the Chelsea sandstone rests upon an erosion surface extending down through lower beds and locally through the Tiawah limestone and underlying Tebo coal. The fine-grained sandstone below the unnamed coal is thus cut out in most places, and the Chelsea sandstone occupies its position. Because of the very restricted area in which this coal horizon is recognized, the complete succession from the Tebo to the top of the Scammon coal is herein regarded as constituting the Scammon formation.

The Scammon formation has not been recognized in the Cabaniss outcrop area in eastern Labette County. This succession should crop out in the area south of Chetopa, but a combination of structural conditions and poor exposures conceal relationships of beds younger than the Bluejacket sandstone but older than the Mineral coal. On Timbered Hill, east of Bluejacket, in Craig County, Oklahoma, the Chelsea sandstone is 10 to 20 feet thick, is conglomeratic, and rests upon an erosion surface extending down at least to the Weir-Pittsburg coal. The magnitude of the unconformity at that and other localities in northern Oklahoma is seemingly controlled by folding or faulting or both. It is suggested that similar conditions are associated with the seeming absence of part of the Cabaniss succession south of Chetopa. Sandstone, believed to be Bluejacket, south of Chetopa along Neosho River is of unusual thickness, compared to that of the outcrop area farther north and east in Kansas and in northern Oklahoma. It may be a composite sandstone, comprising both the Chelsea and the Bluejacket.

The thickness of the Scammon formation ranges from 28 to 32 feet in eastern Crawford County, and from 35 to 45 feet in

central and southern Crawford County and northern Cherokee County.

In southeastern Kansas the following divisions of the Scammon formation are recognized: dark-gray to black fissile shale at the base, including a single limestone bed (Tiawah); fine-grained sandstone and siltstone; medium- to dark-gray shale; sandstone (Chelsea); underclay; and the Scammon coal bed at the top.

Lower dark shale and limestone.—The succession of closely related beds forming the lower division of the Scammon formation characteristically includes 1 to 2 feet of black, fissile shale directly above the Tebo coal, overlain by impure pyritic limestone averaging about 4 inches in thickness, which is in turn overlain by 5 to 7 feet of dark-gray to black fissile shale containing several persistent clay-ironstone beds. This succession is particularly characteristic of the exposures in eastern Crawford County. Exposures in Cherokee County show a somewhat thinner succession, in which the limestone is the principal bed. There are small phosphatic concretions in the black shale over the coal in some exposures.

The limestone bed in the succession is the Tiawah (Lowman, 1932, p. 2). It is correlated with the Seahorne limestone of Illinois (Wanless, 1931a, p. 179-193), and Iowa (Weller, Wanless, Cline, and Stookey, 1942, p. 1588), and with the limestone member of the Loutre formation (McQueen, 1943, p. 71-78) of northern Missouri. The name Tiawah for this bed has had widest usage in this area and was adopted at the Nevada conference (Searight and others, 1953). The Tiawah in eastern Crawford County is typically extremely dense, tough, and pyritic, forming a single resistant ledge. The rock weathers to a soft hematitic and limonitic mass. In exposures in Cherokee County this bed is somewhat shaly and generally carbonaceous, and averages about 4 inches in thickness. In the type area in Rogers County, Oklahoma, this bed reaches a thickness of about 4 feet, and closely resembles the Verdigris limestone.

The Tiawah limestone contains abundant fossils at most exposures. The fauna is chiefly characterized by very abundant gastropods, including *Naticopsis altonensis* and *Trachydomia oweni*, which are regarded as distinctive of this bed. The brachiopods *Mesolobus lioderma*, *Chonetina flemingi*, and *Dictyoclostus*

americanus are also very common in it. In addition to the invertebrate fauna, the Tiawah in many places in Kansas and in Missouri contains a large percentage of tabular masses of algal material, which contributes considerably to the calcium carbonate content of the rock. Figure 8 illustrates the tabular rock structure formed of algal masses. Johnson (1956) has studied material from this and other Pennsylvanian beds and has assigned the algae to the genus *Archaeolithophyllum*. Fossils in the black shale beds below and above the Tiawah consist principally of orbiculoids, but include pelecypods and conodonts.

The lower member of the Scammon formation is present in Crawford and Cherokee Counties, but seemingly is absent in eastern Labette County.

Sandstone above the lower shale and limestone.—In outcrops in the area along the Kansas-Missouri state line north of Mulberry, in eastern Crawford County, Kansas, thinly laminated sandstone and siltstone (Pl. 6A) are present above the lower shale and limestone and below the unnamed coal horizon that

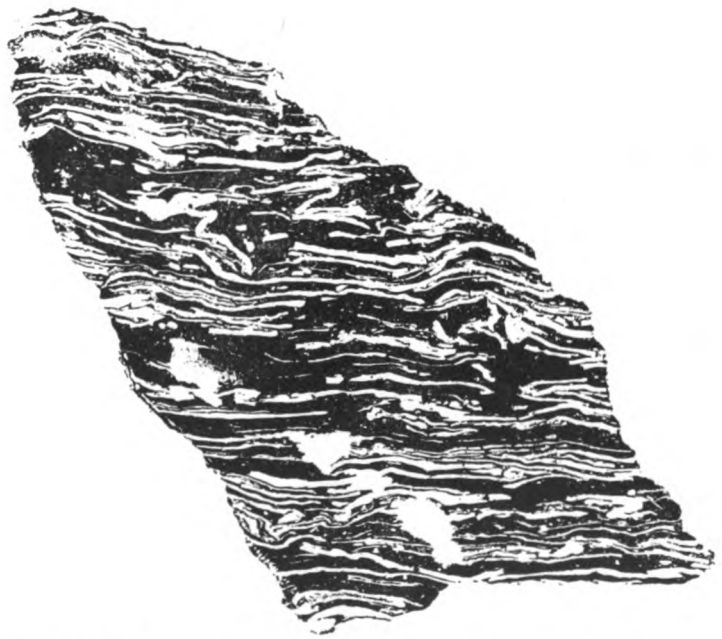


FIG. 8.—Algal laminae in Tiawah limestone, Cherokee County.

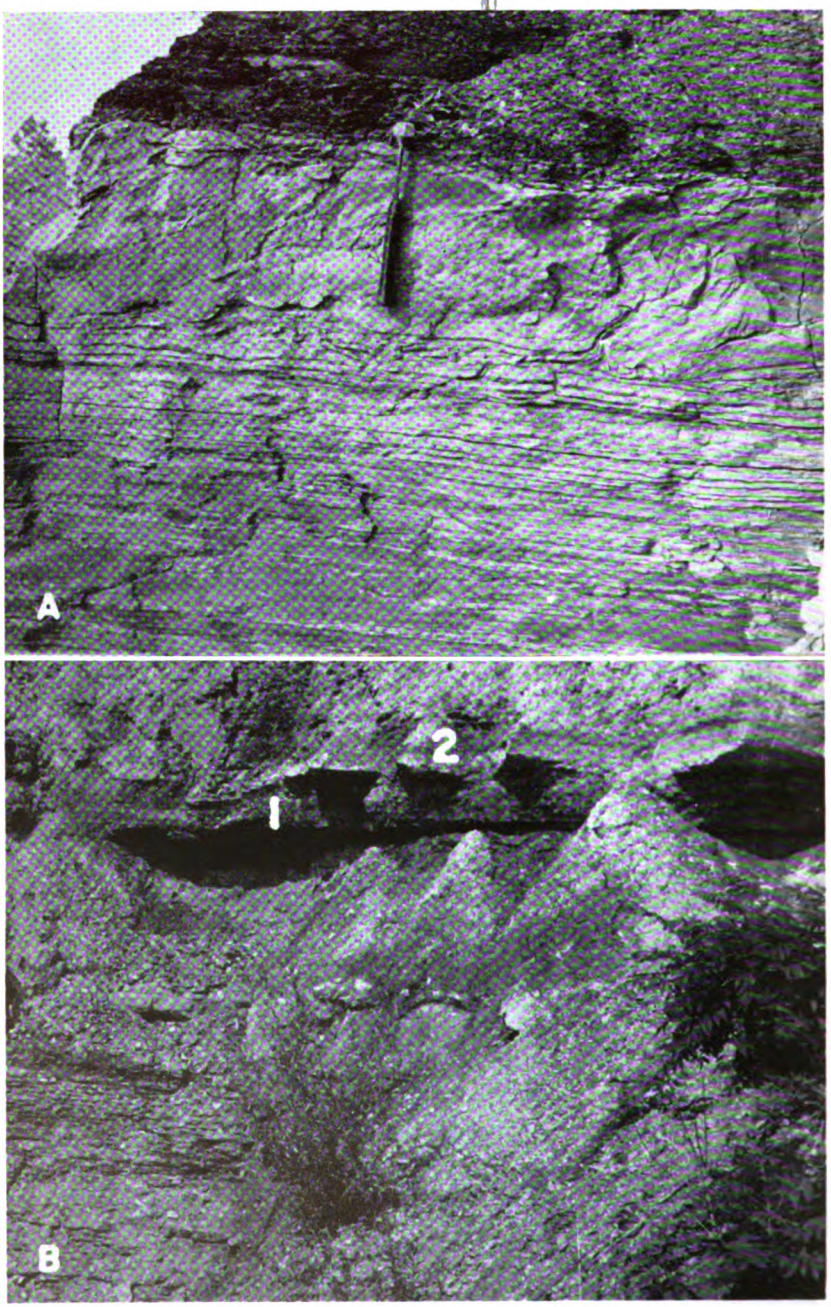


PLATE 6.—**A.** Sandstone above Tebo coal and below unnamed coal horizon (chisel point), SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., Crawford County. **B.** Scammon coal (1) and overlying limestone (2), SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., Crawford County. Note underlimestone at base of underclay.

lies between the Tebo and Scammon coals. This unit consists of thin, ripplemarked, interlaminated beds of fine-grained micaceous sandstone and siltstone, and is 6 to 8 feet thick. The rock contains structures attributed to contemporaneous deformation, and in some places is characterized by abundant worm trails. In other areas where this part of the Scammon succession is exposed, the Chelsea sandstone lies on an erosion surface extending below this bed. Logs of coal prospect drilling in Cherokee and Crawford Counties indicate that the beds constituting the Scammon formation consist chiefly of sandstone and sandy shale above the dark shale and limestone at the base. The lower sandstone could not be identified with certainty in the available logs, and the general presence of the Chelsea sandstone is inferred. In an exposure in a strip pit highwall in the SW¼ sec. 18, T. 33 N., R. 33 W., Barton County, Missouri, the uppermost part of the lower sandstone contains abundant carbonized plant material, and is soft and ferruginous. At all Kansas exposures in which it can be differentiated, the lower sandstone is bounded at the top by a very sharp lithologic break (Pl. 6A). It is overlain by dark shale or by clay-ironstone, which is overlain by dark shale.

Shale above unnamed coal horizon and below Chelsea sandstone.—Dark- to light-gray clay shale is present above the coal horizon that lies between the Tebo and Scammon coal beds in the area adjacent to the Kansas-Missouri state line north of Mulberry, Kansas. This shale unit, dark gray to black at the base, rests upon the thinly laminated sandstone below or upon a thin bed of clay-ironstone, which in turn rests on sandstone. No fossils were observed in this shale. Its thickness is uneven, as the overlying Chelsea sandstone rests unconformably upon it. The maximum thickness in exposures is about 5 feet; the bed is not differentiated in logs. It is probable that its distribution is very local in southeastern Kansas, and also in western Missouri, because of pre-Chelsea erosion.

Chelsea sandstone.—The Chelsea sandstone (Ohern, 1914; Cooper, 1927, p. 161; Oakes, 1944, p. 10) of Oklahoma occurs above the Tiawah limestone, locally cutting through it and resting on lower beds. It is locally conglomeratic, particularly in the lower part. Conglomeratic material in the Chelsea in northern Oklahoma consists almost entirely of fragments of

clay-ironstone concretions, phosphatic nodules, and detrital wood and coal, seemingly all of local origin. In Kansas and in western Missouri, sandstone having the same regional habitude occurs at the same stratigraphic position, hence the usage of the term is extended into that area.

The Chelsea sandstone is present in exposures in strip mines in eastern Crawford County, Kansas, and in western Barton County, Missouri. It also forms the cap of several outliers in the latter area. Logs of coal prospect drilling in Cherokee and Crawford Counties indicate that the Chelsea constitutes most of the rock included within the Scammon formation over most of the two-county area. A maximum thickness of almost 30 feet of Chelsea sandstone is present in the highwall of an abandoned strip mine in the NW¼ sec. 20, T. 32 N., R. 33 W., Barton County, Missouri. At that locality the Chelsea rests on an erosion surface extending below the Tebo coal, and the basal part is conglomeratic (Pl. 7A).

The Chelsea is typically a gray to brown, very fine grained, micaceous, finely to coarsely cross-bedded sandstone. It is extremely friable. Where conglomeratic this bed includes materials of local origin.

At a single exposure (abandoned strip pit in SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., Crawford County, Kansas), sandstone regarded as Chelsea is present beneath the underclay of the Scammon coal and seems to grade laterally to impure limestone. The Chelsea has a maximum thickness of about 5 feet in this exposure, which is in an area where the Scammon formation is relatively thin, and the shale below the Chelsea and above the unnamed coal attains its maximum known thickness. The impure limestone and the Chelsea sandstone are regarded as near equivalents in age.

The Chelsea sandstone has not been identified positively in southeastern Labette County (see discussion under definition and subdivisions).

Underclay.—At the single locality where the complete Scammon succession is exposed, the underclay of the Scammon coal is light gray, plastic, and ironstained. Its thickness is about 3 feet at this exposure.

Scammon coal.—The Scammon coal (Abernathy, 1936, p. 83-84; 1938, p. 195) ranges from 4 to 9 inches in thickness in ex-

PLATE 7.—**A**. Chelsea sandstone, NW¼ sec. 20, T. 32 N., R. 33 W., Barton County, Missouri. Weir-Pittsburg coal was mined here. Tebo coal and Tiawah limestone are cut out. **B.** Breezy Hill limestone in road cut east of Oswego, SE¼ SW¼ sec. 15, T. 33 S., R. 21 E., Labette County. Black shale above is Excello.

posures and in avaliable logs. It is commonly recorded in logs as being about 8 inches thick. This coal is not of minable thickness in southeastern Kansas. It has not been identified in Labette County, but is consistently logged in Cherokee and Crawford Counties. The coal has not been observed in outcrop or recorded in logs in western Missouri (Personal communication, W. V. Searight, April 22, 1954), and has not been identified in northern Oklahoma. Plate 6B is a photograph of this coal and associated beds at a locality north of Mulberry, Crawford County, Kansas.

Mineral Formation

Definition and subdivisions.—The Mineral formation (Searight and others, 1953) includes beds above the Scammon coal and extends upward to the top of the Mineral coal (Pierce and Courtier, 1937, p. 69-70). At the present time, the coal bed (Mineral) included in this formation is the most important strippable coal in the region. Only one exposure is known where the relations of the succession included in the Mineral formation are perfectly clear. The sequence between the Mineral and the next lower minable coal (Weir-Pittsburg) is too great for the two beds to be mined in tandem operation at the present time; thus artificial exposures of the succession are extremely scarce. Most strip mines operating on the Mineral bed expose only the coal and overlying beds, plus the upper part of the associated underclay. Accordingly, logs of coal prospect drilling provided most of the available information relevant to these beds in Kansas. In the single locality (strip-pit highwall in SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., Crawford County) where the succession included in the Mineral formation is exposed, the following divisions are differentiated: limestone (cap-rock of the Scammon coal), dark shale, underlimestone, underclay, and the Mineral coal bed at the top. The thickness of the Mineral formation in Crawford and Cherokee Counties averages about 23 feet. It is somewhat less in northeastern Crawford County, where measurements of less than 15 feet are common. The divisions of the Mineral formation are described in ascending order both from outcrop and from subsurface information.

Lower limestone bed.—The lower limestone bed is recorded from only one exposure (see above). It is almost certainly more extensive in southeastern Kansas, but is not recorded in logs of

coal prospect holes, which in the absence of outcrops represent the most reliable source of information. It is probable that impure limestone is widespread at the base of the formation but has not been logged as such because of the generally dark and shaly nature of limestone at this position.

The limestone identified by Abernathy in the vicinity of the type section of the Scammon coal as the cap-rock of that coal is not regarded as a part of the Mineral formation (see discussion of Scammon formation).

At the only exposure where there is no question as to the relationship of the beds involved, the lower limestone present in the Mineral formation is dark gray to black, and forms a prominent ledge ranging from 2 to 14 inches in thickness (Pl. 6B). Abundant fossils in this bed include: *Dictyoclostus americanus, Neospirifer cameratus, Mesolobus* sp., *Chonetina flemingi* var. *crassiradiatus,* and fusulines.

Dark shale.—In the exposure in the SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., in Crawford County, dark, thinly laminated shale is present above the lower limestone and below impure limestone identified as underlimestone. The thickness of the shale at that locality is about 10 feet. Dark-gray to black shale is recorded between the Mineral coal bed and the Scammon coal bed in nearly all of the available logs of coal prospect holes in Cherokee and Crawford Counties, and in most logs it makes up nearly all of the section involved. Thickness of this shale unit of the formation increases to an average between 18 and 20 feet in the area south and west of Pittsburg. The thickness of the shale is fairly uniform in Cherokee and Crawford Counties, except in the northern part of T. 32 S., R. 23 E., Cherokee County, where it is much less regular, ranging from 14 to 35 feet. The succession between the two coals is logged as containing sandstone and sandy shale only in T. 30 S., R. 24 E., Crawford County, one of ten townships in which reliable subsurface data are available.

Underlimestone and sandstone.—At the only known exposure of the complete Mineral succession (see above), deeply weathered, argillaceous limestone and iron-stained, plastic clay are present below the Mineral coal and above the dark shale described above. The thickness of the underlimestone at this locality is about 2½ feet.

Lateral extent of underlimestone in this formation cannot be

ascertained from well logs, but the bed is probably widespread, in view of the seemingly local distribution of sandstone (see above). Regionally, it is normal for coal beds above the Weir-Pittsburg coal to have either limestone or sandstone below their respective underclays, and the geologist's tendency is to expect one if the other is absent.

Underclay.—Information from logs of coal prospect holes in Cherokee and Crawford Counties indicates that the underclay of the Mineral coal ranges in thickness from 1 to 3 feet.

Mineral coal.—The Mineral coal (Pierce and Courtier, 1937, p. 69-70) is present in minable thickness along most of the line of outcrop in southeastern Kansas, and has been the most important strip-mined coal in the area. It is second in importance to the Weir-Pittsburg bed. It is 18 to 20 inches thick in most exposures in northeastern Crawford County, and ranges from a few inches to about 18 inches in thickness in southeastern Bourbon County. It is 18 to 24 inches thick in central and southern Crawford County and in northwestern Cherokee County, and its maximum logged thickness is 32 inches in T. 31 S., R. 23 E., Cherokee County. In Labette County the Mineral is somewhat thinner, averaging about 12 inches.

The Mineral coal lies 60 to 80 feet above the Weir-Pittsburg coal in Crawford and Cherokee Counties. An interval of 70 to 80 feet is common; lesser intervals separate these beds in areas in Cherokee County where the Weir-Pittsburg and Tebo coals converge (see Tebo formation). The Mineral coal bed has been stripped along nearly all of the crop line in southeastern Kansas. Pierce and Courtier (1937, p. 71) reported that a few shafts had been opened on this bed in the vicinity of Mineral, in Cherokee County, but virtually all of the actual mining of this bed in southeastern Kansas has been strip mining.

The Mineral has also been mined extensively in western Missouri, and to a minor degree in northern Oklahoma. Other names of popular derivation that have been applied to this bed include: "Weir-Pittsburg upper", "Lightning Creek", "Baxter", "22-inch", and "Top vein".

Robinson Branch and Fleming Formations

Definition and subdivisions.—The Robinson Branch formation (Searight and others, 1953) includes beds above the Min-

eral coal and extends upward to the top of the Robinson Branch coal. The Fleming formation (Searight and others, 1953) includes those beds above the Robinson Branch coal and extends to the top of the Fleming coal (Pierce and Courtier, 1937, p. 73).

These formations are described together in this report because the succession called Robinson Branch, although present in both Kansas and Missouri, is very local in its distribution. In the greater part of the area the underclay of the Fleming coal lies on marine shale associated with and lying above the Mineral coal bed; the Robinson Branch coal and overlying limestone and shale are absent. For practical purposes, therefore, the Fleming formation consists of beds above the Mineral coal, including the Fleming coal at the top.

From the facts already noted it is apparent that the succession between the Mineral and Fleming coal beds is erratic. The underclay associated with the Fleming coal is characteristically fairly thick and rests unconformably on the limestone and shale successions associated with the Mineral coal (most common relationship), on those associated with and lying above the Robinson Branch coal, or on the underclay of the Robinson Branch coal. This relationship probably accounts for the locally abnormal thickness of the Fleming underclay; in reality it is in places formed of two separate and unrelated beds of clay.

Robinson Branch Formation

This formation includes strata above the Mineral coal and extends to the top of the Robinson Branch coal, from which the formation is named, and which, in turn, is named for Robinson Branch, a stream in Vernon County, Missouri. The complete succession was formerly exposed in strip pits northeast of Walker, in the SW¼ sec. 2, T. 36 N., R. 30 W., in Vernon County (Personal communication, W. V. Searight, April 22, 1954).

The Robinson Branch together with the Fleming succession is known to be completely developed in southeastern Kansas only in the southern part of T. 32 S., R. 22 E., in Cherokee County. Stratigraphic section 35 includes description of beds between the Mineral and Fleming coals in that locality. The succession is no longer exposed, having been covered by subsequent mining operations. No exposures of the completely developed

Mineral-Fleming sequence other than that at the type locality in Missouri and in the locality described above are known to the writer in either Kansas or Missouri. The spotty distribution of these beds is interpreted as being due to preservation only in isolated structural depressions prior to the period of Fleming sedimentation. The Robinson Branch coal and associated beds above it have not been observed in reconnaissance in northern Oklahoma.

The Robinson Branch formation includes, from the base upward, limestone and calcareous shale (cap-rock of Mineral coal), dark shale, fine-grained sandstone, underclay, and the Robinson Branch coal. Of these the lower limestone and the overlying dark shale divisions are most persistent in the outcrop area in northern Oklahoma, Kansas, and Missouri.

Lower limestone and calcareous shale.—In exposures in Cherokee and Crawford Counties the lower part of the succession of beds classed as the Robinson Branch formation includes lenticular beds of massive coquinoidal limestone (cap-rock of Mineral coal) at the base, and fossiliferous calcareous shale above it or, in the absence of the limestone, directly over the Mineral coal bed. Lenticular limestone at this position is interpreted as having been formed as a biohermal accumulation of organic debris. In eastern Labette County, Kansas, and in Craig County, Oklahoma, limestone at this position forms an almost continuous bed, averaging about 18 inches in thickness. Small rough phosphatic concretions are present in association with this member in Cherokee and Crawford Counties, but are much more common and characteristic of it in eastern Labette County, Kansas, and in Craig County, Oklahoma. Most such concretions have the small phosphatic brachiopod *Orbiculoidea missouriensis* as a nucleus. They persist regardless of the presence or absence of limestone.

Limestone at this position in Cherokee and Crawford Counties ranges in thickness from a featheredge to about 3 feet. In Labette County and in Craig County, Oklahoma, where it is present as a persistent bed, its thickness ranges from about 1 foot to an observed maximum of 30 inches. Branson (1952, p. 191) applied the name Russell Creek to this limestone in Craig County, Oklahoma. Calcareous shale present above the limestone, or over the Mineral coal, in the absence of any limestone, ranges from a few inches to about 3 feet in thickness.

Fossils in the lower limestone and calcareous shale division of the Robinson Branch formation include abundant *Dictyoclostus americanus, Neospirifer cameratus, Composita subtilita,* and crinoidal material. *Mesolobus euampygus* and *Marginifera muricatina* are less abundant. *Fusulina* sp., *Wedekindellina* cf. *euthesepta,* and *Fusulinella?* are also common in the lower division, *Fusulina* predominating. Crinoid columnals found in these beds are in general larger than those found in other beds within the Krebs and Cabaniss subgroups in the region. In the larger columnals the axial canal is slightly off center in many of the specimens examined. Crinoid columnals of this size (½- to ¾-inch diameter) and with this distinguishing earmark seem to be restricted to this zone.

Dark shale.—Dark-gray to black shale, weathering dark to light gray, overlies the lower calcareous shale and limestone unit of the Robinson Branch formation in all exposures observed in the area of this report. The shale is thinly laminated, and in general breaks down rapidly upon weathering. Scattered fossils, principally the brachiopod *Mesolobus decipiens,* are present in the lower part of this unit. In most places this shale member is overlain by the underclay of the Fleming coal bed, the Robinson Branch coal and closely associated clays and shales being absent or indistinguishable. Locally, very fine grained sandstone or siltstone lies between the dark shale and overlying underclay units. The average thickness of the dark shale member of the formation in southeastern Kansas is about 8 feet.

Sandstone and underlimestone.—Sandstone thought to belong at this position has been observed at only one exposure in southeastern Kansas (strip pit highwall, SE¼ sec. 24, T. 31 S., R. 24 E., Cherokee County), where it was 5 to 6 feet thick. At this locality the coal believed to be Robinson Branch is very poorly developed and its relations are uncertain. Sandstone at this position is extremely uncommon in the area of this report. Underlimestone has not been observed in this formation in southeastern Kansas.

Underclay.—In the only locality where it can be identified with certainty (see above), the underclay member of the Robinson Branch formation averages 1 foot in thickness and contains fossil plant material and root impressions.

Robinson Branch coal.—The Robinson Branch coal has been positively identified in Kansas only in a single exposure in Cherokee County (stratigraphic section 35). This was in the highwall of an operating strip mine (now abandoned) in the NE¼ sec. 34, T. 32 S., R. 22 E., Cherokee County, where it ranges from a featheredge to 4 inches in thickness. The only area in which this coal is known to have been of minable thickness is near Walker, Vernon County, Missouri, where there was only local development of coal thick enough to mine. Studies of plant spores contained in this coal by the Missouri Geological Survey provided important corroborative evidence in correlation of coal at this position in Missouri with that in Kansas.

The Robinson Branch coal is present only very locally in Kansas and Missouri, and has not been observed in northern Oklahoma.

Fleming Formation

The Fleming formation is very irregular because of the restricted distribution of lower portions of the succession, and because of the exceptional variation of the Fleming coal itself. Over most of the outcrop area in southeastern Kansas the Fleming formation consists of the Fleming coal and its underclay, lying on underclay or dark shale properly included in the Robinson Branch formation below. The underclay of the Fleming coal bed is characteristically abnormally thick where the underlying Robinson Branch coal and closely associated beds are absent, and is only about 1 foot thick in the very local areas where they are present. Where the Fleming underclay is of abnormal thickness it is interpreted as consisting of the underclay members of both the Fleming and Robinson Branch formations. The Fleming formation, in localities where the complete succession is present, includes from the base upward: calcareous shale and thin beds of limestone, dark shale, sandstone, underclay, and the Fleming coal at the top.

Calcareous shale and limestone.—This portion of the succession has been studied in only a single locality in southeastern Kansas (see above). In nearly all exposures of the Mineral-Fleming sequence the lower part of the Fleming formation as well as the upper part of the Robinson Branch formation is absent. In the NE¼ sec. 34, T. 32 S., R. 22 E., Cherokee County,

where it was exposed during strip-mining operations, this succession includes thin, impure shaly limestone and calcareous shale beds in the lower part and a thin, nonpersistent, massive impure limestone bed above. The lower part is extremely fossiliferous, containing abundant *Mesolobus decipiens,* plus *Marginifera muricatina, Dictyoclostus americanus,* and *Neospirifer cameratus.* Its thickness at the single exposure observed ranges from 16 to 20 inches. The impure massive bed above weathers to a cindery, ferruginous material, and is characterized by an abundance of *Crurithyris planoconvexa.* It ranges in thickness from a featheredge to about 4 inches.

Dark shale.—Dark-gray to black shale above the lower division of the Fleming formation is also known from only a single locality in Kansas (see above). About 4 feet above the base it includes thin limestone beds containing abundant *Marginifera muricatina.* At the single exposure the maximum thickness of this bed is about 9 feet.

Sandstone.—Sandstone below the underclay of the Fleming coal is uncommon in southeastern Kansas. Scattered occurrences are known, and the underclay of the Fleming is commonly somewhat silty in the basal part, a possible indication of somewhat wider extent of sandstone at this position prior to the deposition of the overlying beds. An unusual feature is noted in the NE¼ sec. 34, T. 32 S., R. 22 E., Cherokee County, where a clastic deposit consisting of clay and shale pellets and pebbles of limestone occupies a channel cut through the Robinson Branch formation, and according to miners' reports, very locally through the Mineral coal below. Coarse clastics at this position seem to be uncommon in southeastern Kansas. The maximum thickness of sandstone at this position in Kansas is about 12 feet at the locality described above.

Underclay.—Underclay associated with the Fleming coal in southeastern Kansas ranges in thickness from about 1 foot to 9 feet. The thicker exposures probably include clay properly classed in the Robinson Branch formation below. In most exposures the lower part of the clay is somewhat silty, and may contain small irregular concretions of impure limestone. Fossil root impressions are common in the clay.

Fleming coal.—In southeastern Kansas the Fleming coal is chiefly characterized by its variability in thickness and quality.

It is very commonly seen to grade from a mere streak to a bed 1 foot or more in thickness within a few hundred feet along the highwall in strip mines. Because of this variation in thickness, it is seldom mined exclusively, but is normally mined in conjunction with the Mineral coal when it is of sufficient thickness and of suitable quality. Principal factors affecting quality of this coal are local rashy or "dirty" condition, and its singular characteristic of containing large numbers of coal balls in local areas. The greatest thickness of Fleming coal observed in southeastern Kansas is 26 inches. Popular names applied to this bed include: "Bastard bed", "Mineral rider", "Middle", and "Two-foot".

Croweburg Formation

Definition and subdivisions.—The Croweburg formation (Searight and others, 1953) includes beds above the Fleming coal and extends to the top of the Croweburg (Pierce and Courtier, 1937, p. 74-75) coal. From the base upward the succession includes: massive dark lenticular limestone and dark-gray calcareous shale (cap-rock of Fleming coal), dark-gray to black shale containing clay-ironstone concretions, lenticular sandstone and underlimestone, underclay, and the Croweburg coal member at the top. Each of the above-named divisions of the Croweburg formation is extremely variable in thickness, lithology, and distribution, with the exception of the Croweburg coal, which is regular in thickness everywhere but the southwestern part of T. 30 S., R. 24 E., Crawford County, where it is thin and irregular.

Lower limestone and calcareous shale.—The lowermost division of the Croweburg formation consists of lenticular dark-gray coquinoidal limestone and dark-gray calcareous shale. The limestone, which ranges in thickness from a featheredge to about 3 feet, is interpreted as a biohermal accumulation of organic debris over the Fleming coal, deposited prior to other distinguishable beds. It is very erratic in distribution, and generally is not traceable along the highwall in any individual strip mine. The coquinoidal limestone includes a marked predominance of the brachiopod *Marginifera muricatina*, in addition to *Crurithyris planoconvexa*, *Neospirifer cameratus*, and locally very abundant fusulines.

Above the basal lenticular limestone, or resting directly on the Fleming coal bed, is calcareous shale, ranging in thickness from a few inches to 4 feet. Locally this shale contains fossiliferous limestone concretions, and a thin bed of impure limestone occurs at the top. Common fossils in the calcareous shale are *Crurithyris* and *Marginifera.*

Dark-gray to black shale.—Massive very dark gray or black shale above the calcareous lower member is a characteristic division of the Croweburg formation. This unit generally contains large clay-ironstone concretions, which weather to limonite and hematite. The black shale is very thinly laminated, but not brittle or hard like black shale of the Verdigris and Excello formations. Very large masses of this shale that in some places have been removed in strip-mining operations expand or exfoliate on weathering so as to form soft loose sheets of shale. Expansion of the dark shale seems to be due to the formation of gypsum along bedding planes. Gypsum in weathered shale occurs as large euhedral crystals, and probably was formed concurrently with the weathering of pyrite, which is also present in the shale. The pyrite, chiefly replacement of shell material, is thought to have been formed during diagenesis of the sediments. The basal part of this member contains abundant carbonized plant material, and is black where weathered. The upper portion, much less carbonaceous, may be somewhat silty, and where weathered is light gray or tan and dun.

Thickness of the dark shale member of the Croweburg formation ranges from about 2 feet to a maximum of about 17 feet, the average being approximately 6 feet. In areas where the overlying lenticular sandstone is present the interval may be partly or completely occupied by sandstone.

Underlimestone and sandstone.—In nearly all exposures of the Croweburg succession in the southeastern Kansas area, either impure limestone or massive lenticular sandstone lies beneath the underclay of the Croweburg coal and above the dark shale member of the formation. In exposures where both sandstone and limestone are present, they are judged to be equivalent in age, for the limestone becomes conglomeratic laterally and grades to massive, very fine grained sandstone. This relationship is interpreted as indicating the margin of an area of shallow marine scour and fill, the impure limestone now present having been

preserved in isolated areas that were too shallow to allow extensive accumulation of sand by wave or current action.

Sandstone belonging to this member is marine, as suggested by size distribution of the grains and proved by the contained marine fossils. Laboratory studies of the sand show that 40 to 60 percent (by volume) of the grains pass the 60-mesh and are retained on the 100-mesh screen, and about 30 percent are retained on the 160-mesh screen (Tyler series). It is well-sorted, very fine sand. The unit is a single massive bed in most places, but elsewhere consists of flaggy irregular beds separated by sandy shale. Locally it is calcareous in the upper part, and is characteristically micaceous. In natural exposures the rock is extremely friable, and weathers brown or tan. On fresh surfaces it is medium to light gray.

Sandstone in the Croweburg formation rests unconformably on the dark shale below and ranges in thickness from a featheredge to about 15 feet. At the basal contact, the shale below is so leached by ground water that the bedding is destroyed. The sandstone is interpreted as a scour-and-fill deposit formed in shallow marine water.

Sandstone in the formation is particularly prominent in the south-central part of T. 30 S., R. 24 E., the northern and western parts of T. 31 S., R. 24 E., and in the southeastern part of T. 31 S., R. 23 E. It is also known to be present in the north-central part of T. 33 S., R. 22 E., north of Hallowell, in Cherokee County, and north of Chetopa, in eastern Labette County, as well as in northern Oklahoma. It is not known in the area of outcrop north and east of Pittsburg, in Crawford County.

Marine fossils present in the sandstone include gastropods, pectinoid clams, and the brachiopods *Marginifera muricatina*, *Juresania*, *Composita*, and *Linoproductus*. All are preserved as molds. Fossils are known only from two localities: NW¼ NW¼ sec. 32, T. 31 S., R. 24 E., and SE¼ NE¼ sec. 36, T. 31 S., R. 23 E., both in Cherokee County, and both in the area where the sandstone is most prominently developed.

Impure limestone above the dark shale member of the Croweburg formation and below the underclay of the Croweburg coal is known only where the sandstone prominently developed at this position is absent. It is observed in southeastern Kansas north and east of Pittsburg, Crawford County, and in Cherokee

County, southwest of Mineral. The bed occupies the position of an underlimestone, lying directly beneath underclay. It is extremely irregular in thickness and lithology, varying from an unfossiliferous, silty, nodular or massive irregular bed to impure shaly limestone beds that contain marine fossils and are separated by clay. At one locality portions of this variable bed or beds consist of material identified as mud-crack fillings. In southeastern Kansas the unit ranges in thickness from a few inches to about 4 feet.

Fossils observed in the underlimestone include *Composita, Marginifera, Derbyia, Juresania, Mesolobus, Orbiculoidea, Crurithyris*, clams, and crinoid fragments.

Limestone occurring conformably beneath the underclay of a coal bed is interpreted as having been formed in water too deep to allow the growth and accumulation of plant matter.

Marine underlimestone is found in the Croweburg formation of northern Oklahoma, where it is less irregular in thickness. Seemingly this is the bed called McNabb limestone in Oklahoma.

Underclay.—This unit is commonly sandy to silty and micaceous, and contains abundant carbonized plant material. Impressions of fossil plant rootlets are recognizable in most exposures, and stigmaria with rootlets attached were observed at one locality. Thickness of the underclay ranges from 2 to 6 feet, averaging about 3 feet.

Croweburg coal.—The Croweburg coal (Pierce and Courtier, 1937, p. 74-75) is one of the most persistent beds within the Cabaniss and Krebs subgroups in Kansas, Oklahoma, and Missouri, and has equivalents in Iowa (Whitebreast coal) and Illinois (Colchester No. 2 coal). It is the extensively mined Broken Arrow coal of northern Oklahoma.

In southeastern Kansas, the Croweburg coal bed ranges in thickness from 9 to 15 inches, except in the south-central part of T. 30 S., R. 24 E., Crawford County, where it is very thin and irregular. It has been strip-mined locally along the outcrop in Kansas. This is an important coal in northern Oklahoma. In some of the larger strip mines of Crawford County, it has been mined in tandem operation with the Mineral coal and also the Fleming coal, where the latter is of sufficient thickness and satisfactory quality. Popular names applied to this coal bed include: "Fireclay", "One-foot", "Ten-inch", "Moundville", and "Soap-

stone". Most of these names are based on the normally even thickness of the bed or on its relation to the widespread light-gray shale above.

Verdigris Formation

Definition and subdivisions.—The Verdigris formation (Searight and others, 1953) includes beds above the Croweburg coal and extending to the top of the Wheeler coal (Weller, Wanless, Cline, and Stookey, 1942, p. 1586, 1590; Howe and Searight, 1953, p. 4). The formation takes its name from the exceptionally widespread Verdigris ("Ardmore") limestone (Smith, in Woodruff and Cooper, 1928), which is its most prominent member.

In northern Missouri this formation includes the following members, from the base upward: thinly laminated light-gray clay shale, black fissile shale, Verdigris limestone, underclay, and the Wheeler coal. The Wheeler coal and its associated underclay are not recognized in western Missouri, southeastern Kansas, or northern Oklahoma. Outside the area of occurrence of the Wheeler coal the top of the formation is drawn at the base of the underclay beneath the Bevier coal. In western Missouri and in Cherokee and Crawford Counties, Kansas, the underclay of the Bevier coal lies directly on the Verdigris limestone, and the Verdigris becomes the uppermost member of the formation in these areas. In eastern Labette County, Kansas, and in northern Oklahoma, a succession of shale and sandstone beds occurs between the Verdigris limestone and the Bevier coal. These strata are included in the Verdigris formation because they are judged to be older than the Wheeler coal and underclay, and to have close genetic relation to the Verdigris. This relationship is discussed in the description of the Bevier formation.

The thickness of the Verdigris formation is relatively even along the outcrop in Crawford and Cherokee Counties, increasing somewhat in eastern Labette County, and in northern Craig County, Oklahoma. Marked increase is noted south of Craig County, owing to increase in thickness of the lower shale unit. Thickness of this division of the formation increases locally to approximately 50 feet in Rogers County, Oklahoma.

Gray shale.—In southeastern Kansas, the lower division of the Verdigris formation consists, in most exposures, of thinly

laminated light-gray clay shale ("soapstone") containing scattered small clay-ironstone concretions. No formal name has been applied to this unit in Kansas and Missouri, but its correlative in Illinois has been termed Francis Creek shale (Wanless, 1929, p. 89). The light-gray shale described above is predominant in western and northern Missouri and in northern Oklahoma as well, but locally in southeastern Kansas black fissile shale as much as 2 feet thick forms the base of the unit, directly overlying the Croweburg coal. Such black shale is noted in abandoned strip mines in the SE¼ NW¼ sec. 24, T. 29 S., R. 25 E., and the NW¼ SW¼ sec. 27, T. 30 S., R. 24 E., both in Crawford County. The black fissile shale at the base of the lower shale is not to be confused with black fissile shale containing small phosphatic concretions that normally is observed above the lower shale member, but that in a few places rests directly on the Croweburg coal bed where the lower shale member is absent. This latter relationship was not observed by me but is reported by Pierce and Courtier (1937, p. 75), in the SE¼ NE¼ sec. 8, T. 31 S., R. 23 E., Cherokee County, and near the center of the N½ sec. 17, T. 35 S., R. 21 E., Labette County. Absence of the lower shale member is uncommon in southeastern Kansas, and was not observed in northern Oklahoma.

Fossils in the lower shale member of the Verdigris consist principally of clams and chonetid brachiopods. The pelecypod *Dunbarella* is common, and the brachiopod *Mesolobus decipiens* occurs locally in the gray shale. No fossils were observed in the few exposures of black fissile shale in the basal part of the member.

At some outcrops of the lower shale division, the uppermost part, directly below black, phosphatic fissile shale of the next higher member, is leached and resembles underclay. Whether this clay represents the leached upper portion of the lower shale or is a true underclay is undetermined. In the area of the present report, no coal is known to occur between the lower gray shale and black phosphatic members, and there are no reports of coal at this position in adjacent areas.

Thickness of the gray shale unit in southeastern Kansas ranges from a minimum of about 2 feet in the vicinity of Croweburg, northeastern Crawford County, to a maximum of 18 feet in the NW¼ SW¼ sec. 27, T. 30 S., R. 24 E., also in Crawford

County. The average thickness in the three-county area in which the beds are exposed in Kansas is about 8 feet. The unit thickens slightly in Craig County, Oklahoma, and increases to about 50 feet in Rogers County, Oklahoma.

Black fissile shale.—Black fissile shale containing abundant small phosphatic concretions occurs above the lower shale division of the Verdigris formation and below the Verdigris limestone throughout a widespread area in Oklahoma, Kansas, Missouri, and Iowa; equivalent shale is recognized also in Illinois. In southeastern Kansas, as well as in adjacent areas in Oklahoma and western Missouri, this unit ranges from 2 to 5 feet in thickness, averaging about 3 feet. Because of its extensive distribution and constant association with the overlying Verdigris limestone, it forms an important stratigraphic datum within the Cabaniss subgroup. Fossils observed in this unit consist principally of conodonts and orbiculoid brachiopods. *Marginifera muricatina, Composita,* small ammonoids, and simple corals were found in one exposure, but may be regarded as rare in this unit. Many of the small phosphatic concretions have nuclei consisting of coprolitic masses of fragmentary phosphatic material composed principally of fish scales.

Verdigris limestone.—The Verdigris limestone (Smith, in Woodruff and Cooper, 1928) is the most persistent and also the thickest limestone in the Cabaniss succession. It comprises the bed or beds called Ardmore by Gordon (1893, p. 20-21), in northern Missouri. The term Verdigris, from occurrences along Verdigris River, in Rogers County, Oklahoma, has had wider usage and for that reason was adopted at the Nevada conference (Searight and others, 1953).

The Verdigris member includes several limestones and intervening shale beds. In northern Missouri it is overlain by the underclay of the Wheeler coal. In western Missouri and in most of the outcrop area in Kansas it is overlain by the underclay of the Bevier coal. In Labette County, Kansas, and in northern Oklahoma the Verdigris is overlain by shale and sandstone. These relationships are described in the discussion of the Bevier formation. In the entire area of its outcrop, and to an unknown extent in the subsurface, the Verdigris is underlain by the prominent bed of black fissile shale described in the preceding section.

Along its outcrop area in southeastern Kansas, the Verdigris member consists of three limestone beds and intervening shale units. The uppermost limestone bed is the thickest and most prominent of these subdivisions in Crawford and Cherokee Counties, but it has not been recognized in eastern Labette County, where the Verdigris succession is somewhat thinner and consists mostly of thin flaggy limestone and calcareous shale. It is probable that the principal limestone in eastern Labette County corresponds to the middle limestone of the succession as developed in Cherokee and Crawford Counties, and that only calcareous shale and thin irregular limestone represent the uppermost limestone bed. In Cherokee and Crawford Counties, the upper limestone bed is characteristically a single massive bed of mottled light- and dark-gray limestone (Pl. 8A). The darker masses are angular to irregularly rounded limestone fragments ranging from slightly less than 1 inch to a maximum of about 6 inches in greatest dimension. They are arranged at random in the lighter-gray matrix. Studies of peel sections of this bed indicate that the rock is composed principally of finely disintegrated algal material, and that the darker portions represent reworked limestone formed almost entirely of very fine particles of calcium carbonate. The lighter-colored matrix consists of similar material, but differs in that it contains very abundant foraminiferal detritus, in addition to scattered crinoid ossicles and shells of brachiopods. Slivers of coal also are common in the lighter-gray portion. Foraminifera in the rock consist mainly of fragments of forms referred to *Ptychocladia,* an incrusting type. Fusulines and biserial foraminifers are uncommon. The darker masses in the limestone are more resistant to weathering than the light-colored matrix, seemingly because of their lesser porosity, and form an irregular nodular surface. The rock weathers light gray to buff, and ranges from 18 to 32 inches in thickness, averaging about 24 inches. Jointing has divided the bed into large rhombs (Pl. 8B).

The middle limestone of the Verdigris member is a dense, dark-gray to black bed, but is represented in part of the area only by a prominent zone of dark-gray to black limestone concretions, which are flattened and smooth and form a nearly continuous bed. The middle limestone bed of the Verdigris is separated from the lower one by 1½ to 5 feet of black fissile shale,

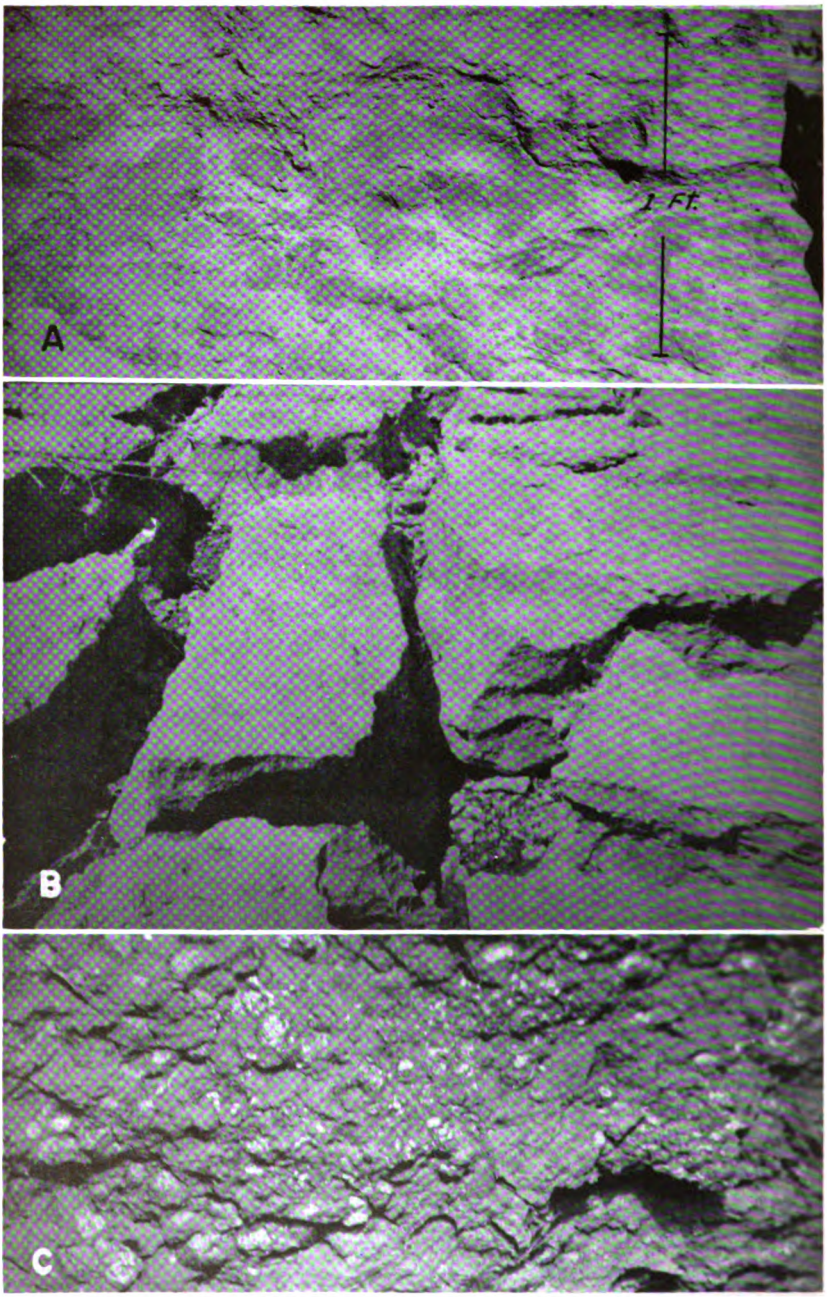


PLATE 8.—**A.** Verdigris limestone, SW¼ SW¼ sec. 32, T. 27 S., R. 25 E., Crawford County, showing nodular character of joint surface. **B.** Prominent jointing in Verdigris limestone at same locality. **C.** Pyritized *Marginifera muricatina* in shale above Bevier coal, SE¼ sec. 6, T. 31 S., R. 22 E., Crawford County.

overlain by light-gray fossiliferous shale. The upper part of this intervening unit is almost everywhere leached by circulating ground water, which has destroyed the bedding. The average thickness of the middle limestone bed is about 8 inches.

The lower limestone bed of the Verdigris member in southeastern Kansas consists of a zone of dark-gray to black limestone concretions. The concretions are nearly spherical, flattened, or dumbbell-shaped forms, and most of them have pyritic rinds about ½ inch thick. Their maximum observed diameter is about 3 feet. At one locality (SE¼ NW¼ sec. 28, T. 29 S., R. 25 E., Crawford County), the concretions are septarian, and are veined with coarse dolomite crystals. This limestone unit is separated from the middle limestone by 10 to 15 inches of dark-gray to black fissile shale. The limestone averages about 10 inches in thickness.

In eastern Labette County, the Verdigris limestone consists of a succession of thin limestone and intervening calcareous shale beds. The most prominent of these strata is a massive, brittle, dense, dark-gray to black limestone forming a single ledge. Outcrops between this area and localities to the north and east where three limestone beds are recognized are insufficient to allow identification of the principal bed in Labette County. On the basis of lithology, the prominent limestone bed of the Verdigris member in the eastern Labette County area is judged to be equivalent to one or the other of the lower limestones, probably the middle one, as it seems to be more nearly continuous in exposures to the north and east.

The Verdigris succession contains abundant fossils, among which the most important are the following: *Marginifera muricatina,* abundant in the shales; *Mesolobus euampygus,* common only in the upper limestone bed; *Fusulina* sp., known only from the upper bed; *Chaetetes milleporaceous,* occurring in the upper bed; *Neospirifer cameratus, Phricodothyris perplexa, Composita subtilita, Crurithyris planoconvexa, Dictyoclostus americanus,* and crinoid fragments, common in various beds of this member.

The Verdigris limestone is the most prominent unit in the Cabaniss subgroup, being virtually continuous from Arkansas River in Oklahoma northward to Iowa, and has correlatives in Illinois (Oak Grove limestone) and in Ohio (Hamden limestone). It is the bed formerly called Ardmore in Missouri.

Upper shale and sandstone.—Gray shale, overlain by fine-grained sandstone, lies above the Verdigris member and below the underclay of the Bevier coal in eastern Labette County and in northern Oklahoma. It is not known in Cherokee and Crawford Counties nor in the outcrop area in Missouri. This succession is 10 to 20 feet thick in Labette County and approximately the same in northern Craig County, Oklahoma. The problem of the original extent of the upper part of the Verdigris formation is discussed under Bevier formation.

Bevier Formation

Definition and subdivisions.—The Bevier formation (Searight and others, 1953) consists of only two members: the Bevier coal and its underclay. The name Bevier was originally applied by McGee (1888, p. 328-336) to the coal mined extensively at Bevier, Macon County, Missouri, after which town it takes its name, and in other areas in north-central Missouri. The "Bevier" coal of the type area consists of two distinct coal beds, separated by a parting of stigmarian sandstone or shale. At the Nevada conference (Searight and others, 1953) the term Bevier was restricted to the upper of the two coal beds, and the Iowa term Wheeler (Weller, Wanless, Cline, and Stookey, 1942, p. 1586, 1590) was adopted for the lower coal. The Bevier coal, as redefined, is the thicker and more widespread of the "Bevier" coals. The succession above the Bevier (restricted) of northern Missouri and that above the single bed called Bevier in southeastern Kansas (Pierce and Courtier, 1937, p. 76) are very similar; because of this similarity and the more widespread distribution of the upper of the "Bevier" coals, the Kansas coal is judged to be correlated properly with the Bevier as redefined. The Wheeler coal bed is not known in western Missouri, southeastern Kansas, or northern Oklahoma.

The Bevier formation in the outcrop area of southeastern Kansas is uniformly overlain by thin beds of limestone and calcareous shale. Relations to underlying strata are more complex. Throughout most of the outcrop area in Cherokee County and all of the outcrop area in Crawford and Bourbon Counties, the underclay member of the formation rests directly on the Verdigris limestone, but in eastern Labette County, and probably in

westernmost Cherokee County, the underclay of the Bevier coal overlies sandstone or sandy shale above the Verdigris limestone. Shale and sandstone above the Verdigris and below the Bevier coal bed are unknown northeast of this area along the outcrop belt in southeastern Kansas, but they are found to be persistent in northern Oklahoma, thickening southward. This succession probably never extended farther northeast, for no remnants of such beds are known in southeastern Kansas or western Missouri. An alternative possibility is that all such shale and sandstone was removed by pre-"Bevier" erosion that cut down only to the relatively thick, resistant Verdigris limestone in areas where underclay of the Bevier or Wheeler coals now rests upon Verdigris instead of shale and sandstone. This area would have had to include at least the outcrop areas in Missouri, and the greater part of that in southeastern Kansas. The sandstone and shale succession found above the Verdigris limestone in Labette County and in northern Oklahoma seemingly is older than the lower coal of the "Bevier" beds in the type area. No coal or coal horizon other than that called Bevier in this report is known between the Verdigris limestone and the Iron Post coal in southeastern Kansas or northern Oklahoma. The relationship of the Bevier formation to the underlying Verdigris formation is illustrated graphically on Plate 1 and Figure 4.

Underclay.—In Bourbon and Crawford Counties, and probably all but the westernmost part of Cherokee County, the underclay of the Bevier coal rests directly on the Verdigris limestone. In a large part of this area the underclay is very thin, accounting for the popular name "Limestone seam" given to the Bevier coal bed. In very few places is the thickness of the underclay in these areas more than 1 foot, and in most places it is less than 6 inches. A maximum thickness of about 4 feet is reported by miners. In the area to the south and west in Labette County, the underclay of the Bevier coal bed lies on sandstone or sandy shale, and is 2 to 3 feet thick. Carbonized plant material and fossil root impressions are abundant in the underclay.

Bevier coal.—The Bevier coal is third in commercial importance among coal beds in the southeastern Kansas area; it has been or is being strip mined very extensively along its outcrop in Bourbon, Crawford, and Cherokee Counties, and in a small area south of Oswego, in eastern Labette County. The coal thins very

rapidly southward from Oswego but is traceable into Craig County, Oklahoma, where it persists as a thin smut. Locally in southern Craig County this coal reaches a thickness of nearly 1 foot (stratigraphic section 1). It is not known to have been mined in northern Oklahoma. The northernmost area of stripping of Bevier coal in Kansas is situated north and west of Garland, southeastern Bourbon County.

The "Stice" coal of Labette County, named by Pierce and Courtier (1937, p. 77-78) for exposures near Stice School, in the NE¼ sec. 33, T. 33 S., R. 21 E., is the Bevier bed, so it is suggested that use of the name Stice be discontinued.

The Bevier coal is characteristically bright, hard, and blocky. Calcite is common along the cleats in this bed. Pyrite occurs as thin persistent layers. Vitrain, and especially clarain, are principal constituents of the coal. At outcrops in Cherokee, Crawford, and Bourbon Counties, the thickness of the Bevier ranges from 15 to 24 inches, but as a rule it is almost uniform in individual mines. Within the small area of stripping in eastern Labette County, however, the maximum thickness of the coal is about 15 inches; south of this area it thins to 1 or 2 inches.

Popular names applied to the Bevier coal in southeastern Kansas include: "Pioneer", "Drywood", "Ironclad", "Limestone", and "Lightning Creek".

Lagonda Formation

Definition and subdivisions.—The Lagonda formation (Searight and others, 1953) includes beds above the Bevier coal and extending to the top of the Iron Post coal (Howe, 1951, p. 2092). The term Lagonda was first used by Gordon (1893, p. 13, 19-20), who applied it to deposits present above the Bevier coal and below the underclay of the Mulky coal.

In the Oklahoma-Kansas-Missouri area the Lagonda formation includes a lower limestone and shale member, shale, sandstone, underclay, and the Iron Post coal bed at the top. Only two of these divisions are persistent throughout the area; they are the thick shale and overlying sandstone units, which constitute most of the formation in the region. The lower limestone and shale member is well developed only in southeastern Kansas, and is not known in northern Oklahoma. The Iron Post coal and

its underclay are known only in Oklahoma. This coal bed is not present in the outcrop area in southeastern Kansas, but its horizon forms the uppermost unit of the formation throughout the region. In Kansas and Missouri the Breezy Hill limestone member of the overlying Mulky formation rests directly on sandstone of the Lagonda formation.

Lower limestone and dark shale.—The lowermost division of the Lagonda formation in southeastern Kansas consists of a succession of thin, fossiliferous, impure limestone beds and intervening fossiliferous dark-gray to black shale beds. Throughout most of the outcrop area in southeastern Kansas extremely fossiliferous shale, which grades laterally to shaly coquinoidal limestone, is present in the lowermost part of the member. This unit forms the cap-rock of the Bevier coal. Several thin impure limestone beds separated by dark shale constitute the upper part. Distinction between the lower limestone and dark shale and the overlying light-gray shale divisions is based principally upon differences in lithology and the general lack of fossils in the light-gray shale. Some of the thin impure limestone beds in the lower member seem to grade laterally to clay-ironstone. Pyritization of fossils in the lower member is common (Pl. 8C), and at many places a thin layer of pyrite containing abundant fossils is found at the base, directly overlying the Bevier coal.

Limestone and intervening shale in the lower part of the Lagonda formation locally contain very abundant fossils in the southeastern Kansas area. Most of the forms are mollusks and productids. *Marginifera muricatina* is especially common, particularly in the basal limestone or calcareous shale.

This division of the Lagonda formation is present consistently in southeastern Kansas, and locally in western Missouri, but is not known in northern Oklahoma, where the Bevier coal-Iron Post coal interval decreases very markedly, and silty or sandy shale rests on the Bevier coal bed. Thickness of the lower limestone and shale member of the Lagonda formation in Kansas is variable, ranging from 2 feet to about 6 feet.

Light-gray shale.—Lying above the thin limestone and fossiliferous shale beds and below the characteristically variable sandstone of the Lagonda formation is one of the thickest shale units in the pre-Marmaton Pennsylvanian succession in south-

eastern Kansas (Pl. 9A). This bed consists of light- to medium-gray, finely micaceous to silty clay shale, averaging somewhat more than 50 feet thick in southeastern Kansas. It is not sharply set off from either lower or higher beds. From northeast to southwest along the line of outcrop the thickness of this unit varies. North of Arma, northeastern Crawford County, it is 70 to 80 feet; it diminishes to about 30 feet in sec. 16, T. 31 S., R. 23 E., west of Cherokee, Cherokee County, and is 40 to 50 feet in the vicinity of Oswego, eastern Labette County. From Labette County southward into Craig County, Oklahoma, it diminishes very rapidly to an observed minimum of about 3 feet in the area west of Vinita, where the Lagonda is very thin and is represented chiefly by sandy shale.

In southeastern Kansas, this shale unit commonly contains vertically orientated dike-like structures attributed to the action of ground water along closely spaced joints. "Dikes" thus formed average 2 or 3 inches in width, are slightly darker than the adjacent shale, and seemingly result from localized oxidation of ferruginous matter in the shale, owing to greater surface area along the joint planes. Calcareous shale concretions are found at some places in the shale.

This shale has been used in southeastern Kansas for the manufacture of red-burning brick and tile.

Sandstone.—In outcrop areas in southeastern Kansas, sandstone classed as a part of the Lagonda occurs in the uppermost portion of the formation and is overlain by the Breezy Hill limestone member of the Mulky formation. In northern Oklahoma, where the Iron Post coal and other beds are present beneath the Breezy Hill, this sandstone is below the underclay of the Iron Post coal. This relationship is illustrated by Figures 4 and 6 and by Plate 1.

Sandstone of the Lagonda formation is widely known as the "Squirrel" sand of drillers. It is characteristically thin, averaging about 8 feet in thickness. The rock is commonly finely cross-bedded, and at some outcrops calcareous concretions contain sparse marine fossils.

Underclay.—Underclay beneath the Iron Post coal is restricted to the area in northern Oklahoma where the coal is present. It is extremely silty, seemingly an expression of the lithology of the underlying sandstone.

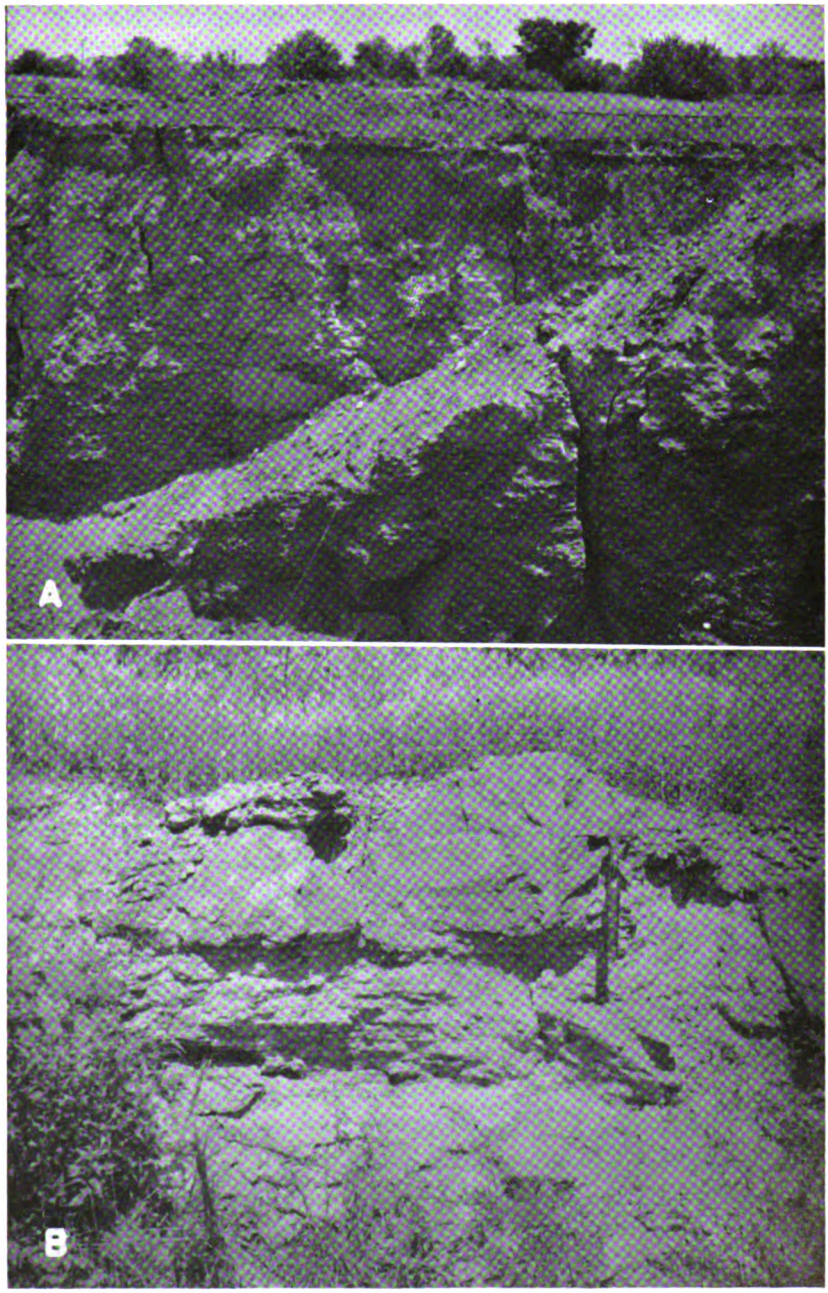


PLATE 9.—**A.** Jointed gray shale in lower part of Lagonda formation, SW¼ sec. 16, T. 29 S., R. 25 E., Crawford County. Thick Quaternary clay at top. **B.** Breezy Hill limestone in road cut north of Arma, in Crawford Count, SW¼ SW¼ sec. 32, T. 27 S., R. 25 E. Thin-bedded sandstone below is Lagonda.

Iron Post coal.—The Iron Post coal is the uppermost unit of the Lagonda formation. The name was applied to this bed in 1951 by Howe (p. 2092) from exposures in northern Craig County, Oklahoma. The coal is not known in areas north of Oklahoma but has been strip mined on a small scale along the outcrop in Craig County. This coal, popularly known as the "Fort Scott coal" or "red coal" in Oklahoma, has been erroneously correlated (Oakes, 1944, p. 16) with the Mulky coal of southeastern Kansas and Missouri. Average thickness of the coal in Craig County is about 10 inches.

Mulky Formation

Definition and subdivisions.—The Mulky formation (Searight and others, 1953) includes beds above the Iron Post coal or its horizon and extending to the top of the Mulky coal bed (Broadhead, 1873, p. 46), after which the formation was named. Thus defined the Mulky formation includes a lower shale (Kinnison), restricted to northern Oklahoma, the Breezy Hill limestone member, an underclay, and the Mulky coal.

Kinnison shale.—The name Kinnison was applied by Howe (1951, p. 2092) to beds above the Iron Post coal and below the Breezy Hill limestone in northern Craig County, Oklahoma. The member is composed of thin, irregular, nonpersistent conglomeratic limestone at the base, overlain by shale, dark gray at the base, and calcareous, containing thin rough limestone beds, in the upper part. The lower conglomeratic limestone is not widespread. It is dark to medium gray and contains fragments of wood and coaly material, and abundant *Marginifera muricatina* and *Derbyia crassa. Chonetes granulifer* and crinoid columnals are very abundant in the calcareous shale. The Kinnison shale and underlying Iron Post coal pinch out very abruptly approximately at the latitude of the Oklahoma-Kansas state line. The thickness of the Kinnison member ranges from 2 to 6 feet in Craig County, Oklahoma.

Breezy Hill limestone.—The Breezy Hill limestone was named by Pierce and Courtier (1937, p. 33) from exposures at Breezy Hill, a short distance southwest of Mulberry, in eastern Crawford County. This member occurs below the underclay of the Mulky coal, where the latter is present, and above the Lagonda

("Squirrel") sandstone in southeastern Kansas or above the Kinnison shale in northern Oklahoma. Identification of this member, however diverse its lithology, is not difficult, because of its consistent relationship to the Fort Scott formation (lower Marmaton).

The lithology of the Breezy Hill is extremely variable along the outcrop in southeastern Kansas. Two distinct types of limestone constitute the member, of which the more widespread is irregularly bedded and sandy to conglomeratic. It is common in southeastern Kansas and is recognized also in western and northern Missouri, but not in northern Oklahoma. Less common in Kansas and unknown in Missouri, but representing the Breezy Hill in its entirety in northern Oklahoma is thin-bedded to massive limestone, which is characteristically dense to medium grained, brown to gray, and weathers buff to brown.

The nodular irregular limestone commonly found in southeastern Kansas at this position is similar to, and occupies the position of, the underlimestones found associated with coal beds at other horizons in the Cabaniss succession. It is made up of angular to rounded fragments of dense dark-gray limestone in a matrix of light-gray, friable, sandy, impure limestone, and weathers to a coarse rubble on the outcrop. Color of freshly broken surfaces is mottled light and dark gray. Locally, in Cherokee and Labette Counties, this bed is composed almost entirely of *Fusulina* tests, embedded in a matrix of calcareous sand and silt. Plates 7B and 9B illustrate the nodular phase of the Breezy Hill. Thickness of the nodular phase of the Breezy Hill ranges from a featheredge to a maximum of about 3 feet.

Thin- to massive-bedded limestone found locally at this position in southeastern Kansas is characteristically argillaceous, dense to medium grained, and weathers brown or buff. Its patchy distribution suggests that it was deposited in isolated shallow basins prior to deposition of the nodular phase. At one locality (NE¼ NE¼ NW¼ sec. 11, T. 29 S., R. 25 E., Crawford County) this type of rock is overlain by massive, though irregular, limestone correlated with the nodular phase, which is well developed in nearby areas (Pl. 10). In southeastern Kansas, this phase of the Breezy Hill has been observed in the type area of the member near Mulberry; in the vicinity of Cherokee, Cherokee County; and at a locality about 5 miles west of Chetopa, Labette

County. In some earlier publications, reports of irregular thickness of the Breezy Hill probably were based on identification of the locally very calcareous upper portion of the underlying Lagonda formation as Breezy Hill. All exposures of the Breezy Hill limestone in northern Oklahoma observed by me consist of massive-bedded limestone, rather than the nodular type. Thickness ranges from about 2 feet in the Breezy Hill area to a maximum of about 16 feet in the area west of Chetopa, Kansas.

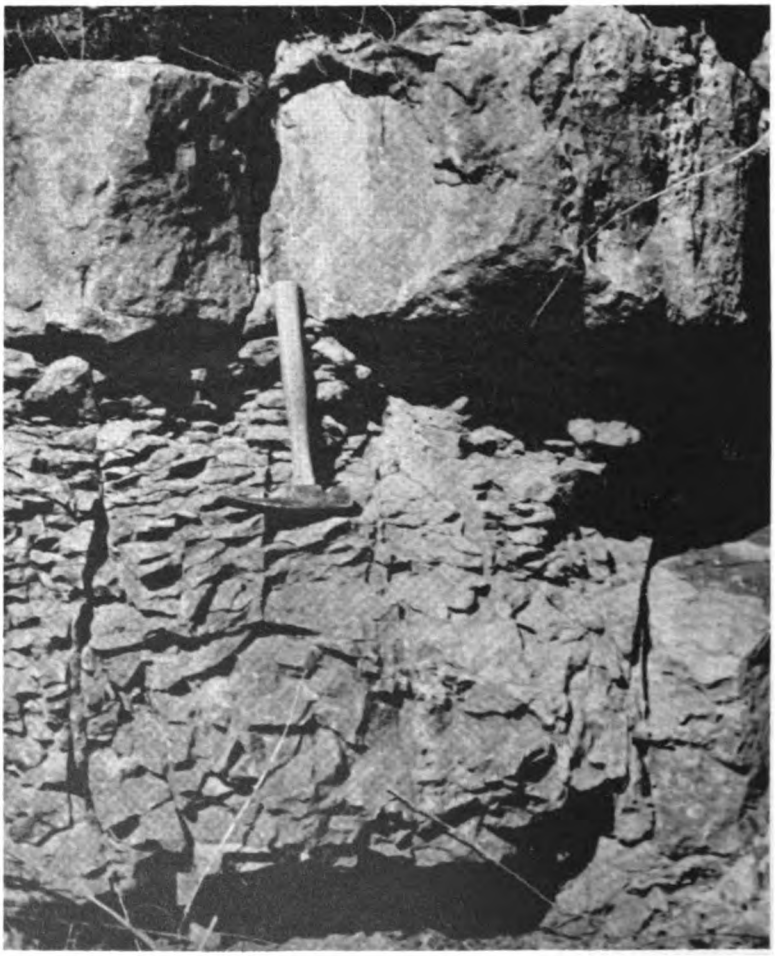


PLATE 10.—Breezy Hill limestone, NE¼ NE¼ NW¼ sec. 11, T. 29 S., R. 25 E., Crawford County.

The Breezy Hill member is extremely fossiliferous at some outcrops in southeastern Kansas. Fossils in the nodular phase consist principally of foraminifera: a small encrusting form, *Ptychocladia,* in Crawford County, and very abundant ***Fusulina*** sp. at several places in Cherokee and Labette Counties. Where developed in southeastern Kansas the bedded to massive phase of the member contains fusulines, but the characteristic fossil is *Dictyoclostus* cf. *portlockianus,* which is present almost everywhere and locally abundant. This species is very uncommon in older beds.

The Breezy Hill member is virtually continuous along the outcrop in southeastern Kansas and northeastern Oklahoma but is known in western and northern Missouri only from a few scattered exposures. In previous reports relevant to the stratigraphy of northeastern Oklahoma, the Breezy Hill has been consistently referred to as the lower Fort Scott limestone.

Underclay.—Underclay associated with the Mulky coal is commonly silty, particularly in the upper part. In some exposures it is possible to differentiate upper and lower portions of the clay, the upper part being silty and the lower part plastic and generally limonitic. Fossil root impressions and other plant material are common in the underclay.

The underclay of the Mulky formation is present throughout the area of distribution of the Mulky coal, and although mostly very thin in part of western Cherokee County and eastern Labette County, it is nevertheless persistent even there, where the coal is not developed. It is not present in northern Oklahoma, where the black fissile shale (Excello) that normally overlies the Mulky coal is in contact with the Breezy Hill limestone. The underclay member, where present in Kansas, ranges in thickness from a featheredge to a maximum of about 11 feet in the SW¼ SW¼ sec. 16, T. 31 S., R. 23 E., Cherokee County. This maximum thickness is exceptional; the thickness of the underclay member in most places where it is overlain by coal is 2 to 4 feet.

Mulky coal.—The Mulky coal is the uppermost coal bed included in the Cabaniss subgroup. It is absent in the southwestern part of the area of outcrop in Kansas, but is mined in northeastern Crawford County and eastern Bourbon County, where the maximum thickness is about 18 inches. The so-called

"Mulky" coal of Oklahoma occurs below the Kinnison shale and is not the true Mulky coal bed of Kansas and Missouri.

The Mulky coal has been strip mined in nearly all outliers in northeastern Crawford County and southeastern Bourbon County, particularly in the vicinity of Breezy Hill, southwest of Mulberry, and west of Garland. In addition, it has been mined along the main crop line in the same portions of these two counties. The coal is stripped only where the overburden is restricted to the overlying black shale and the lower limestone member of the Fort Scott formation; together these beds aggregate only about 12 feet, but they present difficult mining problems. The Mulky coal has not been of major economic importance in Kansas, principally because of the small extent of minable coal, and because of the difficulty of removing the overburden. Local names for this coal bed include "Fort Scott coal", "Red coal", and "Bunker Hill coal".

Excello Formation

Definition and subdivisions.—The Excello formation (Searight and others, 1953) consists of only a single unit, the black fissile shale above the Mulky coal or its horizon and below the base of the Blackjack Creek limestone, lowermost Marmaton. This uppermost division of the Cabaniss was named from the town of Excello, in southern Macon County, Missouri (Personal communication, W. V. Searight).

The Excello shale is conformably overlain by lower Marmaton beds throughout the region. In Missouri and in the northeastern part of the area of outcrop in southeastern Kansas it is underlain by the Mulky coal. Farther south and west in the latter area, and in northern Oklahoma, the shale lies on the Breezy Hill limestone. This shale bed is very widespread; it is known in northern Oklahoma, southeastern Kansas, and in western and northern Missouri. Locally in southeastern Kansas, and notably just west of Garland, in eastern Bourbon County (NW¼ NW¼ sec. 1, T. 27 S., R. 25 E.), it contains large gray to black limestone concretions as much as 2 feet in diameter. These concretions are nearly spherical, have pyritic rinds 1 to 2 inches thick, and show slickensides on the exterior. Fossils in the Excello shale include conodonts and *Orbiculoidea missouriensis.* The shale is almost universally characterized by abundant

round phosphatic concretions or nodules, which have coprolitic nuclei. Thickness of the Excello shale ranges from 2 to 5 feet, averaging almost 5 feet.

SUMMARY

Principal results of this study of the pre-Marmaton Desmoinesian beds in southeastern Kansas are summarized as follows:

1. The completed study includes detailed description of the succession as it is developed in the outcrop area in Kansas, in addition to data on correlation of individual beds with their equivalents in adjacent areas. The classification employed is that recently developed for these strata by state geologists for the northern Midcontinent, and the nomenclature used is accordingly the same as that in adjacent areas.

2. Numerous stratigraphic sections indicate that some of the lithologic subdivisions common to most of the formations described are represented in any given formation by slightly differing facies, which may serve in large part to identify the succession. This is especially true with respect to the dark shale and impure limestone that commonly rest on coal beds.

3. Among the results of this study is the identification of several underlimestones (limestones directly beneath the underclay of a coal bed). Limestone at this position is common in the Cabaniss subgroup in southeastern Kansas and in northern Oklahoma, where at least two become massive, typically marine limestones. Underlimestones seem to mark the position within a formation at which basinward introduction of additional beds may occur.

4. Several coal horizons in the Warner sandstone-Neutral coal sequence in Kansas seemingly are northward equivalents of coal beds in Oklahoma.

5. The Seville limestone, present in western Missouri, and as far north in Oklahoma as Chelsea, has been identified tentatively in only a single exposure in southeastern Kansas. The underlying Bluejacket coal is also absent in most of the outcrop area in Kansas.

6. An unnamed coal horizon occurs between the Tebo and Scammon coal beds. Subsequent to discovery of this horizon in

Kansas, a coal bed equivalent to it has been found in western Missouri.

7. A coal bed (Robinson Branch) occurring between the Mineral and Fleming coals is present only locally in Kansas, as well as in Missouri.

8. In eastern Labette County, and southward into Oklahoma, the Verdigris limestone and Bevier coal are separated by several feet of sandstone and shale, a relationship contrasting to that to the northeast in Kansas and western Missouri, where the underclay of the Bevier coal rests directly on the Verdigris limestone. The term Stice, formerly applied to coal in Labette County now recognized as Bevier, is abandoned.

9. Southward from Labette County, the Bevier coal–Blackjack Creek limestone sequence thins markedly. At the latitude of Vinita, Oklahoma, sandy shale and clay only a few feet thick separate the Bevier coal from the Iron Post coal.

10. The Breezy Hill limestone is typically marine in northern Oklahoma, and directly underlies black fissile shale associated with the Blackjack Creek limestone. In northern Oklahoma the Breezy Hill has in the past been identified as the Blackjack Creek limestone, and the underlying coal (Iron Post) has been called Mulky.

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APPENDIX—STRATIGRAPHIC SECTIONS 1-98

1. *Section along road in SW¼ NW¼ sec. 36, T. 26 N., R. 18 E., Craig County, Oklahoma. Described July 19, 1949.*

	Thickness, feet
Cabaniss subgroup	
Mulky formation	
11. Covered interval to base of Breezy Hill limestone	4.0
Lagonda formation	
10. Coal (Iron Post), estimated	0.5
9. Covered interval	6.0
Bevier formation	
8. Coal (Bevier), estimated	0.8
Verdigris formation	
7. Covered interval	8.0
6. Sandstone	1.0- 3.0
5. Shale	11.0
4. Limestone (Verdigris), medium gray, weathering to brown slabs; dense and brittle; contains irregular masses of gray and white chert in upper part; fossils most abundant in coquinoid layers near base	3.3- 3.8
3. Shale, gray, clayey	0.1- 0.3
2. Shale, black, fissile; large, 1- to 2-inch lenticular and rounded phosphatic concretions	1.5- 1.7
1. Shale, dark gray, weathers light gray	28.0

2. *Exposure in road cuts and along creek in SE cor. sec. 23, T. 27 N., R. 19 E., Craig County, Oklahoma. Described July 11, 1949.*

	Thickness, feet
Cabaniss subgroup	
Scammon formation	
6. Sandstone (Chelsea), thin bedded and slabby in basal part, massive above; exposed	10.0
5. Shale, dark gray to black; light gray in upper 2 to 3 feet	10.0
4. Limestone (Tiawah), dark gray to black, weathering to hematitic red; contains massive pyrite; occurs as 2 or more thin beds; fossiliferous	0.5- 0.6
3. Shale, black, hard, fissile	2.0
Tebo formation	
2. Coal (Tebo)	0.5
1. Clay, light to dark gray; exposed	2.0

3. *Section in operating strip pit of Patch Coal Company, in SW¼ sec. 27, T. 28 N., R. 20 E., Craig County, Oklahoma. Described July 13, 1949.*

	Thickness, feet
Cabaniss subgroup	
Tebo formation	
3. Shale, dark gray to black, weathers drab; exposed	15.0
Weir formation	
2. Coal (Weir-Pittsburg)	1.0- 1.5
1. Clay, reported thickness	6.0

4. *Exposure in operating strip pit in NW¼ NW¼ sec. 21, T. 28 N., R. 20 E., Craig County, Oklahoma. Described July 11, 1949.*

	Thickness, feet
Cabaniss subgroup	
Fleming formation	
5. Sandstone; exposed	3.0
4. Shale, black in basal 4 to 5 feet, lighter above; clay-ironstone layer about 6 to 7 feet above base	15.0
3. Limestone, dark gray to black, tough; thickness variable, averaging	2.5
Mineral formation	
2. Coal (Mineral)	1.3- 1.4
1. Clay; exposed	2.0

5. *Exposure in road cuts and adjacent drainage along south side of sec. 17 and 18, T. 28 N., R. 20 E., Craig County, Oklahoma. Described July 11, 1949.*

	Thickness, feet
Cabaniss subgroup	
Lagonda formation	
18. Sandstone, fine to medium grained	6.0
17. Shale, sandy, gray	5.0- 6.0
16. Shale, black, contains thin coal streaks	1.0
Bevier formation	
15. Coal (Bevier)	0.2
14. Clay and shale, silty, contains root impressions in upper part	4.0
Verdigris formation	
13. Sandstone, massive to thin bedded	5.0- 6.0
12. Shale, containing some limonitic layers; sandy in upper part	16.5
11. Limestone (part of Verdigris), argillaceous to shaly	0.3
10. Limestone (Verdigris), dense, tough, dark gray, weathering buff; fossils include *Phricodothyris* and crinoid material	1.5- 2.0
9. Shale, black, fissile in lower 4 feet, gray, calcareous above; abundant phosphatic concretions in black shale	5.0
8. Covered interval; seemingly all gray shale containing some clay-ironstone in nodules and in layers; approximately	15.0
Croweburg formation	
7. Coal (Croweburg), stripped here; underclay uneven and thin	1.2
6. Limestone (McNabb?), impure, and loosely nodular in clay matrix; weathers to rubble; *Linoproductus* very common	1.0- 3.0
5. Shale, dark at base, containing irregularly rounded clay-ironstone concretions in basal 2 feet; dense, nodular limestone in upper part	8.0
4. Shale, black, weathering brown; thinly laminated; contains large rounded smooth fine-grained black limestone concretions; these occur in zones and average about 6 inches in thickness	5.0
3. Shale, gray, soft	1.3
Fleming formation	
2. Coal (Fleming), good, mined here	1.7
1. Clay, light gray, plastic	—

6. *Section in creek banks and in abandoned strip pits. This is type section of Iron Post coal and Kinnison shale. Located in W½ SW¼ sec. 36, T. 29 N., R. 19 E., Craig County, Oklahoma. Described July 11, 1949.*

	Thickness, feet
Marmaton group	
Fort Scott formation	
8. Limestone (base of Blackjack Creek limestone member)	—
Cherokee group	
Cabaniss subgroup	
Excello formation	
7. Covered interval to base of Fort Scott formation; includes principally black fissile shale	3.0- 4.0
Mulky formation	
6. Limestone (Breezy Hill), brown to medium gray, weathering buff; prominent vertical fracture; most abundant fossils are productids, mainly *Echinoconchus* and *Dictyoclostus, Composita,* and abundant fusulines	3.0
5. Shale (Kinnison), dark at base, lighter above; upper 2 feet calcareous, fossiliferous, and containing nonpersistent rough coquinoidal limestone layers; chonetids and crinoid fragments most common fossil material	6.0
4. Limestone (lower part of Kinnison), dark to medium gray; fossiliferous, containing abundant *Derbyia,* and some *Marginifera muricatina;* conglomeratic, containing fragments of carbonized wood	0.6- 0.8
Lagonda formation	
3. Coal (Iron Post), hard, bright; dull red along joints (iron staining)	0.8
2. Clay, light to dark gray; abundant carbonized plant material	3.0
1. Sandstone, somewhat calcareous, thin-bedded; exposed	4.0

7. *Section in strip pit in SW¼ NE¼ sec. 5, T. 35 S., R. 21 E., Labette County, Kansas. Described June 21, 1949.*

	Thickness, feet
Cabaniss subgroup	
Fleming formation	
5. Shale, weathered; overlain by clay that probably is Pleistocene in age	1.0
4. Zone of discrete round and lenticular septarian clay-ironstone concretions; weathers to limonite and hematite; septarian fillings are selenite; average thickness of concretions	0.5- 0.7
3. Shale, black, thinly laminated; lenses of limestone in basal part; shale weathers dun to light gray; limestone is dark gray to black, contains nautiloids, gastropods, *Marginifera,* and *Phricodothyris,* and large masses of pyrite	7.0
Mineral formation	
2. Coal (Mineral), bright, hard, blocky; much calcite in cleats	0.9- 1.0
1. Clay, reported thickness	6.0

8. *Section exposed in creek bank in SE cor. sec. 24, T. 34 S., R. 20 E., Labette County, Kansas. Described June 23, 1949.*

	Thickness, feet
Cabaniss subgroup	
Lagonda formation	
3. Sandstone, cross-bedded, massive to thin bedded, much of it calcareous, containing *Marginifera, Linoproductus, Neospirifer,* and *Juresania*	10.0
Bevier formation	
2. Coal (Bevier), poor, very bony	0.3
1. Sandstone, massive to thin bedded; grades laterally to sandy shale; upper part dark gray, clayey, containing carbonized plant matter	8.0

9. *Exposure in abandoned strip pit in SW¼ SE¼ sec. 28, T. 34 S., R. 21 E., Labette County, Kansas. Described June 21, 1949.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
5. Clay-ironstone; weathers to shelly limonite; fossils include *Crurithyris* and *Marginifera*	0.3- 0.4
4. Shale, dark gray to black, weathering light gray	2.0
3. Limestone, medium gray, weathers to brown and hematitic red; upper 3 inches is *Marginifera* coquina; only other abundant fossils are crinoidal material; broken into large blocks by jointing; variable thickness	0.3- 2.0
Fleming formation?	
2. Clay and shale	1.0
1. Shale, black, platy; contains isolated large, rounded, septarian clay-ironstone concretions	2.0- 4.0

Note: Coal mined here below water. Thought to be Mineral coal. Sandstone identified as that above the Fleming coal occurs as slump or float blocks in this vicinity. Fleming coal horizon must lie below bed 3.

10. *Section exposed in road cut along U.S. Highway 59, north of Chetopa, in SE¼ SE¼ sec. 28, T. 34 S., R. 21 E., Labette County, Kansas. Described June 21, 1949.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
4. Sandstone, cross-bedded, massive, friable; base uneven, contact on erosion surface; exposed	4.0
3. Shale, calcareous, abundant *Marginifera* in basal 1 foot; black, hard, above; leached to "soapstone" in upper 1 to 2 feet	8.0
Fleming formation	
2. Coal (Fleming); thickness varies	0.6- 0.8
1. Clay, dark gray, silty; contains plant fragments	3.0- 4.0

11. *Section in gully in NW¼ NW¼ sec. 19, T. 34 S., R. 21 E., Labette County, Kansas. Described June 23, 1949.*

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
7. Limestone (Verdigris), shaly, gray, contains *Mesolobus* and *Marginifera;* forms resistant ledge	0.2- 0.3

6. Shale, calcareous, gray 1.0
5. Limestone (Verdigris), black, weathers tan to buff; very dense and brittle; distinctly jointed, the resultant quadrangular pieces weather round; fossils include large *Mesolobus, Marginifera muricatina*, and crinoid material 0.7- 0.8
4. Clay, light to dark gray (represents weathered shale) 0.5
3. Zone of rough shaly limestone concretions; fossils include *Marginifera muricatina* 2.0
2. Shale, black, hard, fissile; contains abundant, rounded phosphatic concretions 2.0
1. Shale and clay; exposed 1.0

12. *Section in abandoned strip pit, in NW¼ NE¼ sec. 33, T. 33 S., R. 21 E., Labette County, Kansas. Described July 8, 1949.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
6. Clay and chert	3.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
5. Shale, gray to dark gray at base, gray above; thinly laminated at base; thin clay-ironstone layers at base	12.0-15.0
4. Limestone, dark gray to black, weathers brick red or brown, argillaceous; contains abundant *Crurithyris* and simple corals	0.4
3. Shale, dark gray	3.0
2. Limestone, lenticular; grades laterally from dark, tough, dense limestone to lighter gray shaly rock; locally conglomeratic, containing silicified wood, limestone and phosphatic nodules, and simple corals; other fossils include fusulinids, *Marginifera Mesolobus*, and crinoids	0.0- 3.0
Bevier formation	
1. Coal (Bevier)	1.2

13. *Section in abandoned strip pit and adjacent road cut in SW¼ SE¼ sec. 27, T. 33 S., R. 21 E., Labette County, Kansas. Described June 22, 1949.*

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
5. Shale, gray	8.0
4. Shale, calcareous, and thin, slabby, fossiliferous limestone; fossils include *Mesolobus, Marginifera, Juresania*, and *Derbyia*	3.0
3. Limestone (Verdigris), black, brittle, dense; weathers buff; fossils include *Mesolobus, Echinoconchus, Juresania*, and *Marginifera*	1.0- 1.3
2. Covered interval; upper 2 feet black fissile shale containing phosphatic concretions	8.0
1. Clay; contains scattered clay-ironstone concretions	2.0

Note: Coal (Croweburg) occurring below bed 1 has been stripped in this locality.

14. *Section exposed in road cut along highway just east of Oswego, in SE¼ SW¼ sec. 15, T. 33 S., R. 21 E., Labette County, Kansas. Described June 23, 1949.*

	Thickness, feet
Marmaton group	
Fort Scott formation	
5. Limestone, base of Fort Scott formation	—
Cherokee group	
Cabaniss subgroup	
Excello formation	
4. Shale, black, hard, fissile; contains phosphatic concretions; fossils include *Orbiculoidea missouriensis*	2.2
Mulky formation	
3. Limestone (Breezy Hill), light and dark gray mottled, weathering tan and buff; sandy, rough, hard, massive; lenticular, though persistent; fossils include shell fragments, *Linoproductus*, and fusulines	0.5- 2.5
Lagonda formation	
2. Sandstone, thin bedded to massive; beds thicken and thin laterally; more massive beds are finely cross-bedded	6.0- 8.0
1. Shale, silty, micaceous, top not well defined, but darker, softer, more thinly laminated than overlying bed; weathering along prominent joints results in dike-like appearance; exposed	30.0

15. *Section in NE cor. sec. 12, T. 34 S., R. 23 E., Cherokee County, Kansas. Described July 12, 1950. Upper part of this section probably same as that in SE cor. sec. 1, T. 34 S., R. 23 E.* **(16).**

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
5. Sandstone (Bluejacket), not measured	—
4. Shale, dark gray, weathering light gray	5.0
Dry Wood formation	
3. Coal (Dry Wood) mostly vitrain	0.3
2. Clay, plastic; contains plant material	2.0- 3.0
1. Shale, dark gray to black; contains layers of clay-ironstone; upper part leached	5.0- 6.0

16. *Exposure in road cut south of Columbus, in SE cor. sec. 1, T. 34 S., R. 23 E., Cherokee County, Kansas. Described July 12, 1950.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
4. Sandstone (Bluejacket), massive, ripplemarked; tan to brown	6.0- 8.0
3. Shale, dark gray to black, weathers light gray, contains clay-ironstone layers	8.0
Dry Wood formation	
2. Coal (Dry Wood), weathered	0.3
1. Clay, gray, containing plant material	0.5

17. *Section in road cut, NW¼ SW¼ sec. 25, T. 34 S., R. 24 E., Cherokee County, Kansas. Described June 14, 1949.*

	Thickness, feet
Krebs subgroup	
Warner formation	
3. Shale, dark gray to black, weathers light gray	12.0
Riverton formation	
2. Coal (Riverton), poor, bony	0.3
1. Clay, light gray; contains plant impressions; limonitic zone in upper 2 inches	4.0

Note: Base of bed 1 is approximately 15 feet above Mississippian-Pennsylvanian contact. Black shale occurs over Mississippian rocks here.

18. *Section exposed in bank of Brush Creek and road cut in SE¼ NE¼ sec. 15, T. 34 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

	Thickness, feet
Krebs subgroup	
? formation	
5. Clay and shale	3.0
4. Clay-ironstone layer	0.3- 0.4
3. Shale, black, hard, fissile at base, softer above	8.0
? formation	
2. Clay, gray, laced with limonitic streaks; lower part contains rough, sandy, limestone concretions	4.0
1. Shale, dark gray to black	3.0

Note: Section occurs below Bluejacket sandstone.

19. *Section in creek bank near road in SE¼ SE¼ sec. 11, T. 34 S., R. 24 E., Cherokee County, Kansas. Described July 12, 1950.*

	Thickness, feet
Krebs subgroup	
Warner formation	
4. Shale, dark gray to black, weathering light gray; contains clay-ironstone layers	5.0
3. Coal horizon	—
2. Clay, silty, contains abundant carbonized plant material and fragments of fusain in upper part	3.0
1. Sandstone (upper part of Warner), fine grained; vertical and nearly vertical root impressions abundant; upper surface uneven	2.5

20. *Section in south bank of Brush Creek and adjacent draw, in NE¼ SW¼ sec. 10, T. 34 S., R. 24 E., Cherokee County, Kansas. Described June 24, 1949.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
21. Clay and gravel	6.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Krebs subgroup	
Bluejacket formation	
20. Shale, gray; leaf impressions along bedding planes	2.5
Dry Wood formation	
19. Coal (Dry Wood), contains large amount of bony material; base of Bluejacket sandstone is approximately 13 feet above Dry Wood coal	1.0
18. Clay, gray, heavily ironstained	2.5
17. Limonitic zone, shaly; deeply weathered	0.5- 0.8
16. Shale, dark gray to black; thin clay-ironstone layer about 1 foot above base; clay-ironstone concretions scattered throughout	9.0

Rowe formation
15. Coal (Rowe), weathered on crop, but seemingly good 1.2
14. Clay, gray, hard, crumbly; contains abundant plant impressions 3.0
13. Shale, dark gray to black, containing layers of clay-ironstone 5.0- 6.0
12. Clay-ironstone, in single layer 0.3
11. Limestone, hematitic red throughout, and containing masses of hematite; fossils are fragmental and not identifiable 0.4- 0.5

Warner formation
10. Coal (Neutral), very bony 0.2- 0.4
9. Clay 2.0
8. Shale, gray, somewhat sandy 3.0
7. Zone of rough, irregular to cylindrical, impure limestone concretions; limestone sandy and ferruginous 0.0- 0.8
6. Clay, gray 2.0
5. Shale, dark gray to black, fissile; contains clay-ironstone concretions in upper part 12.0
4. Zone of clay-ironstone concretions and layers; plant stems vertical or near vertical in clay-ironstone matrix; upper part is marked by zone of small clay-ironstone concretions 2.0- 3.0
3. Shale, gray to black; upper 1 foot leached 6.0
2. Clay-ironstone, in single prominent bed 0.2
1. Shale, gray to black, hard, platy; scattered clay-ironstone concretions 6.0

21. *Section exposed in east bank of Neosho River, in SE¼ NW¼ sec. 25, T. 33 S., R. 21 E., Cherokee County, Kansas. Described June 21, 1949.*

Thickness, feet

Cabaniss subgroup
Fleming formation
3. Shale, black, fossiliferous; contains abundant rough phosphatic concretions; laterally represented by lenticular dark-gray to black limestone as much as 1 foot thick 2.0

Mineral formation
2. Coal (Mineral), generally good, but uneven in thickness; dirty in upper part 0.8- 1.7
1. Clay, dark to light gray; contains plant material 3.0

Note: Section overlain by 12 feet of river gravel.

22. *Exposure in roadside ditch, SE¼ SE¼ sec. 34, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 14, 1949.*

Thickness, feet

Krebs subgroup
Bluejacket formation
10. Sandstone (Bluejacket), light gray to buff; weathers deep reddish brown; thin bedded to massive, cross-bedded; friable to firmly cemented; some conglomeratic beds 16.5

?Dry Wood formation
9. Coal (Dry Wood?), impure, bony 0.3- 0.4
8. Clay, light gray; gradational with bed below 4.0
7. Shale, dark gray to black at base, light gray above 12.0

?Rowe formation
6. Clay, red to gray, sandy 2.0
5. Sandstone, thin bedded to massive; dark grayish brown, weathering light buff and gray; micaceous; sand grains fine to medium and subrounded 8.0

4. Covered interval 16.5
3. Shale and clay 1.0
2. Clay-ironstone layer; mostly weathered to limonite; forms prominent marker 0.3- 0.4
1. Shale, dark gray to black, weathering light gray; clayey zone at top 4.0

Note: Sandstone bed 5 may be "12-foot" sandstone of northern Oklahoma. Beds 1 to 3 probably belong in Warner formation.

23. *Exposure in road cut and nearby sandstone quarry, in SE¼ SE¼ sec. 34, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

Thickness, feet

Krebs subgroup
Bluejacket formation
4. Sandstone (Bluejacket), thin bedded to massive; generally friable, but some beds are well cemented and are quarried; weathers to deep reddish brown 15.0

Dry Wood formation
3. Coal (Dry Wood), impure 0.1- 0.3
2. Clay, gradational with beds below 4.0
1. Shale, dark gray, weathering light gray; wide limonitic joint fillings; clayey in upper part 12.0

24. *Exposure in abandoned strip pit in NW¼ NW¼ sec. 29, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

Thickness, feet

Krebs subgroup
Bluejacket formation
3. Sandstone (Bluejacket), tan to buff, massive; beds 2 to 12 inches thick; exposed 4.0

Dry Wood formation
2. Shale, black, thinly laminated, fissile; upper 2 to 3 feet is clayey, containing fragments of limonite 8.0

Rowe formation
1. Coal (Rowe); mined here; exposed 0.5

Note: Dry Wood coal cut out by erosion preceding deposition of Bluejacket sandstone.

25. *Section exposed in roadside ditch, NE¼ SE¼ sec. 26, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 14, 1949.*

Thickness, feet

Krebs subgroup
Bluejacket formation
5. Sandstone (Bluejacket), light gray, weathers reddish brown; slabby at base, massive above; friable; sand grains angular to subrounded, and nearly all are quartz; exposed 11.0

Dry Wood formation
4. Coal (Dry Wood), poor, bony 0.2- 0.3
3. Clay, light gray, containing considerable limonite; seemingly gradational with shale below 2.5
2. Shale, dark gray to black, weathering light to medium gray; limonitic staining along joints; silty in upper part 15.0
1. Clay, light gray, mottled with light brown; probably marks Rowe coal horizon 5.0

26. *Section exposed in road cut at road intersection in SW cor. sec. 14, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
6. Sandstone (Bluejacket), light gray to dark brown, weathering reddish brown; thin bedded to massive	15.0
5. Clay, gray	1.0
4. Shale, dark gray to black, silty	3.0
3. Covered interval	4.0
2. Clay, gray to reddish brown	2.0
1. Shale, dark gray to black	6.0

Note: Classification of sub-Bluejacket beds uncertain. Bed 3 may include Dry Wood coal and its horizon.

27. *Section exposed at intersection of State Highway 96 and section-line road and along south side of sec. 8, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
7. Sandstone (Bluejacket), light gray to brown, weathers rusty brown; some clayey layers in lower part; massive; friable, but upper part case-hardened	11.0
Dry Wood formation	
6. Coal (Dry Wood), weathered to blossom	0.3- 0.5
5. Clay and shale; clay in upper part; interval much weathered and poorly exposed	5.0- 6.0
4. Clay-ironstone layer; locally weathered to purplish-red ferruginous clay	0.4
3. Shale, dark gray to black, flaky; weathers light gray	8.5
Rowe formation	
2. Coal (Rowe), poor, bony	0.1- 0.3
1. Clay, light gray to buff	2.0

28. *Exposure in creek bank in SE¼ SE¼ sec. 7, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

	Thickness, feet
Krebs subgroup	
Rowe formation	
2. Shale, dark gray in lower 2 feet, light gray and silty above; round sandy clay-ironstone concretions occur approximately 3 feet above base	8.0
1. Clay-ironstone layer	0.1- 0.2

Note: Bed 1 seemingly lies only a few feet above Neutral coal or its horizon.

29. *Exposure in abandoned strip pit northeast of Columbus, in NE¼ SE¼ sec. 7, T. 33 S., R. 24 E., Cherokee County, Kansas. Described June 15, 1949.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
3. Sandstone (Bluejacket), medium gray, weathering light gray; flaggy to massive; exposed	4.0
Dry Wood formation	
2. Coal (Dry Wood), poor, bony	0.2- 0.3
1. Shale, leached and clayey in upper 2 feet	6.0

Note: Rowe coal mined below, but now covered.

30. *Section in road cut in entry to Jayhawker Ordnance Plant, in SW¼ sec. 32, T. 33 S., R. 25 E., Cherokee County, Kansas. Described June 14, 1949.*

Krebs subgroup	Thickness, feet
Warner formation	
4. Sandstone (Warner), medium grained, buff to brown; thin bedded in lower 2 feet, massive and cross-bedded above; lower part of massive portion is blister conglomerate	10.0
Riverton formation	
3. Coal (Riverton), poor, bony	0.3
2. Clay, light gray, ironstained; abundant plant remains	2.0
1. Shale, black, deeply leached in upper portion; weathers to light gray	8.0

31. *Section exposed in roadside ditch, in SW¼ NW¼ sec. 19, T. 33 S., R. 25 E., Cherokee County, Kansas. Described June 14, 1949.*

Krebs subgroup	Thickness, feet
Bluejacket formation	
5. Sandstone (Bluejacket), massive, medium grained; weathers reddish brown	11.0
4. Covered interval; mostly clay and shale, and some interbedded thin sandstone	25.0
3. Sandstone and interbedded shale; fine to medium grained; weathers brown; upper 1 foot massive	4.0
2. Shale, gray, "soapy"	3.0
1. Clay-ironstone layer	0.2- 0.3

Note: Classification of beds below Bluejacket sandstone uncertain because of poor or concealed exposures.

32. *Section in east-draining draw west of bridge over Spring River and south of road in NW¼ NW¼ sec. 14, T. 33 S., R. 25 E., Cherokee County, Kansas. Described August 3, 1949.*

Krebs subgroup	Thickness, feet
Warner formation	
5. Shale, medium to dark gray	3.0
4. Sandstone (part of Warner sandstone), massive to thin bedded; very micaceous; contains layers of shale conglomerate	8.0
3. Shale, black, fissile; leached in upper part	1.2
Riverton formation	
2. Coal (Riverton), bony	0.8
1. Clay, medium gray, tough and hard; shows slickensides; contains abundant plant impressions; lower part contains masses of pyrite	4.0

33. *Section in roadcuts on U.S. Highway 73E, near Kansas-Missouri state line, in NE¼ SE¼ sec. 12, T. 33 S., R. 25 E., Cherokee County, Kansas. Described June 13, 1949.*

Krebs subgroup	Thickness, feet
Warner formation	
5. Sandstone, thin bedded, interbedded with sandy shale; contains some zones of coaly material	25.0
4. Shale and bony coal	3.0
3. Sandstone, gray to brown, thin bedded and slabby	2.0
2. Shale, gray to black; sandy, containing several thin clay-ironstone layers; coaly material interbedded	5.0- 6.0
1. Sandstone, micaceous, massive, medium grained	6.0- 8.0

Note: Probably Warner sandstone and higher beds.

34. ***Exposure in operating strip pit of Pittsburg and Midway Coal Company, in SW¼ SW¼ sec. 35, T. 32 S., R. 22 E., Cherokee County, Kansas. Described July 14, 1948.***

	Thickness, feet
Quaternary System	
Pleistocene Series	
5. Clay, silty, fragments of shale at base; buff, mottled with dark reddish brown and black	6.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
4. Shale, dark gray to black in lower 2 feet, light gray and drab above; layered hematitic and limonite concretions	16.5
3. Limestone, black, weathers gray to red; very earthy, containing abundant gastropods and pelecypods	0.2- 0.5
2. Shale, black, hard, thinly laminated; some scattered dense limestone concretions 1 foot in diameter and very numerous small calcareous concretions having pyritic cores; in one the pyritic core was a replacement of wood	7.8
Bevier formation	
1. Coal (Bevier), bright, blocky	1.7- 2.0

35. ***Section exposed in strip pits of the Pittsburg and Midway Coal Company, in NE¼ sec. 34, T. 32 S., R. 22 E., Cherokee County, Kansas. Described July 26, 1950.***

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
16. Shale, black, fissile; contains abundant phosphatic concretions	2.0
15. Shale, gray, severely weathered and leached; contains ocherous clay; no fossils observed	8.0
Croweburg formation	
14. Coal (Croweburg)	0.8
13. Clay, gray, plastic	6.0
12. Limestone, gray, impure, sandy; irregular, but persistent; no fossils observed	1.0
11. Shale, dark gray to black in lower 15 feet, lighter above; lowermost 1 foot is carbonaceous, containing coalified plant leaves; thinly laminated throughout; breaks with conchoidal fracture in unweathered portions; is somewhat calcareous, containing dark limestone concretions in lower part and clay-ironstone layers in upper part; fossils include *Marginifera muricatina, Crurithyris, Mesolobus,* and bellerophontids	17.0
Fleming formation	
10. Coal (Fleming), particularly characterized by coal balls, and extremely irregular thickness	0.0- 1.7
9. Clay	1.0
8. Shale, dark gray, hard; differs in thickness, owing to pre-Fleming erosion (see note); thin beds of limestone containing *Marginifera muricatina* occur 5 to 6 feet above base where bed is thick enough	0.0- 9.0
7. Limestone, impure, lenticular, forming resistant bed; massive, weathering to ferruginous cinder; characteristic fossil is *Crurithyris*	0.0- 0.3

6. Limestone, impure, slabby and shaly; very fossiliferous, containing abundant *Mesolobus decipiens*, plus *Marginifera muricatina, Dictyoclostus americanus*, and *Neospirifer* 1.3- 1.7

Robinson Branch formation

5. Coal (Robinson Branch) 0.0- 0.3
4. Clay, containing plant impressions 1.0
3. Shale, dark gray to black, hard; dark limestone occurs locally at base; *Mesolobus* scattered throughout 9.0-10.0

Mineral formation

2. Coal (Mineral) 2.0
1. Clay, containing plant impressions ..... —

Note: Locally, in the highwall of this pit, beds 3 through 8 are absent. The interval is filled with a clastic accumulation of clay pellets and pebbles of dense gray limestone. This material is present where the coal between the Fleming and Mineral coal is absent, and the interval between them is decreased. It is a reflection of localized erosion, after the deposition of the middle coal and lower beds but prior to deposition of the Fleming coal.

36. *Section exposed in operating strip pit of Boyd Coal Company, in NW cor. sec. 25, T. 32 S., R. 23 E., Cherokee County, Kansas. Described June 20, 1949.*

Thickness, feet

Cabaniss subgroup

Scammon formation

5. Siltstone and thin-bedded sandstone; some clay-ironstone concretions 10.0
4. Shale, black, fissile 0.7
3. Limestone (Tiawah), dark gray to black; pyrite common; contains gastropod fauna 0.3- 0.4

Tebo formation

2. Coal (Tebo), much tougher than coal below, not blocky; abundant sulfide; nearly all discarded in mining; very uneven contact with coal below; average thickness 1.5

Weir formation

1. Coal (Weir-Pittsburg), bright, blocky; uneven upper surface; average thickness 1.5

37. *Exposure in abandoned strip pit in NE¼ sec. 30, T. 32 S., R. 24 E., Cherokee County, Kansas. Described June 24, 1949.*

Thickness, feet

Cabaniss subgroup

Scammon formation

5. Shale, sandy, and micaceous thin-bedded sandstone 15.0
4. Shale, black, platy; some pyritized fossils: *Juresania, Mesolobus*, and *Linoproductus* 1.5
3. Limestone (Tiawah), dark gray to black, tough; may grade laterally to very fossiliferous black shale; fossils in limestone and shale include ribbed gastropods, *Mesolobus, Dictyoclostus*, and crinoidal material 0.3- 0.8

Tebo and Weir formations

2. Coal (Tebo and Weir-Pittsburg), including thin nonpersistent clay parting between coals 3.3
1. Clay, gray, crumbly; exposed 1.0

38. *Exposure in abandoned strip pit in NE¼ NE¼ sec. 24, T. 32 S., R. 24 E., Cherokee County, Kansas. Described June 21, 1949.*

	Thickness, feet
Cabaniss subgroup	
Tebo formation	
4. Shale, sandy, and thin beds of sandstone; scattered clay-ironstone concretions, mostly weathered to limonite, most abundant near top; bed rests with slight angular unconformity on shale and coal below	15.0
3. Shale, dark gray to black, contains some bony coal; local in occurrence along highwall	0.0- 2.0
Weir formation	
2. Coal (Weir-Pittsburg)	3.7
1. Clay; exposed below coal in pit	0.8

39. *Section in Wilkinson Coal Company strip pit, in SW¼ NW¼ sec. 24, T. 32 S., R. 24 E., Cherokee County, Kansas. Described June 24, 1949.*

	Thickness, feet
Krebs subgroup	
Dry Wood formation	
7. Coal (Dry Wood), weathered	0.5- 1.3
6. Clay, shaly at base; plant impressions abundant in upper part; clay is plastic and shows intense limonite and hematite staining throughout	3.7
5. Limestone, impure, some sand and clay; contains abundant vertical rod-shaped concretions; no fossils observed	0.5
4. Shale, black in lower 2 to 3 feet, gray above	5.5
3. Limestone, dark gray to black; lenticular; contains *Spirifer rockymontanus* and crinoidal material	0.1- 2.5
Rowe formation	
2. Coal (Rowe), hard, bright, very blocky	1.2
1. Clay, hard, gray, contains root impressions	0.5

Note: Bed 7 overlain by Pleistocene clay containing fragments of coal, clay, shale, and sandstone in basal part.

40. *Exposure in operating strip pit of Wilkinson Coal Company, in NE¼ SW¼ sec. 12, T. 32 S., R. 24 E., Cherokee County, Kansas. Described February 18, 1953.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
9. Shale and shaly sandstone (base of Bluejacket sandstone); exposed	2.0- 3.0
8. Coal (unnamed), smut	0.1- 0.3
7. Clay	1.0- 2.0
6. Shale, silty	5.0
Dry Wood formation	
5. Coal (Dry Wood), bright when fresh; uneven thickness	0.3- 1.7
4. Clay, thickness uneven	2.0- 5.0
3. Siltstone, calcareous, ferruginous; weathers to soft red material; basal part sandy	0.5- 1.5
2. Shale, black, fissile, containing thin clay-ironstone layers and concretions; weathers to thin chips; very locally lenses of dark-gray to black carbonaceous limestone are present in the basal part of this unit; limestone ranges from tough, compact rock to impure shaly limestone; abundant fossils	

include *Composita, Derbyia crassa, Spirifer occidentalis, Linoproductus, Prismopora triangulata,* fish teeth, and crinoidal material 3.0- 4.0

Rowe formation

1. Coal (Rowe), very blocky, bright; range of thickness in this pit 1.2- 1.7

41. *Section exposed along Cherry Creek, east of bridge on State Highway 7, in NW¼ sec. 7, T. 32 S., R. 24 E., Cherokee County, Kansas. Described July 6, 1949. This is near Abernathy's type section of the Scammon coal.*

Thickness, feet

Cabaniss subgroup

?Mineral formation

9. Limestone, argillaceous; weathered; fossils include abundant high-spired gastropods, some pelecypods 0.5
8. Shale, black; soft and gray in upper 2 inches 1.0
7. Shale, black, containing abundant fossils, chiefly mollusks 0.3- 0.4
6. Shale, black, fissile 0.7- 0.8
5. Shale, black, contains abundant mollusks 0.2- 0.3
4. Shale, black, slaty 0.2
3. Zone of small, rough, dark-gray to black limestone concretions 0.1
2. Shale, black, fissile 1.0

?Scammon formation

1. Coal (Scammon?), hard, bright 0.5

Note: Bed 1 may be Tebo.

42. *Section exposed in roadside ditch in SE¼ sec. 36, T. 32 S., R. 25 E., Cherokee County, Kansas. Described June 13, 1949.*

Thickness, feet

Krebs subgroup

Warner formation

3. Sandstone (Warner), thin bedded, micaceous; dark gray in basal 5 to 6 feet, light gray to tan above; ironstained and friable throughout; some massive beds in upper portion 22.0

Riverton formation

2. Coal (Riverton), weathered 0.4- 0.5
1. Clay, light gray mottled with sulfur yellow; somewhat silty; plastic; contains carbonized plant fragments 3.0

43. *Section exposed in sinkhole in SW¼ NW¼ sec. 34, T. 32 S., R. 25 E., Cherokee County, Kansas. Described June 27, 1950.*

Thickness, feet

Krebs subgroup

Warner formation

4. Sandstone (Warner), slumped from above ..... —

Riverton formation

3. Shale, black, fissile 8.0- 9.0

Mississippian System

2. Chert rubble (interstitial material is clay and shale), nonstratified 6.0
1. Limestone and chert; exposed 10.0

Note: Section in sink is faulted. Fault is reverse, and trends about N 80° W, and displacement is less than 10 feet.

44. *Section in stream cut east of and adjacent to U.S. Highway 69, in NW¼ SW¼ sec. 20, T. 32 S., R. 25 E., Cherokee County, Kansas. Described July 7, 1948.*

	Thickness, feet
Krebs subgroup	
Rowe formation	
7. Shale, grading upward into thin-bedded, fine-grained sandstone	7.0
6. Clay-ironstone layer; nearly all altered to limonite, forming concretionary blocks	0.3- 0.4
5. Shale, black, fissile; weathered to gray clay in upper 1 foot	7.2
4. Limestone, sideritic; partly altered to limonite and hematite; mottled deep red, brown, and black; no fossils observed	0.1- 0.5
?Warner formation	
3. Clay, light gray; contains some concretions similar to those in bed 2; basal part seemingly is weathered shale	1.0
2. Shale, dark to light gray; zone about 12 inches thick at base is crowded with rod-shaped concretions, which have an irregularly stepped exterior, and may be coprolites or worm trails; these concretions also occur in upper part of unit	3.0
1. Shale, gray; "soapstone"; grades into bed above	2.0

Note: Top of bed 3 tentatively identified as horizon of Neutral coal.

45. *Section exposed in sinkhole in SW¼ NE¼ sec. 9, T. 32 S., R. 25 E., Cherokee County, Kansas. Described July 9, 1949.*

	Thickness, feet
Krebs subgroup	
Warner formation	
14. Shale, black, weathers gray	5.0
13. Clay-ironstone layer	0.2
12. Shale, black	4.0
11. Clay-ironstone layer	0.5
10. Shale, black; contains 10- to 15-inch lenses of aragonite	10.0
9. Cone-in-cone; lenticular; maximum thickness	0.7
8. Shale, black, sandy at base, containing pebbles of coarse asphaltic sandstone at basal contact; abundant crystalline masses of pyrite and marcasite and gypsum along joints	10.0
7. Sandstone (upper part of Warner), fine to medium grained; lower part somewhat asphaltic; upper surface leached and friable; contains tubular molds of rootlets; upper surface uneven, and regarded as a coal horizon	5.0- 6.0
6. Shale, sand, and siltstone, very micaceous, weathers light gray; upper part contains one or more thin sandstone beds	8.0
5. Sandstone (lower part of Warner), medium grained, grains frosted; asphaltic throughout; coarsely cross-bedded throughout, even at contact with coal below	15.0
Riverton formation	
4. Coal (Riverton), good	0.9- 1.1
3. Clay, light gray, nonsilty; contains irregular coal streak in uppermost part; darker gray at base	2.0- 3.0
2. Shale, black, hard in basal 4 to 5 feet, softer above; upper part leached, ironstained; bed contains abundant crystalline masses of pyrite and marcasite along joints and fault planes	13.0
Mississippian System	
1. Limestone and chert; exposed	20.0

Note: Bed 2 may be McCurtain shale of Oklahoma. High-angle fault, probably due to slump, traverses this sink.

46. *Exposure in operating strip pit of Wilkinson Coal Company, SW¼ SW¼ sec. 7, T. 32 S., R. 25 E., Cherokee County, Kansas. Described February 16, 1953.*

	Thickness, feet
Krebs subgroup	
Dry Wood formation	
7. Shale, dark to light gray, thinly laminated; unconformably overlain by recent stream gravel	2.0-10.0
6. Limestone, conglomeratic; containing fragments of coal and large pieces of dense, hard gray limestone	0.0- 0.5
5. Coal (unnamed), from streak to	0.3
4. Limestone, dark gray to black, dense, tough; lenticular	0.3- 0.7
3. Shale, dark gray to black, fissile; contains thin layers of clay-ironstone and clay-ironstone concretions	0.5- 2.0
Rowe formation	
2. Coal (Rowe), bright, exceptionally blocky; range of thickness in pit	1.3- 1.7
1. Clay (underclay); exposed in pit floor	—

47. *Exposure in operating strip pit of Pittsburg and Midway Coal Company, in NW¼ SE¼ sec. 34, T. 31 S., R. 22 E., Cherokee County, Kansas. Described July 14, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
6. Clay and gravel; gravel dispersed in silty clay and composed of brown and white tripolitic chert, plus sandstone and shale fragments, and is restricted to basal 2 to 3 feet	15.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
5. Shale, dark gray at base, lighter above; 1- to 2-inch layers of clay-ironstone at 2- to 3-foot intervals; distinct jointing results in blocky fragments of shale	12.0
4. Limestone, black, pyritic, fossiliferous	0.7
3. Shale, dark gray to black; fossils include clams, *Derbyia*, and *Composita*, and most are pyritized	2.3
Bevier formation	
2. Coal (Bevier), blocky, bright, hard; persistent pyrite layer about 4 inches above base; upper ½ to 1 inch is bone coal	1.3
1. Clay, dark gray, silty, contains coalified plant material and root impressions; exposed	0.5

48. *Exposure in abandoned strip pit in SE¼ NE¼ sec. 36, T. 31 S., R. 23 E., Cherokee County, Kansas. Described June 20, 1949.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
6. Sandstone, massive, calcareous; fossiliferous, containing gastropods, *Marginifera*, and *Juresania*	3.0
5. Shale, light gray, sandy; sandy clay at top; rough argillaceous and ferruginous limestone concretions in upper part	5.0
4. Sandstone, light grav, weathering brown	1.0- 2.0
3. Shale, black, containing clay-ironstone and limonite concretions; silty in upper 1 foot	8.0
Fleming formation	
2. Coal (Fleming)	1.0
1. Clay; exposed	1.0

Note: Remainder of highwall under water; Mineral coal was mined here.

49. *Section exposed in clay pit of the United Brick and Tile Company plant at the southeast edge of Weir City, in NW¼ SW¼ sec. 34, T. 31 S., R. 24 E., Cherokee County, Kansas. Described July 15, 1948.*

	Thickness, feet
Cabaniss subgroup	
Weir formation	
8. Coal (Weir-Pittsburg), partly mined out, and very near cropline	3.5
7. Clay parting	0.2- 0.3
6. Coal (Weir-Pittsburg)	0.4
5. Clay (underclay), dark gray to black, showing numerous slickensides, and containing plant impressions and rashy coal; is "blackjack" of miners	1.4
4. Coal (Weir-Pittsburg?), variable in thickness, but persistent laterally in this exposure	0.3- 0.4
3. Clay (underclay), silty, containing root impressions throughout; used in manufacture of buff-burning brick	7.0
2. Zone of calcareous concretions containing plant fossils	0.2- 0.4
1. Shale, sandy to silty	—

Note: Bed 1 probably top of Bluejacket sandstone. Coal bed 4 is possibly Bluejacket coal. Refer to discussion of Weir-Pittsburg coal.

50. *Exposure in abandoned strip pit in NW¼ NW¼ sec. 32, T. 31 S., R. 24 E., Cherokee County, Kansas. Described August 17, 1948.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
7. Sandstone, ferruginous, weathering brown to red; abundant molds of brachiopods and other fossils including *Juresania, Neospirifer, Composita, Linoproductus, Aviculopecten*	3.0-10.0
6. Clay, light gray, sandy; may be product of leaching of bed below	1.0- 2.0
5. Siltstone and thin-bedded sandstone	3.0
4. Shale, dark gray to black in basal 2 to 3 feet, mottled light and dark gray above; abundant clay-ironstone concretions	11.0
3. Shale, drab to brown, calcareous, fossiliferous; locally contains tough lenticular limestone concretions	0.5- 0.6
Fleming formation	
2. Coal (Fleming), variable thickness; close to crop line and not mined here	0.8- 1.3
1. Clay and shale, light gray, with brown staining; upper part contains root and leaf impressions	5.0

Note: Mineral coal mined here, but not now exposed.

51. *Section exposed in clay pit north of road and east of Weir City, in SE¼ sec. 27, T. 31 S., R. 24 E., Cherokee County, Kansas. Described July 15, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
5. Clay, reddish brown to buff; local concentrations of red and black ironstaining and small ferruginous pellets; filled burrows very common	4.0- 5.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Tebo formation	
4. Shale, dark gray to black, weathering light gray; thinly laminated, showing streaks of sulfur along bedding planes; upper 2 feet contains scattered clay-ironstone concretions	6.0

Weir formation
3. Coal (Weir-Pittsburg), bright, blocky; present only as pillars in old workings; considerable fusain and pyrite replacement thereof 4.2
2. Clay, gray, hard, silty; abundant root impressions, many of which are 6 to 8 inches long; slickensides; rough limestone masses containing *Orbiculoidea* near top; used for making buff-burning brick 5.0- 7.0
1. Siltstone, gray, underlies clay, and forms pit bottom or floor —
Note: Bed 1 probably top of Bluejacket sandstone.

52. *Section exposed in abandoned strip pit in SE¼ sec. 24, T. 31 S., R. 24 E., Cherokee County, Kansas. Described June 20, 1949.*

Cabaniss subgroup	Thickness, feet
Croweburg formation	
12. Sandstone, light to dark gray, weathering brown; massive, cross-bedded, friable; in other exposures nearby, this sandstone forms massive lenses 8 to 10 feet thick, cutting or displacing beds below	5.0
11. Shale, black, platy; leached to "soapy" shale and clay showing limonitic partings in upper 5 feet	10.0
10. Zone of limonite concretions; represents weathered clay-ironstone	0.3- 0.5
9. Shale, black, platy, weathers light gray to dun	2.3
Fleming formation	
8. Coal (Fleming)	0.9- 1.0
7. Clay, light to dark gray and limonitic brown; plant impressions in upper part	4.0
6. Shale, dark gray; "soapstone" in upper part	6.0
?Robinson Branch formation	
5. Coal (Robinson Branch?) ranges from streak to 1 inch in thickness; average	0.08
4. Siltstone, soft; no defined bedding; dark gray	1.3
3. Siltstone containing sandstone as lenses in upper part, gray, calcareous, and massive; siltstone is thin bedded and micaceous	5.0
2. Shale, black, platy; silty in upper 6 to 8 inches	3.3
1. Water level in pit	—

Note: Mineral coal mined here, but not now exposed.

53. *Section in strip pit of Black Diamond Coal Company, in NW¼ sec. 32, T. 31 S., R. 25 E., Cherokee County, Kansas. Described June 14, 1949.*

Quaternary System	Thickness, feet
Pleistocene Series	
6. Clay and gravel	5.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Krebs subgroup	
Dry Wood formation	
5. Shale, medium to dark gray, containing a 3- to 4-inch clay-ironstone layer; exposed	2.0- 4.0
4. Limestone, impure, earthy, silty; locally a conglomerate of plant casts; no invertebrate fossils observed; has thin coal streak below and, locally, above	0.3- 0.4
3. Shale, black, fissile; abundant thin clay-ironstone layers; upper part leached and resembles underclay; thin nonpersistent, but locally extremely fossiliferous limestone at base; fossils include *Spirifer occidentalis, Composita, Derbyia,*	

Juresania, Orbiculoidea capuliformis, Punctospirifer, Neospirifer, Allorisma, Astartella, pectinoid clams, and crinoid ossicles 5.5

Rowe formation

2. Coal (Rowe), very blocky, good; range of thickness in pit 1.0- 1.5
1. Clay, contains root impressions; exposed in pit floor 0.5

54. *Section in road cut west of Cherokee, in SW¼ SW¼ sec. 16, T. 31 S., R. 23 E., Crawford County, Kansas. Described June 11, 1949. Exposure along Crawford-Cherokee County line.*

	Thickness, feet
Marmaton group	
Fort Scott formation	
9. Limestone (base of Blackjack Creek limestone member); exposed	4.0
Cherokee group	
Cabaniss subgroup	
Excello formation	
8. Shale, black, fissile; blocky in basal 18 inches; abundant round and lenticular phosphatic concretions	5.0
Mulky formation	
7. Coal (Mulky), uneven, occurs as nodules or lenses, not as a well-defined bed	0.0- 0.3
6. Clay, light gray, plastic; stained with iron and sulfur yellow; contains coalified plant material	2.5
5. Zone of argillaceous and limonitic limestone concretions	0.4
4. Clay and some shale; light gray, plastic when wet; fresh material is darker gray, hard, and crumbly; coalified plant material occurs throughout	6.0
3. Covered interval	3.0
2. Limestone (Breezy Hill) dark gray to brown, weathering buff; earthy; vertical fracture; weathers to smooth, rounded masses; fossils include *Composita, Dictyoclostus, Fusulina,* and crinoid fragments	3.0- 4.0
Lagonda formation	
1. Covered interval; to top of Verdigris limestone, estimated	31.0

55. *Section exposed in creek bed and bank along Wolf Creek, in SE¼ SE¼ sec. 16, T. 31 S., R. 23 E., Crawford County, Kansas. Described June 30, 1948.*

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
7. Limestone (Verdigris), medium to dark gray, weathering buff; vertical fracture; joint system results in rhombic blocks; rock very dense and brittle; fossils include *Cruithyris, Composita, Dictyoclostus,* and crinoid columnals	2.5
6. Shale and clay; somewhat leached; gray at base, lighter gray above; contains rough limestone concretions in upper part	1.3
5. Shale, drab to gray, fossiliferous, locally a coquina of *Marginifera muricatina*	1.3
4. Shale, black, fissile, hard; is thickest where bed 3 is thin; grades into bed above; abundant flattened specimens of *Composita* and *Marginifera* in upper part	2.3- 2.7
3. Concretionary limestone, black, very dense, carbonaceous, weathers rusty brown; forms nearly continuous bed; some septarian concretions; plant impressions on upper surface; fossils rare, but include nautiloids	0.5- 1.0
2. Shale, black, fissile, hard; blocky fracture	1.3

1. Concretionary limestone; most concretions have pyrite or pyritic limestone rind; rock is dark gray to black; concretions are subspherical and dumbbell shaped and as much as 2 feet in maximum diameter; average thickness 1.0

56. *Exposure in operating strip pit of Apex Coal Company, near Monmouth, in N½ SE¼ sec. 7, T. 31 S., R. 23 E., Crawford County, Kansas. Described July 14, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
5. Clay, sandy, local accumulations of gravel at base; brown to red, mottled with light gray; light gray portions are nearly vertical and may be burrow fillings	10.0
4. Gravel, lying unconformably on shale and coal below; gravel contains fragments of chert, coal, and shale in a clay and sand matrix; unit seeps water; irregular thickness	1.0- 4.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
3. Limestone, black, brittle, dense; weathers red to light gray	0.4- 0.5
2. Shale, black, fissile, hard, tough; some clay-ironstone layers	3.4
Bevier formation	
1. Coal (Bevier), bright, blocky; 1-inch bone layer at top	1.4

57. *Section exposed in operating strip pit of Cheroka Coal Company, in SE cor. sec. 19, T. 31 S., R. 24 E., Crawford County, Kansas. Described June 13, 1950.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
4. Sandstone, massive, micaceous, cross-bedded; lenticular; maximum thickness	6.0
3. Shale, black, fissile, calcareous; blasting results in massive blocks as much as 2 feet thick; contains abundant round and ellipsoidal dense, black clay-ironstone or limestone concretions; *Marginifera* locally abundant; some nonpersistent limestone beds; concretions weather hematitic red; upper surface uneven	8.0-10.0
Fleming formation	
2. Coal (Fleming), good, bright; contains calcite along cleats	2.2
1. Clay, not measured	—

58. *Section in operating strip pit of Barbero Coal Company, in SW¼ NW¼ sec. 14, T. 31 S., R. 24 E., Crawford County, Kansas. Described August 17, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
4. Clay, mottled gray and brown; very silty	6.0-10.0
3. Sand and gravel; gravel composed of fragments of sandstone, shale, and coal	1.0- 3.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Tebo formation	
2. Shale, drab to buff, sandy, containing sandstone lenses	2.0- 8.0

Weir formation
1. Coal (Weir-Pittsburg), near crop and generally poor 3.0- 4.0

Note: Shale bed 2 seemingly lies unconformably on coal. Coal has numerous horsebacks.

59. *Exposure in abandoned strip pit in NW¼ NE¼ NE¼ sec. 13, T. 31 S., R. 24 E., Crawford County, Kansas. Described August 11, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
4. Clay and fragments of sandstone; clay red to buff; overlain by about 1 foot of soil	2.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Tebo formation	
3. Sandstone, drab to light buff; appears massive, but much of it is thinly laminated; generally cross-bedded; basal 1 foot coarsest; upper part contains burrows, which are filled with clay and chert fragments; burrows are as much as 6 inches wide and 3 feet deep	6.0
2. Shale, black or dark gray in basal portion, grading upward to drab "soapstone"; thinly laminated throughout; overlying sandstone in unconformable contact	4.0- 8.0
Weir formation	
1. Coal (Weir-Pittsburg), considerable fusain, most of which is replaced by iron sulfide	2.0

Note: This stripping operation intercepted older shaft mine diggings. Sand (bed 3) may be Chelsea member of Scammon formation.

60. *Exposure in abandoned strip pit in SW¼ NW¼ sec. 4, T. 31 S., R. 24 E., Crawford County, Kansas. Described August 17, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
7. Sand and gravel; contains fragments of chert, phosphatic nodules, and sandstone	2.0- 4.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Croweburg formation	
6. Sandstone, tan to drab, weathering drab; micaceous, cross-bedded; occurs as lenses	1.0- 6.0
5. Shale, dark gray to black; upper part deeply leached to nonbedded clayey material; irregular thickness due to relationship with overlying sand	2.0- 6.0
4. Limestone, black, weathering reddish brown; prominent joints form rectangular slabs; fossils include abundant *Marginifera*	0.1- 0.2
3. Shale, black, fissile, sparsely fossiliferous	1.0
Fleming formation	
2. Coal (Fleming), blocky, but very uneven in thickness	0.3- 0.8
1. Clay, gray, mottled with brown; exposed	1.5

Note: Remainder of highwall under water. Lower coal (Mineral) mined here.

61. *Section exposed in abandoned strip pit on south side of creek in center of NW¼ sec. 15, T. 31 S., R. 25 E., Crawford County, Kansas. Described July 24, 1948.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
5. Sandstone (lower part of Bluejacket), fine to medium grained, slabby, limonitic; exposed	2.0
4. Shale, light gray; leached	2.6
Dry Wood formation	
3. Coal (Dry Wood), deeply weathered; near crop	0.7- 0.8
2. Clay, lower 1 foot gray, containing abundant root impressions; upper 3 inches limonitic and plastic; exposed	1.3
1. Covered interval; to water level, near base of highwall	10.0

Note: Rowe coal mined here, but no longer exposed.

62. *Section exposed in road and adjoining ditch, in SE¼ sec. 36, T. 30 S., R. 22 E., Crawford County, Kansas. Described June 10, 1949.*

	Thickness, feet
Cabaniss subgroup	
Mulky formation	
4. Covered interval to base of black shale (Excello) under Blackjack Creek limestone member of Fort Scott formation	2.0
3. Limestone (Breezy Hill), sandy, gray to buff, weathering brown; fossils include *Dictyoclostus* and *Linoproductus;* uneven thickness	1.0- 2.0
Lagonda formation	
2. Sandstone, fine to medium grained, micaceous, slabby and thin bedded; silty in upper 2 to 3 feet	11.0
1. Shale and sandstone, drab to gray; base not exposed	12.0

63. *Exposure in strip pit in SW¼ SW¼ sec. 34, T. 30 S., R. 24 E., Crawford County, Kansas. Described June 13, 1950.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
5. Sandstone, massive, calcareous, micaceous; occurs as lenses or in channels; maximum thickness	8.0
4. Shale, dark gray to black, weathering light gray; variable thickness due to sand above	4.0- 8.0
3. Shale, dark gray to black, and drab; calcareous, grading laterally to nonpersistent impure limestone; abundant fossils include *Marginifera;* thin limestone stringer at top	3.0
Fleming formation	
2. Coal (Fleming), thickness variable; maximum	1.2
1. Clay, much red and brown staining; abundant plant remains; exposed	3.0

Note: Mineral coal mined here, but not now exposed.

64. *Exposure in abandoned strip pit, in sec. 34, T. 30 S., R. 24 E., Crawford County, Kansas. Described August 6, 1948.*

	Thickness, feet
Cabaniss subgroup	
Croweburg formation	
5. Sandstone, micaceous, fine to medium grained, tan to drab, weathering brown; massive, lenticular; unconformable on beds below	1.0- 4.0
4. Shale, black, fissile; contains lenticular phosphatic concretions in basal 1 foot; leached to "soapy" clay shale in upper part; top uneven	2.0- 4.0
3. Limestone, dark, weathers to red and brown earthy material; fossils include *Marginifera muricatina* and *Crurithyris*	0.3- 0.5
2. Shale, dark in basal 6 to 8 inches, but upper part calcareous shale containing abundant *Marginifera muricatina* and *Crurithyris*	2.5
Fleming formation	
1. Coal (Fleming), exposed	0.2

Note: Bed 1 at water level in pit, but designated thickness seemingly maximum.

65. *Section in abandoned strip pit in NW^1_4 SW^1_4 sec. 27, T. 30 S., R. 24 E., Crawford County, Kansas. Described June 13, 1950.*

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
6. Shale, black, fissile; abundant round phosphatic concretions; occurs beneath Verdigris limestone member; exposed	4.0
5. Shale, medium gray, some limonitic streaks; non-silty "soapstone"; some nonpersistent clay-ironstone layers	16.5
4. Shale, black, hard, fissile; blocky; from featheredge to	2.9
Croweburg formation	
3. Coal (Croweburg)	0.2- 0.3
2. Unconsolidated sand and silt, dark gray, leached; coaly material throughout; represents underclay	2.9
1. Sandstone, white, massive, very hard; somewhat calcareous; locally represented by limestone conglomerate	1.0- 3.0

66. *Section exposed in abandoned strip pit, in NE^1_4 NW^1_4 sec. 27, T. 30 S., R. 24 E., Crawford County, Kansas. Described June 18, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
13. Clay and gravel, containing chert and coral fragments in lower part	2.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Verdigris formation	
12. Shale, drab to buff; several clay-ironstone layers, one marking the base	5.4
11. Shale, black, fissile, sharply defined at top and base; thinly laminated; blocky fracture	1.7
Croweburg formation	
10. Coal (Croweburg), very poor, ranges from featheredge to	0.4
9. Clay, dark gray, sandy, parts very micaceous; upper part nonsandy; showing slickensides	2.0- 3.0
8. Limestone, nodular to brecciated; deeply weathered to red and buff; abundant selenite; average thickness	1.0
7. Shale, light gray, mottled with yellow	2.5

6. Limestone, red to black; rock is essentially a coquina of *Marginifera muricatina*, some *Crurithyris* and some *Neospirifer;* occurs as lenses 0.0- 3.0

Fleming formation

5. Coal (Fleming), bony, and extremely carbonaceous shale 0.3- 0.7
4. Coal (Fleming), hard, bright; uneven thickness 0.4- 0.8
3. Clay, light gray, mottled with yellow; melanteritic; very plastic; silty at base 3.3
2. Limestone, nodular, impure, tough, coarsely crystalline; irregular, ranging from featheredge to 1.0
1. Sandstone, fine grained, thin bedded; only upper portion exposed; calcareous masses in upper part; possibly grades upward into bed above; exposed 1.0

67. *Section in strip pit of Eagle-Cherokee Coal Company, in NW¼ NE¼ sec. 10, T. 30 S., R. 24 E., Crawford County, Kansas. Described June 18, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
6. Clay, buff to light gray; some ironstaining in lower portion; at least partly developed from underlying shale; local gravel, including pebbles of chert, silicified *Chaetetes*, and shale, occurs in basal 2 feet	4.0- 5.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
5. Shale, dark gray at base, drab to buff above; numerous clay-ironstone layers in lower 6 feet	12.5
4. Limestone, earthy, very fossiliferous	0.7- 0.8
3. Shale, black, fissile in lower part, but soft, very fossiliferous 2- to 3-inch layer at base, which is locally represented by limestone; pyrite abundant in lower part; upper part dark gray, containing clay-ironstone layers	4.0- 5.0
Bevier formation	
2. Coal (Bevier), hard, bright; estimated	1.3
1. Clay, very thin; overlies limestone (Verdigris) exposed in pit floor	0.2- 0.3

68. *Section in small strip pit, in SW¼ sec. 36, T. 30 S., R. 25 E., Crawford County, Kansas. Described June 12, 1948.*

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
9. Sandstone (Bluejacket), soft, ferruginous in lower 18 inches; coarse, friable, in upper part; most beds 3 to 4 inches thick	6.0
8. Sandstone and sandy clay	2.5
7. Shale, "soapstone"	3.0
6. Zone of limonitic concretions	0.1
5. Shale, dark gray at base, lighter gray above; lower part contains large amount of carbonized plant material	2.5
Dry Wood formation	
4. Coal (Dry Wood)	0.3- 0.4
3. Clay, gray, hard; contains abundant root impressions and carbonized plant material	2.0
2. Shale, dark gray	4.0
Rowe formation	
1. Coal (Rowe); thickness reported	1.7

69. ***Exposure in abandoned strip pit in SE¼ NW¼ sec. 35, T. 30 S., R. 25 E., Crawford County, Kansas. Described February 19, 1953.***

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
13. Sandstone (base of Bluejacket), silty, thin bedded	2.0
12. Coal (unnamed), weathered	0.2- 0.3
11. Clay, gray, hard; contains plant impressions; upper 4 to 5 inches very silty	2.0
10. Coal (unnamed), weathered	1.0
9. Clay, limonitic brown; upper 1 inch hard scaly limonitic shale; gradational contact with bed below	0.8
8. Clay, gray, contains abundant root impressions; some slickensides	1.5
7. Covered interval	2.0
6. Shale, gray to drab, silty	2.5
Dry Wood formation	
5. Coal (Dry Wood), weathered	0.1- 0.2
4. Clay and sand; fine silty clay in upper 4 to 6 inches	1.3
3. Sandstone, coarse, very micaceous, has many vertical tubules, which seem to be molds of plant roots; single piece of chert 3 inches in length found in the sand	1.0
2. Shale, black, fissile; base not observed in pit	1.5
1. Covered interval to bottom of pit, where the Rowe coal was mined	5.0

Note: Two upper coal beds are regarded as nonpersistent and are included in Bluejacket formation.

70. ***Exposure in roadside ditch and adjacent abandoned strip pit in SE¼ NE¼ sec. 27, T. 30 S., R. 25 E., Crawford County, Kansas. Described July 25, 1948.***

	Thickness, feet
Krebs subgroup	
Bluejacket formation	
4. Sandstone (base of Bluejacket), gray to brown, fine to medium grained, micaceous	2.0
3. Shale and clay, deeply weathered; red and brown staining along bedding and jointing planes	1.5- 1.7
Dry Wood formation	
2. Coal (Dry Wood), bony	0.3- 1.0
1. Clay, gray, laced with limonitic brown along joints; abundant root impressions	2.0

Note: Rowe coal mined below bed 1 in this vicinity.

71. ***Section in part from exposure in newly dug farm pond in SW¼ SW¼ SE¼ sec. 26, T. 30 S., R. 25 E., Crawford County, Kansas. Described February 18, 1953.***

	Thickness, feet
Krebs subgroup	
Dry Wood formation	
6. Coal (Dry Wood), soft, near crop	0.5- 1.2
5. Clay; exposed	1.0
4. Shale	6.0
Rowe formation	
3. Coal (Rowe)	1.0
2. Clay parting	0.2
1. Coal (Rowe)	0.2- 0.3

72. *Section in operating strip pit of Mackie-Clemens Coal Company, in SE¼ NW¼ sec. 28, T. 29 S., R. 25 E., Crawford County, Kansas. Described June 13, 1949.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
21. Clay; to top of highwall	10.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
20. Shale, dark gray to black in lower 2 to 3 feet, gray above	10.0
Bevier formation	
19. Coal (Bevier)	1.3
18. Clay, light buff to brown; contains plant impressions and crinoid stems	0.2- 0.3
Verdigris formation	
17. Limestone (upper bed of Verdigris), mottled dark gray and brown; weathers light gray and buff; very hard, forming single massive bed; upper surface uneven and deeply leached; fossils include *Punctospirifer, Neospirifer, Composita, Crurithyris, Phricodothyris, Marginifera, Mesolobus euampygus, Chaetetes,* and simple corals; large wood fragments occur in deeply leached areas on the upper surface	2.6
16. Shale, black, hard and fissile at base, but lighter, possibly leached, in upper part	1.5
15. Limestone, dark gray to black, dense	0.7- 0.8
14. Shale, dark gray to black, fissile	0.8
13. Limestone (lower part of Verdigris), dark gray, dense; zone of flattened, massive concretions 1 to 3 feet in diameter; many are septarian, containing coarse crystals of pink dolomite, and have pyritic rinds; fossils include *Marginifera, Lingula,* and small ammonoids	0.8- 1.0
12. Shale, black, fissile, slaty; abundant round and lenticular phosphatic concretions; fossils include *Marginifera, Composita, Orbiculoidea,* spirifers, ammonoids, and simple corals	5.0
11. Shale, medium gray, thinly laminated; most common fossils are pectinoid clams	8.5
Croweburg formation	
10. Coal (Croweburg), bright, blocky, much calcite in cleats; coal pyritic in upper part; locally a 1- to 2-inch bed occurs above a 3- to 4-inch gray or black shale parting above this bed	0.8- 1.0
9. Clay, silty to sandy throughout; abundant plant remains; much of plant material (roots) in vertical position	2.2
8. Zone of rough calcareous concretions	1.0
7. Clay, light gray, plastic when wet; contains carbonized plant remains	1.5
6. Limestone, sandy at base, shaly above; numerous fossils include *Composita, Marginifera, Derbyia, Juresania, Mesolobus, Orbiculoidea, Crurithyris,* spirifers, clams, and crinoidal material	2.0
5. Shale, dark gray to black, hard, slaty; gray and silty in upper 1 to 2 feet	7.0- 8.0
Fleming formation	
4. Coaly zone (Fleming)	0.2
3. Clay, silty; compacted and bedded in lower part; plant remains occur throughout and are in or near vertical position	4.0

2. Shale, dark gray to black; 1 to 3 feet of very dark gray fossiliferous limestone in lower part; shale hard, fissile to slaty, fossiliferous in lower part; upper surface uneven and upper 1 foot deeply leached; fossils include *Dictyoclostus, Composita, Allorisma, Derbyia, Mesolobus, Neospirifer,* pectinoid clams, and crinoid columnals of large diameter 7.5

Mineral formation

1. Coal (Mineral) 1.5- 1.7

73. *Section in strip pit of Mackie-Clemens Coal Company, in SE¼ sec. 16, T. 29 S., R. 25 E., Crawford County, Kansas. Described June 10, 1948.*

Thickness, feet

Quaternary System
Pleistocene Series

7. Clay, reddish brown to buff; contains small iron or manganese concretions 5.0

Pennsylvanian System
Desmoinesian Series—Cherokee group
Cabaniss subgroup
Lagonda formation

6. Shale, light to dark gray, massive in appearance, but very thinly laminated; has very distant and persistent joint sets 29.0
5. Limestone, dark gray to black, dense, resistant bed; jointed, pyritic; fossils include *Marginifera muricatina* 0.4
4. Shale, black, slaty; upper part contains concretions and layers of clay-ironstone; fossiliferous 4.3
3. Limestone, dark gray to black, very dense and tough; pyritic; contains abundant productids 1.3

Bevier formation

2. Coal (Bevier), bright; blocky fracture; pyritic in upper part 1.5- 1.7
1. Clay, light gray, uneven thickness; underlain by limestone (Verdigris) 0.3- 0.8

74. *Section in strip pit of Mackie-Clemens Coal Company, south of Breezy Hill area in NE¼ NE¼ sec. 15, T. 29 S., R. 25 E., Crawford County, Kansas. Described June 17, 1948.*

Thickness, feet

Cabaniss subgroup
Lagonda formation

10. Shale and clay, buff to drab; clay may be weathered shale; some local concentration of ironstaining in clay 3.3
9. Shale, drab to buff; weathered condition of numerous clay-ironstone layers indicates that color is weathering product; clay-ironstone is soft, leached, and earthy 3.3
8. Shale, black, grading into dark gray above; contains several clay-ironstone layers 3.5
7. Limestone, dark gray to black, dense; contains fragmental shell material; persistent 0.3
6. Shale, black, thinly laminated; breaks with conchoidal fracture; has 1- to 2-inch clay-ironstone bed near top; contains clams 4.6
5. Limestone, dark gray to black, very dense, tough; contains abundant fragmental shell material 0.2- 0.3
4. Shale, black, fissile; conchoidal fracture; principal fossils are clams 0.7- 0.8
3. Pyrite layer; very fossiliferous; all shells completely pyritized; this bed persistent throughout pit 0.2- 0.3

Bevier formation
2. Coal (Bevier), all very bright; mostly clarain; considerable calcite along cleats; coal of even thickness and quality 1.4- 1.5
1. Clay 0.2- 0.3
Note: Bed 1 underlain by Verdigris limestone.

75. *Section exposed in abandoned strip pit on west side of road in SE¼ NW¼ sec. 14, T. 29 S., R. 25 E., Crawford County, Kansas. Described July 27, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
10. Clay and soil; to top of highwall	3.0- 4.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Croweburg formation	
9. Coal (Croweburg), weathered	0.7
8. Clay, silty, gray, crisscrossed with limonitic staining along certain joints; contains root impressions; base uneven, but well defined	2.0
7. Sandstone, gray to brown, micaceous; varies laterally from soft, clayey, nodular, slabby zone to a single massive bed; base is uneven, intersecting portion of bed below	3.0- 5.0
6. Limestone, earthy, brown and gray below to hematitic red above; single massive bed to 2 or more thin beds separated by fossiliferous shale; fossils include abundant *Mesolobus*, *Marginifera*, and *Crurithyris;* contact with overlying bed sharp	0.8- 1.2
5. Shale, black, fissile, in basal 18 inches, gray above; has prominent limestone "dikes" that extend downward from bed 6 and seem to fill joints	5.8
Fleming formation	
4. Coal (Fleming), hard	0.2- 0.8
3. Clay, gray, hard, silty; contains calcareous nodules throughout	2.5
2. Siltstone and sandstone, gray, micaceous; siltstone is thin bedded; sandstone constitutes upper 10 to 12 inches and is uneven at base and top	3.5
1. Covered interval to the fill in floor of strip pit; the Mineral coal, mined here, lay at approximately the base of this interval	5.5

76. *Exposure in barnyard adjacent to strip mine (abandoned) in NE¼ NE¼ NW¼ sec. 11, T. 29 S., R. 25 E., Crawford County, Kansas. Described February 18, 1953.*

	Thickness, feet
Cabaniss subgroup	
Mulky formation	
5. Coal (Mulky), mined here; not measured	—
4. Clay, mostly covered; estimated	1.0
3. Limestone (upper bed of Breezy Hill), single massive bed; contains 25% residue of very fine angular quartz sand; medium to finely crystalline; brownish gray, weathering about same color; fossils include scattered fragments of crinoids and few *Fusulina* tests	1.0- 2.0
2. Limestone (lower part of Breezy Hill), brown to tan, weathers gray brown; finely crystalline; thin, irregular bedding, hackly fracture; fossils include *Dictyoclostus* cf.	

portlockianus, Fusulina, Rhombopora, and scattered crinoid fragments 1.0- 2.0
Lagonda formation
1. Shale; exposed 5.0

77. *Exposure in abandoned strip pit on hilltop in SE¼ NE¼ sec. 10, T. 29 S., R. 25 E., Crawford County, Kansas. Described June 17, 1948.*

	Thickness, feet
Marmaton group	
Fort Scott formation	
3. Limestone (Blackjack Creek member), gray at base, lighter gray above, weathers light buff; lower 18 to 20 inches dense; beds above this lower prominent bed range from 3 to 8 inches in thickness; fossils include flat *Chaetetes* colonies; bedding uneven, upper part forms slabs upon weathering	10.0
Cherokee group	
Cabaniss subgroup	
Excello formation	
2. Shale, black, fissile; numerous round phosphatic concretions; *Orbiculoidea* only fossil observed, some specimens forming nuclei of concretions; jointing very prominent	4.3
Mulky formation	
1. Coal (Mulky), top only exposed	—

78. *Section exposed in strip pit northeast of junction at Croweburg, Kansas, in SW¼ SW¼ sec. 34, T. 28 S., R. 25 E., Crawford County, Kansas. Described June 10, 1948. This is type section of Croweburg coal.*

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
6. Clay and shale, light gray, soft; fossiliferous; upper part contains persistent zone of dark limestone concretions similar to those below	1.5
5. Shale, dark brown	3.9
4. Shale, black, fissile, thinly laminated; upper part contains large dark limestone concretions as much as 2½ feet in diameter	4.3
3. Clay and shale; contains plant impressions and some carbonized plant material	1.6
Croweburg formation	
2. Coal (Croweburg), hard; blocky fracture; some bone coal; pyrite common	1.1
1. Clay, not measured	—

79. *Section exposed in roadside ditch and railway cut, in SW¼ SE¼ sec. 25, T. 28 S., R. 25 E., Crawford County, Kansas. Described July 28, 1948.*

	Thickness, feet
Cabaniss subgroup	
Scammon formation	
7. Shale and siltstone, gray to brown; 3- to 4-inch sandstone lenses in upper part; some calcareous siltstone concretions	10.0
6. Shale, black, fissile; contains clay-ironstone and limonite concretions	4.0
5. Limestone (Tiawah), dark gray to black, weathering brown and red; slabby	0.2- 0.4
4. Shale, black, fissile; contains abundant small rounded phosphatic concretions; weathered zone above coal at base	1.8
Tebo formation	
3. Coal (Tebo)	0.5

2. Clay, silty, gray, mottled with brown; contains root impressions; well-defined scaly limonitic zone at top 4.0
1. Shale, gray, somewhat silty; very thinly laminated; clay-ironstone concretions abundant throughout; upper 1 foot is gray siltstone 15.0

80. ***Section in abandoned strip pit about 2½ miles north of Mulberry, Kansas, in SE¼ NW¼ sec. 24, T. 28 S., R. 25 E., Crawford County, Kansas. Described June 11, 1948.***

	Thickness, feet
Cabaniss subgroup	
Verdigris formation	
32. Limestone (part of Verdigris member), exposed at surface and weathered to rubble	1.5
31. Shale, black, fissile, hard; containing abundant small round phosphatic concretions throughout, and a zone of large limestone concretions about 3 feet above the base	5.0
30. Shale, gray, weathering brown; upper 1 foot very light gray and clayey; black fissile shale (to 1 foot thick) occurs locally in basal part	8.3
Croweburg formation	
29. Coal (Croweburg), weathered	1.0- 1.3
28. Clay, dark gray, hard, crumbly	4.0
27. Limestone (underlimestone), gray, coarse grained, nodular; nodules in clay and shale matrix; no fossils observed	1.7
26. Shale, black, thinly laminated; displaced laterally in lower part by lenticular dark-gray limestone as much as 18 inches thick	4.4
Fleming formation	
25. Coal (Fleming)	0.8
24. Clay, gray, hard; contains abundant plant impressions	2.7
23. Shale, dark gray to black, fissile, hard; weathers to thin brittle chips	7.0- 8.0
Mineral formation	
22. Coal (Mineral), blocky, weathered (near crop)	1.6
21. Clay	1.0
20. Zone of deeply weathered limestone and shale; argillaceous material, plastic, ironstained, and containing gypsum crystals; calcareous material not fossiliferous; identified as underlimestone	2.4
19. Shale, dark gray, hard; calcareous in upper part	10.0
18. Limestone, dark gray to black, weathering to light buff or gray; dense; forms prominent ledge in this exposure; fossils include large productids, spirifers, *Mesolobus*, *Chonetina*, and fusulinids	0.2- 1.2
17. Coal (Scammon), bright	0.7
16. Clay	3.0
15. Limestone, coarse grained, sandy; seems to grade laterally to massive sandstone 4 to 5 feet thick; considered as a unit, thickness is highly variable	1.0- 5.0
14. Shale, dark gray to black, fissile at base; grades upward to sandy or silty shale	9.0
13. Clay-ironstone; in single layer	0.2
12. Coal horizon (unnamed)	—
11. Sandstone and siltstone, thinly laminated and interbedded; ripplemarked, and containing casts of worm borings; slumps in massive blocks	8.0
10. Shale, dark gray to black, platy	5.5
9. Clay-ironstone layer	0.2

8. Shale, dark gray to black, fissile 0.5
7. Limestone (Tiawah), very dense, fossiliferous; color ranges from dark gray to hematitic red; cone-in-cone common along upper surface 0.4
6. Shale, black, fissile; contains *Orbiculoidea;* weathers to thin brittle chips; scattered small clay-ironstone concretions 1.7

Tebo formation

5. Coal (Tebo), bright; blocky fracture; even in thickness 0.5
4. Clay, gray, hard, crumbly 3.0
3. Limestone, nodular, gray, medium to finely crystalline; no fossils observed; nodules form persistent bed 0.8
2. Shale, gray; "soapstone"; hard, weathers to light-gray chips; grades into bed above 16.4

Weir formation

1. Coal (Weir-Pittsburg), not now exposed in this pit, but thickness in vicinity about 4.0

81. ***Section in road cut 6.3 miles north of Arma, on U.S. Highway 69, in NW¼ SW¼ sec. 5, T. 28 S., R. 25 E., Crawford County, Kansas. Described July 15, 1948.***

	Thickness, feet
Marmaton group	
Fort Scott formation	
10. Limestone (Blackjack Creek member), light to dark gray and reddish brown, weathering light brown; coarse; rusty specks common; some masses of calcite in upper part; bedding uneven; locally where rock is composed predominantly of *Chaetetes* colonies, bedding is absent; beds range from 3 to 10 inches in thickness; fossils include abundant *Chaetetes,* some fusulines, *Neospirifer,* and *Crurithyris*	7.8
9. Limestone (lower part of Blackjack Creek member), dark gray, weathering buff; seemingly concretionary in basal part; vertical tubular fillings (⅛ to 1 inch in diameter) are common; upper part weathered and extremely porous owing to tubular cavities; fossils include cephalopods and brachiopods	1.8
Cherokee group	
Cabaniss subgroup	
Excello formation	
8. Shale, black, fissile, hard; abundant small, rounded and lenticular phosphatic concretions	3.0
Mulky formation	
7. Coal (Mulky), hard, blocky, bright	0.7
6. Clay, gray, hard, silty; large amount of carbonized plant material	0.4
5. Covered interval	2.0
4. Limestone (Breezy Hill), sandy and silty; mottled light blue gray and tan; blue gray is soft and silty; most of rock is darker; forms single uneven ledge; silty material washes out on weathering, leaving residue of coarse brown limestone rubble; no fossils observed	0.8- 1.5
3. Shale, light gray to drab; very sandy, seeps water	0.8
Lagonda formation	
2. Sandstone, fine to medium grained; light gray to drab and buff; median 2 to 3 feet massive, breaking into slabs; finely cross-bedded throughout; upper 1 foot contains thin nonpersistent clay partings; most of material friable	6.0
1. Siltstone, thin-bedded sandstone, and sandy shale, micaceous; exposed	10.0

82. *Section described from roadside ditches at crossroads, SW cor. sec. 2, T. 28 S., R. 25 E., Crawford County, Kansas. Described July 29, 1948.*

	Thickness, feet
Cabaniss subgroup	
Scammon formation	
8. Sandstone (Chelsea), gray, weathering brown; massive to thin bedded; exposed	5.5
7. Shale and clay, light gray, soft; leached; upper contact not well defined	2.0
6. Sandstone and siltstone, gray to drab; micaceous; nonpersistent lenses of sand in upper 3 feet	6.5
5. Shale, dark gray to black, fissile at base; grades upward into thinly laminated silty dark-gray shale	5.5
4. Limestone (Tiawah), dark gray, shaly; weathers red and brown; fossiliferous	0.3- 0.4
3. Shale, black, fissile, very hard and tough	1.0
Tebo formation	
2. Coal (Tebo), weathered	0.4
1. Clay, gray, hard, silty; exposed	3.0

83. *Section in abandoned strip pit and adjoining road cut on U.S. Highway 69, in SW¼ SW¼ sec. 32, T. 27 S., R. 25 E., Crawford County, Kansas. Described July 13, 1948.*

	Thickness, feet
Cabaniss subgroup	
Mulky formation	
13. Limestone (Breezy Hill), dirty dark gray to brown, weathering tan and buff	1.7
Lagonda formation	
12. Sand, poorly cemented, and shale, gray to buff; uneven thickness	0.3- 0.4
11. Sandstone (part of Lagonda), brown to drab, thin bedded, forming slabs; finely cross-bedded; somewhat calcareous	2.0
10. Sandstone and interbedded sandy clay	6.0
9. Shale, medium to dark gray; contains clay-ironstone concretions at base; gray, weathering light gray above; upper part very silty; entire thickness laced by dike-like structures resulting from the action of ground water along joint surfaces	6-9.0
8. Limestone, weathers to thin slabs; fossiliferous	0.3- 0.5
7. Shale, black, platy; contains abundant clay-ironstone concretions	1.8
6. Limestone, dark gray to black; weathers reddish brown; fossils include *Marginifera muricatina* and clams	0.2- 0.3
5. Shale, black, platy	1.4
4. Limestone, dark gray	0.2- 0.3
Bevier formation	
3. Covered interval; includes thin underclay, the Bevier coal (stripped here), and overlying fossiliferous limestone	2.2
Verdigris formation	
2. Limestone (Verdigris), mottled light and dark gray, weathers buff and light gray; nodular, distinctively so on weathered surface; prominent joints form rough rhombs; fossils include *Mesolobus lioderma*, *M. euampygus*, *Marginifera muricatina*, *Neospirifer*, *Composita*, crinoid columnals, fusulines, and gastropods	1.6- 1.7
1. Shale, black, fissile; uppermost few inches drab, fossiliferous, containing *Marginifera* and *Mesolobus*	2.0

84. *Exposure in operating strip pit of Meade Coal Company, in NE¼ SW¼ sec. 28, T. 27 S., R. 25 E., Crawford County, Kansas. Described July 29, 1948.*

	Thickness, feet
Cabaniss subgroup	
Lagonda formation	
4. Shale, "soapstone," even bedding; gray to drab	10.0
3. Shale, black; contains lenticular limestone bodies 1 to 20 inches thick having lenses or nodules of much denser limestone within; limestone is fossiliferous	3.0- 4.0
Bevier formation	
2. Coal (Bevier), hard, bright; layers of pyrite; calcite along cleats	1.3- 1.4
1. Clay, exposed in floor of strip pit	—

85. *Section exposed in roadside ditch, in SW¼ SW¼ sec. 18, T. 27 S., R. 25 E., Bourbon County, Kansas. Described July 13, 1948.*

	Thickness, feet
Marmaton group	
Fort Scott formation	
8. Limestone (lower part of Blackjack Creek limestone member), dense, dark gray, weathers buff; vertical fracture	1.0
Cherokee group	
Cabaniss subgroup	
Excello formation	
7. Shale, black, fissile; very abundant small rounded phosphatic concretions	3.0
Mulky formation	
6. Coal (Mulky), weathered	0.5
5. Clay, dark gray, silty; contains plant impressions; uneven contact with bed below	0.8- 1.4
4. Clay, light gray, very plastic; much limonitic staining	1.6- 2.3
3. Limestone (Breezy Hill), sandy, mottled light and dark gray, weathers brown and buff; seems to grade upward from lower bed; thickness uneven	0.5- 0.7
Lagonda formation	
2. Sandstone, drab to brown, somewhat calcareous; slabby, and thin bedded; ripplemarked; very micaceous	3.7
1. Shale, "soapstone"; exposed	5.0

86. *Exposures in operating strip pit of Pellett Coal Company, in SW¼ SE¼ sec. 18, T. 27 S., R. 25 E., Bourbon County, Kansas. Described July 4, 1948.*

	Thickness, feet
Quaternary System	
Pleistocene Series	
11. Clay, base uneven; darker than that below, crumbly; lower part contains concentration of small pellet-like iron concretions	4.0
10. Clay, drab at base, containing widely distributed coal fragments in basal 2 to 3 feet; lower 4 feet very silty to sandy; upper part uniform; light buff and gray mottled, lighter gray at top	14.7
9. Gravel, consisting of fragments of chert, shale, and coal averaging about 1 inch in diameter; upper part all gravel, but lower part has clay matrix; 2-inch bed of detrital coal at top	1.7
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
8. Shale, dark gray to black at base, gray above; upper surface uneven	1.3

7. Limestone, dark gray to black, weathers brown to deep red; fossiliferous, containing gastropods, pelecypods, and *Crurithyris* 0.3- 0.4
6. Shale, black, fissile; clay-ironstone concretions 1.6
5. Limestone, earthy; contains pelecypods, gastropods, and *Crurithyris;* weathers to soft, chocolate-colored rock 0.2- 0.3
4. Shale, black; has lenticular masses of fossiliferous bituminous limestone; limestone includes black limestone concretions containing *Linoproductus;* shale contains abundant *Marginifera, Mesolobus, Neospirifer, Juresania,* and *Composita;* many fossils pyritized 4.1

Bevier formation

3. Coal (Bevier), hard, bright, blocky fracture; upper 1 inch bony; much "peacock" coal 1.5
2. Clay, dark gray; contains carbonaceous material; micaceous 0.1- 1.0

Verdigris formation

1. Limestone (Verdigris), upper part exposed; reported thickness 2.0

87. ***Section exposed in bed and banks of Dry Wood Creek, in SW¼ NW¼ sec. 14, T. 27 S., R. 25 E., Bourbon County, Kansas. Described July 5, 1949.***

Cabaniss subgroup	Thickness, feet
Croweburg formation	
14. Sandstone, medium to coarse, ferruginous, weathers dark brown; massive, uniform; exposed	11.0
13. Limestone and shale; interval very poorly exposed; pieces of limestone float contain abundant *Marginifera muricatina*	2.0
Fleming formation	
12. Coal (Fleming), not exposed, but was mined here on small scale; estimated thickness	1.0
11. Clay, not well exposed; estimated thickness	1.0
10. Shale, calcareous, containing thick (18-20 inches) nodular masses of coarse, dark limestone	2.0
9. Clay, light gray, containing abundant scaly limonitic material	0.5
8. Shale, black, fissile, at base, gray soapstone above; entire thickness laced by thick dike-like joint fillings of earthy calcareous material; limonitic and clay-ironstone concretions occur in part; small rounded and lenticular phosphatic concretions are found in basal black shale	11.5
7. Limestone, dark gray to black, weathers to soft, earthy, brown and red: joints lined with cone-in-cone; very uneven, as lenses 2 to 30 inches thick: fossils include *Marginifera muricatina, Punctospirifer, Neospirifer, Juresania, Dictyoclostus,* and *Composita*	0.2- 2.5
Mineral formation	
6. Coal (Mineral), very uneven in thickness and in quality; thickest where overlying limestone is thickest; from a streak to	1.5
5. Clay, dark gray, showing slickensides; plastic; occupies position of Mineral coal where coal is absent; upper part contains fragments of coal	3.0- 4.0
4. Shale, gray "soapstone", cut by numerous joint fillings; upper part grades into clay	6.0
Scammon formation	
3. Coal (Scammon), bone	0.2

2. Shale, micaceous, very silty at base; upper part thinly bedded 2.0
1. Sandstone (Chelsea), gray, fine grained, thin bedded, micaceous; joints filled with calcareous material; exposed 3.0

88. *Exposure on Dry Wood Creek bank in SE¼ SW¼ sec. 13, T. 27 S., R. 25 E., Bourbon County, Kansas. Described August 3, 1948.*

Cabaniss subgroup	Thickness, feet
?Croweburg formation	
6. Limestone, very much weathered; a coquina of brachiopods and gastropods; weathers to spongy, red, earthy material	0.3- 0.4
5. Shale, black, fissile	1.8
?Fleming formation	
4. Coal (Fleming?), blocky, somewhat weathered	0.7
3. Clay, dark grayish brown, silty; contains abundant root impressions; some coaly streaks; limonite along joints	1.3
2. Clay, light gray, silty; acid taste; contains rough limestone and pyrite concretions; has well-defined but uneven lines of contact with beds below and above	1.8
1. Sandstone and siltstone, thin bedded, containing prominent calcareous bodies, which were seemingly deposited in crevices in siltstone after its deposition; upper part very uneven	6.0

Note: Bed 4 probably Fleming. Section overlain by recent stream gravel.

89. *Exposure in abandoned strip pit west of Garland, in NW¼ NW¼ sec. 1, T. 27 S., R. 25 E., Bourbon County, Kansas. Described July 4, 1948.*

Marmaton group	Thickness, feet
Fort Scott formation	
4. Limestone (Blackjack Creek member), drab to gray, weathering buff; fine to coarse grained; forms essentially single ledge; fossils project upon weathering and include *Dictyoclostus*, *Chaetetes*, *Syringopora*, and large crinoid columnals (to 1 inch in diameter)	7.4
3. Limestone (lower part of Blackjack Creek), dark gray, dense; distinct from overlying beds	0.8
2. Shale, gray, calcareous	0.1- 0.2
Cherokee group	
Cabaniss subgroup	
Excello formation	
1. Shale, black, fissile; abundant round phosphatic concretions; nearly spherical black limestone concretions as much as 2 feet in diameter, having pyritic rinds 1 to 2 inches thick, are common at this locality; exterior of each shows slickensides	2.0

Note: Mulky coal mined here; pit now full of water.

90. *Section exposed in operating strip pit of Kelly-Carter Coal Company, in SW¼ NW¼ sec. 35, T. 26 S., R. 25 E., Bourbon County, Kansas. Described July 4, 1948.*

Quaternary System	Thickness, feet
Pleistocene Series	
9. Clay, dark brown; small (¼-inch) reddish-orange pellets scattered throughout; base uneven, or may grade imperceptibly into next lower bed; clay characteristically crumbly	1.0- 2.0

8. Clay, light reddish brown, mottled with gray; plastic when wet; somewhat silty; most prominent foreign material is small fragments of shale, most common at base 5.0- 6.0

Pennsylvanian System
Desmoinesian Series—Cherokee group
Cabaniss subgroup
Lagonda formation

7. Shale, dark gray, weathering light gray to drab; thinly laminated; prominent jointing, joint surfaces weathered, forming dike-like structures; basal 6 to 12 inches darker gray, containing pectinoid clams 21.0
6. Limestone, dark gray to black, weathers hematitic red; dense; fossiliferous throughout 0.3- 0.4
5. Shale, black, hard, fissile; contains flattened shells, principally clams; a coaly zone occurs about 8 inches above the base, reaches a thickness of about 2 inches, but is not persistent, and is not associated with clay 1.3- 1.5
4. Limestone, dark gray to black; locally represented by thin-bedded limestone and interbedded fossiliferous shale; limestone contains subcylindrical dense limestone masses with veins of calcite; limestone "matrix" is tough, and contains abundant *Marginifera muricatina*, plus *Linoproductus, Mesolobus*, and simple corals 1.5- 1.7
3. Shale, black, fissile; contains zone of dark limestone concretions 6 to 24 inches thick; concretions are lenticular to rounded and are septarian, some containing *Linoproductus;* shale contains flattened and fragmental shell material, much of it pyritized 4.0

Bevier formation

2. Coal (Bevier), thinly layered; "peacock" coal; contains much calcite in cleats 1.3- 1.4
1. Clay, dark gray, contains carbonized plant material; very hard 0.5- 1.0

91. *Section exposed in operating strip pit, in SE¼ SE¼ sec. 28, T. 26 S., R. 25 E., Bourbon County, Kansas. Described June 9, 1949.*

Thickness, feet

Quaternary System
Pleistocene Series

4. Clay and gravel 6.0

Pennsylvanian System
Desmoinesian Series—Cherokee group
Cabaniss subgroup
Lagonda formation

3. Shale, black, and dark, impure limestone; limestone weathers buff, contains *Linoproductus, Mesolobus, Marginifera, Neospirifer*, and simple corals, and occurs in thin beds; zone of cylindrical concretions of dark dense limestone about 2 feet above base 6.0

Bevier formation

2. Coal (Bevier), hard, bright, blocky 1.3
1. Clay, gray, silty; reported thickness 4.0

92. ***Exposure in road cut at crossroads in NE¼ NW¼ sec. 27, T. 26 S., R. 25 E., Bourbon County, Kansas. Described August 6, 1948.***

	Thickness, feet
Cabaniss subgroup	
Excello formation	
5. Shale, black, fissile; abundant lenticular and rounded phosphatic concretions	2.0
Mulky formation	
4. Coal (Mulky), weathered	1.5
3. Clay, gray, silty; flaky limonitic material in basal 8 inches; upper part contains root impressions	2.0
Lagonda formation	
2. Sandstone (Lagonda), drab to gray and brown; fine to medium grained; pectens in lower 6 to 8 inches; single zone, about 18 inches above base and 6 inches thick, is extremely calcareous, containing calcareous masses; rest is thin bedded, slabby, micaceous throughout	3.5
1. Shale, "soapstone", prominent joints are altered by ground water, forming "dikes"; exposed	6.0

93. ***Exposure in strip pit in low-lying area northwest of Garland, in NW¼ SE¼ sec. 26, T. 26 S., R. 25 E., Bourbon County, Kansas. Described July 4, 1948.***

	Thickness, feet
Cabaniss subgroup	
Lagonda formation	
3. Shale, basal 1 foot dark gray, upper part leached to gray "soapstone"; clay-ironstone concretions; exposed	5.0- 6.0
Bevier formation	
2. Coal (Bevier), "peacock" coal; blocky to conchoidal fracture	1.0- 1.2
1. Clay, dark gray, hard; much mica and carbonaceous material; exposed in floor of strip pit	0.7

Note: Small, deeper stripping adjacent brought up black, fissile shale identified as that below the Verdigris limestone. Presumably the Croweburg coal was mined here for a short time. Interval from Croweburg coal to Bevier coal estimated to be about 10 feet.

94. ***Section exposed in creek and adjacent abandoned strip pit in N½ sec. 25, T. 26 S., R. 25 E., Bourbon County, Kansas. Described August 6, 1948.***

	Thickness, feet
Quaternary System	
Pleistocene Series	
7. Clay, gray, mottled with limonitic brown; contains limonitic rubble at base	3.0- 5.0
Pennsylvanian System	
Desmoinesian Series—Cherokee group	
Cabaniss subgroup	
Lagonda formation	
6. Shale, black, fissile at base, grading upward into gray shale and clay; upper part leached	3.0
5. Siltstone and fine-grained sandstone; gray	4.0
4. Shale, black; basal 4 inches fossiliferous, including *Neospirifer*, *Dictyoclostus*, and large crinoid columnals; upper part black fissile shale containing sparse clay-ironstone concretions	6.0
3. Shale, black, fissile	0.7

Bevier formation
2. Coal (Bevier), estimated thickness 1.4
1. Clay, gray, yellow-brown staining along jointing; contains carbonized plant material and roots; clay is darker gray in upper part and contains streaks of coal 2.5

95. *Section in operating strip pit, in SW¼ NW¼ sec. 25, T. 26 S., R. 25 E., Bourbon County, Kansas. Described July 4, 1948.*

Thickness, feet

Cabaniss subgroup
Lagonda formation
4. Shale and shaly sandstone rubble 2.0
3. Shale, lower 10 inches dark gray to black, fossiliferous, grading into gray shale above; contains clay-ironstone concretions 9.0
Bevier formation
2. Coal (Bevier), slightly weathered; contains pyrite along cleats 1.2
1. Clay, dark gray, micaceous; contains carbonized plant material; exposed 0.5

96. *Exposure in road cut and creek bank in SE¼ SW¼ sec. 4, T. 32 N., R. 33 W., Barton County, Missouri. Described August 2, 1950.*

Thickness, feet

Krebs subgroup
Seville formation
5. Limestone (Seville), shaly at base, upper 4 inches massive, brittle; dark gray, weathering to hematitic purple; abundant *Marginifera* cf. *missouriensis*, *Linoproductus*, and crinoid fragments 0.7
Bluejacket formation
4. Clay and shale; horizon of Bluejacket coal at top 2.0
3. Sandstone (Bluejacket), massive 6.0
Dry Wood formation
2. Clay, silty, hard; contains plant remains and coal streaks; horizon of Dry Wood coal at top 2.0
1. Sand, thin bedded, and siltstone; exposed 5.0

Note: Sandstone and siltstone overlie black shale above bed 5, but these beds are very poorly exposed.

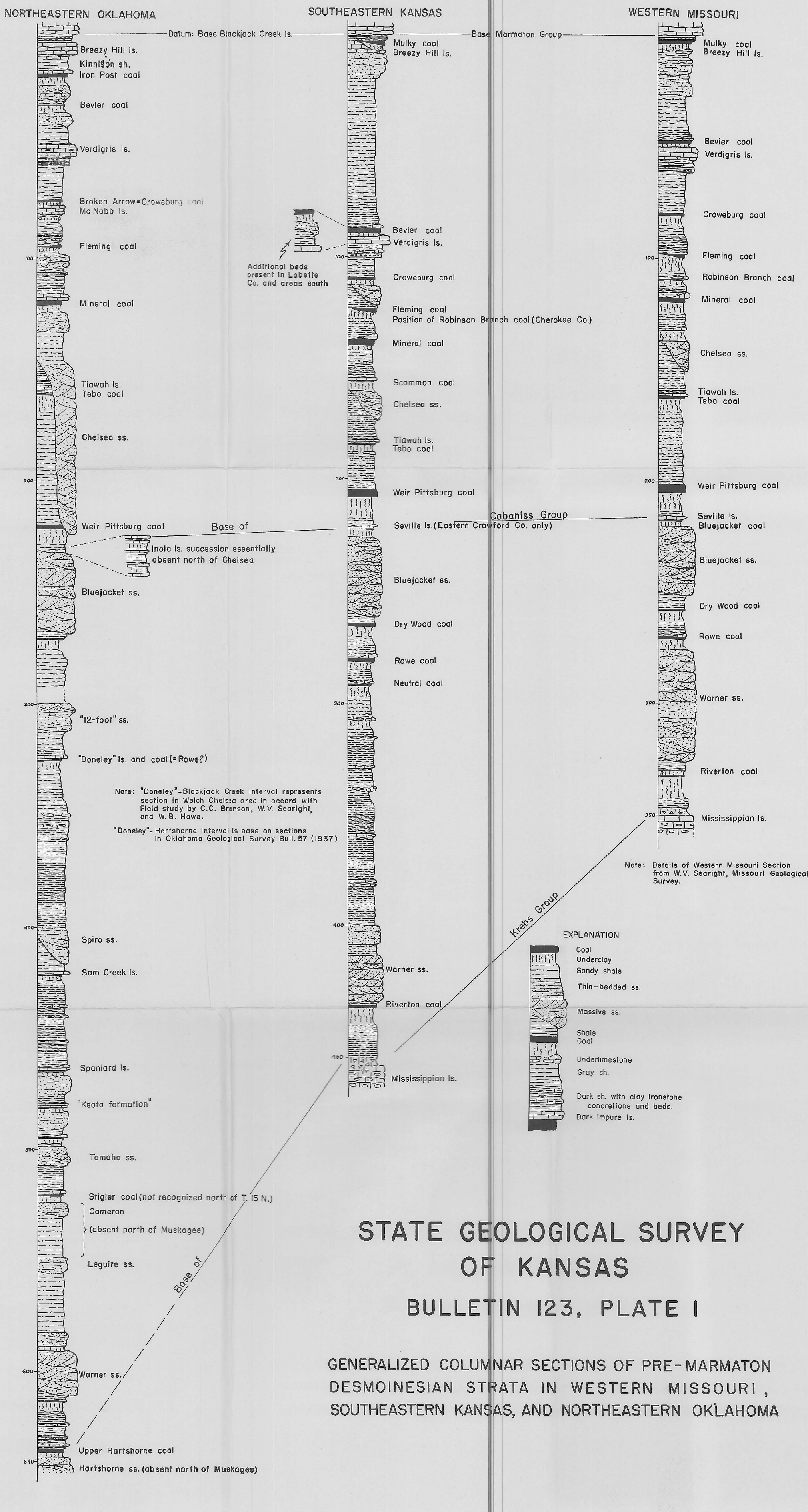
97. *Section described from operating strip pit of Mackie-Clemens Coal Company, in SW¼ sec. 18, T. 33 N., R. 33 W., Barton County, Missouri. Described July 7, 1950.*

	Thickness, feet
Cabaniss subgroup	
Scammon formation	
14. Sandstone (Chelsea), massive, base unconformable, extending locally down below Tebo coal in NW cor. sec. 24, T. 32 N., R. 33 W.; exposed here	10.0-15.0
13. Shale, gray	8.0
12. Shale, dark gray, fissile, at base, grading upward to thinly laminated sandstone; thinly laminated sand is variegated dark and light gray, because of abundance of plant material included; upper part is deeply oxidized, and is soft, brick red; plant material abundant, but broken up	11.0
11. Zone of clay-ironstone concretions, averaging about 1 foot in diameter	0.2
10. Shale, black, fissile	1.2
9. Clay-ironstone layer	0.2
8. Shale, black, fissile	0.6
7. Limestone (Tiawah), dark gray to black, impure, pyritic; forms single ledge	0.4
6. Shale, black, fissile, hard; basal part calcareous and fossiliferous, containing *Marginifera muricatina*; fish scales, orbiculoids, conodonts, and pectinoid clams occur in more fissile, less calcareous part	1.8
Tebo formation	
5. Coal (Tebo)	0.5
4. Clay, gray, very silty; contains root impressions	3.0- 4.0
3. Limestone, impure, nonpersistent; unfossiliferous	0.0- 0.7
2. Shale, gray, silty; lamination at slight angle to plane of coal bed below	14.0- 15.0
Weir formation	
1. Coal (Weir-Pittsburg)	3.0

Note: Unnamed coal horizon within Scammon formation occurs below bed 13.

98. *Exposure in bank of Dry Wood Creek, at point where Missouri State Highway 43 crosses Dry Wood Creek, 4½ miles south of Bronaugh, in Barton County, Missouri. Described June 26, 1950.*

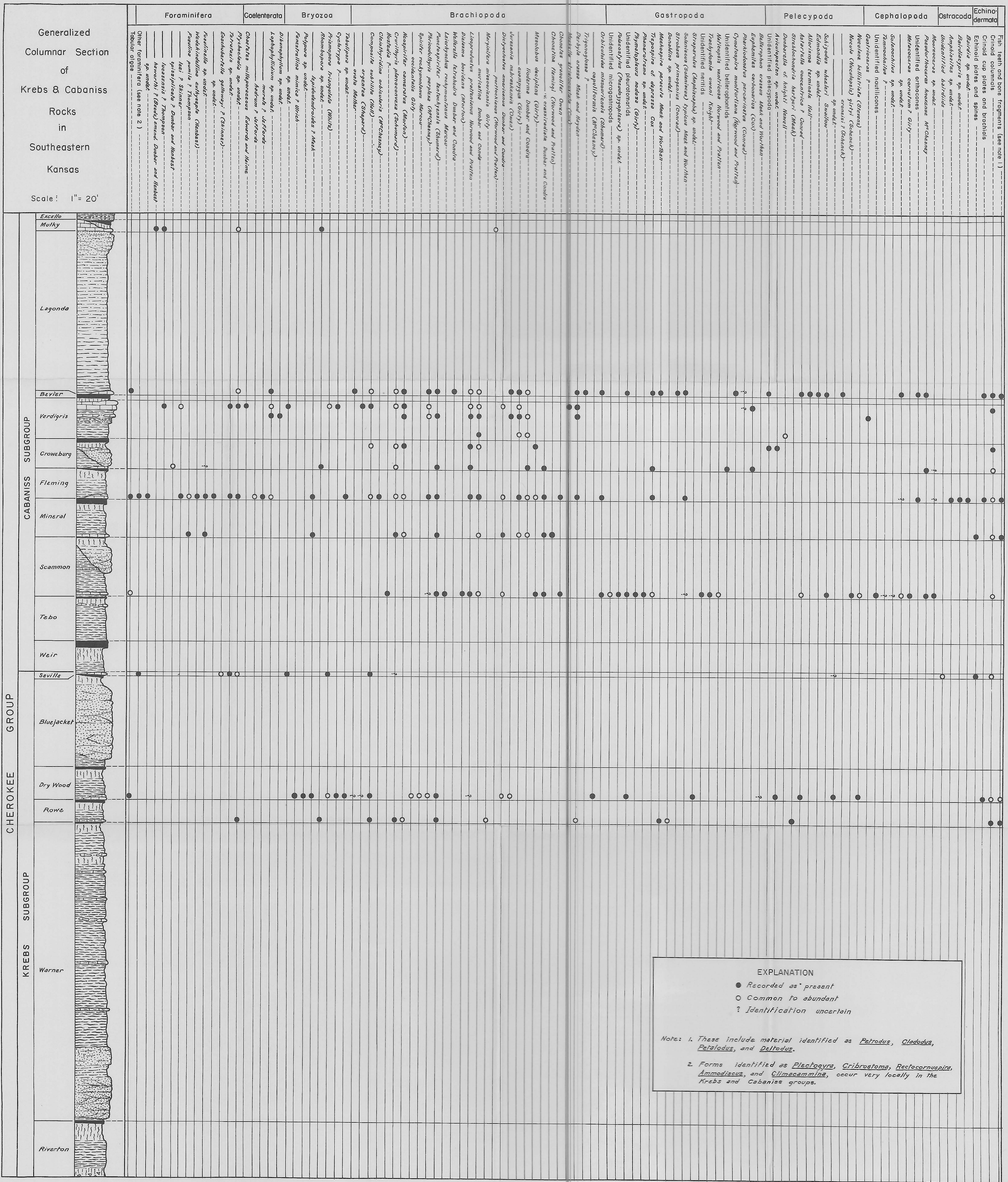
	Thickness, feet
Krebs subgroup	
Seville formation	
6. Limestone (Seville), ferruginous, red and gray; fossils include *Marginifera* cf. *missouriensis, Orbiculoidea, Cruirithyris*, and gastropods	0.3- 0.5
Bluejacket formation	
5. Clay and shale; contains thin coal or coal horizon (Bluejacket) in upper part	1.0- 2.0
4. Sandstone (Bluejacket), massive, cross-bedded; "blister" conglomerate at base; asphaltic	6.0- 8.0
Dry Wood formation	
3. Shale and clay; contains horizon of Dry Wood coal at top	0.2- 0.5
2. Clay, sandy; represents leached upper portion of bed below	1.5
1. Sandstone and siltstone, thin bedded; considerable carbonaceous material	7.0



STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 123, PLATE 1

GENERALIZED COLUMNAR SECTIONS OF PRE-MARMATON DESMOINESIAN STRATA IN WESTERN MISSOURI, SOUTHEASTERN KANSAS, AND NORTHEASTERN OKLAHOMA



STRATIGRAPHIC DISTRIBUTION OF FOSSILS IN KREBS AND CABANISS ROCKS IN SOUTHEASTERN KANSAS