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Geology and Coal Resources of the Southeastern Kansas Coal Field

IN CRAWFORD, CHEROKEE, AND LABETTE COUNTIES

BY
W. G. PIERCE AND W. H. COURTIER

with a report on

PENNSYLVANIAN INVERTEBRATE FAUNAS OF SOUTHEASTERN KANSAS

By JAMES WILLIAMS

Investigation conducted by United States Geological Survey with funds provided for this purpose by Public Works Administration

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By W. G. Pierce and W. H. Courtier

ABSTRACT

The area described includes parts of Crawford, Cherokee, and Labette counties, Kansas, and a small area in Barton and Vernon counties, Missouri, comprising in all about 1,160 square miles. It includes the Cherokee-Crawford district, originally determined by the extent of the Weir-Pittsburg coal, which extends northeastward from northern Cherokee county through eastern Crawford county and into the northwestern part of Barton county, Missouri, and is the oldest and most important coal-mining area in Kansas. Pittsburg is the largest city and is the commercial center of the coal industry.

Since the early development of the coal field most of the prospecting has been done by drilling test holes. The logs of most of them are remarkably accurate, so that they may be correlated with little difficulty. In this investigation approximately 4,500 well logs and drill records of prospect holes were assembled and used in conjunction with detailed plane-table mapping.

Due to coal, zinc, and lead mining, the region is more densely populated than the agricultural areas of the state. The three southeastern counties of Kansas have an average population of sixty people per square mile. In Crawford county over one fifth of the people are employed in coal mines, and in Cherokee county over one fourth are employed in coal, zinc, and lead mines.

The oldest rocks exposed in the area are of Mississippian age. They consist principally of limestone and chert and contain the zinc and lead deposits. They are exposed in a belt trending northeast across the southeast corner of Cherokee county. Except for thin deposits of recent strata, all the rest of the rocks in the area are of Pennsylvanian age. The Cherokee shale, of early Pennsylvanian age, unconformably overlies the Mississippian limestone and consists of shale, sandstone, a few thin beds of limestone, and a number of coal beds from a few inches to 3½ feet thick. It increases in thickness to the west and southwest from 375 to 560 feet, as shown by an isopach map with lines of equal thickness at 20-foot intervals. Two members of the Cherokee which have been recognized in northeastern Oklahoma are extended into Kansas. One is the Little Cabin sandstone member, a brown to buff, medium-grained sandstone that is similar to other sandstones higher in the Cherokee. It is from 10 to 20 feet thick, is underlain by the Riverton coal, and its base is normally 15 to 20 feet above the base of the Cherokee. The other is the Bluejacket sandstone member, which occurs slightly below the middle of the Cherokee, at approximately the horizon of the Bartlesville sand. It is 20 to 50 feet thick and is underlain by the Columbus coal. The Ardmore limestone member of the Cherokee—definitely correlated with the Rich Hill lime-

creasing southward from an average of 2 feet 10 inches to 3 feet 8 inches—and until recently it has been the principal producing bed. A separate map of the Weir-Pittsburg bed shows (1) the areas that have been shaft-mined and strip-mined, (2) the amount of overburden or depth to the coal and (3) the approximate western limit of workable coal. Several thin coal beds occur below the Weir-Pittsburg, but normally they are all less than 18 inches thick and are mined at only a few places. Two thin coal beds occur between the Weir-Pittsburg and Mineral bed 75 feet above, but are unimportant commercially and are not mined. The Mineral coal is the second thickest coal bed of the area and is extensively mined by stripping, from the northeast corner of the area southwestward to Mineral. It is 17 to 24 inches thick. The Fleming and Croweburg coal beds lie above the Mineral bed, but are not extensively mined, due to lack of sufficient thickness in most parts of the area. The Bevier coal overlies the Ardmore limestone and is about 100 feet below the top of the Cherokee. It is strip mined, principally in Crawford county; there the average thickness is 18 inches. The strata between the Bevier coal and the top of the Cherokee are noncoal bearing in Crawford and Cherokee counties. In southeastern Labette county there are several thin beds in the interval, including the Stice coal. The Fort Scott coal is in the uppermost part of the Cherokee and lies only a few feet below the base of the Fort Scott limestone. The coal is from 8 to 12 inches thick in the northeastern part of the area, extending southward to Arma; between Arma and Girard it is discontinuous and is not present farther south. It has been strip mined at many places along its outcrop.

The coal in the southeastern Kansas field is of bituminous rank, is somewhat friable, practically nonslacking, and has a bright appearance. A little pyrite is present and films of calcite commonly occur along joints and fractures. The Weir-Pittsburg bed is the only one that carries a large amount of clay; it occurs in the form of veins or "horsebacks." Proximate analyses of 26 samples collected during the field work are given in Table 1 on page 81.

The southeastern Kansas coal field has produced about 88 percent of the total output of the state, and in 1934 produced 91 percent of the state's output. The tonnage production of strip mines and shaft mines, by counties and for the district as a whole, is shown by graphs covering the period from 1885 to 1934. The field produced 2,300,000 tons of coal in 1934; this represents a progressive advance since 1931, but is less than one third of the tonnage produced in the peak year of 1918.

The coal is mined both from underground workings and open pits. The Weir-Pittsburg bed is the only coal that has been extensively mined underground. Inasmuch as about 75 percent of the workable area of this bed has already been mined, production in recent years has been coming increasingly from the thinner beds, which can be worked profitably only from open pits or strip mines. Steam shovels were first used for stripping the overburden in the open pit mines, but many of them are now replaced by large electric shovels. Although much of the coal is marketed as run-of-mine, a considerable proportion is size-graded. A large amount of the coal is used for steam raising, the railroads being the largest group of consumers. Large quantities are also used for domestic purposes, for power stations, packing plants, and other industries, both in the surrounding territory and in the vicinity of Kansas City. The

INTRODUCTION

Location and Extent of Area

The oldest and most important coal-mining area in Kansas is the Cherokee-Crawford district, which extends northeastward from northern Cherokee county through eastern Crawford county and into the northwestern part of Barton county, Missouri. The limits of the district were originally determined by the extent of a single coal bed, the Weir-Pittsburg coal, but with the advent of large-scale surface stripping of thin coal beds the field has been extended, particularly to the southwest and north. Pittsburg, which, according to the 1930 census, has a population of 18,145, is the largest city and is the commercial center of the coal industry of the district. The area described in this report includes the eastern and southern parts of Crawford county, all of Cherokee county except that part southeast of Spring River, the eastern part of Labette county, Kansas, and a small area in western Missouri, including parts of Barton and Vernon counties. In all about 1,160 square miles are included, of which about 60 square miles are in Missouri and the remainder in Kansas, 375 square miles in Crawford county, 525 square miles in Cherokee county, and 200 square miles in Labette county. (See fig. 1.)

Present Investigation

The known reserves of the principal coal bed of southeastern Kansas—the Weir-Pittsburg bed—have been nearly exhausted and in recent years attention has turned to beds of lesser thickness which may be minable by surface stripping. The approximate extent and thickness of the Weir-Pittsburg bed have long been known from drill records and underground mining, but very little detailed information was available concerning the other coal beds which now constitute the main coal reserves of the area. The Cherokee shale, which is the principal coal-bearing formation, produces a large amount of oil and gas in an area lying west of the coal field, and therefore detailed information on it, where exposed along its outcrop, was also desirable.

Field work was undertaken in the region, through an allotment of funds from the Public Works Administration, to map the geology and determine the coal resources. The coal beds were accurately mapped and about 4,500 well logs and drill records of prospect holes were assembled and correlated, so that a regional picture of the horizontal extent and thickness of the several coal beds could be obtained. In order to show the depth of coal below the surface and the attitude of the coal-bearing strata, altitudes were determined on the coal beds at the outcrop and in drill holes where the coal lay at some depth below the surface.

The field work extended over a period of eight months from April through November, 1934. During April the senior author made reconnaissance obser-

mark elevations along the railroad; the Kansas City Southern Railroad, which supplied benchmark elevations along its right of way. The State Geological Survey of Kansas gave access to maps and other data pertaining to the area. The Kansas Gas & Electric Co. kindly loaned us logs of drilling done in northwestern Cherokee county. The State Highway Department supplied elevations along many of the highways, and the county engineers—E. M. Conrad of Crawford county, L. C. Belt of Cherokee county, and J. R. Jarboe of Labette county—gave us similar information for many county roads. The logs of drill prospecting for lead and zinc, in the southeastern part of Cherokee county, have been made available by the Kansas Explorations, Inc., by several other mining companies, and by W. M. Stewart. George Fowler has kindly furnished many logs and maps showing the depth to the base of the Cherokee shale. The writers also wish to express their appreciation to G. E. Abernathy, State Mine Inspector William Glennon, R. L. Cooper, Earl Tibbets, Giles Overton, the Kansas Well Log Bureau, Hazel & Sons, R. O. Deming, and numerous individuals who supplied information concerning thickness of coal, well logs, and coal samples.

Without the splendid assistance of the members of the party it would not have been possible to assemble the data presented in this report. Their hard and conscientious work is to be commended and is deeply appreciated. The project was carried forward under the direction of H. D. Miser, who also made helpful suggestions in the preparation of the report.

Previous Publications

The first comprehensive report published on Kansas coal was by Haworth[1] and Crane in 1898. A large part of this report deals with the coal of southeastern Kansas, which at that time was in the early stages of development. Since then there has been a great deal of mining and drill hole prospecting, which has furnished needed information in a region of few natural exposures. A report[2] on oil and gas, published by the Geological Survey of Kansas in 1908, contains a good reconnaissance map of the formations in the southeastern part of the state. Another report on Kansas coal in 1925 by Young and Allen,[3] furnished additional data on the district, particularly with reference to the engineering and production methods in use, and the chemical composition of the coal. An excellent description of the stratigraphy of the Cherokee shale, which is applicable to this district, is contained in a report by Greene and Pond[4] on an adjoining area in western Missouri, and by Greene[5] in a later report, gives more recent suggestions on stratigraphic correlations in western Missouri. Moore and Landes[6] have discussed the coal of southeastern Kansas in their

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wheat, and hay the leading crops. In the early history of the region cotton and tobacco were grown with poor success. Flax for a time was a profitable crop. The total value of agricultural products for Crawford and Cherokee counties for the year 1929 was approximately $5,300,000, whereas the coal products for the same year in these two counties was approximately $6,400,000 and the combined coal, lead, and zinc value was approximately $17,400,000.[12]

Accessibility.—A veritable network of railroads, representing a total of nine companies, is operated within the area. These lines are shown on Plate 1 and represent the following companies: St. Louis-San Francisco Railway Co.; Missouri Pacific Railroad Co.; Atchison, Topeka & Santa Fe Railway; The Kansas City Southern Railway Co.; Missouri-Kansas-Texas Railroad Co.; Kansas, Oklahoma & Gulf Railway Co.; The Joplin-Pittsburg Railroad Co. (electric); Northeast Oklahoma Railroad Co. (electric); The Southwest Missouri Railroad Co. (electric).

Several north-south and east-west paved highways make this district readily accessible. There are also roads on nearly all section lines. Many of the roads are surfaced with gravel, with hard black shale, or with tailings from the zinc-lead mines that are locally known as chats.

Surface features.—Although there are not many prominent features in the landscape of southeastern Kansas, the country does not give an impression of monotony and barrenness, for along the small streams and rivers trees are numerous and in addition many have been planted in clusters and along fence rows by the early settlers of the country. The total relief is only about 250 feet—that is, from about 770 to 1,020 feet above sea level, yet it is so distributed that one scarcely realizes that there is such a small departure from a plane surface. The lowest point in the area is on Neosho river at the Kansas-Oklahoma line and the highest point is on the drainage divide southeast of Farlington, in Crawford county.

The area treated in this report lies within two physiographic provinces,[13] the Ozark Plateau and the Central Lowland. The Ozark Plateau is subdivided into two sections, the Boston Mountains and the Springfield-Salem Plateau. The extreme southeastern corner of Kansas lies within the latter section, which includes mainly that part of Cherokee county southeast of Spring river. The plateau is moderately dissected. The Osage Plains, a section of the Central Lowland province, includes all the area described in this report, except for the small part in the Ozark Plateau. The Osage Plains extend south-southwest from Kansas City through southeastern Kansas and across Oklahoma into Texas and bevel strata which in southeastern Kansas are slightly inclined to the northwest. Several low southeastward-facing escarpments are formed by the beds of limestone which are more resistant than the intervening shale. The streams which flow upon areas of shale have rather broad valleys and flood plains, but where they flow on a surface underlain by limestone their valleys are narrower. A shale unit from a feather edge to over 500 feet in thickness comprises the surface formation in practically all of Cherokee county, the southeastern part of Crawford county, and the eastern part of Labette county. This area has been designated the Cherokee Lowland by Moore.[14] The Chero-

12. 15th Census of the United States, U. S. Dept. of Commerce, Agriculture, vol. 3, pt. 1, pp. 1013-1014, 1930; Mines and Quarries, 1929, p. 259, 1930.

13. Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers, Annals, vol. 18, No. 4, pp. 261-353, Dec. 1928.

14. Moore, R. C., The surface features of Kansas (some text on map): Kansas State Geol. Survey (1930), scale 1 inch = 40 miles (approx.).

Mo.[18] (about 3 miles east of the Kansas-Missouri line), shows that in the period from April, 1924, to September, 1933, there was a maximum discharge of 57,400 second-feet on August 17, 1927, and a minimum of 22 second-feet on September 8, 1925. The gaging record of a station on Shoal creek, about four miles south of Joplin (4¼ miles east of the Kansas-Missouri line) shows in the same period a maximum of about 17,200 second-feet on June 27, 1932, and a minimum of 8 second-feet on October 9, 1931. The flow here is regulated by the Great Falls hydroelectric plant and the minimum flow was recorded while the power plant was shut down. Cow creek, with its tributaries, West Cow creek and Little Cow creek, drains a considerable part of the area, for it heads within six miles of the northern boundary and flows southward until it joins Spring river 1½ miles south of Lawton, a distance of approximately thirty miles. It lies wholly within the area covered by this report, and drains that part from the Kansas-Missouri line westward to Girard, and northward to Arma and the divide, about a mile south of Farlington. The lower part of Cow creek carries water throughout the summer, but becomes stagnant in prolonged dry periods. Shawnee creek, which heads just south of Weir, and Brush creek, which begins north of Columbus, flow southeastward and join Spring river in the southeastern corner of the area.

The northeastern corner of the field is drained by Drywood creek and its tributaries, Cox creek, Bone creek, and the West Fork of Drywood creek. Drywood creek flows northeastward into Marmaton river, which empties into Osage river, a tributary of the Missouri river. The divide between the northward drainage into Osage river and the southward drainage into Spring river extends southeastward from Farlington through Arma to Minden.

Surface drainage in this area is generally good, except in lowland areas adjacent to major streams, particularly Neosho river. Subsurface drainage, however, is comparatively poor in much of the area because of a heavy clay-pan subsoil.

Climate.—The climate of this area is mild, but is characterized by wide seasonable variations. About sixty-five percent of the rainfall comes in the growing season from April to September, inclusive, generally as thunderstorms of short duration, but gentle rains occur in the spring and fall. The most damaging winds are the hot winds which usually occur during prolonged dry periods and come from the south or southwest. In spite of an average annual precipitation of 41 to 44 inches, droughts are not uncommon, and crops frequently suffer from lack of moisture, due in large part to the high rate of evaporation and large proportion of sunshine.

The lowest temperature recorded, 30 degrees below zero, and the highest recorded, 114 degrees, give an absolute range of 144 degrees. The winters are usually open until December, and prolonged cold spells are extremely rare. The spring and fall seasons are commonly cool and dry. Outdoor work can usually be carried on throughout the winter with few interruptions. The average frost-free season varies from about 185 days in the northern part of the area to about 197 days in the southern, extending on the average from April 12 to October 20.

18. Idem, p. 90.

STRATIGRAPHY

General Statement

All of the strata exposed in the southeastern Kansas coal field belong to the Carboniferous system. They are all of Upper Carboniferous (Pennsylvanian) age except for the small area of limestone of Lower Carboniferous (Mississippian) age in the southeast corner of Cherokee county. The Cherokee shale, which lies unconformably on the limestone of Mississippian age, is of early Pennsylvanian age. The Cherokee is overlain by alternating beds of limestone and shale which form convenient units for division into geologic formations. The Fort Scott limestone at the base of this overlying series, the Labette shale, and the Pawnee limestone crop out within the area. All of the coal beds of economic importance lie within the Cherokee shale. Figure 2 shows a generalized section of the formations outcropping in the area.

Carboniferous System

Mississippian Series

Rocks of Mississippian age, consisting principally of limestone and chert, are exposed in a belt trending northeast across the southeast corner of Cherokee county. They form the surface over most of the area southeast of Spring river, and for a mile or so west of the river, except for structural depressions which contain patches of Cherokee shale.

Osage subseries[20]

In southeastern Kansas the youngest Mississippian rocks definitely known to be present below the Cherokee shale are beds (Warsaw limestone) belonging to the Osage subseries. Several formations of late Mississippian or Chester age occur between the limestone of Osage age and the lower Pennsylvanian strata in northeastern Oklahoma. Owing to erosion along the unconformity at the base of the Cherokee shale, these formations disappear northward, but some uncertainty exists as to just how far northward some of them extend. In the Joplin District folio, which extends into south-

20. In place of the term Osage subseries, the authors of this report have employed "Boone limestone," a stratigraphic unit that, although shown on the recently published state geologic map of Kansas, is not recognized in the classification of the rocks of Kansas adopted by the State Geological Survey. This is because "Boone" is synonymous with the well-recognized, much older division called Osage, as this is currently defined. The State Geological Survey employs the classificatory designation "subseries," rather than "group," because the stratigraphic unit here embraced is separated by widespread unconformities from older and younger rocks and because of important faunal distinctions which are believed to mark a definite time division.

examined where revision seemed necessary. The areal mapping was not extended southeast of Spring river; for the geology of that area the reader is referred to the Joplin District folio.

Pennsylvanian Series

des moines subseries[24]

Cherokee shale

In 1894 Haworth and Kirk [25] gave the name Cherokee shale to the thick shale and sandstone series lying above the Mississippian rocks and below the Fort Scott or †Oswego limestone. The Cherokee shale outcrops in a northeast-trending belt from 15 to 25 miles wide across Cherokee county and extends northeastward through Crawford county into Missouri. To the southwestward it extends into the easternmost part of Labette county, and on southward into Oklahoma.

In southeastern Kansas the Cherokee shale contains both marine and continental strata, with many recurrences of both types of deposits indicated by many marine fossil horizons and numerous coal beds. As the name indicates, it is predominantly a shale formation, but contains several beds of sandstone from 10 to 50 feet thick and numerous thinner beds of sandstone. In the upper half of the formation the shale is commonly gray in color and well laminated, except that black shale is present above some of the coal beds. Dark-gray and black shale are more abundant in the lower part of the formation. Limestone forms an insignificant part of the total thickness of the Cherokee shale, but two limestone units, each only a few feet in thickness, are classified as members of the formation because they are good stratigraphic markers. The Cherokee contains numerous coal beds, most of them from 6 to 24 inches thick; the thicker and more important coals are in the upper half of the formation.

The basal part of the Cherokee is exposed at places along the belt of outcrop west and north of Spring river, and in recent sink holes, mine shafts, and cave-ins. It consists of 15 to 20 feet of dark to black laminated shale, which rests on either limestone or somewhat fractured chert. No conglomerate was found at the base of

24. The classificatory division called Des Moines subseries, not used by the authors of this report, is incorporated here to correspond with the classification of Kansas rocks adopted by the State Geological Survey of Kansas which recognizes this as one of the very significant subdivisions of the Carboniferous system. It constitutes the lowermost part of the Pennsylvanian series in Kansas, although older rocks (Morrow subseries) of Pennsylvanian age appear south of the Kansas-Oklahoma boundary. The U. S. Geological Survey recognizes Des Moines as a group term.

25. Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 105, 1894.

Little Cabin rests directly on the coal, or the Little Cabin may cut out the coal entirely. Where the Riverton coal is entirely cut out, fragments of coal may sometimes be found in the basal part of the sandstone. Some good exposures in a small eastward draining draw in the NW¼NW¼ sec. 14, T. 33 S., R. 25 E., show significant

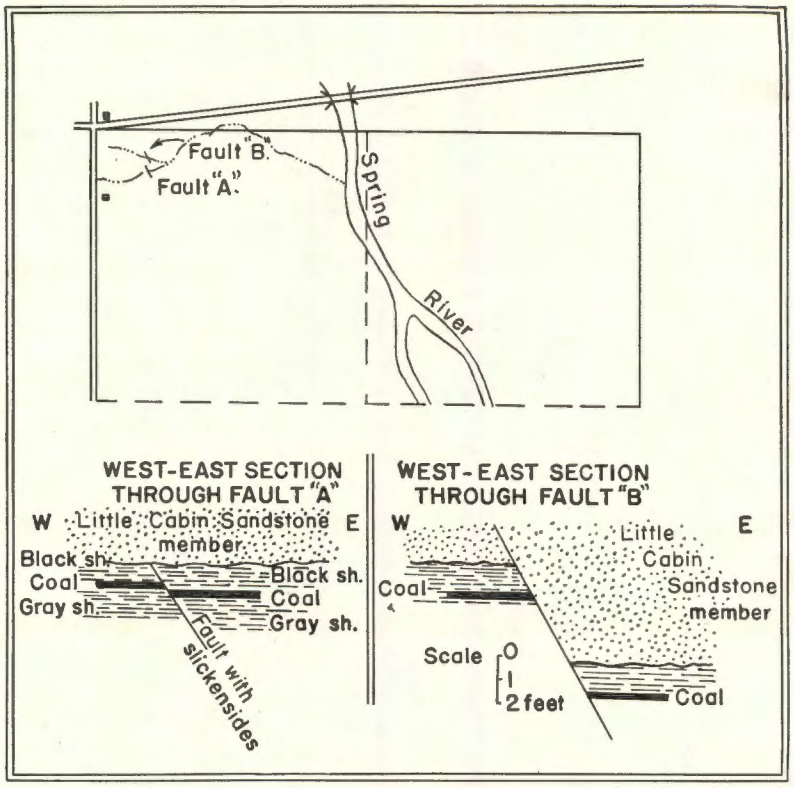

FIGURE 3. Sketch map and cross sections of two small faults in the N½ sec. 14, T. 33 S., R. 25 E.

structural relations of the Little Cabin sandstone to the underlying shale, as shown in figure 3. The fault at "B" in the figure is of no particular interest, except to show slight movement in post-Little Cabin time. The fault "A," however, is of interest in regard to the time interval represented by the erosional irregularity at the base of the Little Cabin sandstone. Fault "A" has only about 7 inches of vertical displacement, but the shale along the fault surface is slickensided in a direction parallel to the dip of the fault. The fault ex-

Section of the lower part of the Cherokee shale and the Little Cabin sandstone member, measured in the undisturbed wall of a recent sink hole, in the NW¼ NE¼ sec. 9, T. 32 S., R. 25 E.

Cherokee shale	*Ft.*
Shale, black, fissile	10+
Little cabin sandstone member:	
Sandstone, dark, fine-grained; weather nodular and pitted	0.4
Sandstone, light brown, white at top; hard	4
Shale, sandy, thin-bedded, dark; local beds of sandstone	5
Sandstone, cross-bedded, brown to black, asphaltic; tabular cavities, some filled with pyrite	11
Coal (Riverton), variable in thickness from 6 to 11 inches	0.9
Shale, gray	3
Shale, black, laminated; contains one fourth to one half inch vertical veins of calcite; in places the lower 6 inches contains a few small angular fragments of chert	11.5
Mississippi series, chert	2+
Total section measured	47.8

Beds between the Little Cabin and Bluejacket sandstone members.—Little is known of the detailed stratigraphy of the 150 feet of beds above the Little Cabin sandstone, except that it consists principally of dark shale with 4 or 5 coal beds from 6 to 18 inches in thickness. It contains a few local sandstone beds which in places crop out as hard sandstone ledges. In Oklahoma this unit contains a 6- to 10-inch bed of limestone which Weidman[32] calls the "Elm Creek limestone." It is described as occurring 10 to 20 feet below the Bluejacket sandstone. However, in Kansas, no persistent limestone was found at this horizon, or in fact in the whole lower half of the Cherokee, although a few thin lenticular, fossiliferous beds were found. Most of these limestone beds are black and rest upon coal.

In the weathered material on the dumps of several shallow coal strip pits many tabular pieces of porous, limonitic, sandy shale an inch or so in thickness were observed. Some are so porous that at first glance they look like fused or clinkered rock. They are particularly abundant in the strata between the Little Cabin and Bluejacket sandstone members. A specimen from a strip mine dump in the SW¼ sec. 18, T. 32 S., R. 25 E., and another from unweathered shale in the NW¼NW¼ sec. 2 of the same township were examined in the Chemical Laboratory of the Geological Survey; a report by Charles Milton states in part:

> An examination of the specimens and of thin sections prepared from them indicates that they are indurated sandy shales, with conspicious brown and black limonite. The more porous specimen shows no definite bedding and in the other the bedding is ill-defined. The limonite is banded, indicating deposition from aqueous solution of the iron in its present form. Both specimens consist of quite stable material and no processes of oxidation, leaching, or the like appear likely to affect them.

32. Weidman, Samuel, op. cit., pp. 25-26.

Although a thickness of 45.5 feet of strata was measured along the south side of Cow creek in the NW¼NW¼ sec. 28, T. 31 S., R. 25 E., their stratigraphic position in the Cherokee is unknown. The entire exposure dips 22 degrees east-northeast, but within a quarter of a mile both to the east and west the strata assume their normal flat-lying position.

Bluejacket sandstone member.—The Bluejacket sandstone was named[34] from the town of Bluejacket, in Craig county, Oklahoma, and has been mapped northward to the Oklahoma-Kansas line. Although the Bluejacket cannot be traced with certainty as a continuous unit in Kansas, the name is applied to the prominent sandstone that is exposed just east and south of Columbus, and that that caps the Timbered Hills 2 miles southwest of Crestline. It is possible that the base of the Bluejacket sandstone in the area southwest of Columbus to the Kansas-Oklahoma line does not represent a continuous bed or even the same stratigraphic horizon, because the lack of outcrops makes it impossible actually to trace any bed more than a few hundred feet. The base of the Bluejacket, as shown on Plate 1, however, represents the base of a fairly thick sandstone unit, so far as could be determined from careful field observations in conjunction with drill hole data. It was not mapped northeastward beyond sec. 33, T. 32 S., R. 24 E., about four miles northeast of Columbus. Sandstone at approximately the horizon of the Bluejacket was observed at a number of places in the area between Pittsburg and Opolis, but is not shown on the map (Pl. 1). In places it is underlain by the Rowe coal bed. The term Columbus sandstone was proposed by Haworth and Kirk[35] for the sandstone exposed southeast of Columbus, but was defined rather loosely and would probably include both the Little Cabin and Bluejacket sandstone members.

The Bluejacket sandstone is between 20 and 50 feet in thickness, and its base is 50 to 100 feet below the Weir-Pittsburg coal. In places the base of the Bluejacket is irregular, possibly as much as 20 feet. At a small strip mine about 800 feet east of the center of sec. 20, T. 33 S., R. 24 E., the Bluejacket sandstone contains a basal conglomerate with cobbles up to 6 inches in diameter that were derived from the shale and concretions of the lower part of the Cherokee. All of the material composing the conglomerate was ap-

34. Gould, C. N., Index to stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35, p. 64, 1925.

35. Haworth, Erasmus, and Kirk, M. Z., op. cit., p. 106.

thin lenses of coal observed a few feet above the base of the sandstone along Brush creek, but, so far as known, the Columbus coal is not present here.

A road cut at the northwest corner of sec. 23, T. 33 S., R. 24 E., made at the time of the field investigation, revealed a fresh exposure of the basal part of the Bluejacket sandstone. When freshly exposed, both the bedding and color of the sandstone are seen to be unusual. The individual beds of sandstone seemingly thin westward, but the thinning apparently is due in part to truncation by each overlying bed. The most prominent bed thickens from 1 to 13 inches in a distance of 25 feet. The two-toned color of the sandstone beds is even more striking, for most of them show a distinct change in color near the middle of each bed. The beds are from an inch or two to a foot thick; the upper half is lighter colored, from buff to light brown, and the lower half is medium to dark gray. The color differences apparently did not orginate as a result of the small normal fault at this locality; neither are they characteristic of the Bluejacket sandstone, for they were not observed elsewhere. A specimen was submitted to the chemical laboratory of the Geological Survey; the report of an examination by Charles Milton is as follows:

> The sandstone consists of over 95 percent of uniform, angular to subrounded, quartz grains with little interstitial clayey material. A few black areas, not over a millimeter across, are visible in the hand specimen; under the microscope much smaller opaque areas are seen distributed throughout the rock. The gray color in the lower part of the bed is due to organic matter, or some form of carbon. On strong ignition, the rock burns white. On heating in a closed tube, only a doubtful odor is observed. The difference in color of the two parts of the rock is due, however, to more carbonaceous matter being present in the dark part as shown by the following experiment: A portion of a few grains of the gray rock was placed in a test tube with 10 c. c. of $KMnO_4$ solution, and a similar tube of $KMnO_4$ prepared as a blank. After one day, the tube with the gray rock showed marked reduction of the $KMnO_4$ as compared with the blank. After a week, the blank was virtually unchanged; the $KMnO_4$ with the gray rock almost decolorized. Similarly, a portion of the gray rock, and one of the light rock, were treated with $KMnO_4$. The gray rock decolorized the $KMnO_4$, and the light rock hardly affected it at all after three days. It is concluded that the dark color in the lower part of the bed is due to carbonaceous material, which reduces $KMnO_4$, and can be burnt off; the light-colored rock does not contain this reducing material. Solubility tests with organic solvents were negative, indicating that the material is not a hydrocarbon, but probably of a coaly nature. An attempt was made to measure the relative quantity of organic matter in the two portions of rock, by treating the crushed rock with hot dilute H_2SO_4, filtering, and adding $KMnO_4$ to the filtrate. The reduction, however, was negligible, indicating that the carbonaceous material did not dissolve to any appreciable extent. The crushed rock was then added to the filtrate, and the mixture heated to boiling; the permanganate solution (approximately .03) was added from a burette. The light-colored rock showed a permanent end point on addition of 4 c. c.; the gray rock after 13. The gray rock was visibly bleached by this treatment, approaching the buff-colored rock. It is concluded that the carbonaceous matter in the gray rock is on the order of three times that in the light colored.

nutely laminated. The shale, however, does not seem to be unconformable on the coal. The many thin beds of shale each appear to thicken slightly and thus produce the pseudo dip. This feature is well exposed in the north wall of a pit at the center of the north line of the NE¼ sec. 19, T. 30 S., R. 25 E., and also in a pit in the NW¼ sec. 8, T. 32 S., R. 24 E. (See Pl. 2-B.)

The interval between the Weir-Pittsburg coal and the Ardmore limestone member consists of shale, sandy shale, some sandstone, and five coal beds which are described in detail under the discussion of coal. Some of the coal beds are overlain by a few inches of lenticular black limestone. The most distinctive bed in this unit is a black shale which contains both large and small calcareous and pyritic concretions and lies between the Croweburg coal and the Ardmore limestone. This black shale with the concretions is very helpful in identifying the Croweburg coal and is more fully described in the discussion of that coal bed. A photograph and sketch of the bed are shown in Plate 8-B and figure 8. The thickness of the strata between the Weir-Pittsburg coal and the Ardmore limestone is about 100 feet in Tps. 27 and 28 N., and increases to the south-southwest to about 135 feet. The Mineral coal is somewhat above the middle of this unit. Its outcrop has been mapped and is shown on Plate 1.

Ardmore limestone member and overlying shale.—In 1893 the name Ardmore limestone was used in a Missouri Geological Survey report on the Bevier topographic sheet,[37] in north-central Missouri. In 1926 Greene and Pond[38] used "Rich Hill" for a limestone known to be near the same horizon as the Ardmore, and in a later report Greene[39] indicates that he regards them as equivalents. The authors had correlated this limestone of southeastern Kansas with the adjoining "Rich Hill" of Vernon county, Missouri, and favored using this term, but decision as to which name should be extended into Kansas was left to the Kansas Geological Survey. A conference of that survey on nomenclature for southeastern Kansas favored extension of Ardmore rather than "Rich Hill." Ardmore, as therefore used in this report, is an exact equivalent of the "Rich Hill" of Vernon county and the approximate and probable equivalent of the Ardmore of north-central Missouri. It is locally known as the

37. Gordon, C. H., A report on the Bevier sheet: Missouri Geol. Survey, vol. 9, 1st ser., pt. 2, p. 20, 1896, Sheet Rept. No. 2, 1893.

38. Greene, F. C., and Pond, W. F., The geology of Vernon county: Missouri Bur. Geol. and Mines, vol. 19, 2d ser., pp. 51-52, 1926.

39. Greene, F. C., Oil and gas pools of western Missouri: Missouri Bur. Geol. and Mines 57th Bien. Rept., Appendix 2, 1933.

The "Squirrel sand" lies just below the Breezy Hill limestone and extends downward an indefinite distance. An exposed thickness of 35 feet of sandstone was measured at a few places, with the strata below that depth concealed. Usually the sandstone is thinner than this and grades imperceptibly into shale below. It is mostly fine-grained and grades laterally into sandy shale, so that in places there is no sandstone present beneath the Breezy Hill limestone.

A peculiar type of weathering commonly occurs in the outcrops of the "Squirrel sand," producing the dikelike structures shown in Plate 3-B. Bands of sandy shale or shaly sandstone, consisting of the same material as the adjoining strata, lie at various angles to the bedding. These bands may be prependicular to the bedding and thus simulate dikes, or they may curve from a vertical to a horizontal position. Where two or more bands intersect there may be a series of concentric bands like the layers of an onion. The bands are thought to be related to the action of ground water along joints and fractures in the sandy shale.

Breezy Hill limestone member and overlying shale.—The Breezy Hill limestone member of the Cherokee shale is here named from the exposures at Breezy Hill, just southwest of Mulberry, Kan. Throughout much of its extent in southeastern Kansas it is a gray, impure, concretionary to nodular limestone from 6 inches to 2 feet thick, but in places exhibits considerable variation, both in thickness and in the character of material. In most places it is from 1 to 3 feet below the Fort Scott coal; where the coal is absent the Breezy Hill still occupies its same stratigraphic position and is from 4 to 8 feet below the top of the Cherokee shale. The Breezy Hill limestone is underlain by the "Squirrel sand."

On the west side of Breezy Hill, the Breezy Hill limestone consists of a foot or two of impure limestone. In the eastern part of the hill, however, it thickens to a maximum of 8 feet and is similar in appearance to the lower member of the Fort Scott limestone. In a section measured by Greene[41] near Mulberry, Kan., the limestone called Breezy Hill in the present report was erroneously correlated as the lower member of the Fort Scott limestone. In Vernon county, Missouri, however, he recognized the Breezy Hill limestone as a bed within the Cherokee shale.[42] Where the Breezy Hill limestone is thick it simulates the lower member of the Fort Scott in appear-

41. Greene, F. C., and Pond, W. F., Geology of Vernon county: Missouri Bur. Geol. and Mines, vol. 19, 2d ser., p. 89, 1926.
42. Greene, F. C., and Pond, W. F., op. cit., p. 54.

ance, but the two can be differentiated by the fact that the lower member of the Fort Scott limestone is underlain by several feet of black, slaty shale, whereas the Breezy Hill limestone is underlain by gray, sandy shale or fine-grained sandstone.

In a paper on correlation and extent of Pennsylvanian cyclothems, Wanless and Weller give several generalized sections.[43] The one for western Missouri and eastern Kansas shows a limestone—the Breezy Hill of this report—below the lower Fort Scott limestone. It is indicated as equivalent to the fresh-water limestone of the Summum cyclothem of Illinois. Many fossil collections were made from the Breezy Hill limestone in southeastern Kansas and according to the report by Williams, which follows, all of the fossils are marine.

An unusual facies of the Breezy Hill limestone occurs along the highway, 5 miles due west of Pittsburg. There the upper part of the Breezy Hill limestone consists of about 3 feet of gray, crystalline, fossiliferous limestone with 6½ feet of massive, sandy, micaceous limestone below. It is underlain by 6 feet of brown thin-bedded sandstone, the upper half of which is calcareous.

Near the Kansas-Oklahoma line, in Labette county, the Breezy Hill limestone increases greatly in thickness. Along the west line of the NW¼NW¼ sec. 1, T. 35 S., R. 20 E., it is 20 feet thick and consists of crystalline limestone, some thin beds of sandstone or sandy shale, and chalky limestone. At other places in this vicinity, where the Breezy Hill is only a few feet thick, other thin beds of limestone were observed below it. This fact, in conjunction with the practically continuous 20-foot limestone section noted above, suggests that the Breezy Hill increases in thickness with an interfingering relationship to the underlying sandstone.

Above the Breezy Hill limestone is a foot or so of gray clay-shale, overlain by several feet of black fissile shale. In the northern part of the field the Fort Scott coal occurs at the base of the black shale. A more detailed description of this coal and its associated strata is given in the discussion of the Fort Scott coal. The contact between the Cherokee shale and the overlying Fort Scott limestone is conformable, but is sharp and distinct, for the limestone of the Fort Scott rests upon the black shale at the top of the Cherokee. Neither stratigraphic nor paleontologic data indicate any time break between Cherokee and Fort Scott deposition.

Thickness of the Cherokee shale.—The thickness of the Cherokee

43. Wanless, H. R., and Weller, J. M., Correlation and extent of Pennsylvanian cyclothems: Geol. Soc. America Bull., vol. 43, No. 4, fig. 2, p. 1011, 1932.

Cherokee, and Labette counties by means of isopach (equal thickness) lines. Logs of numerous drill holes and wells were used for the compilation of the map. In those parts of the area where the top of the Cherokee is not present, particularly in Cherokee county, the depth from some recognizable horizon to the base of the shale was determined and to this figure was added the average interval from that horizon to the top of the shale.

The Cherokee shale is only 375 feet thick in the northeast corner of Crawford county. It increases in thickness to the southwest, and in southern Labette county reaches a thickness of 560 feet. This increase in thickness is gradual and occurs principally in the lower half of the formation. The thickness of the upper half of the Cherokee shale remains remarkably uniform, except for two small local areas in the northeastern part of the district. On the east side of Breezy Hill, the interval from the top of the Cherokee to the Weir-Pittsburg coal is 30 to 40 feet less than the average, and on a hill near Oskaloosa the interval from the Ardmore limestone to the top of the Cherokee is about 60 feet less than the average. The thinning at both of these localities takes place mostly in the noncoal-bearing interval between the Bevier and Fort Scott coals.

Unconformity at the base of the Cherokee shale.—The Cherokee shale lies unconformably, though without stratigraphic discordance, upon the Boone limestone. The nature of the terrane upon which the Cherokee was deposited has been described by some earlier writers[46] as one of considerable relief and irregularity, with a karst topography of sink holes and subterranean rivers. Later work,[47] however, has tended to minimize the amount and extent of erosional irregularity at the top of the Mississippian. Recent papers by the senior author[48] have called attention to evidence indicating that the Cherokee was deposited upon a surface of low relief.

Drill-hole data show marked irregularities in the contact between the Cherokee shale and the Mississippian limestone; for example, one hole may strike the limestone at a depth of 200 feet, whereas another hole at the same elevation and only a few hundred feet

46. Haworth, E. (assisted by Crane, W. R.), Special report on coal: Kansas Univ. Geol. Survey, vol. 3, p. 15, 1898.
Smith, W. S. T., and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Joplin District folio (No. 148), 1907.

47. Fowler, G. M., and Lyden, J. P., The ore deposits of the Tri-State District (Mo.-Kan.-Okla.): Am. Inst. Min. and Met. Engrs. Trans., vol. 102, p. 226, 1932.
Weidman, Samuel, The Miami-Picher zinc-lead district, Oklahoma: Oklahoma Geol. Survey, Bull. 56, p. 21, 1932.

48. Pierce, W. G., Some significant features of the Mississippian-Pennsylvanian contact in the Tri-State District: Proc. Geol. Soc. Wash., May 8, 1935 (abstract); Contour map of the base of the Cherokee shale in the zinc-lead district of southeastern Kansas: U. S. Dept. Interior Memo. for the Press, July 19, 1935.

within the Cherokee shale. A sandstone between the Weir-Pittsburg and Pilot coal beds also exhibits an unconformable relationship at a few places, notably near the Fairview school in the northeast corner sec. 19, T. 32 N., R. 33 W., Barton county, Missouri, where there are excellent exposures in strip pits to the north, northeast, and east. In the pit to the north there is a coarse conglomerate a foot above the base of the sandstone, composed of material presumably derived from the Cherokee shale. Plate 3-C shows this sandstone lying unconformably on the shale above the Weir-Pittsburg coal. A sandstone about 16 feet above the Mineral coal shows a sharp irregular contact with the underlying shale in an exposure in a strip pit near the center of the west line sec. 13, T. 29 S., R. 25 E.

It is a question whether these horizons within the Cherokee shale represent time intervals of importance or are simply the record of change of conditions of sedimentation that took place during the deposition of the Cherokee shale. The writers prefer to consider them in the latter category until it is definitely demonstrated by future work that they indicate sizable time intervals represented by nondeposition and possible erosion which extended over a considerable area.

Correlations.—Correlations of coals in the Cherokee shale in western Missouri with those of southeastern Kansas, are shown graphically in figure 5. The writers have little doubt as to the validity of the correlations shown above the Weir-Pittsburg coal, near the middle of the Cherokee shale, for they apply not only to contiguous areas, but the distinguishing characteristics of individual coal beds and their overlying strata, which are described in the discussion of coal, tie the sections in perfectly. Paleontologic data given in the report following, by Williams, is also in harmony with the lithologic correlations that we have carried across to the southeastern Kansas coal field. The generalized sections of the strata below the Weir-Pittsburg coal are distinctly different in the two areas and the tentative correlations indicated are theoretical and are offered only as suggestions.

Eleven collections of fossil plants, ranging stratigraphically from near the base to within 30 feet of the top of the Cherokee shale of southeastern Kansas, were submitted to C. B. Read, of the United States Geological Survey, for identification and suggestive correlation with the Oklahoma section. His report in part is as follows:

> The collections are too small to permit extremely close age determination. I believe that the Cherokee shale, which yielded these fossils, is all of Allegheny age. The small flora from the Little Cabin sandstone suggests the

plies only in the instance of the extension of my Oklahoma floral zone (Am. Assoc. Petroleum Geologists Bull., vol. 18, p. 1056, 1934) into Kansas. Collections from the Weir-Pittsburg coal are too small to furnish much information. It is possible that this coal may be lower Boggy in age. The collections from the Mineral coal and from 30 feet below the top of the Cherokee are from horizons higher than those for which I have information in Oklahoma. I am inclined to guess they are upper Boggy or higher.

The several localities from which fossil plants were obtained and the names of the species as identified by C. B. Read are given below.

From 1 to 1½ feet above top of Little Cabin sandstone member, 1½ miles northwest of Lawton, Kan.: *Neuropteris scheuchzeri,* n. sp.; *Annularia sphenophylloides.*

From a bed 10 feet below Bluejacket sandstone member, NE¼ sec. 28, T. 33 S., R. 23 E.: *Neuropteris rarinervis.*

From shale 18 feet below top of well in SW¼ SE¼ sec. 9, T. 31 S., R. 25 E.: *Neuropteris scheuchzeri, N. missouriensis.*

From shaly zone in lower part of Bluejacket sandstone member (collection of C. M. Cooper, Columbus, Kan., obtained from ditch excavation in southeast part of Columbus), NW¼ NE¼ sec. 24, T. 33 S., R. 23 E.: *Neuropteris ovata* (abundant), *N. desorii, N. scheuchzeri, Pecopteris richardsoni, Annularia stellata, Sphenophyllum majus?.*

From bed a few feet below Bluejacket sandstone member, SE¼ sec. 7, T. 33 S., R. 24 E.: *Stigmaria ficoides.*

From bed a few feet below Weir-Pittsburg(?) coal, 1,500 feet west of southeast corner sec. 15, T. 33 S., R. 22 E.: *Alethopteris serlii.*

From bed 25 feet above Weir-Pittsburg coal. Strip pit in SE¼ sec. 17, T. 32 N., R. 33 W., Barton county, Missouri: *Sigillaria tessellata* s., *S. hexagona.*

From bed 2 to 4 feet above Mineral coal, at small "island" in abandoned strip pit, SW¼ SE¼ SW¼ sec. 26, T. 28 S., R. 25 E.: *Neuropteris ovata, N.* sp. cf. *N. missouriensis, N. scheuchzeri, N. rarinervis, Linopteris* sp., *Pecopteris vestita, Asterophyllites* sp., *Annularia stellata, Calamites suckowi, Cordaites communis.*

From sandstone below Stice coal, sec. 26, T. 33 S., R. 21 E.: *Stigmaria ficoides* (rootlets).

From bed 10 feet below base of Breezy Hill limestone member, south line of NW¼ sec. 7, T. 31 S., R. 24 E.: *Neuropteris scheuchzeri.*

From bed about 30 feet below top of Cherokee, in small strip pit in SW¼ sec. 5, T. 35 S., R. 21 E. (invertebrate fossils also collected from same bed): *Neuropteris rarinervis, Mariopteris occidentalis, Pecopteris vestita, P. unita, Odontopteris* sp., *Annularia stellata, root fragments.*

Five collections of fusulinids were made from the Cherokee shale, extending stratigraphically from just above the Pilot coal to the Breezy Hill limestone. They were submitted to L. G. Henbest, of the U. S. Geological Survey, for examination.

In the following list of determinations, the number indicates the locality at which the collection was made (see pages 114 to 122). 7749, *Fusulina sp.;* 7763, *Fusulina sp.;* 7802 (from limestone above Mineral coal), *Fusulina sp., F. problematica?* and *F. kayi;* 7803 (from limestone above Mineral coal), *Fusulina sp.;* 7829, *Wedekindellina euthysepta.*

In regard to *Wedekindellina euthysepta,* in collection No. 7829, Henbest states:

The *Wedekindellina euthysepta,* which are from a limestone above the Pilot coal, occur abundantly in the limestone overlying Murphysboro No. 2 coal of southwestern and western Illinois, and in the Stonefort limestone member of the Tradewater formation, an age-equivalent horizon of southern

reported by Berger[54] may be due in part to inclusion of the Breezy Hill limestone member of the Cherokee shale with the Fort Scott, or possibly the two merge so that there they are indistinguishable.

Lower member of Fort Scott limestone.—The lower member of the Fort Scott limestone is from 10 to 20 feet thick in southeast Kansas, averaging 13 feet. It is commonly a gray, crystalline, fossiliferous limestone, occurring in beds from a few inches up to 2 feet in thickness. The lower foot or two has a conchoidal fracture, is gray to light brown in color and weathers yellow, and is therefore distinct from the overlying beds. Plate 4-A shows a typical exposure of the lower part of the Fort Scott limestone and also shows its contact with the underlying black shale at the top of the Cherokee.

The lower member of the Fort Scott limestone is the so-called "cement rock" from which hydraulic cement is manufactured in the vicinity of Fort Scott.

Six collections of fusulinids that were identified by L. G. Henbest are reported, together with his comments, as follows (numbers refer to collecting localities listed at end of report):

7780, 7783, 7785, 7788, and 7790, *Fusulina girtyi;* 7784, *Fusulina haworthi?*. The lower member of the Fort Scott contains a large number of *Fusulina girtyi* (Dunbar and Condra) and an abundance of *Fusulina haworthi* Beede (a synonym of this is *F. stookeyi* Thompson). The species *F. girtyi* and *F. haworthi* are recorded by Thompson from the "18-foot limestone" which lies 18 feet above the Mystic coal in Iowa. In Illinois, *F. girtyi* (variously called *Fusulina ventricosa, Girtyina ventricosa,* etc.) has long been recognized as the most generally distributed and the most characteristic fossil of the Brereton limestone. Associated with *F. girtyi* locally in Illinois is *F. haworthi.*

The supposition has arisen and is generally accepted that the Brereton limestone of Illinois and the upper member of the Fort Scott limestone are correlative. This supposition appears to have grown from some more or less indefinite records of *F. girtyi* as having been found in the upper Fort Scott. Judging from the fusulinid collections from Kansas and my numerous collections from Illinois, in conjunction with the restricted range of *F. girtyi* in Illinois, I would be more inclined to correlate the lower member of the Fort Scott and the Brereton limestone.

Shale between the lower and upper members of the Fort Scott.—Between the two limestone members of the Fort Scott is a shale unit from 3 to 7 feet thick. The upper half of this unit consists of black shale with some small concretions, and the lower part consists of gray shale and clay. To the north and east of Crawford county a coal bed occurs between the two members of the Fort Scott, but in the area described in this report it is thin or absent.

Upper member of Fort Scott limestone.—The upper member of the Fort Scott limestone is from 13 to 19 feet thick in southeastern Kansas, averaging 17 feet. It is a light-gray to white crystalline

54. Berger, W. R., op. cit., p. 620.

limestone, weathering to various shades of gray. The lower few feet weather more rapidly than the overlying part and have a yellow-brown color. In most places it is also thinner bedded than the middle and upper parts. The top 5 feet of the upper member of the Fort Scott consists of nodular and argillaceous limestone that weathers buff. It is seldom exposed, owing either to its lesser resistance to erosion than the underlying beds or to erosion prior to deposition of the Labette shale. The coral *Chaetetes milleporaceus* is very abundant in the upper member.

Two collections of fusulinids, made from the upper member of the Fort Scott limestone, were identified by Henbest with the following comment:

7793, *Fusulina sp.;* 7794, *Tetrataxis sp., Polytaxis sp., Fusulina sp., Fusulina girtyi?*.

The collections from the upper member of the Fort Scott contains a new species of small *Fusulina* which is unlike any I have seen in the upper part of the *Fusulina* zone. *Fusulina girtyi* is rare in the upper Fort Scott and is known only in a single old collection from Oswego, Kan., which is reported to be from the upper member of the Fort Scott.

Englevale channel sandstone [55]

The channel sandstone for which the name Englevale has been proposed [56] is typically exposed near the town of Englevale, in northeastern Crawford county, Kansas.

The areal distribution of the Englevale channel sandstone is linear, trending north-northwest from Arma for a distance of at least 9 miles (Pl. 1) to the Crawford county line. As field work did not extend beyond Crawford county, data are lacking on its northward extent into Bourbon county. Erosion has removed any traces that may have been present south of Arma. The sandstone belt, as at present exposed, has an average width of about four tenths of a mile, but just southeast of Cato it is somewhat wider.

The Englevale sandstone is younger than the Fort Scott limestone, for the channel in which the sandstone was deposited trenches the limestone; possibly the sandstone is younger than the lower part of the Labette shale, but it was not observed cutting the upper part of the Labette shale or the Pawnee limestone. So far as could be observed, the upper limit of the sandstone is gradational into the lower

55. This stratigraphic unit is a basal element of a cyclothem (cyclic sedimentary formation) that forms part of the Labette shale. In the classification of the Kansas Geological Survey the Englevale is accordingly ranked as a member of the Labette shale.—R. C. Moore.

56. Pierce, W. G., and Courtier, W. H., The Englevale channel sandstone of Pennsylvanian age, southeastern Kansas: Am. Assoc. Petroleum Geologists, Bull., vol. 19, No. 7, pp. 1061-1064, 1935.

than the Cherokee, Henrietta (this includes the Pawnee, Labette, and Fort Scott), or lower part of the Pleasanton (which corresponds to the Bandera shale and overlying formations to the base of the Hertha limestone in Kansas), but have not been seen to cross upper Pleasanton or higher strata. The Englevale sandstone, therefore, cannot be correlated with the Warrensburg and Moberly sandstones from the information available. Greene and Pond [61] correlate their Walker conglomerate and sandstone—a channel-like deposit in Vernon county, Missouri, which rest upon the shale above the Williams coal (Bevier of this report)—as a southern continuation of the Warrensburg channel sandstone. Greene states, however, that the exact age cannot be determined, as there is no evidence in Vernon county that their Walker formation was ever overlain by other strata. Several other channel sandstones have been noted [62] in the Pennsylvanian, but they are all considerably higher in the section than the Englevale sandstone.

During future work on the Pennsylvanian channel deposits of this region the possibility of younger channels either superimposed or near older ones should be kept in mind, for the Englevale channel sandstone indicates that some channel sands were formed prior to the Warrensburg sand.

Labette shale

The shale overlying the Fort Scott limestone was described by Bennett[63] in 1896. In 1898, at the suggestion of George I. Adams, it was named the Labette shale by Haworth and Crane.[64] It is exposed along an irregular line extending southward through Tps. 27 and 28 S., R. 24 E., then southwestward through Girard to the northeast corner of Labette county. From this point to the southwest corner of the area all of the outcrop of the Labette shale lies west of the Neosho river. For the most part, the width of the outcrop is slightly less than a mile, but at several places the Labette shale is the surface formation over areas of several square miles. The shale is much softer than the limestone units immediately above and below it and consequently occupies the slopes and valleys between limestone escarpments and benches. The contact between the La-

61. Greene, F. C., and Pond, W. F., The geology of Vernon county: Missouri Bur. Geol. and Mines, vol. 19, 2d ser., pp. 62-65, 1926.

62. Hinds, Henry, and Greene, F. C., U. S. Geol. Survey Geol. Atlas, Leavenworth-Smithville folio (No. 206), pp. 6, 10, 1917.
Moore, R. C., Elias, M. K., and Newell, N. D., A graphic composite section of the Pennsylvanian and "Permian" rocks of Kansas: Kansas Geol. Survey, 1934.

63. Bennett, J. A., A geologic section along the Missouri Pacific Railway from state line, Bourbon county, to Yates Center: Kansas Univ. Geol. Survey, vol. 1, p. 91, 1896.

64. Haworth, Erasmus, and Crane, W. R., Special report on coal: Kansas Univ. Geol. Survey, vol. 3, p. 36, 1898.

Pawnee limestone

The Pawnee limestone was named by Swallow[65] in 1866 from exposures along Indian and Pawnee creeks and southward to Bone creek. Pawnee creek heads a few miles northwest of Farlington and flows northward into the South Fork of Marmaton river about 7 miles southwest of Fort Scott. The Pawnee limestone crops out in the western part of Tps. 27 and 28 S., R. 24 E., and also along the divides in the eastern parts of those townships and the southern part of T. 29 S., R. 23 E. West of Neosho river it caps numerous low hills and divides along the western border of the area.

The Pawnee is a light-gray to white, fine crystalline, and somewhat cherty limestone. It is fossiliferous, but less so than the Fort Scott limestone, which it resembles. It contains very few clay or shale partings, is usually thick-bedded, and locally may be massive. In many bluff exposures the massive character is destroyed by vertical and horizontal joints, the latter giving an appearance of thin bedding, whereas when seen in fresh quarry cuts there are actually few thin beds in the Pawnee. A coral-bearing zone was noted about 6 feet above the base of the formation. Also at this horizon coarse chert fragments weather out; the limestone below has more yellow and brown weathering material than above. The average thickness of the Pawnee in this area is about 22 feet.

The base of the Pawnee is not as well exposed as the base of the Fort Scott limestone, but can usually be determined approximately within a few feet. At several places in the northwestern part of T. 31 S., R. 21 E., an 8-inch bed of black shale occurs approximately 26 inches above the base of the formation. The Pawnee lies conformably on the Labette shale and is overlain by the Bandera shale. The top of the Pawnee was not observed within the area shown on Plate 1.

Tertiary or Quaternary Gravels

Deposits younger than Pennsylvanian in age were not studied in detail and are not shown on the map (Pl. 1). The following brief description is based upon a cursory examination of these materials.

Chert pebbles embedded in clays occur on some of the upland in southern and western Cherokee county at altitudes from 820 to 900 feet above sea level. The chert is light gray, buff, reddish-brown, or pink in color, and is in various stages of decomposition,

65. Swallow, G. C., Preliminary report of the Geological Survey of Kansas, p. 24, 1866.

The gravel deposits along Neosho river are from about 780 to 870 feet above sea level. They are more abundant on the west side of the river. The higher of these gravels, that is, those above 820 feet in elevation, are coarse and consist of white, brown, and red chert, and rest on beds as high stratigraphically as the Pawnee limestone. The gravels on the Pawnee limestone may have been deposited contemporaneously with the upland gravels of southern Cherokee county.

The lower terrace gravels are exploited in many places along the old flood plain of Neosho river. A deposit in the SW¼SE¼ sec. 9, T. 35 S., R. 22 E., covers several acres and is known to extend to a depth of at least 23 feet (Pl. 4-*b*). This pit has supplied a considerable amount of gravel for road metal. The gravel is mostly a coarse brown chert, contains very little sand or clay, and is well sorted.

The Quaternary gravels in Labette county contain brown chert, which, in conjunction with their regional location, suggests that they were derived from the chert in the limestones of Pennsylvanian age which now lie to the northwest. The chert gravels in the southeastern part of this district, along Spring river and Shoal creek, bear a closer resemblance to the cherts in the Mississippian limestone from which they presumably were derived.

Alluvium.—The alluvium, as here described, includes both the terrace and present flood-plain deposits of streams, for in many places it is difficult to differentiate them. Alluvium occupies the valleys of the larger streams—notably Spring river and Neosho river—and varies in width from less than a quarter of a mile in the smaller valleys to about 4¼ miles along Neosho river east of Chetopa.

It is difficult to map alluvial boundaries in this region, for the thick soil cover grades imperceptibly into the alluvium and some of the alluvial filling in preëxisting valleys is detectable only from drill records. The alluvium as shown on Plate 1 is sketched from soil maps[70] and the Joplin district folio,[71] supplemented by field observations. The alluvial boundary, as mapped along Neosho river, represents approximately the high-water limit of the river in flood stage.

The alluvium varies greatly in depth. Along the lower stretches

70. Soil survey of Cherokee county, Kansas: U. S. Dept. Agriculture, Bur. of Soils, 1914. Soil survey of Labette county, Kansas: U. S. Dept. Agriculture, Bur. of Chemistry and Soils No. 30, series 1926.
Soil survey of Crawford county, Kansas: U. S. Dept. Agriculture, Bur. of Chemistry and Soils No. 3, series 1928.

71. Smith, W. S. T., and Siebenthal, C. E., op. cit.

STRUCTURE

The geologic structure of the area treated in this report is shown by the contour map (Pl. 5). A preliminary edition of the map in practically its present form was published in 1935.[74]

The description of the geologic structure is divided for convenience of description into two parts, one comprising the southeastern Kansas coal field and the other that part of the Tri-State zinc-lead district lying within the area described in this report. The structure contours are drawn on the Weir-Pittsburg coal or its equivalent horizon.

Structure of the southeastern Kansas coal field.—The area here termed the southeastern Kansas coal field comprises all of the area of Plate 5, except the southeastern half of Cherokee county. It lies northwest of the Ozark uplift and, accordingly, the prevailing dip is to the northwest. The general direction of strike is northeast, but in detail it is usually either north or east. The change in trend from north to east, or even to southeast, is abrupt and when represented by contour lines forms a zigzag pattern.[75]

The most prominent structural feature is the Pittsburg anticline, which is here named from the town of Pittsburg in southeastern Crawford county. It has a maximum structural relief of about 70 feet and ranges in width from 4 miles in the southeastern part to 2 miles in the northwestern part. The anticline extends for an undetermined distance in Missouri. It enters Kansas near the southeast corner of T. 30 S., R. 25 E., trends northwestward to Capaldo, and then swings west-northwest to Girard. In T. 30 S., R. 25 E., the crest of the anticline plunges to the northwest, but beyond Capaldo it rises again and the anticline is a narrow, slightly domed fold which has a minimum closure of about 20 feet.

Closed depressions from 10 to 20 feet in depth are not uncommon in the area. These may be due in part to compaction phenomena. Others, however, are of much greater depth and are probably attributable to some other cause—perhaps to solution of the Mississippian limestone, with subsequent sinking of the overlying Cherokee shale.

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74. Pierce, W. G., and others, Map showing geologic structure of southeastern Kansas coal fields and the Kansas zinc-lead district: Kansas Geol. Survey, 1935.

75. Since this report was written a paper by Rich, on the "Fault-block nature of Kansas structures suggested by elimination of regional dip," was published in Am. Assoc. Petroleum Geologists Bull., October, 1935. Time did not permit an analysis of the structure of the southeastern Kansas coal field with the regional dip eliminated, but the structure of this area is in a general way like that in the area discussed by Rich and should furnish interesting material for speculation if subjected to similar treatment.

feet to the mile. As stated on page 38, it is the writers' opinion that the Cherokee was deposited upon a surface of low relief and, therefore, exclusive of the slight and gradual eastward thinning of the Cherokee, the interval between the base of the Cherokee and the Weir-Pittsburg coal varies, for the most part, less than the contour interval of 20 feet.

The structure map of the zinc-lead district, as described in a previous publication,[76] shows two directions of structural trend—one approximately N. 35° E., the other N. 40° W. The sharp northeastward-trending depression that extends from Commerce, Okla., through Picher and into Kansas has been variously termed the "Commerce trough," "Miami fault," "Miami trough," "Miami syncline," and "Miami shear trough." The name "Miami trough" is here used for this feature, which seems to represent along its extent a combination of three features—folding, faulting, and solution followed by collapse. Cross sections of the trough drawn from logs of holes drilled at intervals of 400 feet along the line of section, one of which is shown in figure 6-*B*, indicate that the lower beds of the Cherokee have been folded or faulted into the deeper parts of the trough. An unusual structural feature of the trough, as shown on the structure map, Plate 5, is the irregularity along its axis—that is, low parts separated by high areas. This irregularity, if not due entirely to structural deformation, may be caused in part by shallow synclinal folding accompanied by fracturing of the underlying limestones followed by solution and collapse. However, the northwestward-trending structural features must certainly have produced some of the irregularities in the Miami trough at the places where they intersect it. There is a suggestion of smaller troughlike trends on both sides of the Miami trough and parallel to it, but the available data are not sufficient to indicate them definitely.

The two most prominent northwestward-trending structural features are the troughs near Lawton and Treece. The Lawton trough, which extends southeastward into Missouri, is just southwest of and parallel to the Joplin anticline. It continues with some interruptions beyond the Miami trough, its presence being indicated by the previously mentioned depressions southeast of Weir and Cherokee and also by a depression 5 miles northwest of Cherokee. The trough trending northwestward from Treece is known from mine workings and undoubtedly extends northwestward beyond the limits shown. There is also a fairly definite northwesterly alinement of depressions

76. Pierce, W. G., U. S. Dept. Interior Memorandum for the Press, July 19, 1935.

PLATE 6. *A*, Small fold in the Bluejacket sandstone member of the Cherokee shale, exposed along west side of road, near center east line sec. 36, T. 34 S., R. 23 E.; *B*, A fossil sink hole exposed in the wall of a recent sink in the NE¼ sec. 9, T. 32 S., R. 25 E. The top of the Mississippian limestone is exposed on the right near the bottom of the sink; the Cherokee shale above it is in its normal stratigraphic position. A fault near the center of the picture marks the wall of a fossil sink with the beds to the left of it dipping steeply into the fossil sink hole. The fault seems to be curved in plan, dips 78 degrees to the west (left) and has a throw of about 6 feet.

The formation of some of the sink holes was preceded by a slight sagging of the ground, but in others a hole of about the present size and depth formed without warning. The history of two of the recent sinks, as told by local residents, is interesting. In 1911 a cultivated cornfield occupied the area where the northwestern one of the group of sinks in the W½ sec. 34 is now located. A few years prior to 1911 a slight sag about 14 feet in diameter was noticed in the field, similar to the "buffalo wallows" of the high plains, except that it did not hold water. No preliminary cracks were noted. Then one day, while the field was being cultivated, a great open hole was observed where previously there had been only a slight depression. The hole was about 15 feet in diameter, with vertical walls, and after obtaining a piece of twine its depth was determined as 72 feet. Water was present in the bottom of the sink when it was first observed. Since its formation, the sides of the sink have occasionally slumped off, gradually enlarging the hole. In the winter of 1933 an area around the north rim sank about 20 feet. The sink hole near the center of the E½ sec. 9, T. 32 S., R. 25 E., which formed in 1929, was indicated about 5 years previously by a crack which formed a few feet from the present west rim of the sink. A few years ago water from Cow creek flooded the bottom land, completely covering the sink hole. Shortly after the flood subsided the sink was examined and found to contain water only at the very bottom. The water that had filled the hole presumably drained out rapidly through an underground channel. Water has always been present in the bottom of the sink, but at the time of the field examination it stood 27 feet below the water in Cow creek, which is only 250 feet south of the sink hole. The fact that the water flowing in the creek was much higher than water in the sink hole indicates that the creek flows on a perched water table.

In four of the recent sinks the walls and steeply inclined or faulted beds of fossil sink holes may be seen. The surface of the ground above the fossil sink holes does not now give any indication of their presence, but the strata in them reveal the usual succession of the lower beds of the Cherokee formation dropped below their normal position. A photograph of a fossil sink exposed in the wall of a recent sink is shown in Plate 6-*B*. The owner of the land capitalized on this sink hole by putting it on exhibition at 10 cents per person and is reported to have done a good business for several months. The large opening shown in the photograph is the recent sink hole. In the right half of the picture is a normal section of lower beds of the Cherokee. The top of the Mississippian limestone

MINERAL RESOURCES

Coal

General Statement

All of the economically important coal beds in the southeastern Kansas coal field occur in the Cherokee shale. The thickest coal bed in the field is the Weir-Pittsburg bed, which is near the middle of this shale unit. There are seven to nine thin coal beds below it in the Cherokee shale, uncertainty in number being due to lack of determination of continuity owing to the thinness of the beds in this area; some have been mined locally, mostly by surface stripping. The Cherokee shale contains six coal beds in the stratigraphic interval of about 120 feet from the Weir-Pittsburg coal up to and including the coal just above the Ardmore limestone. Of these six beds the Mineral and Bevier coals have been extensively mined commercially and two others have been worked at a few places where the coal thickens locally. The Fort Scott coal near the top of the formation, is the only coal in the upper 100 feet of the Cherokee shale in Cherokee and Crawford counties. In southeastern Labette county there are a few thin, local beds between the Ardmore limestone and the top of the Cherokee; these beds probably continue southwestward into Oklahoma.

For a graphic summary of the coal beds the reader is referred to figure 2 on page 19, which shows the relative position of the beds and the approximate intervals from them to other coal beds and recognizable stratigraphic units.

Many of the coal beds to be discussed in this report have not been named in the literature. Most of the beds have local names, but such names are sometimes extended laterally only a few miles, and in some cases several local names are used in different localities for the same bed. It therefore seemed desirable at this time to exercise considerable care in the selection of names for the coal beds of this area. At the suggestion of the State Geological Survey of Kansas the authors sent that Survey a list of the tentative names which we were proposing for the coal beds of southeastern Kansas. A conference on southeastern Kansas nomenclature,[77] which included members of the Kansas Survey and a member of the Missouri Geological Survey, considered the questions involved in the naming of the various coal beds and stratigraphic units and, through corre-

77. Those attending the meeting at Lawrence, Kan., in March, 1936, were R. C. Moore, K. K. Landes, C. M. Young, G. E. Abernathy, and N. D. Newell. A second meeting in April included the same members and also F. C. Greene.

vidual coal beds have not been mapped, but places where the coal has been stripped are indicated on the map (Pl. 1). The greater part of the strip mining of these beds has been done in T. 31 S., R. 25 E., the eastern part of T. 32 S., R. 24 E., and T. 32 S., R. 25 E. Considerable stripping has been done along Taylor Branch, west and southwest of Opolis. The thicknesses of these local beds vary from a few inches to 16 inches. In a highway borrow pit just west of Taylor Branch and on the south line of sec. 14, T. 31 S., R. 25 E., there is 16 inches of coal (upper 1 inch dirty coal) overlain by greenish-gray shale and underlain by hard gray clay. A mile down the creek, near the south line of section 23, there are two coal beds which are probably lower than the one just mentioned. The upper one of the two is not completely exposed; where measured it was 8 inches thick. Its total thickness is unknown, however, because the top has been eroded. About 3 feet below this coal is another which has been mined from the bed of the creek. It is reported to be from 3 to 6 inches thick. A drill hole near this locality shows that this bed is about 85 feet above the base of the Cherokee. There are other small strippings and coal outcrops for several miles down the creek.

Several thin coal beds have been stripped along a tributary of Cow creek, in secs. 7, 17, 18, and 20, T. 32 S., R. 25 E. In a strip pit in the NW¼NE¼ sec. 20, 15 inches of coal was measured. In the E½ of the SW¼ sec. 18, a coal bed from 18 to 20 inches thick has been stripped. About 10 feet above this is a bed of weathered coal a few inches thick. In the NW¼NW¼ sec. 18 there are also two coal beds, perhaps the same beds as just mentioned. The thickness of the coal that has been stripped was not determined, but about 8 feet above it is another bed from 12 to 15 inches thick, the upper half of which is dirty.

The Meyer mine, in the NE¼ sec. 30, T. 32 S., R. 25 E., is worked from a shaft 70 feet deep. The coal is reported to be from 3 to 3½ feet thick, which is twice as great as any of the other coal beds in this part of the Cherokee shale. The mine was closed at the time of the field examination, so there was no opportunity to examine the coal. The coal is seemingly between 40 and 90 feet above the base of the Cherokee. A line of drill holes, at intervals of 600 to 1,000 feet apart, extending from the southwest corner sec. 29, T. 32 S., R. 25 E., to the center of the north line of that section, show a sharp trough; the altitude of the base of the Cherokee drops from 780 feet to 710 feet. Shale exposures in the southwest quarter of the section adjoining on the north show a south dip of about

The Rowe bed is named from the Rowe school at the northeast corner of sec. 34, T. 30 S., R. 25 E. Although the Rowe coal is from 10 to 15 feet below a bed of sandstone, this bed cannot be identified as Bluejacket sandstone, since the latter could not be traced into southeastern Crawford county and thereby furnish a means of correlation. The records of drill holes that begin above the Weir-Pittsburg coal and extend some distance below, likewise could not be used for precise correlation, for the Rowe coal could not be identified in the logs. Consequently the stratigraphic relation of the Columbus coal to the Rowe coal is unknown, but they are thought to be at approximately the same horizon. The Rowe bed is unique, in that it contains a persistent shale parting that serves for identifying and correlating this coal. In the local area of outcrop, shown on Plate 1, the Rowe bed consists of 14 to 16 inches of coal at the top, a gray clay-shale parting about 2 inches thick, and 3½ to 4 inches of coal at the base. The following section was measured at the Ridge Coal Co. strip pit:

Section of Rowe coal and overlying beds in the NW¼ sec. 35, T. 30 S., R. 25 E:

		Ft.	*in.*
Soil		3	
Sandstone, light gray, micaceous			10
Shale, bluish-gray			8
Shale, gray, with ironstone bands		2	
Coal, usually much thinner or absent		1	4
Shale, yellow			5
Shale, bluish-gray, hard		6	6
Coal	Rowe bed	1	4
Clay-shale, gray	Rowe bed		2
Coal	Rowe bed		4

The Rowe bed has been mined from a drift near the center of the east line of sec. 27, T. 30 S., R. 25 E. Here the underclay beneath the coal has been mined to a limited extent along with the coal for pottery clay. The same coal has been stripped in the section to the east in the NW¼ SW¼ sec. 26. The largest strip pit on the Rowe coal is in the NW¼ sec. 35, T. 30 S., R. 25 E., where a small steam shovel is used to remove the overburden. The Rowe bed has been mined from drifts along the south side of the creek in the S½ sec. 35. The coal extends on southward into T. 31 S., R. 25 E., but could not be definitely traced much beyond the north line of the township, because of structural irregularities and steep local dips in the Cherokee shale.

Coal between the Columbus and Weir-Pittsburg beds.—Within an area bounded by Girard, Pittsburg, Columbus, and Monmouth,

mining of the Weir-Pittsburg bed are fairly well known. Arcadia is near the northern end. The southern limit does not extend much beyond a line drawn from Columbus to Mineral, for beyond this point the coal thins to less than 2 feet. The northwestward limit of workable coal in the Weir-Pittsburg bed is known approximately from mine workings and numerous drill records and is indicated on Plate 7 by the 2½-foot thickness line extending from Mineral to the northeast corner of Crawford county. Young[81] believes that this western limit as now known has been determined by some factor other than thinning of the coal, and suggests two possibilities: (1) Stream channels which cut out the coal in a narrow belt, and (2) either faulting or a change in dip which has changed the bed from its normal position. The structure map (Pl. 5) shows that this latter possibility need not be considered. From a study of the stratigraphy of the strata overlying the Weir-Pittsburg coal and the regional extent and character of the coal bed, the writer interprets the western workable coal limit as due to thinning near the margin of the basin in which the coal was deposited with the Cherokee sea lying to the west and land to the east.

The Weir-Pittsburg bed thins rapidly north of Arcadia. In Vernon county, Missouri, it is called the "Weir-Pittsburg lower," and in the southwestern part of that county is 5 to 9 inches thick; in the northern and western parts of the county drilling shows this coal to be very thin or absent.[82]

A line drawn through points where the thickness of the Weir-Pittsburg coal is reported as 2½ feet is shown on Plate 7. The thickness of the coal is determined from drill-hole data and mine workings. West of this line the average thickness of the coal is reported to be less than 2½ feet and east of it the average thickness is reported as 2½ feet or more. This line may be regarded as the approximate western limit of workable coal at the present time. The "workable thickness" of a bed mined by underground methods, however, is dependent upon economic and other conditions, as well as the thickness of the coal, and for that reason may change from time to time. Of course, where the coal can be mined by stripping the overburden, the workable limit may be much less, and consequently some areas that are not workable by underground methods may be mined by stripping if the overburden is not too great.

81. Young, C. M., and Allen, H. C., Kansas coal: Univ. of Kansas Bull., vol. 26, No. 5, pp. 25-28, 1925.

82. Greene, F. C., and Pond, W. F., The geology of Vernon county: Missouri Bur. Geology and Mines, 2d ser., vol. 19, p. 47, 1926.

overlain by a distinctive series of beds which readily identify it from the other Cherokee coals. The coal is from 3 to 7 inches thick overlain by 12 to 20 inches of dark shale, which is followed by a 3-inch bed of ironstone, limestone, or a peculiar red, porous "clay." The following sections show the characteristic types of lithology in the strata above the Pilot coal:

Section of Pilot coal and overlying beds measured 1,000 feet east and 200 feet south of the NW corner sec. 13, T. 28 S., R. 25 E.

	Ft.	in.
Clay-shale, light gray with reddish specks	8	
Sandstone, thin-bedded	6	
Shale, bluish-gray, with gray disc-shaped concretions	9	
Ironstone, dark gray, dense, weathers yellow with rouge-red streaks		2
Shale, dark gray		8
Limestone, hard, black, fossiliferous		2
Shale, black, slaty	1	10
Coal, Pilot bed		7

Section of Pilot coal and overlying beds measured in strip pit in SW¼ SW¼ sec. 17, T. 32 N., R. 33 W., Barton county, Missouri

Sandstone, buff, laminated	5+	
Shale, dark gray, laminated, with rusty yellow disc-shaped concretions,	4	
"Clay"?, dark red, contains cavities and numerous gastropods		4
Clay-shale, red to black	1	1
Coal, weathered, Pilot bed		3

The Pilot bed is not of sufficient thickness in Kansas to be of economic value. It was noted at many places in northeastern Crawford county, but seems to be less continuous in the southeastern part of the county and in Cherokee county. Most of the logs of drill holes in both counties, however, show a thin coal at its approximate horizon. The Pilot coal lies from 8 to 30 feet above the Weir-Pittsburg bed; in northeastern Crawford county the interval is usually about 20 feet.

The Pilot bed is correlated with the Walker coal[83] of Vernon county, Missouri.

Coal between the Pilot and Mineral beds.—Practically all of the logs of the drill holes available to the authors record a thin coal bed from 25 to 40 feet above the Pilot bed, and from 15 to 20 feet below the Mineral bed. The only exposures of this coal that were noted are along the west line of the NW¼ sec. 14, T. 28 S., R. 25 E. There the coal has a maximum thickness of 8 inches and is underlain by gray clay and overlain by gray-brown shale containing small concretions. The thickness of the coal, according to drill logs, is from 3 to 12 inches.

Mineral coal bed.—The Mineral coal bed is named from the town

83. Greene, F. C., and Pond, W. F., The geology of Vernon county: Missouri Bur. Geology and Mines, 2d ser., vol. 19, pp. 47-48 and fig. 3, 1926.

The Mineral coal lies between 65 and 80 feet above the Weir-Pittsburg coal, and is approximately 150 feet below the top of the Cherokee shale. Drill records show that the interval between the Mineral and Weir-Pittsburg coals increases to the northwest, but on the average the increase is not more than 2 to 3 feet to the mile. The Mineral coal is in many places overlain by a cap rock of black fossiliferous limestone, from a few inches to a foot in thickness. The limestone is not a continuous bed; where it is not present the coal is overlain by black shale. In strip pits the Mineral coal can usually be identified by its relation to the Fleming coal bed which occurs a few feet above it. (See Pl. 8-A.)

The coal is usually between 17 and 24 inches thick. The average of two measurements in a strip pit in the NE¼ sec. 34, T. 28 S., R. 25 E., is 17 inches; three measurements in a pit in sec. 23, T. 29 S., R. 25 E., gave an average of 19½ inches; the average of three measurements in the pit in sec. 4, T. 30 S., R. 25 E., is 19 inches; two measurements in the strip pit in the SW¼ sec. 34, T. 30 S., R. 24 E. averaged 24 inches; one measurement in sec. 20, T. 31 S., R. 24 E., shows 26 inches of coal; the average of two measurements in the pit in the NW¼ sec. 9, T. 32 S., R. 23 E., is 20½ inches. A few clay rolls and horsebacks were observed in the Mineral bed, but they are not nearly as numerous as in the Weir-Pittsburg bed and do not seriously affect mining operations.

In recent years the Mineral bed has become increasingly important as a commercial coal bed. It has been strip-mined at numerous places, extending southwestward from the northeastern part of Crawford county and into Cherokee county as far as Mineral (see Pl. 1). There are also a few small strip pits in southeastern Labette county. A few shaft mines have been opened on the Mineral bed in the vicinity of Mineral and Cherokee, but the coal is not thick enough for extensive underground mining.

Greene[87] correlated the Rich Hill coal of Missouri with the coal bed between the Pilot and Mineral beds of Kansas. His Kansas section, however, was measured near Mulberry where the upper half of the Cherokee is abnormally thin and the sequence of beds is not typical. The writer correlates the Rich Hill coal of Missouri with the Mineral bed, because it bears the same relationship to the older and younger coals as do the coals described in Vernon county,[88] because similar strata overlie both coals, and because the average

87. Greene, F. C., and Pond, W. F., op. cit., p. 40.
88. Greene, F. C., and Pond, W. F., op. cit., fig. 3 and p. 48.

interval from the top of the Cherokee shale to the coals is practically the same, being 146 feet for the Rich Hill coal, and between 145 and 150 feet for the Mineral coal.

Fleming coal bed.—The Fleming coal is so named from exposures in strip pits just north of the village of the same name, which is in southern Crawford county between the towns of Pittsburg and Cherokee. The coal which has been strip-mined at Fleming is the Mineral coal, but the Fleming coal is exposed in the walls of the strip pits. In a previously published section[89] the authors called this coal the "Mineral Rider" because of its association with the Mineral coal. Locally it is known as the "Bastard bed" and is exposed in many other pits where the Mineral coal is stripped. It is from 7 to 20 feet above the Mineral coal; in northeastern Crawford county it averages about 9 feet above the Mineral coal, in east-central Crawford and southern Crawford county it averages 12 feet above, near Fleming it is 14 feet above the Mineral coal, and in the vicinity of Mineral the average interval is 19 feet.

The Fleming coal is extremely variable in thickness. In the walls of many strip pits it can be seen to thin from 6 inches to only a trace of coal. In Crawford county it is from 0 to 10 inches thick, but in the vicinity of Cherokee and Mineral it is usually about a foot thick and locally attains a thickness of 18 inches. A notable characteristic is the lack of a distinct difference between the strata above and below the coal, both usually being medium gray shale. (See Pl. 8 *A*.) The Fleming bed is strip-mined in a part of the Commercial Fuel Companies' mine No. 2, in the NE¼ sec. 20, T. 31 S., R. 24 E. The coal mined here is from the Mineral bed, except for a small area in the northern part of the pit, where the Mineral coal is reputed to be thinner and has a greater overburden. In this part of the pit the Fleming coal slopes down into a synclinal depression, and coincident with this increasing depth there is a thickening of the coal and also a change in the strata above and below the coal. (See fig. 7.) The depression or syncline, however, does not appear to be reflected in the coal below. The Fleming coal reaches a maximum measured thickness of 20 inches in this depression.

Drill holes in sec. 31, T. 32 S., R. 22 E., and adjoining sections show that there are several coal beds present below the surface, varying in thickness from a few inches to 2 feet. The coal beds recorded in these holes are correlated with the Croweburg, Fleming, and Mineral beds. The bed which is correlated with the Fleming

89. Pierce, W. G., and others, op. cit.

area, the coal was actually observed at many places, and drill records likewise show it to be present. The Croweburg coal lies 17 to 35 feet, averaging 25 feet, above the Mineral coal.

The Croweburg coal is overlain by 3 to 8 feet of shale, the upper half light gray and the lower half somewhat darker in color. Above this unit is 2½ to 5 feet, averaging 3 feet, of fissile black shale, containing black siliceous limestone concretions, many of which are 18 inches in diameter, and some 3 feet in diameter were noted. Small phosphate nodules, about three fourths of an inch in diameter, are common in the black shale. Some of the larger concretions and many of the smaller ones contain nuclei of fossils. The large concretions have the shape of flattened spheres, whereas the small ones may be round, flattened, or several may be grouped together like

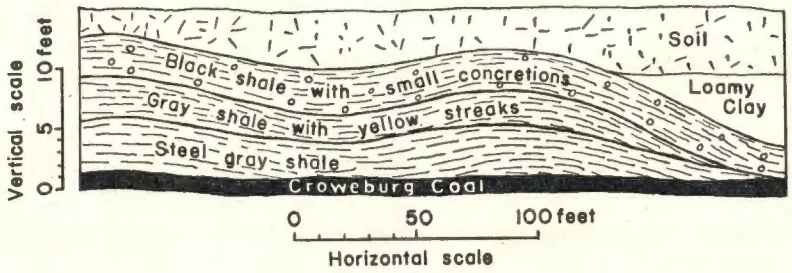

FIGURE 8. Sketch showing an unusual relationship of the Croweburg coal to the black shale above it, as exposed in a strip pit near the center of the N½ sec. 17, T. 35 S., R. 21 E.

peanut brittle. The succession of strata just described—that is, a coal overlain by gray shale, and then a black shale with concretions —furnishes an excellent means of identifying the Croweburg coal, for none of the other coals in the Cherokee shale have a similar succession of strata associated with them. A typical view of the black shale unit with the concretions is shown on Plate 8-*B*. At two localities—one in the SE¼ NE¼ sec. 8, T. 31 S., R. 23 E., and another near the center of the N½ sec. 17, T. 35, S., R. 21 E.—the black shale was observed to rest directly on the Croweburg coal. This relationship is illustrated in figure 8.

The Croweburg coal is 10 to 18 inches, averaging 12 inches in thickness. It has been mined at several strip pits in northeastern Crawford county and southeastern Labette county and at places between these areas, such as along Deer creek in T. 32 S., R. 22 E., as shown on Plate 1.

line of outcrop. The largest of these is along Lighting creek, extending from a point a mile west of Monmouth to within 2 miles of Sherman.

The Bevier coal could not be traced across Neosho valley. Apparently the coal becomes discontinuous in the area along the lower part of Lightning creek, for on the west side of the Neosho river there is no coal just above the Ardmore limestone, but local beds do occur somewhat higher—in the part of the Cherokee shale that to the northwest is noncoal-bearing.

The Bevier coal is normally 80 to 100 feet below the top of the Cherokee shale, and the average interval is 100 feet. The one exception to this—which was mentioned on page 66—is southwest of Mulberry, in the vicinity of the outlier of Fort Scott limestone on the hill known locally as Breezy Hill, where the interval from the Bevier coal to the top of the Cherokee decreases to 65 feet. The Bevier coal is underlain by 6 to 12 inches of gray clay, and below that is the Ardmore limestone. It is overlain by several feet of dark-gray to black shale, which usually contains from 1 to 4 thin beds of dark, impure limestone. The Ardmore limestone below and the thin limy beds in the shale above serve as identification for the Bevier coal.

The Bevier coal has an average thickness of 18 inches along the outcrop in Crawford county. In the S½ T. 32 S., R. 22 E., in Cherokee county, it is thinner and could not be definitely traced in the logs of drill holes. In this area where it is thinner another thin coal bed is recorded about 10 feet above the horizon of the Bevier coal. The Bevier coal does not extend into Labette county, but coal beds occur above the Ardmore limestone, whereas in Cherokee and Crawford counties the interval between the Bevier and Fort Scott coals is barren.

The Bevier coal has been strip-mined in Tps. 27 and 28 S., R. 25 E., sec. 25, T. 29 S., R. 24 E., the north-central part of T. 30 S., R. 24 E., and from numerous small pits in T. 31 S., Rs. 22 and 23 E., and the north half of T. 32 S., R. 22 E., as shown on Plate 1.

The Bevier coal of Kansas is correlated with the Williams coal of Vernon county, Missouri, because of its position in the Cherokee shale with similar identifying strata above and below the coal. Greene[93] states that the Williams coal is probably the Bevier coal of northern Missouri.

Stice coal bed.—The Stice coal is named from the Stice school, in the NE. corner sec. 33, T. 33 S., R. 21 E. The outcrop of the bed

93. Greene, F. C., and Pond, W. F., op. cit., p. 52.

In northeastern Crawford county—that is, in that part north and east of Franklin—the Fort Scott coal is from 8 to 12 inches thick. The average thickness in T. 28 S., R. 25 E., and in the vicinity of Cato is 8 inches; at Breezy Hill, southwest of Mulberry, the average thickness is 12 inches. In T. 29 S., R. 24 E., it is from 0 to 6 inches thick, and to the south and west of this township the Fort Scott coal is absent, except for a few places where the coal may be present locally with a thickness of a few inches.

The Fort Scott coal has been strip-mined in secs. 25 and 26, T. 27 S., R. 24 E., and at numerous places along the base of the Fort Scott limestone in T. 28 S., R. 25 E., and at Breezy Hill in the NE¼ T. 29 S., R. 25 E. (See Pl. 1 for location of strip pits.)

Coal in Fort Scott limestone.—In Bourbon county, Kansas, which lies to the north of Crawford county, and in Vernon county, Missouri, the shale unit between the upper and lower members of the Fort Scott contains a coal bed from 0 to 2 feet thick. In the area of this report, however, no coal was observed in this interval and the drill records examined likewise do not record any coal.

Coal in the Labette shale.—Several thin coal beds were observed in the Labette shale, but none of them have been mined in southeastern Kansas, as they are too thin for commercial value. The generalized section shown in figure 2 shows the approximate position of three of these thin beds. In addition, a few drill holes in the extreme northern part of Crawford county record a few inches of coal about 7 feet above the base of the Labette shale.

Physical and Chemical Character of Coal

The coal in the southeastern Kansas field is all of bituminous rank. It is somewhat friable, but is practically nonslacking and has a bright appearance. Some pyrite is present in the coals, but much of it is removable by sizing and washing operations. Calcite commonly occurs as film-like veins along joints and fractures. The Weir-Pittsburg coal is the only bed mined that carries a large amount of clay. This is present as clay veins and "horsebacks," and in some areas may average as much as 10 percent of this coal bed. In some places a "rash," consisting of a mixture of shale and clay with streaks of coal, occurs above the Weir-Pittsburg coal.

The quality of coal is represented analytically by two methods of analysis—"proximate" and "ultimate." Moisture, volatile matter, fixed carbon, and ash are determined in a proximate analysis. In ultimate analyses the percentage of the chemical elements that form the combustible and volatile matter of the coal is determined, these

6—3172

TABLE 2. Average Chemical Analyses of Southeastern Kansas Coals by Beds.

COAL BED.	Number of analyses averaged.	"As received" analyses.						"Moisture and ash free" analyses.				Softening temperature of ash, °F.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.	Sulphur.†	Volatile matter.	Fixed carbon.	British thermal units.	Sulphur.†	
Fort Scott	3	2.8	40.3	47.4	9.3	13,286	3.9	46.0	54.0	15,130	4.5	2060
Bevier	6	3.8	37.8	48.6	9.8	13,026	2.6	43.7	56.3	15,077	3.1	2458
Fleming	1	2.8	39.3	47.3	10 6	13,090	2.3	45.4	54.6	15,120	2.7	2330
Mineral	9	4.3	34.3	48.7	12.6	12,488	3.8	41.3	58.5	15,029	4.5	2014
Weir-Pittsburg*	8	6.1	33.3	50.7	9.9	12,622	3.7	39.5	60.4	15,007	4.4	2044
Uncorrelated beds below Weir-Pittsburg	3	5.0	30.7	48.1	16.1	11,576	6.8	39.0	60.9	14,696	8.7	2023

† From ultimate analyses.
* Average for Weir-Pittsburg bed is figured from analyses in U. S. Bureau of Mines Technical Papers Nos. 366 and 455.

ties, begin in 1885.[95] Prior to that date, production figures are for the state as a whole. The accompanying graphs (figs. 9, 10, and 11) were made from the reports of the Kansas State Mine Inspector, supplemented by reports of the United States Geological Survey and the United States Bureau of Mines.

Figures 9 and 10 show the tonnage of coal produced from 1885 to 1934 in Cherokee and Crawford counties—the principal coal-producing counties of the state. Where the data are available, the amount mined by shaft or underground methods is shown separately from that mined by surface stripping; the total annual production from

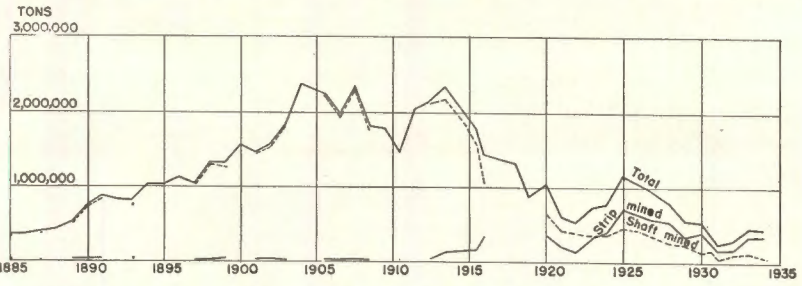

FIGURE 9. Coal production, Cherokee county, Kansas. Compiled from reports of the Kansas State Mine Inspector, supplemented by statistical reports of the U. S. Geol. Survey and the U. S. Bureau of Mines.

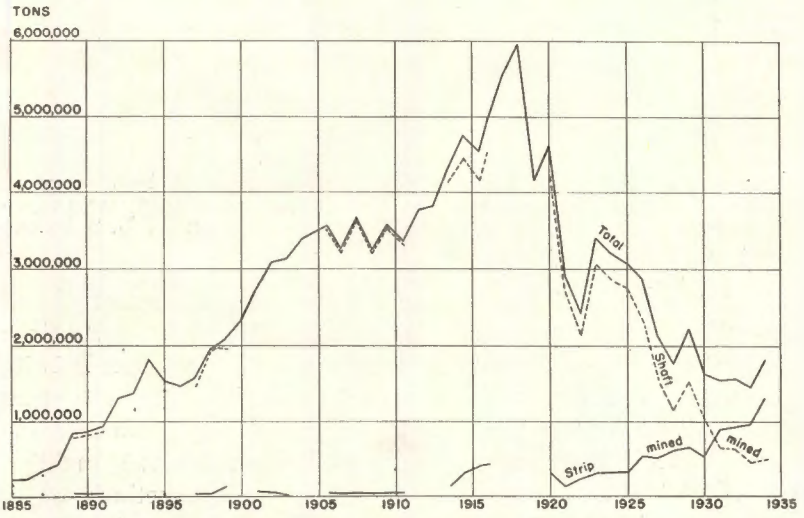

FIGURE 10. Coal production, Crawford county, Kansas. Compiled from reports of the Kansas State Mine Inspector, supplemented by statistical reports of the U. S. Geol. Survey and the U. S. Bureau of Mines.

95. Annual reports of the State Inspector of coal mines.

since 1921. It surpassed the tonnage of shaft-mined coal in 1931, and the increased total production of 1934 over 1933 is due almost entirely to the increased production of strip-mined coal. The combined coal production of the three counties, shown in figure 11, is essentially an integration of the production of Cherokee and Crawford counties, for Labette county production represents less than one half of one percent of the total. The total annual production for the area reached a maximum of over 7,250,000 tons in 1918, declined to about 1,830,000 tons in 1931, and in 1934 was about 2,300,000 tons. Strip-coal tonnage first exceeded shaft-coal tonnage in 1931, and in 1934 strip-coal tonnage was nearly three times that of shaft coal.

TABLE 3. Total coal production* in Cherokee, Crawford, and Labette counties, Kansas, 1885 to 1934, and total Kansas production 1869 to 1934 and 1885 to 1934.

COUNTIES.	Shaft mines.	Strip mines.	Total.
Cherokee	49,890,114	7,097,271	56,987,385
Crawford	117,783,184	11,441,922	129,225,106
Labette†	.....	172,346	172,346
Totals	167,673,298	18,711,539	186,384,837
Kansas (total production)		1885–1934	213,117,707
Kansas (total production)		1869–1934	220,719,336

* Short tons. Compiled principally from annual reports of Kansas State Mine Inspector.
† Records not available for years 1886, 1888, 1898, and 1900-1923, inclusive.

From table 3 it may be seen that this district has produced about 88 percent of the total output of the state. In 1934, 91 percent of the state's production came from southeastern Kansas.

Domestic and commercial usage of gas and oil as fuels has been a serious factor in reducing the production of coal. Young[96] has estimated that oil alone has replaced coal to the extent of more than 1,162,000 tons per year.

The potential coal production of the country as a whole is far in excess of demand. Consequently, southeastern Kansas coal meets keen competition with coals from other areas. Because more than 75 percent of the Weir-Pittsburg coal bed, in excess of 2½ feet thick, has been mined by shaft and strip methods, future production in this district will come mainly from stripping operations in the somewhat thinner, higher coals, particularly the Mineral and Bevier beds, and from the development of deep-shaft mines in the vicinity of Edna and Angola in Labette county.

96. Young, C. M., Kansas coal: Univ. of Kansas Bull., vol. 26, No. 5, p. 58, 1925.

PLATE 9. A, View of an area of about 600 acres that has been stripped for the Bevier coal. The coal is about 20 inches thick. View looking south from near the center of south line sec. 9, T. 28 S., R. 25 E.; B, Type of electric shovel used in removing overburden from the coal in the southeastern Kansas coal field. Note ordinary steam shovel below boom.

is loaded into the box of a so-called bank machine that hoists the coal out of the pit and dumps it into cars that run on a track laid at the top of the bank along the working face of the strip pit.

The loading is accomplished by steam or electrical shovels that operate with a horizontal boom, the dipper being forced out horizontally, passing along the top of the underclay and picking up the coal with very little breaking.

For a given size of shovel the width of a pit varies with the thickness of the overburden, the stripped width becoming narrower as the depth of the coal increases.

Although much of the coal produced is run of mine coal, including that used in the domestic market, a considerable proportion of the coal shipped is now being size-graded. The sizing and cleaning of coal is now one of the most important steps in producing coal for market. In the early years of the district a large percent of the coal was screened in the mine, the fine coal being thrown back into the mine and not hoisted. With the development of the coal field, size-grading of mined coal passed through successive stages of development. Discontinuance of screening coal in the mines led, first, to the use of bar screens in the mine tipple, then rotary screens, and finally to the use of shakers and re-screening arrangements. In the last few years still more modern methods have been installed for size-grading and cleaning of coal, and today several of the larger companies use some combination of washing and mechanical sizing. A few years ago four sizes of coal were shipped—slack, pea, nut, and lump. At the present time the modern plants produce some fifteen different sizes, ranging from size zero to 8-inch coal. Pyrite is removed by floating the coal in a heavy liquid, consisting of a mixture of clay and water. The heavier iron sulphide sinks and some of the coal that contains masses of pyrite likewise sinks and is thrown out as waste. Norton washers are used at several plants for cleaning the coal, and at the Pittsburg and Midway plant both the Norton washers and a cone type of washer are used. In the washing operations a large part of the pyrite and clay is removed, which otherwise would be included in the coal and reduce the heat value per ton and increase the ash content.

Uses and Markets

A large amount of the coal mined in southeastern Kansas is used for steam raising. Although a considerable number of oil-burning locomotives are in use, the railroads are still the largest single consumers of coal from this district. Large quantities of steam coal are

This field is from one fourth of a mile to half a mile wide and is about 3 miles long. The south end of the field is near the southeast corner of sec. 1, T. 31 S., R. 21 E.; the field extends north of this point for a mile, then trends north-northeast for about 2 miles. Production comes from a sandstone 15 to 25 feet thick that is from 175 to 200 feet below the top of the Cherokee shale. This sandstone is about 75 feet above the Bluejacket sandstone and is also slightly above the horizon of the Weir-Pittsburg coal.

A number of wells in the vicinity of Oswego produce small quantities of gas, some gas being obtained from a sand 320 to 420 feet below the top of the Cherokee, and also from near the base of the Cherokee shale. Gas in small quantities is obtained from numerous other wells, located mostly in Labette county.

Clay and Shale for Ceramic Industries

Building and paving brick, sewer pipes, conduits, and pottery are manufactured in this area. At Pittsburg, tile and brick are manufactured from a sandy shale occurring in a portion of the Cherokee shale below the Weir-Pittsburg coal. The raw material is mined from an open cut, and run-of-pit material is used in the brick plant.

A brick plant at Weir uses a slightly sandy shale that lies below the Weir-Pittsburg coal. At this locality the coal is only a few feet below the surface of the ground, and is considerably weathered.

Some of the better underclays are used at Pittsburg in the manufacture, on a small scale, of various kinds of pottery.

Road Metal

Four main types of materials are used in this area for road surfacing, namely, the black shale immediately below the lower member of the Fort Scott limestone; shale from mine dumps; chats, which are the tailings from mills in the zinc-lead district; and chert gravel from deposits along the Neosho river valley. In a few places the Fort Scott limestone is crushed and used for road metal.

Roads on which the black shale is used are dusty and seldom are smooth. The same disadvantages apply to roads surfaced with shale from mine dumps.

The chats consist of crushed rock—mainly chert—from which the zinc-lead ores have been removed. This material is very abundant, easily handled, and with proper usage makes excellent road material.

older beds. The other species are characteristic of lower Cherokee in Kansas. The utility of most of the pelecypod and gastropod species is diminished because of their relative scarcity.

The relative abundance of certain long-ranging species and varieties is a means of identifying certain beds. Such species are *Marginifera muricatina* Dunbar and Condra and *Chonetes* (*Mesolobus*) Norwood and Pratten, which are especially abundant in the Cherokee formation, and *Chonetes* (*Mesolobus*) *mesolobus euampygus* Girty, which is more abundant in the Fort Scott limestone than in the Cherokee.

Invertebrate fossils of the Cherokee and immediately overlying beds are most useful in correlation of near-by outcrops when consideration is given to the associated lithologic sequences. For this purpose the relative abundance of various species, as well as the ranges and the total faunal composition, is important. Possible changes of faunules due to lateral changes in ecological conditions, including lithologic or facies changes, to migration, to different basins of deposition, or to the accidents of collecting must also be borne in mind constantly. When all these things are considered, the faunules aid materially in the solution of many stratigraphic problems, and permit the recognition of thin zones within the Pennsylvanian series.

Extensions of the reported ranges of several species, especially within the Cherokee formation, were noted in connection with the study of these collections. These extensions need not be mentioned here, but they can be determined by reference to the faunal tables and comparison with previously published tables.

A real or at least apparent relation between lithologic facies and certain types of faunules is shown by a number of collections. All of the conodonts collected came from black fissile "paper-thin" shales, but possibly conodonts are present in other shales which were not carefully examined. Small coiled cephalopods and fragments of fish bone were most commonly found in phosphatic nodules in black fissile shales. *Aviculipecten rectilaterarius* (Cox) is commonly found in black shales, but it also occurs sparingly in tan shales; at some localities it is associated with plants. Most of the species in the limestones and calcareous shales are of brachiopods, but corals, especially *Chaetetes*, are common in some limestones, and this one genus is more or less restricted to limestones. Small gastropods, occasional small cephalopods and small pelecypods, are the predominating fossils in some calcareous zones that are also pyritic or otherwise ferruginous. These suggest that depauperizing conditions existed when these beds were deposited.

Complete fossil lists are given for most, but not all, of the collections. A few of the collections have not been thoroughly studied and only the general characters of their faunules are shown in the tables. Most detailed identifications were made of forms which, because of good preservation or unusual occurrences, seemed to promise stratigraphically useful results. Other forms are referred to the genera to which they belong without a specific determination. Quotation marks around a fossil name indicate that I recognize objections to the way the name is being used, but am not ready to decide what changes, if any, should be made.

The identifications on which this report is based were made during May and June, 1935. Changes in nomenclature made in literature reaching my

their *Dictyoclostus americanus, Linoproductus magnispinus, Cryptacanthia compacta* (White and St. John), and a chonetid designated by them as *Chonetina flemingi.* The first species was discovered from the Fort Scott in the present investigation. A form from the Fort Scott, which is here called *"Productus" (Linoproductus) prattenianus* n. var., is closely related to their *L. magnispinus* and may actually be the same form. The other two species are rare in the Pawnee and were not collected during our studies. Beede and Rogers[101] list about a dozen species from five localities in Kansas, but most of them are mollusca or other forms that are rare in the limestones of this part of the stratigraphic column. Our collections show no species of invertebrates that does not also occur in the Fort Scott. Consequently, the identification of the Pawnee in this area rests largely on stratigraphic tracing, on the absence of species known elsewhere only from lower formations, and on the identification of the Fort Scott limestone with the Fort Scott of the type region and of near-by regions in Missouri.

COLLECTIONS FROM THE LABETTE SHALE

Collections were made from three zones in the Labette shale. One came from a black shale, probably from beds only a few inches below the top of the formation, three are from a zone from 6 to 7 feet lower, and two are from a zone 22 feet below the top of the Labette shale.

The collection (number 7799) from the black shales at the top of the Labette is from eastern Labette county, 1¾ miles west and ½ mile south of Montana, and is composed wholly of fragments of fish bone in black nodules.

The three collections from the zone 6 to 7 feet below the top of the Labette shale came from a thin black limestone. One of these collections contains the following forms.

Fossils from the upper Labette shale 6 miles north and 1 mile west of Montana, Labette county, Kansas (Collection 7797):

Horn coral, indeterminate fragment.
Crinoid columnals.
Derbya crassa? (Meek and Hayden), fragment of young.
Chonetes (Mesolobus) mesolobus lioderma (Dunbar and Condra).
Composita subtilita (Hall).
Phanerotrema? sp. indet., crushed specimen.

The following forms were identified in another collection from approximately the same locality. Except for the corals, the individuals are all small and the fauna may be depauperate. Many indeterminate fragments of small shells are visible on the surfaces of slabs.

Fossils from the upper Labette shale, 6 miles north and 1 mile west of Montana, Labette county, Kansas (Collection 7798):

Lophophyllum profundum (Edwards and Haime).
Crinoid columnals.
Fenestrellina? sp. indet., non-poriferous side.
Derbya sp. indet.
Chonetes (Mesolobus) mesolobus? Norwood and Pratten.

101. Kansas Univ. Sci. Bull. No. 2, p. 469, 1904.

COLLECTIONS FROM THE FORT SCOTT LIMESTONE

The Fort Scott limestone consists of two limestone members separated by shale. At many places, especially in Missouri and near-by areas in Kansas, a thin coal occurs in the shale.

Thirty-two collections were made from this formation. Of these, 12 came from the upper limestone member, 19 from the lower limestone member, and one from the shale. The species found in the individual collections are recorded in Plate 10.

Collections from the upper limestone member.—Collections from the upper member of the Fort Scott limestone were made in Crawford and Labette counties. The collections from Crawford county, with two exceptions, came from a light-gray, finely crystalline but not dense, limestone which weathers yellow brown. One of the expected collections came from a 3- to 6-inch bed of yellow-brown to olive-drab or light chocolate-brown, finely crystalline limestone that occurs at some localities above the light-gray limestone and is at the very top of the upper member. The other came from a light chocolate-gray, finely crystalline limestone. The faunules, taken as a whole, contain many fusulinids and many colonies or "heads" of *Chaetetes milleporaceus* Edwards and Haime. In places nearly one third of the limestone beds consist of large or small subspheroidal colonies of *Chaetetes* and *Syringopora*. Large crinoid columnals, robust specimens of *Composita subtilita* (Hall), and individuals of *"Productus" (Dictyoclostus) portlockianus* Norwood and Pratten, are important elements in the faunules. An unusual type of echinoid spine, which differs from the more common types by having conspicuous pustules on the sides of the shaft, is interesting.

Most of the collections from Labette county are from near Oswego, the type locality of the so-called "Oswego limestone." The faunules and lithologies of the various outcrops are more varied in this county than in Crawford county. The most common type of lithology is very faint purplish-gray to yellow-gray, finely crystalline limestone. At some outcrops the beds are brownish yellow. As in Crawford county, large colonies of *Chaetetes*, large crinoid stems, large compositas, and individuals of *"Productus" (Dictyoclostus)* are important elements in the faunules. Fusulinids are less abundant here. The Labette county collections contain several forms such as *Meekella striatocostata grandicosta* Dunbar and Condra, *"Productus" (Echinoconchus) semipunctatus knighti* (Dunbar and Condra), and *"Productus" (Linoproductus) insinuatus* Girty, that were not obtained in Crawford county. The last two of these are unknown from beds older than the Fort Scott, and the first is doubtfully recorded from older beds. Gastropods are more important here than in Crawford county, but the faunules consist chiefly of brachiopods.

Collection from shale between the upper and lower limestone members.—Only one collection (No. 7795) was made from the shale between the two limestone members of the Fort Scott. This came from a black shale about 30 inches below the base of the upper limestone in northeastern Crawford county. The only fossils observed were conodonts, which have not yet been studied.

Collections from the lower limestone member.—Most of the collections from the lower member of the Fort Scott formation were obtained from faintly purplish-gray, finely crystalline limestone, but some of them are from whitish gray limestone, and others are from brownish-yellow limestone.

rare or absent from the upper Fort Scott. Fusulinids and *Chaetetes* colonies are common in collections from Crawford and northern Cherokee counties, but are not commonly seen in collections from southern Labette county. Echinoid spines and prismoporas occur from widely separated areas, but are absent, however, in many localities. Bryozoans and squamularias are relatively more important in southeastern Labette county, but the collections from this area were made hurriedly and may not represent the faunules adequately.

Species in our collections whose occurrence in the Fort Scott of this general region is worthy of note are *"Productus" (Dictyoclostus) americanus* (Dunbar and Condra), *"Productus" (Krotovia?)* sp., probably new, *Marginifera muricatina* Dunbar and Condra, a new (?) variety which approaches var. *missouriensis, Wellerella osagensis immatura* Dunbar and Condra, a large undescribed species of *Edmondia* (?), echinoid spines with conspicuous pustules on the sides of the shaft, an undescribed species of *Cystodictya,* and an undetermined species of *Pinnatopora.*

Faunal characteristics of members and zones of the Fort Scott limestone.— Our collections show a number of forms from the lower limestone that are not in our collections from the upper limestone. These are *Pinnatopora* (?) sp. indet., *Cystodictya* n. sp., *Prismopora triangulata, Chonetes (Mesolobus) mesolobus euampygus, "Productus" (Dictyoclostus) americanus, "Productus" (Krotovia?)* n. sp., *Marginifera muricatina, Wellerella osagensis immatura, Wellerella osagensis tetrahedra,* and some rare gastropods. Of these, the most significant are *P. triangulata, Co. mesolobus euampygus, Cystodictya* n. sp. and the *Krotovia*(?). All the others, except perhaps the *Pinnatopora,* are listed from the upper limestone or higher beds in near-by regions in other reports. Dunbar and Condra have also reported *C. mesolobus euampygus* from higher horizons. Beede and Rogers report *P. triangulata* from both the upper and lower limestones, but our collections suggest it is more abundant in the lower limestone.

Only a few forms from the upper limestone member do not occur in our collections from the lower limestone member. These are *Syringopora* sp. indet., *Meekella striatocostata grandicosta, "Productus" (Dictyoclostus) portlockianus, "Productus" (Echinoconchus) semipunctatus knighti,* and *"Productus" (Linoproductus) insinuatus.* All of them, with the possible exception of *P. insinuatus,* have been reported either in the upper part of the Cherokee or the lower member of the Fort Scott, or both, and their absence from our lower Fort Scott collections is probably due to the accidents of collecting.

To the few species discussed above that now serve to distinguish our lower from upper Fort Scott collections, one may add the somewhat greater variety of fossils in the lower Fort Scott at most localities and the greater number of individuals of *Chaetetes milleporaceus, Marginifera muricatina,* and *Prismopora triangulata* in the lower Fort Scott. Of course the greater abundance of the above species cannot be used for each individual outcrop, but is useful in a broad way.

Beede and Rogers[103] cite over 30 species from the upper Fort Scott that they do not cite from the lower, and about an equal number from the lower Fort Scott that they do not have from the upper Fort Scott. Most of these species are of mollusks, which are not common in the Fort Scott limestone, and

103. Op. cit., pp. 463-468.

triangulata from above the Fort Scott in Missouri, but Beede and Rogers report it from the Pawnee in Kansas. It is more abundant generally in the Fort Scott, however. The three species just mentioned are the only ones in our collections that now can be used safely for distinguishing Fort Scott from Pawnee. When combined with the differences in the relative abundance of certain species mentioned above and of *P. triangulata,* they serve as a basis for distinguishing these two formations.

The criteria suggested for distinguishing the Pawnee and Fort Scott limestones are not sufficient to separate the latter from beds in the Cherokee formation, unless the Fort Scott collections contain nearly all of the species mentioned above as distinctive of it. A discussion of the differences between the Fort Scott and upper Cherokee faunas is given at the end of the section devoted to the Cherokee shale.

COLLECTIONS FROM THE CHEROKEE SHALE

General Statement

The Cherokee shale has yielded a much larger number of fossils than other horizons included in this study, and so far as I am aware they represent the greatest number to be collected zone by zone from the Cherokee of a restricted area.

Most of the collections came from Crawford and Cherokee counties. It was possible, by detailed mapping, to recognize and follow many lithologic zones more or less continuously between fossil localities in this area. In the eastern and especially the southeastern part of Labette county, across the Neosho river to the southwest from most of the other fossil localities the stratigraphic section is more variable than in the two more easterly counties. There the Cherokee shale contains beds not recognized in the other counties. For this reason, the collections from the Labette county localities are discussed separately.

In the following pages the faunal and to some extent the lithologic characters of the various zones are discussed in order from younger to older. The individual collections are shown in Plate 11, arranged according to zones.

Collections from the Cherokee shale of Crawford and Cherokee counties.—Fossil collections were made from 17 zones of the Cherokee shale in Crawford and Cherokee counties. Some of these zones were abundantly fossiliferous and contained faunas which, when correlated with certain persistent types of lithology, were more or less distinctive. Others were sparsely fossiliferous or did not have distinctive faunas. The characteristics of the most distinctive zones are discussed after the description of individual faunas.

The zones from which collections were made are described below, the youngest first and the oldest last, and are shown in the generalized section, figure 12.

Collections from black shale 1 to 3 feet below top of Cherokee shale (fossil zone 1 CC).—Collections from fossil zone 1 CC occur in three types of lithology. Conodonts and *Orbiculoidea missouriensis* (Shumard) were obtained from black, fissile, "paper-thin" shales: *O. missouriensis,* from a large pyritic and calcareous black nodule about 15 inches in maximum diameter; and *O. missouriensis,* a larger species of *Orbiculoidea,* and fragments of fish bone from small phosphatic nodules about one inch in diameter. Three collections of plants were also obtained from this zone.

Collections from Breezy Hill limestone member (fossil zone 2 CC).—The Breezy Hill limestone is somewhat irregular in thickness and highly variable in lithology. The faunules are also variable. Gastropods are a relatively important element in some faunules. Other faunules are composed entirely of crinoid columnals and a few common species of brachiopods. All of them are marine. One collection is from a thin, light-gray, very sandy limestone or calcareous sandstone; two are from slightly sandy, reddish-brown to brownish-gray, medium to finely crystalline limestones; and the remaining collections are from argillaceous, very finely crystalline to dense, medium to dark neutral gray limestones, which weather to a light yellow-brown. One collection consisted entirely of fusulinids.

Collections from shales 2 to 10 feet below the Breezy Hill limestone member (fossil zone 3 CC).—A light tan-gray shale zone about 6 feet below the Breezy Hill limestone is very fossiliferous, and a large and varied faunule consisting of 8 or 10 species of brachiopods and of pelecypods, gastropods and cephalopods was obtained from it. A dark-brown to chocolate shale which occurs at about the same horizon, but at a different locality from the above collection has a faunule of pelecypods and gastropods but lacks the brachiopods so conspicuous in the faunules in the tan-gray shale.

Collections from local limestone 20 to 25 feet below the top of the Cherokee shale *(fossil zone 4 CC).*—Four collections were made from a local limestone 20 to 25 feet below the top of the Cherokee. They all came from an area northwest of Cherokee less than a mile across. The outstanding characteristic of the faunules is the overwhelming abundance of one species, *"Productus" (Dictyoclostus) portlockianus* Norwood and Pratten. The limestone is about 14 inches thick and in places is almost a coquina of this one species.

Collections from shale 28 feet below top of Cherokee and 3 feet below limestone of zone 4 CC (fossil zone 5 CC).—A gray micaceous shale 3 feet below the limestone of zone 4 CC contains a rather large and varied faunule. The brachiopod, *Marginifera muricatina* Dunbar and Condra, is very abundant and individuals of it outnumber those of all other species combined. Collections were obtained from only one locality.

Collections from shales and thin limestones less than 6 feet above Bevier coal (fossil zone 6 CC).—Fossil zone 6 CC includes three or four thin limestones which are separated by thin shales. Collections were made both from the limestones and the shales. Three of the four collections are from black limestones—two from a 3- or 4-inch black finely crystalline very clayey limestone immediately above the Bevier coal, and one from a finely crystalline black or dark-brown, slightly ferruginous, somewhat clayey limestone about 6 feet above it. The limestone at each of these localities has white calcite "threads," some of which are probably fillings in *Serpulopsis* excavations. The limestone immediately on the Bevier coal has a rather large fauna, chiefly of brachiopods, of which *Chonetes (Mesolobus) mesolobus* Norwood and Pratten and *Marginifera muricatina* Dunbar and Condra are the most abundant. The limestone 6 feet above the Bevier is not very fossiliferous and except for the *Serpulopsis,* our collection from it has only some small brachiopods, most of which are of *Crurithyris planoconvexa* (Shumard). The prevalence of small individuals in the collection suggests a depauperate fauna.

Only one collection was made from the shales between the limestones. It contains only a few long-ranging species.

the fauna contains several pelecypods, small gastropods and small orthoceroids not present in the collection from the shale in place.

Collections from shales a few inches to 4 feet above the Croweburg coal (fossil zone 9 CC).—The 3 to 8 feet of light neutral to light lead-gray shale immediately above the Croweburg coal is unfossiliferous at many localities, especially in the northern part of the area. One small collection made from these shales contained several individuals of *Aviculipecten whitei* Meek and some plant impressions. Another collection from within a few feet of the top of the Croweburg coal, was made from a brownish-gray shale and from ironstone "layers" within the shale. It contained six species of brachiopods and two or three species of gastropods.

Collections from shales a few inches to 2 feet above the Fleming coal (fossil zone 10 CC).—Two types of lithology are represented in the collections from the shale above the Fleming coal. A brownish-gray ferruginous shale, about 1 foot above the coal, contains a large brachiopod fauna. Black, calcareous, and in places pyritic shales almost on the coal are at some localities almost a coquina of fragmentary *"Productus" (Dictyoclostus) portlockianus* Norwood and Pratten. At one locality, these calcareous shales yielded a small collection of brachiopods and gastropods.

Collections from thin black limestones above Mineral coal (fossil zone 11 CC).—The thin, black, clayey, lenticular limestones and the calcareous shales immediately above the Mineral coal constitute one of the most fossiliferous zones in the Cherokee formation. This zone is characterized by a variety as well as an abundance of fossils. Especially abundant and more or less distinctive because of their abundance are spirifers, linoproductids, chonetids, and Marginifera muricatinas. The abundance of these forms, when combined with the lithology and the variety of organisms represented, makes this a zone that is recognizable at least locally, and may be distinguished from other zones of similar lithology. In addition to the abundant brachiopods, fusulinids are abundant at some localities; crinoid columnals are common at most localities; corals, bryozoans, pelecypods, cephalopods, and trilobites are occasionally found. Brachiopods do, however, form the preponderant element in nearly all collections.

Collections from thin limestones, ironstones, and shales above but within 2 feet of Pilot coal (fossil zone 12 CC).—Thin limestones and calcareous ironstones occur in the interval from 0 to 2 feet above the Pilot coal. These beds are separated from the coal and from each other by thin shales. Where collections were made, the ironstones occur above the fossil-yielding limestones and shales. Collections from the ironstones and ferruginous limestones and limy shales are preserved in yellow-brown or reddish-brown matrices. Many of the shells are crushed and hence unidentifiable. Although outnumbered by brachiopods, fragments and molds of small gastropods are common and because they are not very common at other localities, they are here conspicuous. Pelecypod fragments are also common. Incomplete small and large cephalopods occur at one locality. Collections from "paper-thin" shales above the coal contain only conodonts, but where the shales are not so thinly bedded and are in part calcareous, lingulas, orbiculoideas, chonetids and other brachiopods, and occasional fragmentary pelecypods, gastropods and cephalopods occur.

Collections from shales immediately above Weir-Pittsburg coal (fossil zone

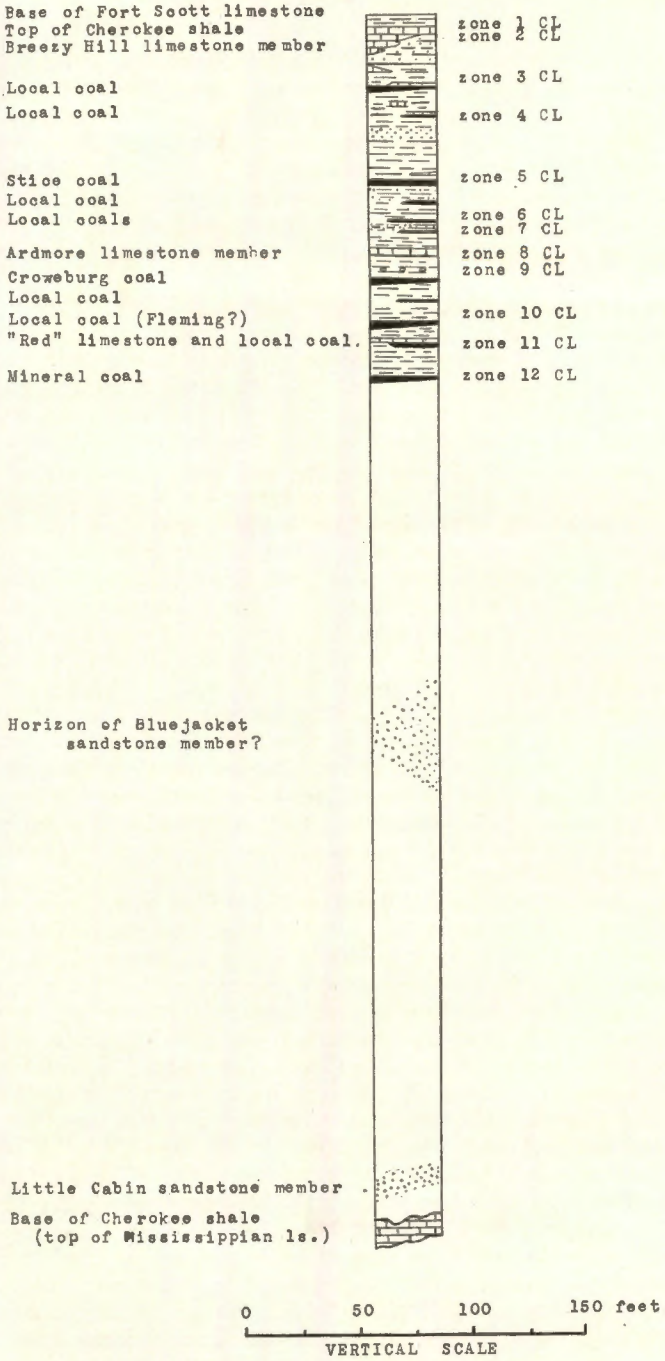

FIGURE 13. Generalized columnar section of the Cherokee shale of Labette county, Kansas (after W. G. Pierce), showing positions of fossil zones. (CL is abbreviation for Cherokee shale of Labette county.)

Collections from a limestone 40 to 45 feet below top of Cherokee shale and above a local coal (fossil zone 4 CL).—Collections were made from two uncorrelated local limestones 40 to 45 feet below the top of the Cherokee shale. One collection came from a dark-gray to black, very fossiliferous limestone overlying a local coal in an old strip pit. The other came from within a few hundred feet of the first collection but outside the strip pit. The lithology is a tan, finely granular, silty limestone. Both collections are largely of species of brachiopods which have long ranges in lower Pennsylvanian rocks. One species each of corals, crinoids, and bryozoans is represented.

Collections from this shaly limestone above Stice coal and about 70 feet below top of Cherokee (fossil zone 5 CL).—Fossils are abundant at three or four localities in a thin, black, shaly limestone overlying the Stice coal. In one place this limestone is almost a coquina of marginiferas and occasional other brachiopods. Among the more common elements in the faunules are, in addition to the marginiferas, chonetids of the *mesolobus* type, *Spirifer cameratus,* hustedias, wellerellas, and compositids. A few gastropods and an occasional orthoceraconic cephalopod are found in the faunules.

Collections from sandstone between Stice coal and Ardmore limestone (fossil zone 6 CL).—A tan to steel-gray, medium-grained, friable, micaceous sandstone, which occurs between the Stice coal and the Ardmore limestone, contains fossil plants at some localities and at others fossil invertebrates. The invertebrates are preserved mainly as external molds and it is difficult to tell whether or not the shells had been worn before being enclosed in the sandstone matrix. The well-preserved impressions of rather long spines suggests, however, that they had not been eroded. The only common form is the brachiopod, *"Productus" (Linoproductus) prattenianus* Norwood and Pratten. Three pelecypod species and another brachiopod, an *Orbiculoidea,* also were obtained from this sandstone.

Collections from shales and thin limestones directly on a local coal about 95 feet below top of the Cherokee (fossil zone 7 CL).—Two collections that may not be from precisely the same stratigraphic positions were made from this zone in Labette county. One, from a hard, black, but slightly calcareous shale, contains plant impressions, two indeterminate brachiopods and *Aviculipecten rectilaterarius* (Cox). The other, whose stratigraphic relations are not surely known, contains seven species of brachiopods that are common in the Cherokee shale. The specimens appear to be from a weathered slope and the label is not clear regarding their precise relation to the coal.

Collections from the Ardmore limestone member, including some collections of uncertain position (fossil zone 8 CL).—Collections definitely from the Ardmore limestone came either from tan limestones or from dark to medium neutral gray, fine-grained, silty limestones that weather tan. The faunules are almost entirely of brachiopods, and in this respect resemble those of the Ardmore of the more northeasterly outcrops. Among the more abundant brachiopods are *Chonetes (Mesolobus) mesolobus* and its variety *decipiens, Marginifera muricatina, Marginifera wabashensis, "Productus,"* including *"Productus" (Linoproductus) prattenianus* Norwood and Pratten and *"Productus" (Juresania) nebrascensis* Owen, and *Squamularia perplexa* (McChesney). Bryozoans are not uncommon. A *Naticopsis?* occurs in one of the collections and other gastropods occur in other collections; and indeterminate specimens of *Gastrioceras* occur in two collections.

which ranges but a short distance below the Ardmore. On the other hand, *Marginifera muricatina missouriensis* and *Spirifer occidentalis* are more characteristic, if not actually restricted in this part of southeastern Kansas to beds below the Ardmore. Large cephalopods seem also to be more common in the lower part of the Cherokee in southeastern Kansas. *Spirifer matheri* occurs only in our Breezy Hill collections and comes from both the Crawford-Cherokee county and Labette county areas. *Marginifera wabashensis* was collected only from the Ardmore limestone and occurs in it in both areas. The significance of the restricted ranges of these two forms and of *Spirifer occidentalis* in our collections cannot, however, be considered great, as they have wider ranges elsewhere.

Three or four of the thinner zones of the Cherokee are very distinctive in Cherokee and Crawford counties. One of the most distinctive is a very fossiliferous zone in a black calcareous shale or limestone that occurs above the Mineral coal. At nearly every locality from which collections were made from this zone in Crawford and Cherokee counties a large and varied fauna was obtained. This zone is characterized by its abundance of fossils, by its relatively large number of *Spirifer cameratus*, *"Productus"* (*Linoproductus*) *prattenianus*, and *Marginifera muricatina* and by the great numbers and several varieties of chonetids. Fusulinids are abundant at many localities. The fusulinids and chonetids in this zone locally distinguish it from our collections from a somewhat similar zone above the Bevier coal. The zone above the Mineral coal also has several bryozoans and some pelecypods not collected from the zone above the Bevier coal and in addition, *Spirifer occidentalis*, a brachiopod not collected from as high as the Bevier coal during this study.

Another distinctive zone within the Cherokee in Crawford and Cherokee counties is a black shale zone between the Ardmore limestone and the Croweburg coal. This zone somewhat resembles a zone at the very top of the Cherokee, one to three feet below the Fort Scott limestone. Both contain black "paper-thin" shales, with small phosphatic nodules and large calcareous nodules. In the zone beneath the Ardmore, small cephalopods are very frequently found by splitting the small phosphatic nodules.

The Breezy Hill limestone is characterized by its variability in faunules as well as in lithology. At some localities, gastropods are abundant; at others, brachiopods are nearly the only fossils collected.

An unnamed limestone that is 25 feet below the Fort Scott and has a limited areal extent in the northeast corner of T. 31 S., R. 23 E., is characterized by an abundance of one species of productid, *"Productus"* (*Dictyoclostus*) *portlockianus*. All collections from it show an abundance of this species, and they are so abundant in at least two localities as to suggest the term, productid coquina. It is the only gray limestone bed seen in which this species is so abundant and may be easily distinguished locally.

A zone from a few inches to 2 feet above the Fleming coal may be easily distinguished at most localities from the zone above the Mineral coal, by the small variety of fossils occurring in it.

Zones below the Mineral coal are in general less fossiliferous than zones above it. A zone above the Pilot coal is characterized by thin ironstones and ferruginous limestones, containing a large proportion of small gastropods and some cephalopods. Trachydomas occur in at least two collections.

The characteristics of the other zones not specifically mentioned here have been given in the discussions of their faunas.

appears not to be represented in beds collected from in the Crawford-Cherokee county area. Zone 12 CL has in general the same species and to a certain extent the same proportions of species as zone 11 CC, black calcareous shale or limestone above the Mineral coal. When the evidence from the stratigraphic sequence is also considered, there appears to be sufficient faunal data to allow their correlation. Zones 12 CC to 17 CC are thought to be older than the oldest zone from which fossils were obtained in Labette county.

Differences Between the Cherokee and Fort Scott Formations and Regional Correlation of the Cherokee

An inspection of the collections here studied if taken alone would suggest several faunal means of distinguishing the Fort Scott and the Cherokee limestones. Some of these are probably valid; others are shown to be invalid by the published findings of other paleontologists.

The following species in our Fort Scott collections do not occur in our Cherokee collections: *Chaetetes milleporaceus, Cystodictya* n. sp., *Meekella striatocostata, Meekella striatocostata grandicosta, "Productus" (Echinoconchus) semipunctatus knighti, "Productus" (Krotovia?)* sp. undescribed, and several pelecypod and gastropod species. The first and third have, however, been reported by Girty from the upper limestones of the Cherokee, and the fourth may occur in the Cherokee. Another species that might be significant is *Prismopora triangulata.* It occurs in only one of our collections from the Cherokee and is there rather doubtfully identified, but it is common in our Fort Scott collections. However, it also has been reported from the upper part of the Cherokee by Girty and hence cannot be used as a diagnostic form of the Fort Scott. *"Productus" insinuatus* has been considered as a Fort Scott or higher index fossil, but it was also found in one collection from the Breezy Hill limestone made by one of the field assistants.

Several species and varieties occur in the Cherokee collections that do not occur in the Fort Scott, but most of them are from beds low in the Cherokee. They include: *Rhombopora lepidodendroides* n. var., *Marginifera muricatina missouriensis, Spirifer matheri, Spirifer rockymontanus* and a number of pelecypods and gastropods. These appear to be valid fossils for distinguishing the lower limestones of the Cherokee from the Fort Scott, but only a few can be used in distinguishing high Cherokee limestones from the Fort Scott limestone.

Our collections suggest that in southeastern Kansas the most useful means of distinguishing the Fort Scott and upper limestones of the Cherokee are: the greater abundance in the Fort Scott of *Chaetetes milleporaceus, Prismopora triangulata, "Productus" insinuatus,* and *Chonetes (Mesolobus) mesolobus euampygus,* and the greater abundance locally in the Cherokee of *Chonetes (Mesolobus) mesolobus, Marginifera muricatina,* and *Marginifera wabashensis.* Some more or less rare species, some of which have been discussed above, may be of use at times and when lower beds of the Cherokee are involved *Marginifera muricatina missouriensis* and certain spirifers that have been mentioned are useful. A number of rarer forms that can at times be used are mentioned by Beede and Rogers.[106]

106. Beede, J. W., and Robers, A. F., Coal measures faunal studies: Kansas Univ. Sci. Bull. 2, pp. 459-463, 1904.

7750. Cherokee county, 1¼ miles west and 1 mile north of Mineral. Along stream, about 1,700 feet east and 1,000 feet north of southwest corner of sec. 36, T. 31 S., R. 22 E. Cherokee shale, Ardmore limestone member. (Fossil zone 7 CC.)

7751. Cherokee county, 2¼ miles south and 3 miles west of Mineral. Along road at small creek, near center of east line of NE¼ sec. 22, T. 32 S., R. 22 E. Cherokee shale, Ardmore limestone member; from slabs. (Fossil zone 7 CC.)

7752. Labette county, 1½ miles south and ½ mile east of southeast limits of Oswego. Road cut on quarter section line road, 100 feet south of a concrete bridge in sec. 27, T. 33 S., R. 21 E. Cherokee shale, Ardmore limestone member?; from limestone and shales below. (Fossil zone 7 CC.)

7753. Crawford county, same locality as 7744. Cherokee shale, from thin black limestone within 4 or 5 feet above Bevier coal. (Fossil zone 6 CC.)

7754. Crawford county, same locality as 7744, except in strip pit about an eighth of a mile north of 7744 and about 50 feet east of road on west line of section 21. Cherokee shale, from 3 to 4 inch black fine-grained clayey limestone with white calcite "threads," within 4 or 5 feet above Bevier coal. (Fossil zone 6 CC.)

7755. Cherokee county, 2 miles west and 1½ miles north of Mineral. In strip pit, 500 feet north and 1,300 feet west of southeast corner of section 26, T. 31 S., R. 22 E. Cherokee shale, shale about 8 feet above Ardmore limestone member. (Fossil zone 6 CC.)

7756. Crawford county, same locality and horizon as 7749.

7757. Crawford county, same locality as 7759. Cherokee shale, gray micaceous shale 3 feet below local limestone. (Fossil zone 5 CC.)

7758. Labette county, just east of Oswego, NW¼ NW¼ sec. 15, T. 33 S., R. 21 E., about 1,200 feet east of a bridge over Neosho river and on south side of river and 5 feet above water. Cherokee shale, hard, black shale above a local coal and about 95 feet below top of formation. (Fossil zone 7 CL.)

7759. Crawford county, 2 miles north and 1 mile west of Cherokee. On road along west line of sec. 1, T. 31 S., R. 23 E. Four tenths of a mile north of southwest corner of said section and 50 feet south of south end of first bridge one meets in going north from southwest corner of sec. 1. Cherokee shale, local limestone 20 to 25 feet below base of Fort Scott limestone, 14-inch medium dark neutral gray, finely crystalline to dense limestone which weathers yellow-brown and is almost a coquina of productid shells. (Fossil zone 4 CC.)

7760. Crawford county, same locality and horizon as 7749 and 7756.

7761. Crawford county, about 2 miles south and 1¼ miles east of Girard. On north line of sec. 5, T. 30 S., R. 24 E.; in pasture along small stream east and about 100 feet south of where stream crosses road which runs along north line of section. Locality is about one fifth of a mile east of the northwest corner of section 5. Cherokee shale, Breezy Hill limestone member. (Fossil zone 2 CC.)

7762. Crawford county, same locality as 7749, except a few hundred feet west of 7749 and nearer to but still east of top of a hill; opposite and a few feet east of east limits of a cemetery. Cherokee shale, Breezy Hill limestone member; very finely crystalline to dense, dark neutral gray limestone that weathers light yellow-brown. (Fossil zone 2 CC.)

7763. Crawford county, one mile east of Arma. On south line sec. 4, T. 29 S., R. 25 E., about 2,300 feet west of southeast corner of section. North side of road in cut below crest of hill. Cherokee shale, Breezy Hill limestone member; from a thin sandy limestone. (Fossil zone 2 CC.)

7764. Crawford county, one mile north of Englevale. In southeast corner SW¼ NE¼ sec. 13, T. 28 S., R. 24 E. In field along creek east of a point on railroad midway between first cut north of south line of section 13 and next cut north; and north of small trestle where this creek crosses railroad and about 100 to 150 feet east of railroad, on west bank of stream. Cherokee shale, Breezy Hill limestone member; from a sandy, reddish-brown to brownish-gray, medium to finely crystalline limestone. (Fossil zone 2 CC.)

7765. Labette county, about 3 miles east and half a mile south of Bartlett. In ditch to south of road, about 300 feet west of northeast corner of sec. 36, T. 34 S., R. 20 E., and about halfway down a hill and below a black shale. Cherokee shale, Breezy Hill limestone member. (Fossil zone 2 CL.)

7766. Labette county, 1½ miles south and half a mile east of Oswego. In road cut near center of section and 100 feet south of a concrete bridge in sec. 27, T. 33 S., R. 21 E. Cherokee shale, shale about horizon of a local coal and about 95 feet below top of formation. (Fossil zone 7 CL.)

7767. Labette county, about 1 mile south of Oswego, from north end of a strip pit and

strip pit mine 100 feet south of east-west road in NE¼ NW¼ NW¼ sec. 5, T. 28 S., R. 25 E. Fort Scott limestone, basal 5 feet of lower limestone member.

7791. Labette county, same locality and horizon as 7788.

7792. Labette county, 1½ miles south and 1½ miles west of Bartlett. Along creek near center south line of sec. 32, T. 34 S., R. 20 E. Fort Scott limestone, upper limestone member.

7793. Crawford county, 1¼ miles west and half a mile north of Englevale. In pasture to north of and just across fence from (25 ft. north of fence) road between sections 14 and 23, T. 28 S., R. 24 E., 1,250 feet west of southeast corner of sec. 14, and about 50 yards east of 7794. Fort Scott limestone, upper limestone member; from a 3- to 6-inch bed of yellow brown to olive, finely crystalline limestone at top of upper Fort Scott.

7794. Crawford county, 1 mile west and half a mile north of Englevale. In pasture along stream, just across fence south of road between sections 14 and 23, T. 28 S., R. 24 E. About 1,400 feet west of northeast corner of section 23. Fort Scott limestone, upper limestone member; from a light neutral to whitish-gray, finely crystalline limestone that weathers yellow-brown.

7795. Crawford county, same locality as 7786. Fort Scott limestone, black shale about 30 inches below base of upper limestone member.

7796. Labette county, 1½ miles north and 1 mile east of Bartlett. In southeast corner SE¼ sec. 15, T. 34 S., R. 20 E. Fort Scott limestone, lower limestone member.

7797. Labette county, 6 miles north and 1 mile west of Montana. In NE¼ sec. 7, T. 31 S., R. 21 E. (precise location uncertain). Labette shale, about 6 feet below top; from thin black limestone.

7798. Labette county, 6 miles north and 1 mile west of Montana. In SW¼ SE¼ NE¼ sec. 7, T. 31 S., R. 21 E. Labette shale, about 7 feet below top; from a thin black limestone.

7799. Labette county, 1¾ miles west and half a mile south of Montana. Roadside ditch at southwest corner of road intersection and across road from northwest corner sec. 18, T. 32 S., R. 21 E. Top Labette shale; from phosphatic nodules from black shales.

7800. Labette county, 2½ miles north and 2 miles west of Chetopa, along a draw about 2,400 feet east and 1,900 feet south of northwest corner of section 20, T. 34 S., R. 21 E. Cherokee shale, shale 1 to 3 feet below Ardmore limestone member. (Fossil zone 9 CL.)

7801. Labette county, 2 miles north and 1½ miles west of Chetopa, from strip pit along road and about 1,800 feet south of northwest corner of sec. 21, T. 34 S., R. 21 E. Cherokee shale, shale 1 to 3 feet below Ardmore limestone member; from small black phosphatic nodules. (Fossil zone 9 CL.)

7802. Crawford county, about 1 mile north and three quarters of a mile west of Mulberry. From a strip pit in NW¼ SW¼ sec. 26, T. 28 S., R. 25 E. Cherokee shale, cap limestone of Mineral coal; from a black shaly limestone. (Fossil zone 11 CC.)

7803. Crawford county, 1 mile north and 3½ miles east of Englevale. From strip pit near center of sec. 15, T. 28 S., R. 25 E. Cherokee shale, cap limestone of Mineral coal; from a very shaly black limestone or calcareous shale. (Fossil zone 11 CC.)

7804. Vernon county, Missouri, one mile north and three quarters of a mile east of Arcadia. From a strip pit about 3,000 feet west and 1,500 feet north of southeast corner of sec. 31, T. 34 S., R. 33 W. Cherokee shale, shale less than 6 feet below Ardmore limestone member; from small phosphatic nodules and large black calcareous nodules. (Fossil zone 8 CC.)

7805. Crawford county, half a mile south and 2 miles east of Englevale. Along Cox creek, opposite where tributary that drains strip pit empties into Cox creek, about in SW¼ SW¼ sec. 21, T. 28 S., R. 25 E. Cherokee shale, shale less than 6 feet below Ardmore limestone member; from a large calcareous concretion which had been removed a foot or so from where it probably came. (Fossil zone 8 CC.)

7806. Crawford county, 1 mile south and 2½ miles east of Farlington, along road between sections 16 and 21, T. 28 S., R. 24 E., on bank above roadside ditch to south of road, and just west of top of hill. About 2,000 feet west of northeast corner of sec. 21. Pawnee limestone.

7807. Labette county, 1¾ miles south and three quarters of a mile west of Montana. Along road on east side of sec. 19, T. 32 S., R. 21 E., about 2,400 feet south of northeast corner of section and in SE¼ SE¼ NE¼ sec. 19. Labette shale; from six-inch black limestone about 7 feet below top.

7808. Labette county, 5 miles north and a quarter of a mile west of Montana. In road cut in NE¼ NW¼ sec. 17, T. 31 S., R. 21 E. Lower part of Pawnee limestone.

7809. Crawford county, 2 miles west of Englevale. About a quarter of a mile due south

northwest corner of sec. 9, T. 32 S., R. 23 E., and about 300 feet east of a church. Cherokee shale, cap limestone of Mineral coal; from a 4- to 6-inch black shaly limestone represented by blocks which were loose but came from immediately above the coal. (Fossil zone 11 CC.)

7827. Cherokee county, same locality as 7815 but from lower beds. Cherokee shale, beds above Mineral coal; from a very limy black shale within a few inches of the top of the coal. (Fossil zone 11 CC.)

7828. Cherokee county, 3 miles south and 1 mile west of Mineral. Old abandoned pit in field 150 feet north of road on south side of sec. 24, T. 32 S., R. 22 E., and about half a mile east of southwest corner of section 24. About 75 feet west of a small stream which crosses road under a concrete culvert, which is the first concrete culvert from the southwest corner of section 24. Cherokee shale, cap limestone of Mineral coal; from a thin black limestone and limy shale zone a few inches above the coal. (Fossil zone 11 CC.)

7829. Crawford county, about 1½ miles south of Arcadia. From along a small creek, 10 to 50 feet west of a bridge of poles and stones, and 90 feet south and 900 feet east of northwest corner of sec. 13, T. 28 S., R. 25 E. This is across road south of a mine dump and is about 3,000 feet west of Kansas-Missouri line. Cherokee shale, 3- to 4-inch limestone about 20 inches above Pilot coal; the limestone is 10 inches below a 1- to 2-inch ironstone bed. (Fossil zone 12 CC.)

7831. Cherokee county, 5 miles south of southeast limits of Pittsburg. Along south bank of Cow creek, about 1,000 feet south and 100 feet east of northwest corner of sec. 28, T. 31 S., R. 25 E. Cherokee shale, limestone below Weir-Pittsburg coal; exact distance below coal unknown, but thought to be about 25 feet. (Fossil zone 14 CC.)

7832. Crawford county, same locality as 7829, but from black "paper-thin" shale below limestone that yielded collection 7829 and above Pilot coal. (Fossil zone 12 CC.)

7833. Cherokee county, in west edge of Scammon. On south bank of a stream and about 150 feet east of section-line road (Highway 7) about four tenths of a mile south of northwest corner of sec. 7, T. 32 S., R. 24 E. From bed of creek at point where stream turns from southward to westward to cross highway. Cherokee shale, shale less than two feet above Pilot(?) coal; from black calcareous shale below a 3- or 4-inch ferruginous limestone. (Fossil zone 12 CC.)

7834. Cherokee county, same locality and horizon as 7833.

7835. Cherokee county, same locality as 7833, but from a 3- to 4-inch bed of very ferruginous limestone a few inches above beds of 7833.

7836. Same locality and horizon as 7828.

7837. Barton county, Missouri, 2½ miles east of Mulberry. Along south line SW¼ SW¼ sec. 4, T. 32 N., R. 33 W. Cherokee shale, limestone below Weir-Pittsburg coal; from a brownish red limestone of unknown position, but thought to be 20 to 25 feet below coal. (Fossil zone 14 CC.)

7838. Barton county, Missouri, about 3 miles north of Minden. From strip pit about 400 feet east and 50 feet north of southwest corner of sec. 17, T. 32 N., R. 33 W., and across road and a little north and about 400 feet east of Fairview school Dist. No. 6. Cherokee shale, shale about 24 inches above Pilot coal; from a red very ferruginous 4- to 6-inch shale. (Fossil zone 12 CC.)

7839. Cherokee county, about 3½ miles south and 1 mile east of Columbus, near northeast corner sec. 6, T. 34 S., R. 24 E. On rise across side ditch to west from road, within 10 to 15 feet of ditch, and about 75 yards west and then south of a railroad viaduct, which viaduct is just before road turns definitely south. Cherokee shale, from a thin brownish red ferruginous and calcareous shale or ironstone about 50 feet below Bluejacket sandstone member. (Fossil zone 16 CC.)

7840. Cherokee county, 11 miles south and 1 mile west of Columbus. From mine in sec. 10, T. 35 S., R. 23 E. Cherokee shale, basal beds, 5 to 10 feet above Mississippian limestone. (Fossil zone 17 CC.)

7841. Cherokee county, 5 miles south and 2 miles west of Columbus. Along stream in SW¼ SE¼ sec. 9, T. 34 S., R. 23 E. Cherokee shale, limestone 10 to 14 feet below Bluejacket sandstone member. (Fossil zone 16 CC.)

7842. Cherokee county, 4 miles south of Columbus. On west bank of a small stream on west side of old strip pit in SW¼ SW¼ sec. 6, T. 34 S., R. 24 E. Cherokee shale, 10- to 12-inch impure lenticular limestone 20 feet below Bluejacket sandstone member; approximately same stratigraphic horizon as the Elm Creek limestone of Weidman. (Fossil zone 16 CC.)

7866. Crawford county, 3 miles due west of Cherokee. About 400 feet west of center of east line of sec. 16, T. 31 S., R. 23 E., and just south of a railroad trestle. Cherokee shale, Ardmore limestone member; from a calcareous conglomerate or lime-pellet bed. Fossils may be transported but are more probably indigenous. (Fossil zone 7 CC.)

7867. Crawford county, same locality as 7813. Cherokee shale, Ardmore limestone member. (Fossil zone 7 CC.)

7868. Crawford county, southwest edge of town of Mulberry. From strip pit 1,900 feet west and 600 feet north of center of sec. 1, T. 29 S., R. 25 E. Cherokee shale, from upper bed of a series of 3 or 4 limestones within 4 or 5 feet above Bevier coal; from fine-grained black limestone with white calcite "threads." (Fossil zone 6 CC.)

7869. Crawford county, 1½ miles north and 2 miles west of Cherokee. At center of west line NW¼ NW¼ sec. 11, T. 31 S., R. 23 E. Cherokee shale, unnamed local limestone 25 feet below top. (Fossil zone 4 CC.)

7870. Cherokee county, 2 miles north of Mineral. At center of east line SE¼ sec. 30, T. 31 S., R. 23 E. From ditch on west side of road. Cherokee shale, shale 2 to 6½ feet below Breezy Hill limestone member. (Fossil zone 3 CC.)

7871. Labette county, 3 miles west of west limits of Chetopa. Railroad cut near east line of sec. 36, T. 34 S., R. 20 E., and about 1,800 feet north of southeast corner of section 36. Cherokee shale, Breezy Hill limestone member; from a very sandy but fine-textured limestone. (Fossil zone 2 CL.)

7872. Crawford county, same locality and horizon as 7762.

7873. Labette county, 3 miles west of west limits of Chetopa. On west line of sec. 31, T. 34 S., R. 21 E., about 2,200 feet south of northwest corner of section. Cherokee shale, Breezy Hill limestone member; from a coarse sandy limestone. (Fossil zone 2 CL.)

7874. Labette county, 1 mile south and half a mile east of Bartlett. From near the southwest corner NE¼ sec. 34, T. 34 S., R. 20 E. Fort Scott limestone, lower limestone member; from a single slab of rock.

7875. Labette county, half a mile north and 3 miles west of Chetopa. SW¼ sec. 30, T. 34 S., R. 21 E. Fort Scott limestone, lower limestone member.

7876. Labette county, half a mile north and 3 miles west of Chetopa. In SW¼ sec. 30, T. 34 S., R. 21 E. Fort Scott limestone, lower limestone member.

7877. Labette county, 1¾ miles north and half a mile west of Bartlett. In bed of Dry creek near the west center of the SE¼ sec. 16, T. 34 S., R. 20 E., and about 2,200 feet west and 1,200 feet north of the southeast corner of section 16. Fort Scott limestone, lower limestone member.

7878. Labette county, 1½ miles east of Bartlett. NW¼ NW¼ SE¼ sec. 26, T. 34 S., R. 20 E. Fort Scott limestone, lower limestone member.

7879. Labette county, in city park of Oswego overlooking Neosho river. NW¼ sec. 15, T. 33 S., R. 21 E. Fort Scott limestone, lower limestone member; from a piece of light yellow-brown limestone float, taken from near lower limestone outcrops.

7880. Cherokee county, same locality and horizon as 7822.

7881. Labette county, half a mile north and 3 miles west of Chetopa. Along road on south line SW¼ sec. 30, T. 34 S., R. 21 E., about 900 feet east of southwest corner of section. Fort Scott limestone, lower 2 feet of upper limestone member.

7883. Crawford county, 2 miles south and 4 miles west of Girard. Along north side of a draw about 700 feet west and 1,000 feet north of southeast corner of sec. 31, T. 29 S., R. 23 E. Fort Scott limestone, upper limestone member.

7884. Labette county, half a mile north and 1¼ miles west of Bartlett. On west side of creek near southeast corner sec. 20, T. 34 S., R. 20 E. Fort Scott limestone, upper limestone member.

7886. Crawford county, same locality and horizon as 7794.

7887. Labette county, 1½ miles north and 1¼ miles west of Chetopa. From strip pit on east side of road about 700 feet south of northwest corner of sec. 28, T. 34 S., R. 21 E. (locality somewhat ambiguous on label). Cherokee shale, cap rock Mineral coal; from black limestone directly on coal. (Fossil zone 12 CL.)

7888. Labette county, 3 miles west of west limits of Chetopa. On north side of Missouri Pacific railroad. On center west line SW¼ sec. 31, T. 34 S., R. 21 E. Cherokee shale, Breezy Hill limestone member?; about 15 feet below Fort Scott limestone. (Fossil zone 2 CL.)

7889. Labette county, 1 mile south and 2 miles west of southwest limits of Chetopa. In team strip pit, about 1,000 feet east of southwest corner of sec. 5, T. 35 S., R. 21 E., 40