# THE CHEROKEE OF SOUTHEASTERN KANSAS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

ILLUSTRATIONS

ILLUSTRATIONS CONTINUED

# CHAPTER I

## INTRODUCTION

The object of this report is to record the results of a detailed survey of the Cherokee shale. The different members of the Cherokee are described so that they may be recognized and differentiated from each other. Some of these members are correlated with recognized members of the Cherokee in the adjacent areas of Missouri and Oklahoma. The economic geology of the Cherokee within the area of the outcrop and its geologic history are summarized.

The Cherokee has been commonly defined as the lowest division of the Pennsylvanian system in Kansas[1/], or the beds which lie between the base of the Ft. Scott limestone and the upper unconformable surface of the formations lying within the Mississippian system. It consists of shales, sandstones, coals and limestones, which are of considerable geological importance, because of their content of coal, oil, gas, and clays, and because they contain several peculiar sequences of beds that always occur in the same order and indicate the nature of their geologic history. Of the 129 formations recognized in the state of Kansas, there are only four that have a greater thickness than the Cherokee, which is about 450 feet thick[2/]. These are the Pierre shale

1/Haworth, Erasmus, Stratigraphy of the Kansas Coal Measures; University Geological Survey of Kansas, vol. 3, p. 21, 1898.

2/Moore, Raymond C., Rock Formations of Kansas; Kansas Geological Survey, 1935.

and the Niobrara chalk of the Cretaceous system, and the Enid and Wellington formations of the Permian system.

In southeastern Kansas the Cherokee has a thickness of about 450 feet which equals the average thickness for the state, but southward in Oklahoma equivalent beds thicken to about 10,000 feet or more.[3] The Cherokee sediments in Kansas are predominantly shale but include some very thin limestone members and a number of important oil-and-gas producing sandstone beds and lenses. The well known Bartlesville sand belongs to the Cherokee. It also contains several wide-spread and economically important coal beds. Its members in southeastern Kansas are more persistent laterally than has been indicated by most writers. The limestone members become thicker and are more numerous to the west, while the sand members thicken to the south.

The lithologic character, the thickness, and lateral persistence of the beds of the Cherokee in Missouri is described as extremely variable, however in Vernon County sandstone makes up a large part of the formation.[4]

The sub-surface distribution of the Cherokee is extensive. It is known to underlie a large part of Kansas, Missouri, Nebraska, Iowa and Oklahoma.

3/Moore, Raymond C., Pennsylvanian Cycles in the Mid-Continent Region. Illinois State Geological Survey Bull., No. 60, p. 249, 1931

4/Greene, F. C., and Pond, W. F., The Geology of Vernon County, Missouri: Bureau of Geology and Mines p. 35, 1926.

Although considerable work has been done on the Cherokee, little has been definitely accomplished in the way of correlation of its divisions within Kansas. Several workers on the Pennsylvanian have expressed the need for such correlation; yet no serious effort has been made to segregate the different divisions within the state. This failure is no doubt due to the paucity of fossils, the lack of persistent hard layers producing prominent escarpments, and the comparatively thick mantle of rock debris which has accumulated from the weathering and disintegration of weak shales and which more or less completely obscures the outcropping beds of coal, sandstone, and thin limestone.

## Location and Extent

The Cherokee outcrop in Kansas forms a belt which is approximately 20 miles in width and extends northeast and southwest across the southeastern corner of the state. It has an area of 1000 square miles and includes the southeastern part of Labette County, the southeastern part of Bourbon County, the southeastern half of Crawford County and almost all of Cherokee County. The type locality of the Cherokee is in Cherokee County Kansas. The location and extent of the Cherokee outcrop in Kansas is shown on map in Fig. 1.

## Topography

The topography of the Cherokee belt is controlled to a great extent by the lithologic character and the structure of the beds. Most of the outcrop area is a plain called the Cherokee Lowlands.[5/] It is dissected by broad, shallow, flat-bottomed valleys along the larger streams. The plains area is bounded on the west by the prominent, steep, east-facing escarpment of the resistant limestone members of the Ft. Scott formation, which extends from the Oklahoma state line southwest of Chetopa in Labette County, northeastward to the Missouri state line about eight miles northeast of Ft. Scott in Bourbon County. It is bounded on the east by the outcrop area of the Mississippian limestone, which covers an area of about forty square miles in the southeastern corner of Cherokee County. The elevation of the Cherokee plain in Kansas ranges from 800 to more than 1,100 feet.

The Cherokee Lowlands are divided into two major drainage areas by a prominent north and south divide that extends from Treece near the Kansas-Oklahoma line northward through Columbus and Weir in Cherokee County and through Cherokee, Beulah, Girard, and Farlington in Crawford County. The western slope of this divide is drained by the Neosho river and its tributaries, Lightning, Deer, and Cherry

5/Adams, G.I., Phsiography and Geology: Kansas Adacemy of Science, vol. 14, p. 53. 1899.

creeks. The eastern slope of the divide is drained by the Spring river and its tributaries, Cow, Brush, and Willow creeks.

The only persistent limestone that outcrops in the region does not form a conspicuous escarpment at some localities for two reasons. The first is because there is a reversal of dip at its outcrop, which is as much as 60 feet to the mile in a southeast direction, in contrast to the normal dip to the northwest of about 20 feet to the mile. The other reason is thick beds of shale overlying the relatively thin bed of limestone disintegrate and form a thick mantel of soil which in most places obscures the outcrop.

## Soil

The soils of the Cherokee outcrop area may be divided into two major groups: (1) Residual soils, and (2) Transported or bottom land soils.

Residual soils. Residual soils are defined as the soils formed by the disintegration and decomposition of rock materials at the place where the soils are now found. They occur on the tops and sides of hills, or on level plains; in fact, they are widely distributed over this entire outcrop area except in the stream valleys. The residual soils may be subdivided into (1) those derived from the disintegration and decomposition of limestone, (2) those derived from the disintegration and decomposition of sandstone, (3) those derived from the disintegration and decomposition of shales, and (4) combinations of the three types.

The limestone residual soil occupies a narrow belt four to ten miles in width along the western border of the outcrop area and parallel to the escarpment of the Ft. Scott limestone formation. It covers about ten square miles in the extreme northeastern part of Cherokee County and in that part of southern Crawford County that is drained by Thunderbolt and Limestone creeks. From Girard to the Missouri state line the limestone soil belt is from three to four miles in width and covers only the hill-tops on the upland plains.

Sandstone residual soil occurs largely in the south-eastern part of Cherokee County, covering an area of about 100 square miles between Columbus and Spring river.

Shale residual soil occupies all of the remainder of the area with the exception of the stream valleys.

Transported soils. Transported soils are defined as made up of particles that have been transported some distance from the place of origin. The soils of this type in the Cherokee Lowlands are stream-borne or alluvial. These soils cover the flood plains bordering the major streams, sometimes having a width of several miles. Because of the variety of minerals of which they are composed, they are the most fertile soils of the area.

## Previous Work

Important contributions to the geological literature on the coal fields of southeastern Kansas have been made be G. C. Broadhead, Erasmus Haworth, G. I. Adams, G. H. Girty, David White, W. R. Crane, M. Z. Kirk, J. W. Beede, A. F. Rogers, John Bennet, C. R. Keyes, and Raymond C. Moore. The work of Henry Hinds and F. C. Greene on the coal fields of adjoining areas in Missouri and the work of J. Marvin Weller and H. R. Wanless in Illinois also bear on the geology of southeastern Kansas.

The earlier reports of explorations, of the geology of Kansas, and of the Coal Measures, give no mention of the Cherokee shales. The southeastern Kansas coal field is mentioned and very briefly described by Broadhead[6/] in 1882. In the same year a paper on the coal fields of Cherokee County by Erasmus Haworth,[7/] then of Empire City, Kansas, was read before the Kansas Academy of Science and was published in their Transactions in 1883.

6/Broadhead, G.C., Kansas City Review, vol. 6, pp. 172-175, 1882.

7/Haworth, Erasmus, The coal fields of Cherokee County: Kan. Acad. Sci., Trans., vol. 8, pp. 7-11, 1883.

The "Cherokee shales" is the name given to the lowest formation of the Pennsylvanian system in Kansas. The name was first used by Haworth[8] in 1894, who indicated that he desired the name to apply to the lowest member of the Coal Measures of Kansas, or the beds between the upper surface of the Mississippian and the Ft. Scott limestone, provided that the bed of limestone which had been named the "Swallow" and found to outcrop to the south of the town of Oswego about 80 feet below the Ft. Scott limestone, should be found not persistent over a wide area. If the "Swallow limestone" member should be found persistent, he desired the name "Cherokee shales" to apply only to that part of the shales below this member.

The name "Swallow limestone" did not survive for two reasons: first, the name was not a geographic one, and, second, the member had been previously described by Gordon[9] in 1893 and given the name of Ardmore from a town in the center of the Bevier coal mining district of Missouri. The name was used with only a local application for a number of years. In 1915 Hinds and Greene[10] in a discussion of the Cherokee in Vernon County, Missouri, make no mention

8/Haworth, Erasmus, Stratigraphy of eastern Kansas: Kan. Quart., No. 2, pp. 126-129, 1894.

9/Gordon, C.H., Sheet Report No. 2, p. 20, 1893, A report on the Bevier sheet: Mo. Geol. Survey, vol. IX, 1st seri, pt. 2, 1896.

10/Hinds, Henry, and Greene, G.C., The stratigraphy of the Pennsylvanian Series in Missouri: Mo. Bur. Geology and Mines, vol. 13, p. 38-61, 1915.

of the Ardmore, but refer to the "Mulky coal and its characteristic diamond-rock cap." This is not at all clear, but from other references it is assumed to mean the Tebo coal and the Ardmore limestone. In 1926 Greene and Pond[11] adopted the name Rich Hill limestone for this member, stating that it is probably the member to which Gordon applied the name Ardmore. They also state that the name Diamond Rock is applied to the same member in western Vernon County. In 1933 Greene[12] correlated the Rich Hill limestone with the Ardmore and Verdigris. Because of its early and fairly persistent use, the name Ardmore will be used in this report for this limestone.

There has been no published description of the Ardmore member in Kansas other than the mention of its existence by Haworth more than forty years ago. Recently the writer traced the outcrop of this limestone from Vernon County, Missouri, into Kansas and across the southeastern corner of the state to the Oklahoma line.

The paleontology of the Cherokee shales was described by Beede[13], and by Beede and Rogers[14], they give a

11/Greene, F.C., and Pond, W.F., The geology of Vernon County: Mo. Bur. Geology and Mines, p. 51, 1926.

12/Greene, F.C., Oil and gas pools of Western Missouri: Appendix II., Bien. Rept. of the State Geologist, Mo. Bur. Geology and Mines, p. 14-15, 1933.

13/Beede, J.W., Carboniferous invertebrates: Univ. Geol. Survey of Kansas, vol. 6, pp. 1-189, 1900.

14/Beede, J.W., and Rogers, Austin F., The faunal division of the Kansas coal: Univ. Geol. Survey of Kansas, vol. 9 pp. 337-340, 1908.

a list of twenty-eight species as the total number that had been found in the Cherokee.

The principle of cyclic sedimentation applied by Udden[15/] to the Coal Measures of Illinois, and more recently by Weller[16/] and Wanless[17/] in Illinois and by Moore[18/] in the northern Mid-Continent region, can be applied to the remarkable sequence of alternating beds of coal, shale, sandstone, and limestone so characteristic of the Cherokee of southeastern Kansas.

## Field Work

Field studies of the outcrop area of the Cherokee have been carried on by the writer more or less continuously since 1924. The early work in this type area was confined largely to economic and structural studies. Work on correlation of subdivisions of the Cherokee during this part of the work was rather discouraging because of

15/Udden, J.A., Geology and mineral resources of Peoria quadrangle, Illinois: U.S. Geol. Survey, Bull. 506, p. 47, 1912.

16/Weller, J. Marvin, The concept of cyclical sedimentation during the Pennsylvanian period: Ill. Geol. Survey, Bull. 60, pp. 163-177, 1931.

17/Wanless, H.R., Pennsylvanian cycles in western Illinois: Ill. Geol. Survey, Bull. 60, pp. 179-193, 1931.

18/Moore, Raymond C., Pennsylvanian cycles in the Northern Mid-Continent region: Ill. State Geol. Survey, Bull. 60, pp. 247-257, 1931.

the apparent discontinuity of beds and the failure to find definite faunal zones.

Later, however, stimulated by the work of Doctors Weller and Wanless in Illinois and of Doctor Moore in Kansas on cyclic sedimentation in the Pennsylvanian, the picture of irregular beds has changed into one having definite and characteristic order. The lack of fossils was largely apparent, for with each cycle of sedimentation there are in many places two well defined faunal zones with abundant marine fossils.

The structural maps (Figures 3 and 15) and geologic sections (Figures 4,5,6, and 7) were prepared from data obtained from the logs of more than 500 drill holes and a plane table survey which furnished the elevation of the surface of the ground at each drill hole.[19] The line of survey was run along each east and west section line, which was in most cases a county road, with side shots taken to the drill holes. The contour datum is the base of the Weir-Pittsburg coal bed, which is the lowest persistent coal bed and has the widest areal distribution of any coal bed of the Cherokee. A number of sections were taken at strip (coal) mines. The sections were perfectly

19/Elevations were also obtained from the St. Louis & San Francisco Railroad Company, the Atchinson Topeka and Santa Fe Railroad Company, the Missouri Pacific Railroad Company, the Crawford County engineer, and from the map of the Southeastern Kansas Coal Fields by W.G. Pierce, published by the U. S. G. S. and the Kansas State Geological Survey.

exposed at the time of observation, but most have been completely destroyed by subsequent stripping operations. Other sections were made from natural outcrops, underground workings, mine shafts, and drill records.

## Acknowledgments

This study of the Cherokee and its correlation was suggested by Dr. Raymond C. Moore and has been made under his supervision. His advice and criticisms have proved of great value, and to him the writer makes very grateful acknowledgment. To Dr. Kenneth K. Landes of the University of Kansas the writer is under obligation for many helpful suggestions and the general supervision of the preparation of this manuscript. The writer is grateful for the suggestions and advice of Professors W. H. Schoewe, and G. L. Knight of the University of Kansas, and to Maxim K. Elias and Dr. Norman D. Newell of the Kansas Geological Survey. The writer is also grateful to Professor C. M. Young of the University of Kansas for his criticisms on the chapter of Economic Geology. The Pittsburg and Midway Mining Company was helpful in supplying many valuable records of well logs. Some logs were also obtained from the Crowe Coal Company and the Western Coal and Mining Company. Valuable information was also supplied by the State Mine

Inspection Department, the Marion Shovel Company, Mr. Ira Clemmens; Mr. J. J. Stephenson, the Commercial Fuel Company, and the W. S. Dickey Clay Manufacturing Company. I also acknowledge the help of Gene Abernathy, who assisted with the plane table survey and mine mapping.

# CHAPTER II

## STRUCTURE

The Cherokee shale outcrops in southeastern Kansas on the western flank of the Ozark uplift. The strata of the Cherokee conform for the most part to the regional dip of the formations of southeastern Kansas and dip at a rate of from fifteen to twenty feet a mile in a direction slightly north of west. When the structure is examined in detail, many superimposed local irregularities may be noted, shown in Fig. 3. These minor folds are of importance because of their effect on the coal beds and because of the mining problems they introduce.

The detailed structure was determined by obtaining the elevation of readily recognized key beds penetrated by drilling. The key beds most used were the Ardmore limestone and the Weir-Pittsburg coal, the latter being of very uniform character, occurrence and distribution.

In parts of the field where the key beds are not present or not definitely identifiable, the contours shown in Fig. 2 have been projected on the basis of structural and stratigraphic data from adjacent areas. Where data are incomplete, contours are represented by dotted lines.

Cross-sections also illustrate the attitude of the beds along selected lines across the area. Fig. 4 is a cross-section along the strike of the coal beds, from the N. W. ¼ of section 20, T. 29 S., R. 25 E., to the N. W. ¼ of the S. E. ¼ of section 1, T. 32 S., 23 E., a distance of seventeen miles. Figure 5 shows a cross-section along the dip of the formations, from the center of section 18, T. 30 S., R. 24 E., to the outcrop of the Weir-Pittsburg coal bed in the S. W. ¼ of section 27, T. 30 S., R. 24 E., a distance of about five miles. Figure 6 shows a cross-section from the S. W. ¼ of section 36, T. 30 S., R. 23 E., to section 34, T. 30 S., R. 24 E., a distance of five miles. Figure 16 is two cross-sections of the beds in section 29, T. 31., R. 24 E. Figure 17 is a typical section of the 15 cyclothems recognized in the Cherokee.

## General Features

The more important structural features of the Cherokee are the following: 1. The regional structure, 2. An erosional unconformity within the Cherokee, 3. Prominent northwest and southeast anticlines, 4. A series of low folds of irregular size and form, 5. Minor faulting.

The regional structure. In the area of its outcrop in Kansas the Cherokee has an average dip of 20 feet to the mile, in a direction a little north of west. This steep dip changes abruptly near the western limit of its outcrop, to a very moderate dip, the beds lying nearly horizontal. (The regional dip is shown in Fig. 5.) The inclination of the strata in southeastern Kansas shows that a considerable amount of the warping of the coal basin occurred after the deposition of the Cherokee group. The regional dip of the Cherokee conforms closely with the surface of the underlying Mississippian.

Erosional unconformities. Most sandstone beds of the Cherokee rest unconformable upon a surface of considerable relief that resulted from erosion. In every case the sandstone beds are believed to be of continental origin. At some localities an unconformity cuts out several marine beds as well as a coal bed. At other localities an unconformity is indicated by the presence of a gravel conglomerate that rests upon the truncated edges of the underlying beds. And at other localities the unconformity is "non-evident." A well defined erosional unconformity occurs above the Weir-Pittsburg coal bed. This unconformity gives rise to the so-called "faults," which are so common as to be characteristic of the Weir-Pittsburg coal. A detailed examination of the underground workings of six large coal mines disclose that from 40 to 60 percent of the mine area is affected by the "faults." It is a common practice of the mining engineers when estimating the tonnage of strip-pit properties to allow a 20 percent loss because of so-called "faulty" coal.

A well developed stream channel was uncovered at this horizon by stripping operations in sections 1, 12, 13, and 24, T. 30 S., R. 24 E. The bottom of the channel was about two feet above the coal bed, and the channel sandstone had a maximum thickness of twenty-five feet and a width of more than a mile. Cross-bedding and ripple marks clearly showed stream action in the deepest part of the channel, which was filled with fairly well sorted sand. The sandstone, like the enclosing shale, is void of fossils.

## Local Features

Prominent anticlines. The most pronounced anticline in the district strikes N.W. and S.E. and extends from sec. 1, T. 30 S., R. 24 E., to sec. 36, T. 30 S., R. 25 E. The flanks of this anticline dip as much as sixty feet to the mile. Other anticlines less prominent than this are in general either parallel to it or at right angles. In some of the mines in the Weir-Pittsburg coal, very strong dips have been encountered. In extreme cases the coal bed dips as much as 75 feet in a horizontal distance of 300 feet. In many mines local dips are sufficiently strong to render mine haulage a serious problem. An excellent example of such a dip occurs in northern part of Cherokee County. Here the coal is sharply downfolded into a pronounced trough. It occurs in the center of sec. 36, T. 31 S., R. 23 E., in mine No. 7 of the Mayer Coal Company. From this location the axis strikes N. 40 degrees E., passing through mine No. 44 of the Central Coal and Coke Company located in the S.E. ¼ of sec. 30, T. 31 S., R. 24 E., in mine No. 1, of the Hamilton Coal Company in the N.E. ¼ of sec. 28, T. 31 S., R. 24 E., and in mine No. 23½ of the Kansas and Texas Coal Company in the S.W. ¼ of sec. 23, T. 31 S., R. 24 E. The dip of the coal is so steep at these locations that the coal could not be profitable extracted. Fig. 16

shows two sections across this syncline. These anticlines appear to be closely related in origin to the Ozark uplift and to have occurred in Pennsylvanian or post-Pennsylvanian time. Although the mid-continental basin was in existence before Pennsylvanian time, Weller[21/] finds that a certain amount of structural accentuation of the basin occurred during the Pennsylvanian period. He points out that the slight deepening of the basin which occurred from time to time during the period was balanced by the deposition of somewhat thicker sediments in this area so that the general eveness of the surface was maintained. The actual truncation of steeply dipping beds by an erosion surface cause different strata to end abruptly against the base of the overlying sandstones. Evidence that the warping which produced these anticlines took place during the Pennsylvanian time is the fact that the coal beds overlying the Weir-Pittsburg bed are not folded.

A series of low folds of irregular size and form. These folds vary in area from a few hundred square feet to a square mile or more. They have no regular pattern of form or arrangement. They have a relief of from five to fifteen feet. This type of fold, common throughout the Cherokee shale, is most common and has the most pronounced relief at the Weir-Pittsburg coal horizon. (A typical example

21/Weller, J. Marvin, Illinois State Geological survey, Bulletin No. 60, p. 166, 1931.

of an area containing these folds is shown in Fig. 3) Its origin is thought by the writer to be due to the differential compaction of the beds below the Weir-Pittsburg coal bed.

Minor faulting. Actual faults are not common. Crane[22/] states that the greatest displacement observed is eight feet in the Mount Carmel Coal Company mine. The strike of this fault is parallel to the fractures in the Tri-State lead and zinc district and probably made by the same forces which uplifted the Ozark dome.

The writer observed a normal fault in Mine 15 of the Jackson and Walker Coal Company, on Nov. 24, 1924 in the 22nd southeast entry. Here the strike is north 42 degrees east and the dip is 37 degrees southeast, with a vertical displacement of twelve feet. This fault was traced for about two miles.

22/Crane, W. R., The University Geological Survey of Kansas, vol. 3, p. 213, 1898.

## CHAPTER III

## ECONOMIC GEOLOGY

### Coal

Coal mining is the most important industry in southeastern Kansas. The geology of coal is of considerable interest because of the economic importance of coal.

<u>History</u>.[23/] The earliest record of coal mining in this district indicates that coal was mined between 1850 and 1860 in Cherokee County from open pits at the outcrop and hauled by wagon to Missouri, where it was used for blacksmithing. In 1870 the first railroad (The Missouri River, Ft. Scott and Gulf Railroad, later the Kansas City, Ft. Scott and Memphis, now the St. Louis and San Francisco Railroad) was built into the district for the purpose of tapping the coal field.

The early operations were carried on near Ft. Scott, but shallow coal was soon mined along the outcrop as far south as the former town of Stilson near the present town of Scammon. In 1874 Scammon brothers put down the first shaft mine north of Scammon, which produced as much as forty cars per day. In 1879 the Joplin and Girard Railroad was built from Joplin, Missouri, to Pittsburg, Kansas,

23/Material for the history of this district has been drawn freely from information furnished the writer from the offices of the State Mine Inspector, The Marion Shovel Company, The Pittsburg and Midway Coal Company, and the Commercial Fuel Company.

for the purpose of obtaining coal from the Kansas fields.

Since the opening of the Scammon shaft mine in 1874, the method of mining has been of the same type, the room-and-pillar system. An exception to this was in the mine of the Southeast Coal and Improvement Company at Mineral, where in 1879 the longwall system of mining was employed. This mine was also equipped with modern machinery, such as an electric hoist and an electric coal mining machine.

In the room-and-pillar system of mining, the rooms are about 24 feet wide and 150 feet long, with intervening pillars of coal six feet wide left to support the roof. Entries are driven from the shaft bottom to the outer limit of the property for ventilation and haulage purposes; these are from six to eight feet wide and about seven feet high. Most of the wider entries require timber to support the roof, the most common type of timber used being the three-piece set consisting of two posts and a cap. Rooms are turned off at regular intervals of thirty feet from the entries and the coal mined from them. The roof of the rooms usually stands without support, or at most requires only an occasional post, except in "fault" areas, where a great deal of timber support is required.

The coal is drilled by the hand auger type of drill, and shot with black powder "off the solid,"[24] then loaded by

[24] "Off the solid" is a term used by coal miners, indicating that the coal has not been undercut and there is only one free face to break to when blasting.

hand into small cars of about one ton capacity which the miner pushes out to the main line haulage. When a train of cars is gathered, it is hauled by mule or electric locomotive to the shaft called the "bottom" and hoisted to the tipple, where the mine cars are automatically dumped on a screen and the coal sized and loaded into railroad cars ready for market.

The first mining machine used in this district was installed in 1897. At present there are 20 mining machines in operation, two in one mine in Cherokee County and 18 in eight mines in Crawford County. The coal mined by these machines represents about 25 percent of the deep mine production of the district.

In the early history of the district coal was sometimes hoisted from the mines by a horse "whim." Of the 65 deep mines in the district in 1897, nine had horse-power hoists, 55 had steam hoists, and one had an electric hoist. In 1913, out of 128 mines, 25 hoisted by horse-power, 102 hoisted by steam, and one by electricity. The district contained 112 mines in 1935, with 80 hoists operated by gasoline engines, 19 by electric motors and 13 by steam engines. None was operated by horse-power; this type of hoist has been displaced by the gasoline engine.

The mines using a gasoline hoist are the so-called "dinky" type, usually operating on a cooperative plan with four or five miners. They are all shallow, ranging in depth from 12 to 140 feet, with an average depth of 32 feet. The mines operating by electric hoists are somewhat deeper, ranging from 35 to 140 feet with an average depth of 91 feet. The steam hoists are in mines having a depth of 26 to 285 feet, with an average of 175 feet. The Sheridan Coal Company's mine No. 21, which is 285 feet deep, is the deepest in the district. This mine is located about two miles west of Arma in Crawford County.

The average production per man-day for shaft mines in the district is about two and one-half tons. The smallest production per man-day reported for 1934 was 0.15 tons by the Wyatt Coal Company. The highest production per man per day in 1934 was 4.5 tons. This high record of production was from the Sheridan Coal Company mine No. 21, where eight mining machines were in operation. The Western Coal Mining Company's mine No. 24 produced the largest tonnage of any mine in the district, 127,592 tons or 3.32 tons per man-day.

The first mining operations in the southeastern Kansas coal district were carried on as strip mines called "wagon pits," at places where the coal beds were near the outcrop and covered by only a few feet of overburden. No record of an exact date is available, but it was probably some time before the Civil War. The early method of stripping was as follows: The areas to be stripped, which were from 50 to 100 feet in width and 200 to 400 feet in length, were selected along the creek banks where the overburden was usually shallow and there was a convenient place for teams and scrapers to dump the dirt and waste rock. After the overburden had been removed from the coal, the latter was broken up and loaded by hand into wagons and hauled to market.

Railroad contractors soon became interested in the problem of removing the overburden by mechanical means. As a result a steam shovel was first used for stripping coal in this district in 1877. This was also the first time a shovel had been used for this purpose in the United States. This shovel was built by the Otis Shovel Company and was operated near Pittsburg, Kansas, by the Hodges-Armil Company. This type of shovel was used at various localities in the district with but very little success and then only where the overburden was not more than a few feet thick. In 1900 John Miller stripped coal by means of a belt conveyor, but the method proved a failure. In 1910 an enterprising engineer by the name of Russell employed by the Vulcan Steam Shovel Company sought to overcome the mechanical defects leading to the failure of the railroad type shovel for coal mining. He was directed to consult with the operators of this district, and as a result of consultations with them and particularly with Ira Clemens, designed the first revolving shovel, making it possible to dump on either side of the pit. In 1905 three small shovels were built by this company. These had a two-yard dipper and were designed to remove fifteen feet of overburden. One was put to work in Crawford County, just north of the Kansas City Southern railroad shops at Pittsburg and was operated by J. J. Stephenson. The other two were operated in Cherokee County near Scammon by J. H. Durkee. Larger shovels with three-yard dippers were built in 1911 by the Bucyrus and the Marion companies: they weighed about 150 tons. These shovels enabled the stripping operations to be successful with a little thicker overburden. In 1915 many shovels were operated in the district that weighed about 335 tons, with a boom 75 feet long and a dipper of 6 cubic yards capacity, although a few had a dipper with eight cubic yards capacity and a boom 85 feet long. At this time all shovels in the district were operated by steam with the exception of one electric shovel operated by the Pittsburg and Midway Coal Mining Company a few miles northeast of Pittsburg near the state line. Between 1925 and 1935 there was a steady increase in size of stripping shovels. The largest at the present time has a weight of 1550 tons, a boom 90 feet long and a dipper of 18 cubic yards capacity. A factor furthering the development of the stripping shovels has been crawler or caterpillar traction for all forms of shovels. Previously they were mounted on four trucks with four wheels each. Another development of construction is a device for leveling the shovel by means of four hydraulic jacks. The most recent development with the power shovels is the aluminum dipper. The average weight of a twelve cubic yard steel dipper is 40,161 pounds. The average weight of a yard of dirt is 2,700 pounds. Therefore a shovel using the ordinary steel dipper of twelve cubic yards capacity can operate an aluminum dipper having fifteen cubic yards capacity, thereby increasing the production about thirty per cent. The present price of the aluminum dippers is $1,000 per cubic yard capacity. By 1935 Crawford County had six electric shovels and 17 steam shovels operating, and Cherokee County had two electric shovels and two steam shovels.

While the large type of shovels shown in figures 7 and 8 is the most interesting item of stripping equipment, the shovels are used only in removing the overburden from the coal bed.

In the early days all loading was done by hand. Later small steam shovels similar to the stripping shovels were used but were unsatisfactory because they produced an undesirable amount of crushed coal. A different type of power shovel loads the coal. This shovel has a dipper that is forced out horizontally at the base of the coal bed. It is then elevated, and the coal is dumped into two-ton pit cars and hauled by dinky locomotives from the pit to the tipple, where it is screened and loaded into railroad cars. This loading shovel; and the method of loading coal into cars in the pit is shown in figure 9 and the method of loading into trucks in the pit is shown in figure 10. The most recent practice is to load the coal into standard railroad cars standing on the bank. This is accomplished by the use of an additional machine, a so-called bank machine, to lift the coal from the pit. The machine is a revolving shovel with a drag-line boom. This type of shovel and the method of loading coal into cars standing on the bank is shown in figures 11 and 12.

The largest production from one shovel in 1934 was 301,482 tons of coal, from the Pittsburg and Midway Coal Company's mine No. 17 in Crawford County. They reported 100 men working 117 days, giving 27.7 tons of coal per man-day, which was also the highest production per man-day in the district.

The coal produced from strip mines in Crawford and Cherokee counties is about 70 per cent of the total tonnage of coal produced in the district. More than sixty per cent of all the power shovels stripping coal in Kansas are operating in Cherokee and Crawford Counties.

<u>Nature of the coal</u>. All coal can be classified into three major groups: lignite, bituminous and anthracite. The coal in this district belongs to the bituminous class. Some mines have sometimes produced a coal which has a brilliant luster and is noticably harder than the normal coals; however it is still classed as

bituminous coal. The shale overlying this harder coal contains many "slickenside" surfaces, indicating movement.

Bituminous coal is often called "soft" coal to distinguish it from "hard" coal or anthracite. Bituminous coal is also known as xyloid or woody coal. It is black in color and made up of bands having a brilliant luster known as glance or vitrain and bands of dull or mat coal known as durain.

Microscopic study of coals shows that the bright layers are made up largely of the bodies of plants and trees and that the dull layers are made up largely of the twigs, leaves, bark, waxes, resins, spores and pollen grains. The dull layers ordinarily have a higher per cent of ash due to the mineral matter which accumulated in the form of dust and mud at the time of origin of the coal.

The sulphides of iron are common impurities in the coal mined in this district. Marcasite and Pyrite are generally present as finely disseminated grains, as concretionary masses, and veinlets. Calcite and gypsum are also common impurities occurring principally as a filling of vertical joints. At some localities kaolin may occur in a similar way. The "Red-coal" which is found just beneath the Ft. Scott limestone owes its color to the presence of iron oxides within the joint cracks. Sphalerite and galena are sometimes found in the "horsebacks" in the coal but never directly within the coal.

The following proximate analysis is the average obtained from 337 samples of coals in Crawford and Cherokee Counties.[25/]

| Moisture | Volatile | Fixed Carbon | Ash | Sulphur | B.T.U. |
|---|---|---|---|---|---|
| 4.65 | 39.24 | 60.76 | 13.21 | 4.8 | 13,510 |

The coal from Crawford and Cherokee Counties has a high B.T.U. content and a fairly high per cent of sulphur. Most of the coal is the coking type.

Coke. The first coke produced in Kansas was from three ovens built in 1880 and operated until 1884 by Bouvard and Dixon near Scammon. In 1885 these coke producers built six ovens at Weir, and then sold their interest to Keith and Perry who built and operated twenty-four more coke ovens. Each oven was charged with eight or ten tons of coal which produced four or five tons of coke. The average production of the plant was about two cars of coke per day. The coke was used as fuel in the zinc smelters at Pittsburg and Weir. The manufacture of coke continued until 1910. There has been no coke produced in Kansas since the zinc smelter in Pittsburg was abandoned. However the by-product coke industry may in the future revive coal mining in southeastern Kansas.
It is interesting to note that Alabama, Illinois, Indiana, Michigan, New York, Ohio, and Pennsylvania each consume

25/Young, C. M., and Allen, H. C., Kansas Coal, Engineering bulletin No. 13 of the University of Kansas, p. 191, 1925.

more coal annually in the manufacture of by-product coke than the state of Kansas produces annually.

Raw coal used as smelter fuel. Some of the shallow strip pit coal was used raw in the zinc smelter at Pittsburg. Because of its non-coking qualities it was especially adapted for smelter fuel, and commanded a premium in price. This coal was known as "dead coal" "Mother of coal" and coal "blossom." It was the outcrop coal of the Weir-Pittsburg coal bed, and was mined extensively near the Kansas City Southern Railroad shops.

Origin of coal. It is a widely accepted view that coal has been formed by the chemical and physical changes and decomposition of vegetation that has accumulated under water in swamps that were near sea level.

Two stages may be recognized in the formation of coal from vegetable matter; (a) the biochemical stage, and (b) the metamorphic stage.

Biochemical change is generally thought to be due to the action of anaerobic bacteria on easily attacked tissue, producing the xyloid type coal. The decomposition of the original cellulose liberates methane, carbon dioxide, and carbon monoxide. If the biochemical changes continue long enough the vegetable matter is reduced to a gelatinous substance called peat.

The metamorphic stage includes chemical and physical changes. The exact nature and causes of chemical changes are not yet thoroughly understood. The heat and pressure produced by the weight of overlying sediments, or by folding are thought to have been important factors in the metamorphic process. As the process continues there is progressive devolatilization, a loss of oxygen and hydrogen, with an increase in the per cent of carbon. In this manner peat may be changed to lignite, and lignite to bituminous or anthracite coal. It is probable that the minute laminations of the coal bed and the thin layers of organic debris that are on these planes are the result of seasonal changes that caused a change of water level, a greater concentration of toxic products, temporary exposure of the peat surface spreading thin layers of the fusain on the surface of the coal, and a slight leaching of the surface.26/ Twenhofel27/ thinks that the thin layers of fusain in the coal represent woody debris lying in situ on the surface of the peat, in the zone of biochemical decomposition at times of evaporation of the water covering the peat. The debris on the surface of the deposit would thus be very thinly incrusted with humic matter derived from the concentration of the humic solution by evaporation. The woody fragments would not again be subject to decomposition by bacteria but would be preserved as

26/White, David, Climatic implications of the Pennsylvanian flora. Bull. No. 60, Illinois Geological Survey. pp. 271-281, 1931.

27/Twenhofel, William H., Treatise in Sedimentation. p. 380, 1932.

"mineral charcoal" or "fusain."

From the nature of the plant remains found in the coal of southeastern Kansas it is assumed that the vegetation accumulated in fresh water swamps. However, most of the coal beds are directly overlain by a limy shale or black shale rich in marine fossils. At one locality marine fossils are found within the coal bed, which indicates that the sea at least occasionally advanced upon the broad coastal plain of fresh water swamps or marshes. Each advance of the sea brought swarms of marine life characteristic of the black fossiliferous shale which overlies each coal bed. It is significant that at the locality where brachiopods are found within the coal bed they have all been replaced by iron sulphide. This indicates that the scarcity of marine fossils in the coal is probably not due to the failure of the occasional advancing sea to bring in marine life, but that the conditions for preservation were not suitable.

Rock beds associated with the coal beds. The occurrence of at least thirteen well defined coal beds in the upper part of the Cherokee group shows the existence of successive coal-forming conditions. A black marine shale overlies each coal bed at every locality examined by the writer, which indicates the swampy coal forming conditions were brought to a close by the advance of a sea. The black shale grades upward into a gray shale, then to a sandy shale and in many places the sandy shale is succeeded by sandstone, which indicates that mud and sand were carried by streams or currents and spread over the coal bed. Elevation of this area made possible a new coal swamp and coal-forming conditions.

Structural features of the coal beds. The coal beds are in some cases separated by thin beds of shale, sandstone, or narrow bands of pyrite, called partings. The divided beds of coal are called "splits." Partings and "splits" are not common in the district. The feature called a parting in this district is known in some districts as a "horseback." Another feature called a roll, is the dipping of the roof of the coal bed down into the coal.

The term "horseback" in Kansas refers to a clay filled fissure or vein that cuts the coal bed. The formation of horsebacks or clay filled veins was secondary to the consolidation of the coal.

The width of the "horseback" is from a few inches to a maximum of eight feet. The average width is about four feet. They often bifurcate or divide into several branches. Most of them are nearly vertical and extend upward from the underclay, which is beneath the Weir-Pittsburg coal bed, to the next coal bed above. Many of them penetrate into the Weir-Pittsburg coal bed only a short distance and disappear within a few feet above the coal. At no place has a horseback ever been found to cut more than one bed of coal. They commonly occur in groups or bands having a pattern strikingly similar to the drainage pattern developed in regions having mature erosion topography.

The content of the fissures is very similar to the underclay in appearance. In many places the material has a lenticular structure produced by the movement that forced the underclay or overlying shales into the fissures. Slickenside surfaces that are well grooved characterize the material of horsebacks. In a few instances the clay filling contains angular fragments of coal. The coal found within the horsebacks is a very hard coal, has a brilliant luster, and breaks with a conchoidal fracture.

After the examination of numerous horsebacks both in deep mines and in strip mines, the writer is of the opinion that the cause of the fracturing is two-fold, first a shrinkage of the beds of shale underlying the coal bed by the process of differential compaction, and second, crustal disturbances in the underlying harder limestones. The only coal bed in which this structural feature is known to be common is the Weir-Pittsburg bed which lies about 250 feet above the basal unconformity or the upper surface of the Mississippi limestone.

Many writers have discussed differential compaction and it is an accepted fact that sediments undergo compaction after they are laid down. The decrease in volume produced by a closer spacing of particles and expulsion of water, commonly exceeds 50%, rarely 75%.[28] Drill records in the Tri-state mining district which is less than fifteen miles from the coal district show that the surface of the Mississippian limestone is very irregular, the local relief being as much as 100 feet.[29] The sediments, mostly mud deposited on the irregular surface of the Mississippian limestone had a variable thickness. They were at least 100 feet thicker over the old valleys than on the crest of hills. Greater compaction over the old valleys due to the greater thickness of the muds created a structural relief of 50 to 75 feet. This corresponds closely to the observed structures in the district.

This differential compaction caused fracturing of the shales and the Weir-Pittsburg coal bed at places where the folding was sharp or at the crest of the folds. The location of the fracturing was controlled by the relief of the old Mississippian erosion surface. Crustal disturbances of the Mississippian also played an important part in the formation of these fractures. Haworth,[30]

28/Twenhofel, William H., Treatise on Sedimentation, p. 745, 1932.

29/Fowler, George M., and Lyden J. P., The Ore Deposits of the Tri-State District. Transactions, American Institute of Mining Engineers. p. 210, 1932.

30/Haworth, Erasmus: The University Geological Survey of Kansas, vol, VIII, p. 91, 1904.

Crane,[31] and Fowler[32] say that crustal disturbances were the cause of "horsebacks." The writer is of the opinion that the major folds in the Cherokee were formed by crustal disturbances in the Mississippian, and that the minor folds were formed by differential compaction of the sediments of the lower Cherokee. Both types of folds produced fracturing of the shales and coal beds. After the formation of these fractures, subsequent movements and pressure of overlying sediments caused a filling of these fractures with clay material and formed "horsebacks." Therefore both types of folds were factors in the origin of horsebacks.

The Weir-Pittsburg coal bed is the youngest coal bed in which horsebacks commonly occur. Therefore most of the warping of the Cherokee occurred soon after the formation of the Weir-Pittsburg coal bed.

There are two features in this district called faults. One, that is in accordance with geological usage, is where relative movement has taken place along a fracture plane. This structural feature is very uncommon but nevertheless a few faults have been recorded. One was found in mine No. 17 of the Jackson & Walker Coal Co.,

31/Crane, W. R., Special Report on Coal, The University Geological Survey of Kansas, vol., VIII, p. 205, 1898.

32/Fowler, George M., Personal communication.

about one mile south of Franklin. It is a normal fault with a throw of twelve feet and a strike N. 40 degrees E. and a dip of 37 degrees S.E.

The other feature commonly known as a "cut-out," but locally known as a "fault" is in no way related to a geological fault, yet is an important structural feature of the coal beds. It occurs where the normal shale above the coal has been subjected to surface erosion and channels of variable width and depth cut into it, sometimes cutting out a part or all of the coal bed. In each case the channel has been filled with sand. When the channel sands form the roof of the coal mines it always requires extra timber for support, as the rock is a weak loosely cemented sandstone. A typical cross-section is shown in figure 14.

The so-called "faults" like the horsebacks are found to occur in the lower Weir-Pittsburg. They also occur in the overlying coal beds. The normal occurrence and distribution of the so-called "fault" areas in deep mines is shown in figure 15. The irregularly shaped and disconnected areas are characteristic of their underground appearance.

The Weir-Pittsburg coal bed has a rather uniform regional dip to the northwest, but is locally folded into numerous irregular structural highs and lows caused by the differential compaction of the underlying sediments.

This compaction took place subsequent to the formation of the coal bed and previous to the channel erosion of the land surface.

This erosion surface which sometimes cuts the lower Weir-Pittsburg bed is wide spread throughout the district. It is several feet above the coal bed in some places, but in many others it is just at the top of the coal bed. In some cases some or all of the coal has been eroded away, depending upon whether the erosion surface cut across the coal bed on the crest of an anticline or the shale beds in the trough of a syncline. This irregular contact between the erosion surface and the coal bed gives rise to a very irregular pattern of fault areas. In some localities this relationship has been somewhat obscured by subsequent warping which has distorted the erosion surface. The most important structural feature of lower portion of the Cherokee shales as well as the Weir-Pittsburg coal bed is this unconformity.

Production statistics of coal in Crawford and Cherokee Counties.[33]

SHAFT MINES IN CRAWFORD COUNTY

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | 6,066 | 44 | 3,537,937 |
| 1909-1910 | 6,323 | 48 | 3,323,419 |
| 1910-1911 | | No Report | |
| 1911-1912 | 5,994 | 48 | 3,651,109 |
| 1912-1913 | 7,051 | 71 | 4,167,978 |
| 1913-1914 | 7,345 | 63 | 4,447,444 |
| 1914-1915 | 6,978 | 65 | 4,167,254 |
| July-Dec. 1915 | 7,827 | 64 | 2,395,812 |
| Calendar Year | | | |
| 1916 | 7,737 | 77 | 4,526,172 |
| 1917 | 7,661 | 87 | 5,141,804 |
| 1918 | 6,988 | 82 | 5,101,789 |
| 1919 | 6,917 | 94 | 3,787,251 |
| 1920 | 7,232 | 154 | 4,304,584 |
| 1921 | 7,017 | 152 | 2,769,999 |
| 1922 | 6,722 | 179 | 2,519,126 |
| 1923 | 7,266 | 152 | 3,091,473 |
| 1924 | 6,556 | 152 | 2,868,647 |
| 1925 | 6,199 | 126 | 2,752,984 |
| 1926 | 5,406 | 105 | 2,325,108 |
| 1927 | 4,443 | 85 | 1,570,305 |
| 1928 | 3,577 | 85 | 1,144,078 |
| 1929 | 3,185 | 73 | 1,535,488 |
| 1930 | 3,268 | 67 | 1,065,196 |
| 1931 | 2,326 | 64 | 661,737 |
| 1932 | 1,897 | 61 | 632,525 |
| 1933 | 1,735 | 57 | 480,694 |
| 1934 | 1,556 | 62 | 514,953 |

33/Compiled from the records in the office of Wm. Glennon, State Mine Inspector of Kansas.

STRIP MINES IN CRAWFORD COUNTY

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | 30 | 2 | 48,829 |
| 1909-1910 | 25 | 4 | 50,650 |
| 1910-1911 | | No Report | |
| 1911-1912 | 304 | 5 | 167,641 |
| 1912-1913 | 281 | 8 | 150,753 |
| 1913-1914 | 389 | 9 | 320,520 |
| 1914-1915 | 455 | 10 | 428,955 |
| July-Dec. 1915 | 459 | 8 | 248,638 |
| Calendar Year | | | |
| 1916 | 446 | 8 | 422,085 |
| 1917 | 408 | 9 | 354,103 |
| 1918 | 595 | 14 | 574,977 |
| 1919 | 579 | 16 | 326,138 |
| 1920 | 330 | 11 | 325,146 |
| 1921 | 275 | 14 | 162,628 |
| 1922 | 351 | 15 | 259,446 |
| 1923 | 302 | 13 | 324,545 |
| 1924 | 310 | 15 | 332,685 |
| 1925 | 324 | 21 | 338,711 |
| 1926 | 441 | 27 | 571,080 |
| 1927 | 468 | 24 | 547,626 |
| 1928 | 463 | 25 | 627,737 |
| 1929 | 444 | 22 | 691,876 |
| 1930 | 485 | 23 | 569,751 |
| 1931 | 454 | 22 | 908,865 |
| 1932 | 557 | 21 | 948,618 |
| 1933 | 511 | 23 | 993,044 |
| 1934 | 740 | 28 | 1,324,108 |

# TOTAL COAL PRODUCTION IN CRAWFORD COUNTY

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | 6,096 | 46 | 3,586,766 |
| 1909-1910 | 6,348 | 52 | 3,374,069 |
| 1910-1911 | | No Report | |
| 1911-1912 | 6,298 | 53 | 3,818,750 |
| 1912-1913 | 7,332 | 79 | 4,318,731 |
| 1913-1914 | 7,734 | 72 | 4,767,964 |
| 1914-1915 | 7,433 | 75 | 4,596,209 |
| July-Dec. 1915 | 8,286 | 72 | 2,644,450 |
| Calendar Year | | | |
| 1916 | 8,183 | 85 | 4,948,257 |
| 1917 | 8,069 | 96 | 5,495,907 |
| 1918 | 7,583 | 96 | 5,676,766 |
| 1919 | 7,496 | 110 | 4,113,389 |
| 1920 | 7,562 | 165 | 4,629,730 |
| 1921 | 7,292 | 166 | 2,932,627 |
| 1922 | 7,073 | 194 | 2,778,572 |
| 1923 | 7,568 | 165 | 3,416,018 |
| 1924 | 6,866 | 167 | 3,201,332 |
| 1925 | 6,523 | 147 | 3,091,695 |
| 1926 | 5,847 | 132 | 2,896,189 |
| 1927 | 4,911 | 109 | 2,117,931 |
| 1928 | 4,040 | 110 | 1,771,813 |
| 1929 | 3,629 | 95 | 2,227,364 |
| 1930 | 3,753 | 90 | 1,634,947 |
| 1931 | 2,780 | 86 | 1,570,602 |
| 1932 | 2,454 | 82 | 1,581,143 |
| 1933 | 2,246 | 80 | 1,473,738 |
| 1934 | 2,296 | 90 | 1,839,061 |

SHAFT MINES IN CHEROKEE COUNTY, KANSAS

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | 3,460 | 33 | 1,976,740 |
| 1909-1910 | 3,190 | 36 | 1,442,944 |
| 1910-1911 | | No Report | |
| 1911-1912 | 3,403 | 37 | 2,106,685 |
| 1912-1913 | 3,257 | 40 | 2,188,781 |
| 1913-1914 | 2,957 | 32 | 1,914,799 |
| 1914-1915 | 2,486 | 29 | 1,387,997 |
| July-Dec. 1915 | 2,063 | 3 | 665,912 |
| Calendar Year | | | |
| 1916 | 1,594 | 26 | 1,078,200 |
| 1917 | 1,588 | 66 | 987,735 |
| 1918 | 973 | 40 | 676,824 |
| 1919 | 1,610 | 58 | 614,440 |
| 1920 | 1,302 | 84 | 667,285 |
| 1921 | 1,135 | 89 | 403,805 |
| 1922 | 1,093 | 101 | 394,671 |
| 1923 | 997 | 100 | 392,392 |
| 1924 | 908 | 90 | 383,717 |
| 1925 | 1,006 | 80 | 479,180 |
| 1926 | 747 | 67 | 429,762 |
| 1927 | 722 | 68 | 369,105 |
| 1928 | 594 | 63 | 272,483 |
| 1929 | 538 | 56 | 233,798 |
| 1930 | 435 | 47 | 138,331 |
| 1931 | 225 | 42 | 57,202 |
| 1932 | 334 | 49 | 107,230 |
| 1933 | 376 | 53 | 120,530 |
| 1934 | 268 | 51 | 92,575 |

## STRIP MINES IN CHEROKEE COUNTY, KANSAS

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | | | |
| 1909-1910 | | 1 | 10,865 |
| 1910-1911 | | | |
| 1911-1912 | | 2 | 47,687 |
| 1912-1913 | 158 | 9 | 144,139 |
| 1913-1914 | 204 | 9 | 155,842 |
| 1914-1915 | 233 | 7 | 195,297 |
| July-Dec. 1915 | 317 | 9 | 178,213 |
| Calendar Year | | | |
| 1916 | 365 | 12 | 358,416 |
| 1917 | 397 | 12 | 312,518 |
| 1918 | 224 | 8 | 234,056 |
| 1919 | 272 | 10 | 242,997 |
| 1920 | 255 | 15 | 385,443 |
| 1921 | 283 | 17 | 207,195 |
| 1922 | 258 | 14 | 154,093 |
| 1923 | 208 | 12 | 337,327 |
| 1924 | 251 | 10 | 242,997 |
| 1925 | 354 | 17 | 724,263 |
| 1926 | 375 | 18 | 659,274 |
| 1927 | 248 | 15 | 543,012 |
| 1928 | 219 | 12 | 337,327 |
| 1929 | 244 | 14 | 354,892 |
| 1930 | 251 | 15 | 401,539 |
| 1931 | 114 | 14 | 198,135 |
| 1932 | 97 | 11 | 205,300 |
| 1933 | 207 | 13 | 375,817 |
| 1934 | 246 | 10 | 365,752 |

# TOTAL COAL PRODUCTION IN CHEROKEE COUNTY

| Fiscal Year | Employees | Mines | Tons Produced |
|---|---|---|---|
| 1908-1909 | 3,460 | 33 | 1,976,740 |
| 1909-1910 | 3,190 | 37 | 1,453,809 |
| 1910-1911 | | No Report | |
| 1911-1912 | 3,403 | 39 | 154,372 |
| 1912-1913 | 3,415 | 49 | 2,332,920 |
| 1913-1914 | 3,161 | 41 | 2,070,641 |
| 1914-1915 | 2,719 | 36 | 1,783,294 |
| July-Dec. 1915 | 2,380 | 32 | 844,125 |
| <u>Calendar</u> <u>Year</u> | | | |
| 1916 | 1,959 | 38 | 1,436,616 |
| 1917 | 1,985 | 78 | 1,300,253 |
| 1918 | 1,197 | 48 | 910,880 |
| 1919 | 1,882 | 68 | 857,437 |
| 1920 | 1,537 | 99 | 1,052,729 |
| 1921 | 1,418 | 106 | 611,000 |
| 1922 | 1,351 | 115 | 548,764 |
| 1923 | 1,205 | 112 | 729,719 |
| 1924 | 1,159 | 100 | 799,706 |
| 1925 | 1,360 | 97 | 1,203,443 |
| 1926 | 1,122 | 85 | 1,089,036 |
| 1927 | 970 | 83 | 912,117 |
| 1928 | 813 | 75 | 816,918 |
| 1929 | 782 | 69 | 588,690 |
| 1930 | 686 | 62 | 539,890 |
| 1931 | 339 | 56 | 256,337 |
| 1932 | 431 | 60 | 312,530 |
| 1933 | 583 | 66 | 496,347 |
| 1934 | 514 | 61 | 468,327 |

The total production of the state of Kansas from 1869 to 1935 is 217,869,774 tons, the total production of Crawford and Cherokee Counties from 1869 to 1935 is 203,484,507 tons. The annual production of coal from the Cherokee outcrop area is about 90 per cent of the total coal production of the entire state. In 1934 Crawford and Cherokee Counties produced more than 91 per cent of all of the coal mined in Kansas. In the same year Crawford County alone produced more than 71 per cent of all the coal mined in Kansas. The larger part of the production from Crawford and Cherokee Counties is used for locomotive fuel. Some of the larger mines are operated by the fuel departments of the railroad companies. In such cases none of the product is marketed as commercial coal.

It is interesting to note the figures on coal consumption in Kansas.[34/] In 1930, 2,755,313 tons was consumed. This amount does not include coal consumed by the railroads, which was more than 50 per cent of all the coal mined or more than 1,214,964 tons. In the same year only 2,109,151 tons of coal was mined in the state. The number of tons of coal consumed was almost twice the number of tons of coal mined.

34/Tryon, F. G., Mann, L., Rogers, H. C., Mineral Resources of the United States, 1930, Part II, p. 677.

## Iron Sulphides

The common iron sulphide minerals associated with the Cherokee coal are pyrite and marcasite. They are hard, crystalline or massive, and pale brass-yellow in color.

Iron sulphide commonly occurs as layers, lenses, granules, nodules, and concretions in the beds of black shale and coal of the Cherokee formations of southeastern Kansas. The layers and lenses commonly occur along bedding planes and range from one millimeter to three feet in thickness. The granules, nodules and concretions occur disseminated throughout the beds and range from a microscopic size to three feet in diameter. Shells replaced with iron sulphide commonly occur in the black shales and occasionally in the coal beds. In most cases the shells occur along the bedding planes, but in some localities the replaced shells lie at various angles with the bedding planes.

Iron sulphide was contemporaneous in origin with the enclosing beds. Iron was carried in solution to basins where an abundance of carbonaceous matter was in the process of decay and in contact with matter. The iron was precipitated as iron sulphide, probably by the reaction with hydrogen sulphide liberated by bacteria from decaying carbonaceous material.

An iron sulphide recovery plant is being installed by the Pittsburg and Midway Coal Mining Company at Mineral. It has a capacity of 90 tons of iron sulphide concentrate per day.

## Clay

Clay is a naturally occurring, finely divided mixture of hydrous aluminum silicate with some colloidal matter.

Origin. Clay is the result of chemical disintegration of rock containing aluminum minerals. Residual clays are those found at the place where the previous rock was disintegrated. Transported clays deposited in the ocean are called marine clays; when deposited in lakes, they are known as lake clays; when deposited on the flood plains of rivers they are known as alluvial clays or flood plain clays.[35]

When clay is dry, it is often carried by the wind as dust and accumulated as beds called loess. Loess, however may be a deposit formed in lakes or broad sluggish streams.

The above types of transported clays are called sedimentary clays. When such clays are consolidated, they are known as shales.

History. The first clay products plant in southeastern Kansas was a brick plant at Pittsburg, built in 1895 by the Nesch Brick Company. In 1900 another brick plant was built in Pittsburg by Lanyon and Nesch. The W. S.

35/Ries, H., Economic Geology, p. 172, 1925.

Dickey Manufacturing Company[36] bought this plant in 1905 and had operated it continuously since that time. The products from the plant have always been "hollow-ware" or sewer pipe and tile. The plant has operated at full capacity throughout the period of the depression. Continuous operation has been possible because of low production costs and the geographical location of the plant. The annual production of the plant at present is about 25,000 tons of "hollow-ware."

The Nesch Brick Plant was put in operation north of Lincoln Park in Pittsburg in 1895. It operated more or less intermittently until 1927. Its capacity was 50,000 bricks per day.

The Metropolis Brick Company built a plant in 1920 just north of the Nesch Brick Plant in Pittsburg. This plant had a capacity of 50,000 bricks per day and operated more or less continuously for about ten years.

Stratigraphic position of the shale beds. The clay industry of this district is confined to Crawford County, where beds of Cherokee shale are mined by open-pit methods. The shale bed mined is the gray shale immediately above black shale and the Weir-Pittsburg coal bed. The underclay below the Weir-Pittsburg coal, commonly called fire clay, is an excellent brick clay, but has never been used by the plants at Pittsburg.

[36]/Figure 13 is a photograph of this clay plant.

Nature of the shale. The shale from which the clay products are made is a marine shale, light gray in color, high in silica content, and non-fossiliferous. The following is an analysis of the clay used by the W. S. Dickey Manufacturing Company.[37]

| | Per cent |
|---|---|
| Moisture (soluble) | 0.2 |
| Volatile matter at 105 degrees C. | 3.2 |
| Ignition loss | 4.8 |
| Oxides or Carbon | 0.12 |
| Moisture combined (by differences) | 4.68 |
| Silica | 64.02 |
| Aluminum oxide | 19.34 |
| Iron oxide | 10.28 |

Very little work has been done on the chemical and physical properties of the southeastern Kansas clays. Some of the beds of underclay or so-called "fire-clays" are several feet in thickness and are persistent over large areas. These beds merit considerable chemical research.

37/Information furnished from the Pittsburg office of the W. S. Dickey Manufacturing Company.

# CHAPTER IV

## STRATIGRAPHY

The rocks of southeastern Kansas are made up of limestone strata of Mississippian age; of sandstone, shale, and limestone beds alternating with beds of coal, all of Cherokee age; and of alluvium of recent age.

Position of the Cherokee in the stratigraphic column of Kansas. The Cherokee shale is the lowest division of the Pennsylvanian system in southeastern Kansas. It rests unconformably upon beds of the Mississippian system.

The Cherokee was classified by Shepard[38] as a stage, or a division intermediate between a series and a formation or what is now commonly classed as a group. It was classed as a formation by Hinds and Greene[39], and by Moore and Landes[40].

In this report Cherokee is proposed as a group name, and is differentiated into formations and members. Various names have been applied by several authors to a few divisions of the Cherokee. Some of the names applied have

38/Shepard, Edward M., Missouri Geological Survey Report, vol. 12, p. 49.

39/Hinds, Henry, and Greene, F. C., The Stratigraphy of the Pennsylvanian series in Missouri: Mo. Bur. Geology and Mines, vol. 13, pp. 36-37, 1915.

40/Moore, Raymond C. and Landes, Kenneth K., Underground resources of Kansas: State Geological Survey of Kansas, Bull. 13, p. 18, 1927.

been very local.[41/] This use of various names is confusing to all readers except those who have made a special study of the local stratigraphy. Pierce[42/] uses the name Rich Hill limestone, a local name in the Rich Hill, Missouri coal district[43/] and applied this name to a member in the southeastern Kansas coal fields that had been previously named and locally known as the Ardmore limestone. He also used the names Mineral Rider coal and Fire Clay coal. These names are not in common usage locally, they are unknown to the Kansas Coal Mine Inspection Department, they are not geographic names and are not appropriate to the coal beds in this district and will not be used in this report. The following tables show the position of the Cherokee in the Pennsylvanian, the divisions and subdivisions.

41/Greene, F. C. and Pond, W. F., The Geology of Vernon County: Mo. Bur. Geology and Mines, vol. 79, p. 35, 1926.

42/Pierce, W. G. Map of Southeastern Kansas Coal Fields. U.S.G.S., 1934.

43/Greene, F. C., and Pond, W. F., The Geology of Vernon County, The Missouri Bureau of Geology and Mines, vol. 19, p. 51, 1926.

## GENERALIZED SECTION OF THE PENNSYLVANIAN IN SOUTHEASTERN KANSAS

| System | Series | Group | Formation or Cyclothem |
|---|---|---|---|
| Pennsylvanian 44/ | Des Moines | Marmaton | Pawnee<br>Labette<br>Ft. Scott |
| | | Cherokee | Mulky<br>Bevier<br>Ardmore<br>Cato<br>Coalvale<br>Fleming<br>Mineral<br>Scammon<br>Pilot<br>Weir<br>Kniveton<br>Bluejacket<br>Columbus<br>Neutral<br>Riverton |

44/Moore, Raymond C., Rock Formations of Kansas, Kansas Geological Survey, 1935

The following table shows the formations or cyclothems of the Cherokee and their members or phases that have been recognized in southeastern Kansas.

GENERALIZED SECTION OF THE CHEROKEE

| Formation or Cyclothem | | Member or Phase | | |
|---|---|---|---|---|
| No. | Nomenclature | No. | Lithologic Nature | Thickness in Feet |
| 15 | Mulky | 15.7 | Limestone | 6.0 |
| | | 15.5 | Black shale | 8.0 |
| | | 15.4 | Coal "Ft. Scott" | 2.0 |
| | | 15.3 | Underclay | 2.0 |
| | | 15.2 | Sandy shale | 40.0 |
| | | 15.1 | Sandstone | 11.0 |
| 14 | Bevier | 14.5 | Black shale | 6.0 |
| | | 14.4 | Coal | 2.0 |
| | | 14.3 | Underclay | 1.5 |
| 13 | Ardmore | 13.7 | Limestone | 4.0 |
| | | 13.3 | Underclay | 1.0 |
| 12 | Cato | 12.5 | Black shale | 7.5 |
| | | 12.4 | Coal | 1.5 |
| | | 12.3 | Underclay | 9.0 |

GENERALIZED SECTION OF THE CHEROKEE CONTINUED

| Formation or Cyclothem | | Member or Phase | | |
|---|---|---|---|---|
| No. | Nomenclature | No. | Lithologic Nature | Thickness in Feet |
| 11 | Coalvale | 11.6 | Gray shale | 1.0 |
| | | 11.5 | Black shale | 1.0 |
| | | 11.4 | Coal | 1.0 |
| | | 11.3 | Underclay | 2.2 |
| | | 11.2 | Sandy shale | 3.0 |
| | | 11.1 | Sandstone | 1.0 |
| 10 | Fleming | 10.8 | Shale | 2.0 |
| | | 10.5 | Black shale | 6.0 |
| | | 10.4 | Coal | 1.0 |
| | | 10.3 | Underclay | 1.6 |
| | | 10.2 | Sandy shale | 12.0 |
| | | 10.1 | Sandstone | 1.0 |
| 9 | Mineral | 9.6 | Gray shale | 1.0 |
| | | 9.5 | Black shale | 7.0 |
| | | 9.4 | Coal | 1.8 |
| | | 9.3 | Underclay | 2.0 |
| 8 | Scammon | 8.8 | Shale | 2.0 |
| | | 8.7 | Limestone | 0.5 |
| | | 8.6 | Gray shale | 2.0 |
| | | 8.5 | Black shale | 7.0 |
| | | 8.4 | Coal | 0.8 |

GENERALIZED SECTION OF THE CHEROKEE CONTINUED

| Formation or Cyclothem | | Member or Phase | | |
|---|---|---|---|---|
| No. | Nomenclature | No. | Lithologic Nature | Thickness in Feet |
| | | 8.3 | Underclay | 1.5 |
| | | 8.2 | Sandy shale | 4.0 |
| | | 8.1 | Sandstone | 4.0 |
| 7 | Pilot | 7.6 | Gray shale | 2.0 |
| | | 7.5 | Black shale | 8.0 |
| | | 7.4 | Coal | 0.5 |
| | | 7.3 | Underclay | 1.0 |
| | | 7.2 | Sandy shale | 16.0 |
| | | 7.1 | Sandstone | 8.0 |
| 6 | Weir | 6.5 | Black shale | 1.0 |
| | | 6.4 | Coal "Weir-Pittsburg" | 2.5 |
| | | 6.4 | Blackjack | 2.0 |
| | | 6.4 | Coal | 0.5 |
| | | 6.3 | Underclay | 0.5 |
| | | 6.1 | Sandstone | 30.0 |
| 5 | Kniveton | 5.6 | Gray shale | 16.0 |
| | | 5.5 | Black shale | 7.0 |
| | | 5.4 | Coal | 0.7 |
| | | 5.3 | Underclay | 1.0 |
| | | 5.1 | Conglomerate | 1.0 |

GENERALIZED SECTION OF THE CHEROKEE CONTINUED

| Formation or Cyclothem | | Member or Phase | | |
|---|---|---|---|---|
| No. | Nomenclature | No. | Lithologic Nature | Thickness in Feet |
| 4 | Bluejacket | 4.7 | Limestone | 3.0 |
| | | 4.6 | Gray shale | 21.0 |
| | | 4.5 | Black shale | 4.0 |
| | | 4.3 | Underclay | 8.0 |
| | | 4.2 | Sandy shale | 12.0 |
| | | 4.1 | Sandstone | 20.0 |
| 3 | Columbus | 3.5 | Black shale | 1.0 |
| | | 3.4 | Coal | 1.3 |
| | | 3.1 | Sandstone | 28.0 |
| 2 | Neutral | 2.6 | Gray shale | 5.0 |
| | | 2.5 | Black shale | 3.0 |
| | | 2.4 | Coal | 1.0 |
| | | 2.3 | Underclay | 3.0 |
| | | 2.4 | Coal | 1.0 |
| | | 2.3 | Underclay | 10.0 |
| 1 | Riverton | 1.6 | Gray shale | 24.0 |
| | | 1.5 | Black shale | 4.0 |
| | | 1.4 | Coal | 2.0 |
| | | 1.3 | Underclay | 3.0 |
| | | 1.1 | Sandstone | 5.0 |

## Cyclical Sedimentation

Certain successions of strata are repeated a number of times in the rocks of the Cherokee in southeastern Kansas. Weller[45] proposed that the subdivisions of the Pennsylvanian in western Illinois, each of which is composed of a similar series of strata arranged in the same order, be considered as a formation of the Pennsylvanian system. He named this unit characterized by cyclical sedimentation a "cyclothem" which signifies cyclic formation. The writer has found the Cherokee of southeastern Kansas made up of divisions each of which is composed of a similar succession of strata arranged in the same order. The ultimate basis for the divisions of the Cherokee shale is crustal disturbances. These have resulted in alternate submergences and emergences of the coal basin that have caused change in the lithologic nature of the sediments, interruption of sedimentation, and occurrence of erosional unconformities. In practice the discovery of these breaks in the record is made possible by the repetition of similar sequences of beds and lithologic characters. A sequence of lithologic units may be used to define formations in the same

45/Weller, J. Marvin, Cyclical Sedimentation of the Pennsylvanian period and its significance: Journal of Geology, vol. 38, No. 2, pp. 97-135, 1930.

manner, as Dunbar[46/] shows, that long-ranging species may give the beds individuality and when they occur in an extensive faunal succession, make possible an exact and detailed correlation of these beds. The writer proposes that each division be considered a formation and for the purpose of correlation, the formation be called a cyclothem. Weller[47/] defines a cyclothem as the deposits of a sedimentary cycle. It is desirable to introduce a name for each of the fifteen cyclothems recognized in the Cherokee. However, to indicate properly their genetic relationships and their subdivisions, the writer proposes to designate the cyclothems by whole numbers and the phases or subdivisions by decimals. The lowest cyclothem of the Cherokee is 1, and the lowest division of the normal cyclothem is 0.1. Therefore this bed is designated as Phase 1.1, which indicates the position of the phase in the cyclothem and the position of the cyclothem in the Cherokee.

The succession of beds at most localities is incomplete, and some beds present are poorly developed. Such

46/Dunbar, Carl O., and Condra, G. E., Brachiopoda of the Pennsylvanian System in Nebraska. Bull. No. 5, Nebraska Geological Survey, pp. 28-29, 1932.

47/Weller, J. Marvin, Cyclical Sedimentation of the Pennsylvanian period and its significance: Journal of Geology, vol. 38, No. 2, p. 101, 1930.

beds, however, usually occur in their proper position in the cyclothem at other localities. The phases of the typical cyclothem in southeastern Kansas are as follows:

| | |
|---|---|
| Shale...................... | 0.8 |
| Limestone................. | 0.7 |
| Gray shale................ | 0.6 |
| Black shale............... | 0.5 |
| Coal...................... | 0.4 |
| Underclay................. | 0.3 |
| Sandy and micaceous shale. | 0.2 |
| Sandstone................. | 0.1 |
| Unconformity | |

The lower phases of the cyclothem, 0.1, 0.2, 0.3, and 0.4 are of continental origin, while the upper phases, 0.5, 0.6, 0.7, and 0.8, are of marine origin. The continental sediments are the local accumulations that were derived by the erosion of a nearby land surface. The sediments were carried by streams and deposited in the low places of the basin. Their continental character is indicated by their cross-bedded and ripple-marked structure and by their content of coal balls, vegetable remains, and impressions. There is no transition between continental and marine phases. The coal bed, the highest phase of the continental sediments, makes a sharp contact with the overlying black shale, the lowest phase of the marine sediments. Marine conditions prevailed during the accumulation of sediments that represent phases 0.5, 0.6, 0.7, and 0.8. Their marine origin is indicated by the occurrence of marine fossils. While fossils are only abundant at particular horizons, they are sometimes found at various horizons throughout the upper phases of the cyclothem. Phases 0.5, 0.6, 0.7, and 0.8 are the result of the normal advance of a sea upon a continent. The beds of black shale and gray shale, or phases 0.5 and 0.6, represent the sediments deposited by an encroaching sea. The limestone or phase 0.7 represents the time of maximum flooding of the sea. The shale above the limestone, or phase 0.8 represents the sediments deposited during the retreat of the sea in the normal sedimentary cycle.

Underclays. Underclays, locally called "fireclays," are plastic clays which commonly occur under the coal beds in southeastern Kansas. The thickness of the underclays ranges from a few inches to as much as fifteen feet. They are fine grained plastic clays. Their light gray color appears to be the result of alteration.

Underclays unaccompanied by coal beds are by no means rare, but this condition is usually local. If the underclay is traced a few miles, a bed of coal usually appears in its normal position immediately above the clay bed. Cyclothem 13 contains the Ardmore limestone, which occurs directly over a bed of underclay twelve inches thick. This relation is not local but general throughout the district and characteristic of this cyclothem. In Cyclothem 12 a bed of black shale seven feet thick occurs directly over a bed of underclay nine feet thick. This relation of the beds is characteristic of the cyclothem.

The origin of underclays has been discussed by various writers. Moore[48] considers them the remains of the soil in which coal plants grew. Stout[49] considers them to have been formed from fine-grained sediments that accumulated in shallow basins under conditions favoring the decay of plant life. Weller[50] thinks the underclays were completely developed by long-continued exposure of a land surface to atmospheric agents before peat accumulation began. Ashley[51] finds that the underclays in the basins of the coal fields of Indiana, are commonly thicker in the center of the basins and thin out on the flanks. He also finds that where cannel coal occurs at the bottom of the bituminous coal, the underlying rock is commonly ordinary shale that has not been leached out. In Cyclothem 12 the coal bed is directly overlain by the under-

48/Moore, Elwood S., Coal, p. 153, 1922.

49/Stout, W., Coal Formation Clays, Geological Survey of Ohio. Bull. 26, p. 547, 1923.

50/Weller, J. Marvin, Cyclical Sedimentation: Illinois State Geological Survey, Bull. 60, p. 175, 1931.

51/Ashley, George H., Pennsylvanian Cycles in Pennsylvania. Illinois State Geological Survey, Bull. No. 60, p. 244, 1931.

clay of the next younger Cyclothem 13. Phases 12.3, 12.5, 12.6, and 12.7 are completely absent at most localities within the outcrop area. As a result of this missing series of phases a coal bed occurs between two beds of underclay. At many localities the coal bed is not perfectly horizontal but has numerous small, low folds. The underclay below the coal is folded in a similar manner which indicates the time of folding was subsequent to the formation of the coal bed. The overlying underclay is not folded, and its upper surface is nearly horizontal. This bed is thin and sometimes cut out completely on the crest of anticlines in the coal bed. This indicates that the folded coal bed formed the bottom of a basin into which fine silt was carried. The writer is of the opinion that the underclays were deposited as fine-grained muds in shallow basins. They have, however, been considerably altered. There is a gradual transition from the underclays to the underlying beds. This evidence indicates the underclays are the result of alteration of sediments underlying the coal beds. Clark[52] suggests that the sediments under moors are often kaolinized, through the action of carbonated waters.

The section exposed at the Pittsburg and Midway mine

52/Clark, Frank Wiggleworth, Data of Geochemistry: U.S.G.S. Bull., 770, p. 495, 1924.

No. 17 in sec. 34, T. 31 S., R. 24 E., Crawford County, shows Cyclothems 9, 10, and 11. In Cyclothem 11 the coal bed is resting upon a floor of sandy shale (Phase 11.2) made uneven by the erosion of a land surface. The underclay (Phase 11.3) of this cyclothem is missing at localities where the coal bed dips steeply or at the higher elevations of the old erosion surface. In the same cyclothem the underclay occurs at the lower elevations of the coal bed or at the localities where the fine-grained muds accumulated in the basins. In Cyclothems 9, and 10 the beds of underclay were laid down on a surface of sandy shale that appears to have been horizontal at the time the coal-forming material accumulated. The coal beds are here underlain by a uniform thickness of underclay.

In some localities underclays contain abundant fragments of poorly preserved leaves and stems, but the writer has never observed fragments of roots or any other evidence that the underclay represents the soil on which the peat swamp grew. The close association of underclays with coal beds indicates that they were deposited in the coal basins as muds, and that the time of their deposition, weathering, and leaching preceded the accumulation of the plant material that formed the coal. It is commonly conceded that the first requisite for the accumulation of coal-forming material is the existence of a swamp. The basins which contained the swamps were the result of irregular deposition of continental sediments and a differential subsidence of the land surface. The basins thus produced and the elevated areas which flanked the basins were subjected to weathering and leaching. The clay material formed in the basin areas by the process of weathering and leaching was subsequently covered by the accumulation of coal-forming carbonaceous matter and thereby preserved to the present time. The clay material formed on the slightly elevated areas that flanked the basins was eroded by the next advance of the sea and deposited with other marine muds upon the newly formed coal material in the basins.

Black shales. The black shales are finely laminated and highly fissle or platy shales which generally are only a few feet in thickness but occur over large areas. Their black color is due to finely divided iron sulphide and partly decomposed plant matter.

Well preserved fossils occur abundantly in the black shales but are largely confined to occassional horizons that are literally crowded with delicate forms. In many places the black shales contain fragments of crinoid stems and, the shells of Orbiculoidea, Marginifera, Mesolobus, Chonetes, and Linoproductus generally carbonized or composed of iron sulphide. In rare cases the original limy material of the shells is well preserved. Marine fossils are abundant in the black shale Phases 6.5, 14.5, irregular deposition of continental sediments and a differential subsidence of the land surface. The basins thus produced and the elevated areas which flanked the basins were subjected to weathering and leaching. The clay material formed in the basin areas by the process of weathering and leaching was subsequently covered by the accumulation of coal-forming carbonaceous matter and thereby preserved to the present time. The clay material formed on the slightly elevated areas that flanked the basins was eroded by the next advance of the sea and deposited with other marine muds upon the newly formed coal material in the basins.

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The association of these black shale beds with marine beds, their wide distribution, and the occurrence of marine fossils indicate they are marine deposits. With few exceptions a bed of black shale occurs directly above each coal bed. This constancy of relation is characteristic of the cyclothems of the Cherokee shale. The nature of the contact of the coal beds with the black shales indicates that the process of peat formation was interrupted by the invasions of shallow seas. The lowlying land areas surrounding the areas of coal-forming swamps were covered with dense vegetation and black soil. The black soil and carbonaceous matter were transported from the areas surrounding the swamps and deposited on top of the newly formed peat in the swamps. The presence of marine fossil horizons in the black shale indicates the occassional connection of the swamps with the sea. In localities where the black shale contains marine fossils, layers of mineral charcoal or fusain never occur at the top of the coal bed, while in localities where mineral charcoal and fusain do occur, marine fossils are absent. The presence of marine fossils or the mineral charcoal appears to be characteristic of certain beds. David White [53]

53/White, David, Notes of Fossil Floras of the Pennsylvanian in Missouri, Missouri Bureau of Geology and Mines. vol. 13, p. 257, 1915.

says that the roof shales (black shales) are mostly lacking in plant fossils and commonly contain brackish-water or marine shells as a result of a submergence of the swamps, unaccompanied by an inwash of sediments. The flooding killed the fresh water plants and left them exposed to decomposing agents. It appears that extensive submergence prevented a rapid inwash of sediments at times when large areas, if not the entire basin, were submerged, while at those times when the submergence was slight, low elevations of land immediately surrounding the peat swamps were subjected to erosion and large quantities of sediments were therefore washed into the deeper parts of the basin.

The high content of sulphur in the black shales indicates the presence of strong reducing conditions during the accumulation of the muds. Weathering of the black shale usually produces crystals of selenite and native sulphur. Selenite is formed by the decomposition of pyrite and the action of sulphuric acid set free by the reaction on lime carbonate. Sulphur is formed by the reducing action of the bituminous content of the black shale on gypsum.

Correlation. The basis for correlation of these beds is diastrophic movements. The field evidence is not confined to one criterion, but to several which, as suggested by Moore[54], are (1) continuity of beds, (2) lithologic character, (3) sequence of beds, (4) unconformities, and (5) paleontologic characters.

The continuity of beds is of considerable value in the correlation of the cyclothems of the Cherokee shales. One limestone member, the Ardmore, and one coal bed, the Weir-Pittsburg, have sufficient continuity to be extremely important in the correlation of two cyclothems in this area. Coal beds, underclays, black shales, and limestones are commonly persistent laterally but frequently changes by a gradual transition from shale to sandy shale. Commonly one or more phases of a cyclothem are remarkably persistent throughout the outcrop area. Each cyclothem or cyclic succession of beds, therefore, has a remarkable lateral persistence. By means of well logs, outcrops and coal mines the cyclothems have been recognized and traced throughout the Cherokee outcrop area of Kansas. While no section has been found where all of the eight phases of all of the fifteen cyclothems are present, only one small area has been found where whole cyclothems, in this instance two of them, are completely absent. Cyclothem 8, in which occur the beds commonly known as the Ardmore limestone and the Bevier coal, was traced across the State

54/Moore, Raymond, C., Correlation of Pennsylvanian Formation of Texas and Oklahoma. The Bulletin of the American Association of Petroleum Geologists. vol. 13, No. 8, p. 885, 1929.

line into Missouri and into Oklahoma. The Bevier coal bed, Phase 14.4, has been recognized by White[55] as identical with a coal at the base of the Allegheny formation of the Appalachian trough, a coal which in Illinois is the base of the Carbondale formation.

Lithologic characters, like paleontologic characters, are reflections of the environmental conditions at the time of deposition of the sediments and are aids in correlation. Vertical variations in the lithologic character of the beds are in most cases more abrupt than are the horizontal variations. Coal beds and limestones usually make distinct contacts with the beds above and below them. The shales are quite variable in thickness, and their lithologic character changes both vertically and horizontally by gradual transition from shales to sandstones and sandy shales. The black shale beds are always separated by a distinct contact with the underlying coal beds. However, the black shale usually changes vertically by a gradual transition into gray shale.

The sandstones are made of poorly sorted sands that rapidly change in character laterally and vertically. Mica occurs abundantly in the channel sands. Mud cracks, current-ripples, and fragments of plant fossils indicate that the sandstones of the Cherokee are continental in

55/White, David, Pottsville-Allegheny Boundry in the Interior Province, Bulletin of the Geological Society of America, vol. 24, p. 716, 1913.

origin rather than marine.

Like sequences of beds are of great aid in the correlation of the Cherokee, which is made up of fifteen cyclothems or similar series of strata. The normal sequence of a cyclothem consists of continental sandstone, sandy shale, underclay, and coal, followed by marine black shale, limestone, and shale. The sequence of beds of some cyclothems is diagnostic because the sequence is normal. The sequence in other cyclothems is characteristic because of the absence of certain beds. The sequence of beds of Cyclothem 3 is typical of a normal cyclothem, each of the eight phases or beds being represented. Cyclothem 9 is characterized by the absence of the sandstone and sandy shale phase. In Cyclothem 12 the coal occurs beneath a thin bed of black shale and over a bed of underclay nine feet thick. Cyclothem 13 consists of only two phases, the underclay and limestone. Cyclothem 12 is characterized by the coal bed occurring commonly between the underclay of the series and the underclay of Cyclothem 13.

Unconformities are also of importance in the correlation of the Cherokee. Distinct erosional unconformities occur beneath each of the sandstone phases. The sandstone phase of Cyclothem 7 almost directly overlies the coal bed of Cyclothem 6 a short distance east of Pittsburg and at some places cuts out the coal. A few miles farther west there is twelve to fifteen feet of intervening shale. In section 34, T. 31 S., R. 24 E., the sandstone phase of Cyclothem 12 rests directly upon a distinct erosional unconformity. As a result of this unconformity the highest or shale phase of Cyclothem 11 ranges from one to eleven feet in thickness. In section 25, T. 29 S., R. 25 E. in the mine of the Alston Coal Company, the coal bed of Cyclothem 7 is practically horizontal for a distance of one-half mile. Yet at the south end of the mine it is separated from the coal bed of Cyclothem 6 by an interval of eight feet of sandy shale and by an interval of 30 feet at the north end of the mine.

Paleontologic characters are often of great aid in correlation. Though the Cherokee shale in Kansas has but few "guide fossils" and no species that are diagnostic of definite horizons, the fauna of the Cherokee shale is, however, of distinct aid in correlation. In the alternating shales, sandstones, and limestones that occur in the Cherokee shale of southeastern Kansas, certain phases are characterized by one species or by a group of species, while other phases are given a distinctive character by different assemblages. Correlation of this nature can be made, as pointed out by Dunbar and Condra[57], with long

57/Dunbar, Carl O., and Condra, G. E., Brachiopoda of the Pennsylvanian System in Nebraska, Nebraska Geological Survey Bulletin No. pp. 26-29, 1932.

ranging species. For example, Phase 9.5 in section 32, R. 25 E., T. 29 S., bears an exceptional abundance of Chonetes granulifer, Mesolobus mesolobus var. lioderma and Linoproductus missouriensis, while Phase 14.5 has an abundance of crinoid stems, Marginifera muricatina, Mesolobus mesolobus var. lioderma, and Neospirifer triplicatus. Phase 13.7 is characterized by Squamularia perplexa and Chatetes milleporaceaus.

## Characteristics and Nomenclature of the Cyclothems and Phases

The cyclothems may be recognized by a cyclical repetition of certain beds called phases. The phases are identified by thickness, color, texture, fossils, and lithologic nature.

Cyclothem 1. Cyclothem 1 is the oldest cyclothem of the Cherokee. It occurs at the base of the Pennsylvanian system and marks the line of contact between that system and the underlying Mississippian system. The oldest phase locally present lies unconformably upon the eroded surface of the Mississippian system. The cyclothem has an average thickness of about 38 feet. It usually consists of Phases 1.1, 1.3, 1.4, 1.5, and 1.6. The cyclothem is named Riverton (named from Riverton, Cherokee County, Kansas) in this report. The beds of this cyclothem outcrop in the southern part of the district in the area near Riverton.

Section of the beds of Cyclothem 1 in sec. 24 T. 34 S., R. 24 E.

| | | Feet |
|---|---|---|
| Gray shale | (Phase 1.6) | 14.0 |
| Black shale | (Phase 1.5) | 10.0 |
| Coal | (Phase 1.4) | 0.7 |
| Underclay | (Phase 1.3) | 1.0 |
| Sandstone | (Phase 1.1) | 10.0 |

Phase 1.1 has a thickness of five feet at Pittsburg, Girard, and Weir, but increases in thickness to 20 feet in the southern part of the district. It is a coarse-grained,

poorly sorted, micaceous sandstone.

A bed of underclay three feet thick separates the sandstone from an overlying bed of coal.

The coal bed ranges from three to ten inches in thickness and is widely distributed over the district. This has never been named, although it was one of the first coal beds mined in the district. It probably corresponds to the lower Dederick of Vernon County, Missouri. It is designated as Phase 1.4 in this report.

The marine beds of this cyclothem, Phases 1.5 and 1.6, have a combined thickness of 24 feet at Pittsburg and 110 feet at Cherokee, which is only 15 miles southwest of Pittsburg. No fossils have been observed in these beds.

Cyclothem 2. An unconformity separates the beds of Cyclothem 2 from the beds of the underlying cyclothem. It has an average thickness of about 26 feet. It consists of Phases 2.2, 2.3, 2.4, 2.5, and 2.6. The cyclothem is named Neutral (named from Neutral, Cherokee County, Kansas) in this report. The beds of this cyclothem outcrop in the southern part of the district in the area near Neutral. No fossils have been observed in the beds of this cyclothem.

The characteristic bed of the cyclothem is a coal bed two feet thick which is divided by a shale parting that varies from one to three feet in thickness. The parting occurs near the middle of the coal bed. This coal bed has never been named but probably corresponds to the middle Dederick of Vernon County, Missouri. It is designated as Phase 2.4 in this report.

<u>Cyclothem 3</u>. An unconformity separates Cyclothem 3 from the beds of the underlying cyclothem. It has an average thickness of 30 feet and is widely distributed over the district. The characteristic features of the cyclothem are the absence of an underclay (Phase 3.3) beneath the coal bed, the thick bed of sandstone (Phase 3.1) which is the basal member of the cyclothem, and the absence of fossils in the marine beds above the coal. It consists of Phases 3.1, 3.4, and 3.5. The cyclothem is named Columbus in this report. It outcrops southeast of Columbus in a broad belt and strikes N. E., but in most places the beds are obscured by a thick accumulation of soil. At Locality 12 a recently formed sink hole, about 100 feet in diameter and 40 feet deep, forms an excellent exposure. Near the center of sec. 9, T. 32 S., R. 25 E., the beds of this cyclothem are vertical as a result of a subsidence on the irregular surface of the Mississippian limestone. It also outcrops at Localities 31, 32, and 33.

A bed of sandstone (Phase 3.1) underlies the coal bed of this cyclothem. The sandstone phase has an average thickness of 28 feet. It contains abundant mica and the sand grains are poorly sorted and weakly cemented. Its outcrop does not form a conspicuous escarpment, but the weathering of the bed produces a sandy soil.

The coal bed of this cyclothem has an average thickness of 16 inches. It has been mined near its outcrop for a number of years and in many localities furnishes a sufficient supply of coal for local consumption. The bed which occurs widely distributed over the area, corresponds to the Dederick coal bed of Vernon County, Missouri and is known in Kansas as the "Columbus" coal. It is designated as Phase 3.4 or the Columbus coal bed in this report.

Cyclothem 4. Cyclothem 4 is the oldest fossiliferous cyclothem of the Cherokee group. It has an average thickness of 68 feet and overlies Cyclothem 3 from which its beds are separated by a non-evident unconformity. It is separated from the overlying basal conglomerate of Cyclothem 5 by an erosional unconformity. The most characteristic features of this cyclothem are the basal sandstone member (Phase 4.1), the absence of fossils in the black shale (Phase 4.5), the presence of fossils in the limestone member (Phase 4.7), and the presence of an "iron ore" band beneath the limestone. The cyclothem is named Bluejacket in this report. The outcrop of this cyclothem forms a broad belt extending in a northeast direction from an area northeast of Columbus to the state line north of Opolis. However, the outcrop is in most places obscured by a thick accumulation of soil. Sections were measured at Localities 24 and 40.

<u>Section of the beds in Cyclothem 4 in sec. 28, T. 30 S., R. 25 E. at Locality 24</u>

| | Feet |
|---|---|
| Shale (Phase 4.8) | 5.0 |
| Limestone (Phase 4.7) | 1.0 |
| Iron ore (Phase 4.7) | 0.5 |
| Gray shale (Phase 4.6) | 10.0 |
| Black shale (Phase 4.5) | 8.0 |
| Coal (Phase 4.4) | 1.5 |
| Underclay (Phase 4.3) | 6.0 |
| Sandy shale (Phase 4.2) | 8.0 |
| Sandstone (Phase 4.1) | 20.0 |

The lowest member of this cyclothem is a fine-grained, massive, cross-bedded, and brown colored sandstone. Locally the stone is used for building purposes. The bed has an average thickness of about 20 feet. Its weathered outcrop forms a row of conspicuous hills extending from the Oklahoma state line in a northeast direction as far as Crestline. The outcrop can be traced from Crestline to the state line near Opolis. This sandstone was given the name "Clear Creek" by Broadhead[58]. The same sandstone was named "Columbus" by Haworth[59]. Neither of these names are valid, however, because of previous use for other stratified rocks. This sandstone is designated as Phase 4.1 or Bluejacket in this report. The interval between it and the base of the Cherokee increases in the southern part of the

58/Broadhead, G.C., The Geology of Barton County. Missouri Geological Survey. Rept. p. 100, 1874.

59/Haworth, E., and Kirk, M.Z., Kansas University Quarterly vol. 2, p. 106, 1894.

district. At Pittsburg the interval is 91 feet, at Cherokee it is 150 feet, and at Weir City 168 feet.

Phase 4.7 is the lowest limestone member in the Cherokee of Kansas. The limestone is dense, fine-grained, massive, and dark gray in color. A horizon near its base contains an abundance of fossil fragments.

Fossils collected at Locality 24 from Phase 4.7.

| | |
|---|---|
| Crinoid segments.................................. | (common) |
| Fossil fragments.................................. | (abundant) |
| Marginifera muricatina Dunbar and Condra......... | (rare) |
| Linoproductus prattenianus (Norwood and Pratten) | (common) |
| Squamularia perplexa McChesney.................. | (abundant) |
| Cleiothyridina orbicularis McChesney............ | (common) |

Cyclothem 5. An unconformity forms the line of contact between the beds of Cyclothem 5 and the beds of Cyclothem 4. The average thickness of Cyclothem 5 is about 24 feet. It consists of Phases 5.1, 5.3, 5.4, 5.5, and 5.6. The cyclothem is named Kniveton (named from Kniveton Crawford County, Kansas) in this report. The characteristic features of the cyclothem are the absence of marine fossils and the continental phases of sandstone and sandy shale. The cyclothem outcrops at Localities 12, 13, and 24.

Section of the beds in Cyclothem 5 in sec. 28, T. 30 S., R. 25 E., at Locality 24:

| | Feet |
|---|---|
| Gray shale (Phase 5.6)........... | 3.0 |
| Black shale (Phase 5.5).......... | 3.0 |
| Coal (Phase 5.4).................. | 0.0 |
| Underclay (Phase 5.3)............ | 1.0 |
| Gravel conglomerate (Phase 5.1).. | 1.0 |

The lowest member of the cyclothem is the bed of underclay (Phase 5.3). It ranges from 12 inches to 3 feet in thickness. It is characterized by an abundance of fragments of plant fossils.

Above the underclay is an unnamed coal bed that has an average thickness of eight inches. This coal bed is designated as Phase 5.4 in this report.

Phase 5.5 is a black fissle shale that overlies the coal bed. It has an average thickness of three feet. Fossils have never been observed in it.

Cyclothem 6. Cyclothem 6 is separated from the beds of Cyclothem 5 by an unconformity. It consists of Phases 6.1, 6.3, 6.4, and 6.5. The characteristic features of the cyclothem are the widely distributed coal bed of uniform thickness, the parting of "black-jack" 24 inches thick within the coal bed, the abundance of plant fossils at the horizon of the contact of the coal bed with the black shale, the occurrence of "rash"[60/] above the coal at some localities, the complete absence of marine fossils, the existence of numerous channel sand deposits in the marine beds, and the common occurrence of "horsebacks" or clay veins in the coal bed. The cyclothem is named Weir (named from Weir, Cherokee County, Kansas) in this

60/Rash is a mixture of inorganic sediments with fragments of coal and "mineral-charcoal" or "mother of coal" which is preserved organic debris, consisting of fragments of wood, ferns, bark, and leaves.

report. The cyclothem outcrops over a wide area in the Pittsburg district; at most places however, the beds are obscured by soil. Sections were measured at Localities 11, 16, 17, and 29.

Section of the beds of Cyclothem 6 in sec. 24, T. 29 S., R. 25 E., Locality 11.

| | Feet |
|---|---|
| Gray shale (Phase 6.6) | 7.0 |
| Black shale (Phase 6.5) | 5.0 |
| Coal (Phase 6.4) | 2.5 |
| Blackjack (Phase 6.4) | 1.5 |
| Coal (Phase 6.4) | 0.5 |
| Underclay (Phase 6.3) | 1.0 |
| Sandstone (Phase 6.1) | 3.0 |

Phase 6.1, the basal member of the Cyclothem, is a fine-grained, thin-bedded sandstone light-brown in color. It ranges in thickness from one to eight feet.

The coal bed has an average thickness of about three feet. It is a good grade of coal and has been the most extensively mined of any coal bed in Kansas. In the vicinity of Pittsburg the bed ranges from a few inches to 150 feet beneath the surface. The coal has a large number of bands with a brilliant luster known as glance or vitrain; it also contains numerous planes of lamination parallel to the bedding planes along which the coal readily parts. The planes of lamination are horizons containing abundant plant remains, usually well preserved by having been replaced with iron sulphide. The upper surface of the coal bed is crowded with the carbonized fragments of delicate forms of plant life. This coal bed is known as the "Lower Weir-Pittsburg." It was called "Pittsburg lower" by Haworth[61/] in 1895, and the "Weir-Pittsburg lower" by Haworth[62/] in 1898. The same name was given to this bed by Greene and Pond[63/]. Locally the bed is called the Weir-Pittsburg. However, some local coal operators call this bed, as well as other beds, the "Cherokee" coal bed. It is designated as Phase 6.4 or the Weir-Pittsburg coal bed in this report. The "blackjack" parting which characterizes this coal bed is about two feet thick. It consists of a mixture of inorganic sediments and carbonized organic debris. The parting occurs in most instances about one foot above the base of the coal bed.

The channel sands that are prominently associated with this cyclothem are not a part of it but belong to the cyclothem superimposed upon it. This feature is well exposed at Locality 35.

Cyclothem 7. Cyclothem 7 overlies Cyclothem 6, and is separated from it by an erosional unconformity.

61/Haworth, Erasmus, Stratigraphy of the Kansas Coal Measures, American Journal of Science, p. 467, 1895.

62/Haworth, Erasmus, Special Report on Coal, University of Kansas Geological Survey, p. 151, 1898.

63/Greene, F.C. and Pond, W.F., The Geology of Vernon County, Missouri Bureau of Geology and Mines, vol. 19, p. 38, 1926.

Its characteristic features are the common occurrence of Phases 7.1, 7.2, 7.3, 7.4, 7.5 and 7.6; the uniform thickness, distribution, and interval between the coal bed and the base of the cyclothem; the occurrence of a faunal zone in the black shale near its contact with the coal bed; and the jointed and laminated nature of the black shale. The cyclothem is named Pilot in this report. It is exposed at Localities 11, 16, and 17.

<u>Section of the beds in Cyclothem 7.0 in sec. 24,</u>

<u>T. 29 S., R. 25 E.</u>

| | Feet |
|---|---|
| Gray shale (Phase 7.6) | 2.0 |
| Black shale (Phase 7.5) | 8.0 |
| Coal (Phase 7.4) | 0.5 |
| Underclay (Phase 7.3) | 1.0 |
| Sandstone (Phase 7.2) | 10.0 |

Phase 7.1 is the basal bed of the cyclothem. It consists of a bed of sandstone about eight feet thick made up of poorly sorted grains. The sandstone is thin-bedded and contains numerous current-ripple marks. Lenses of this sandstone occupy well defined stream channels and valleys which have been eroded by surface streams into the underlying beds of Cyclothem 6.

The coal bed (Phase 7.4) is of no economic importance because of its thinness. It is commonly used by drillers as a key bed. This coal bed was named the Walker by Greene and Pond.[64/] In this district the bed is commonly

64/Greene, F.C., and Pond, W.F., The Geology of Vernon County, Missouri Bureau of Geology and Mines, vol. 19, p. 47, 1926.

known as the "Pilot" bed. It is designated as Phase 7.5 in this report.

The black shale (Phase 7.5) is extremely fossiliferous, but the fossils are, as a rule, extremely fragile.

Fossils collected from Phase 7.5 at Locality 11.

| | |
|---|---|
| Rhombopora sp................................. | (rare) |
| Orbiculoidea missouriensis (Shumard)....... | (common) |
| Chonetes granulifer Owen .................. | (common) |
| Mesolobus mesolobus var. euampygus (Girty). | (common) |
| Wellerella osagensis Swallow............... | (common) |
| Punctospirifer kentuckyensis Shumard....... | (common) |
| Nuculana arata Hall........................ | (rare) |

Cyclothem 8. Cyclothem 8 has an average thickness of 33 feet. Its beds overlie the beds of Cyclothem 7 and are separated from them by an unconformity. Its most characteristic features are the common occurrence of all the phases of a normal cyclothem: the presence of a limestone member; two fossiliferous horizons, the limestone and black shale members; and the presence of cephalopod and the abundance of pelecypod shells. The cyclothem is named Scammon in this report. It is exposed at Localities 11, 17, and 20.

Section of the beds in Cyclothem 8 in sec. 26, T. 31, S., R. 24, E., Locality 17.

| | Feet |
|---|---|
| Shale (Phase 8.8) | 10.0 |
| Limestone (Phase 8.7) | 1.0 |
| Gray shale (Phase 8.6) | 4.0 |
| Black shale (Phase 8.5) | 1.0 |
| Coal (Phase 8.4) | 0.3 |
| Underclay (Phase 8.3) | 1.9 |
| Sandy shale (Phase 8.2) | 8.0 |
| Sandstone (Phase 8.1) | 8.0 |

The black shale bed (Phase 8.5) is very fossiliferous. The fossil fauna is characterized by the presence of cephalopod and the abundance of pelecypod shells. This bed is well exposed along the banks of Cherry Creek, where it crosses State Highway 7 near Scammon in Cherokee County, at Locality 20.

<u>Fossils collected from Phase 8.5 at Locality 20.</u>

| | |
|---|---|
| Orbiculoidea missouriensis (Shumard) .......... | (common) |
| Chonetes granulifer Owen...................... | (common) |
| Marginifera muricatina Dunbar and Condra....... | (abundant) |
| Wellerella osagensis Swallow.................. | (rare) |
| Ambocelia planoconvexa (Shumard)............... | (rare) |
| Nuculopsis ventricosa Schenck.................. | (rare) |
| Nuculana arata Hall............................ | (abundant) |
| Yoldia knoxensis McChesney..................... | (rare) |
| Trepospira sphaerulata Hall.................... | (common) |
| Pleurotomaria sp............................... | (common) |
| Euphemites carbonarius Cox..................... | (common) |
| Naticopsis scintilla Girty..................... | (rare) |
| Domatoceras williamsi.......Miller and Owen.... | (common) |

Phase 8.7 is a dark gray dense limestone with an average thickness of six inches. It commonly contains fossils but they are not abundant.

<u>Fossils collected from Phase 8.7 at Locality 17.</u>

| | |
|---|---|
| Crinoid stems | |
| Marginifera muricatina Dunbar and Condra....... | (common) |
| Squamularia perplexa (McChesney)............... | (rare) |
| Chonetes granulifera Owen ..................... | (rare) |
| Bellerophon sp................................. | (rare) |
| Orthoceras sp.................................. | (rare) |
| Pseudothoceras knoxensis McChesney............. | (rare) |
| Bactrites cherokensis Miller and Owen.......... | (rare) |
| Metacoceras pottsvillensis Morningstar......... | (rare) |
| Temnocheilus harneri Miller and Owen........... | (common) |
| Domatoceras williamsi Miller and Owen.......... | (common) |

Cyclothem 9. Cyclothem 9 has an average thickness of about 12 feet. It consists of Phases 9.3, 9.4, 9.5, and 9.6. The characteristic features of the cyclothem are the uniform thickness and distribution of the coal bed, the absence of "faults" and rare occurrence of "horse-backs" in the coal bed, the abundance of fossils (individuals and species) in the black shale. The cyclothem is exposed and sections were measured at Localities 2, 4, 14, 15, 17, and 23.

Section of the beds in Cyclothem 9 in sec. 34, T. 32 S., R. 24 E., Locality 14.

| | Feet |
|---|---|
| Gray shale (Phase 9.6) | 2.0 |
| Black shale (Phase 9.5) | 7.0 |
| Coal (Phase 9.4) | 1.9 |
| Underclay (Phase 9.3) | 2.0 |

The coal bed of this cyclothem has an average thickness of about 22 inches. It is free of faults but contains a few "horse-backs." Well preserved brachiopod shells have been collected from it.[65] The "Rich Hill" coal bed occurs at this horizon in Missouri. The bed is known locally as the upper "Weir-Pittsburg," "22 Inch," "Lightning Creek," and Mineral. It is designated as Phase 9.4 or Mineral coal bed in this report.

65/Greene, F.C., and Pond, W.F., The Geology of Vernon County, Missouri Bureau of Geology and Mines, vol. 19, p. 48, 1926.

The black shale bed (Phase 9.5) is extremely fossiliferous. The fossils occur largely at definite horizons, apparently along bedding planes near the base of the bed. They are distinctive in that most of them consist of white calcite, which makes a striking contrast with the black shale, for most fossils from the black shale beds of other cyclothems consist of molds and casts. The fossils of this bed are characterized by the abundance of Mesolobus mesolobus var. decipiens, Orbiculoidea missouriensis, and Linoproductus prattenianus. Marginifera muricatina, a common fossil of the fossiliferous beds of the Cherokee in Kansas, rarely occurs in this bed.

Fossils collected from Phase 9.5 at Locality 23.

| | |
|---|---|
| Crinoid stems.................................. | (common) |
| Rhombopora sp.................................. | (rare) |
| Orbiculoidea missouriensis (Shumard)............ | (abundant) |
| Derby crassa (Meek and Hayden).................. | (rare) |
| Chonetes granulifer Owen........................ | (rare) |
| Mesolobus mesolobus var. decipiens (Girty)...... | (abundant) |
| Mesolobus mesolobus var. euampygus (Girty)...... | (rare) |
| Marginifera muricatina Dunbar and Condra........ | (rare) |
| Linoproductus prattenianus (Norwood and Pratten) | (abundant) |
| Linoproductus magnispinus Dunbar and Condra..... | (common) |
| Linoproductus missouriensis (Sayre)............. | (rare) |
| Squamularia perplexa McChesney.................. | (rare) |
| Neospirifer triplicatus (Hall).................. | (rare) |
| Ambocelia planoconvexa (Shumard)................ | (rare) |
| Cleiothyridium orbicularis (Shumard)............ | (rare) |
| Bactrites sp.................................... | (rare) |

The coal is a good steam-coal but has a higher ash content than the lower "Weir-Pittsburg" bed (Phase 6.4).

More coal is now produced from this bed (Phase 9.4) than from all other beds in the district. During 1935 the coal produced from this bed was 70 per cent of the total coal produced in the district.

Cyclothem 10. Cyclothem 10 has an average thickness of 24 feet. It consists of Phases 10.1, 10.2, 10.3, 10.4, 10.5, and 10.8. Its characteristic features are the wide distribution of the coal bed and the absence of fossils. The cyclothem is named Fleming (named from Fleming, Crawford County, Kansas) in this report. It is exposed at Localities 17, 23, 2, 14, and 15.

Section of the beds in sec. 34, T. 30 S., R. 24 E., Locality 14.

| | Feet |
|---|---|
| Shale (Phase 10.8) | 2.0 |
| Black shale (Phase 10.5) | 6.0 |
| Coal (Phase 10.4) | 1.0 |
| Underclay (Phase 10.3) | 0.6 |
| Sandy shale (Phase 10.2) | 4.0 |

The coal bed ranges from 2 to 12 inches in thickness. It occurs over a large area but has been mined only at a few localities in Kansas and has, therefore, never been named. It probably corresponds to the bed known as the "Middle coal" or "Two-foot" in Vernon County, Missouri. It is designated as Phase 10.4 in this report.

Cyclothem 11. Cyclothem 11 has an average thickness of only nine feet. It consists of Phases 11.1, 11.2, 11.3, 11.4, 11.5, and 11.6. The cyclothem is characterized by the irregular thickness of the beds and the absence of fossils. At many localities some of the beds are extremely thin or absent. The cyclothem is named Coalvale (named from Coalvale, Crawford County, Kansas) in this report. It is exposed at Localities 4, 5, 6, 17, and 23.

Section of the beds in Cyclothem 11 in sec. 23, T. 30 S., R. 24 E., Locality 4.

| | Feet |
|---|---|
| Gray shale (Phase 11.6) | 1.0 |
| Black shale (Phase 11.5) | 1.0 |
| Coal (Phase 11.4) | 1.0 |
| Underclay (Phase 11.3) | 2.3 |
| Sandy shale (Phase 11.2) | 3.0 |

The coal bed has an average thickness of 12 inches. A characteristic feature is its uneven contour. It is not parallel with the bedding of the underlying beds, as it appears to have accumulated on a swamp floor that was very uneven. The coal has never been mined in Kansas and has, therefore, never been named. It probably corresponds to the bed known as the "One-foot," "Ten-inch," and "Soapstone" in Vernon County, Missouri. It is designated as Phase 11.4 in this report.

Cyclothem 12. Cyclothem 12 lies unconformably upon the beds of Cyclothem 11 and has an average thickness of 18 feet. It consists of Phases 12.3, 12.4, and 12.5. The characteristic features are the extremely thick bed of underclay; the occurrence of a workable coal bed above the underclay; the absence of all of the marine beds with the exception of a bed of black shale that occurs locally; and, when present, lies between the coal bed and the bed of underclay of the overlying cyclothem. This cyclothem is named Cato in this report. It is exposed at Localities 21 and 36.

Section of the beds in Cyclothem 12 at Locality 36.

| | Feet |
|---|---|
| Black shale (Phase 12.5) | 7.0 |
| Coal (Phase 12.4) | 2.0 |
| Underclay (Phase 12.3) | 9.0 |

The coal bed of this cyclothem is mined in the northeast part of the district, especially in the vicinities of Breezy Hill and Mulberry and in an area northeast of Croweburg. The coal bed is probably the one known as the "Tebo" and the "One-foot" in Missouri. Hinds[66] states that the "Tebo" had long been in use in Henry County and had later been used in all parts of the state. The coal bed is known locally as the "Fireclay" and "Pioneer," the latter name being more commonly used. It is designated as Phase 12.4 or the Cato coal bed in this report.

The black shale bed (Phase 12.5) is very fossiliferous and is easily identified by its fossils and its relation with the other phases of this cyclothem.

66/Hinds, Henry, The Coal Deposits of Missouri, Missouri Bureau of Geology and Mines, vol. XI, p. 12, 1912.

Fossils collected from Phase 12.5 in sec. 32, T. 29 S., R. 25 E., Locality 6.

| | |
|---|---|
| Prismopora sp | (rare) |
| Rhombopora sp | (rare) |
| Fusulina sp | (rare) |
| Crinoid stems | (abundant) |
| Orbiculoidea missouriensis (Shumard) | (common) |
| Derbya crassa Meek and Hayden | (common) |
| Chonetes granulifer Owen | (common) |
| Mesolobus mesolobus var. lioderma Dunbar and Condra | (abundant) |
| Marginifera muricatina Dunbar and Condra | (abundant) |
| Squamularia perplexa McChesney | (rare) |
| Neospirifer triplicatus Hall | (common) |
| Dictyoclostus portlockianus var. crassicostatus Dunbar and Condra | (rare) |
| Neospiriferer cameratus Morton | (rare) |

Cyclothem 13. Cyclothem 13 has an average thickness of five feet. It consists of Phases 13.3 and 13.7. The characteristic features of the cyclothem are its extreme thinness, the occurrence of only two phases, the absence of a coal bed, the wide distribution of the limestone bed, and the fossil content of the limestone member (Phase 13.7). The cyclothem is named Ardmore in this report. It is exposed at Localities 3, 21, 9, 10, and 17.

Section of beds in Cyclothem 13 at Locality 10.

| | Feet |
|---|---|
| Limestone (Phase 13.7) | 3.0 |
| Underclay (Phase 13.3) | 1.0 |

This limestone commonly occurs as a single bed that ranges from one to four feet in thickness. It is a dense, fine-grained, dark gray, and fossiliferous limestone which weathers to a buff color. Characteristic fossils are Composita subtilita and Squamularia perplexa. The limestone occurs over the entire district except where it has been removed by erosion. Its outcrop can be traced along U. S. Highway 59 from a point on the northern Crawford County line to a locality in the vicinity of Arma; from here its outcrop strikes southwest and passes through Lone Oak and Cherokee County, then turns south and passes out of the state near Chetopa. This limestone was called "Rich Hill" by Greene and Pond[67], it was named the Ardmore by Gordon[68], and is the limestone that Haworth[69] named the "Swallow" limestone. The term Ardmore is in good standing. It is designated as Phase 13.7 or Ardmore limestone in this report.

Fossils collected from Phase 13.7 in sec. 8, T. 28 S., R. 25 E., at Locality 10.

| | |
|---|---|
| Crinoid stems | (common) |
| Marginifera muricatina Dunbar and Condra | (common) |
| Squamularia perplexa McChesney | (abundant) |
| Composita subtilita(Hall) | (common) |
| Composita argentea (Shepard) | (rare) |
| Pleurotomaria ornatiformis Morningstar | (rare) |

Cyclothem 14. Cyclothem 14 has an average thickness

67/Greene, F. C., and Pond, W. F., The Geology of Vernon County, Missouri Bureau of Geology and Mines, p. 51, 1926.

68/Gordon, C.H., A report on the Bevier Sheet. Missouri Geological Survey, vol. 9, 1st. series, pt. 2, 1896, Sheet Report No. 2, p. 30, 1893.

69/Haworth, Erasmus, Stratigraphy of Eastern Kansas: Kan. Quart., No. 2, p. 126, 1894.

of about nine feet, and consists of Phases 14.3, 14.4, and 14.5. Its characteristic features are the widespread occurrence of a coal bed 24 inches thick, the blocky and gnarled appearance of the coal, the abundance of fossils in the black shale, a cap-rock, and a limestone phase which occurs as three beds separated by black shale partings a few inches thick. The cyclothem is named Bevier in this report. It is exposed in the northern part of the district at Localities 8, 9, 10, and 21.

<u>Section of beds of Cyclothem 14 in sec. 8, T. 28 S., R. 25 E., at Locality 10.</u>

| | Feet |
|---|---|
| Black shale (Phase 14.5) | 6.0 |
| Coal (Phase 14.4) | 2.0 |
| Underclay (Phase 14.3) | 1.4 |

The coal bed is the third most important coal bed in the district and is extensively mined in the northern part of the district. It has an average thickness of about two feet. A bed of underclay is usually associated with this phase. The bed has numerous joints and fractures, and the planes of lamination have a gnarled, twisted appearance. The bed is usually overlain by a cap-rock of calcareous shale containing a considerable quantity of iron sulphide. It is the only coal bed in the district from which marine fossils have been collected. Well preserved shells (pyritized) of <u>Marginifera muricatina</u> were identified from Locality 8. This coal bed is known in Vernon County, Missouri, as the "Williams" and the Bevier coal.[70] It is probably the Bevier coal of northern Missouri.[71] Locally it is known as the "Limestone," and "Baxter" coal. It is designated as Phase 14.4 or the Bevier coal bed in this report.

The limestone member (Phase 14.7) overlies the black shale bed at most localities. Where observed at the exposures in the northern part of the district, it is divided into three thin beds, 12 inches, 8 inches, and 4 inches thick, separated by thin partings of black shale a few inches thick. The limestone is a dark-gray color, dense, fine-grained, and fossiliferous.

Fossils collected from Cyclothem 14 at Locality 8.

Squamularia perplexa McChesney.......(common)
Composita subtilita (Hall)...........(common)

Cyclothem 15. Cyclothem 15 has an average thickness of 65 feet. It consists of Phases 15.1, 15.2, 15.3, 15.4, 15.5 and 15.7. The characteristics of the cyclothem are the great thickness of the cyclothem, the red color of the coal, the concretionary character of the upper bed of black shale, and the fossils that occur in the limestone

70/Greene, F.C., Oil and Gas Pools of Western Missouri, Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist, p. 14, 1933.

71/Greene, F.C., and Pond, W.F., The Geology of Vernon County, Missouri Bureau of Geology and Mines. vol. 19, p. 52, 1926.

and upper black shale bed. The beds of this cyclothem are exposed in the northern part of the district. The cyclothem is named Mulky in this report. Sections were measured at Localities 10, 18, 19, 37, and 38.

<u>Section of beds in Cyclothem 15 in sec. 31, T. 28 S., R. 25 E. at Locality 10.</u>

| | Feet |
|---|---|
| Black shale (Phase 15.5) | 4.0 |
| Limestone (Phase 15.7) | 6.0 |
| Black shale (Phase 15.5) | 8.0 |
| Coal (Phase 15.4) | 2.0 |
| Underclay (Phase 15.3) | 2.0 |
| Sandy shale (Phase 15.2) | 40.0 |
| Sandstone (Phase 15.1) | 11.0 |

The non-marine beds of this cyclothem are extremely thick, averaging more than 50 feet. The sandstone varies from a fine-grained shaly type to a comparatively coarse type.

The coal bed has an average thickness of about 20 inches. It is commonly underlain by a bed of underclay two feet thick. The coal is reddish because of the iron oxide that fills the joint planes, cracks, and lamination planes. It was the first bed developed in Kansas. It is extensively mined (by small mines) in the northern part of the district and is mined to some extent in the vicinities of Chetopa and Oswego. This coal bed is known as the "Mulky"[72/]

72/Greene, F.C., Oil and Gas Pools of Western Missouri, Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist. p. 14, 1933.

in Missouri. Locally it is called the "Ft. Scott" coal or the "Red" coal. It is designated as Phase 15.4 or the Mulky coal bed in this report.

The limestone member (Phase 15.7) is underlain by eight feet of non-fossiliferous black shale and overlain by four feet of fossiliferous black shale. The limestone is fine-grained, compact, light gray, impure, and fossiliferous; it averages about six feet thick. It caps most of the higher hills in the area between Arma and Dry Wood Creek. The bed contains a large number of individual marine fossils but comparatively few species.

Fossils collected from Phase 15.7 at Locality 18.

Fusulina sp......................................(common)
Crinoid stems....................................
Chaetetes milleporaceus Milne-Edwards and Haime.(common)
Squamularia perplexa (McChesney)................(common)
Hustedia marmoni (Marcou)........................(common)
Myalina sp.......................................(rare)

The upper black shale member (Phase 15.5) is very fossiliferous; however, only one species is common. Orbiculoidea missouriensis occurs abundantly and frequently within concretions. The small spherical concretions, range in size from $\frac{1}{4}$ to $\frac{3}{4}$ inches in diameter, occur abundantly, and are characteristic of the upper black shale.

## Summary

The Cherokee group in southeastern Kansas is differentiated into fifteen cyclical formations called cyclothems and are designated by whole numbers from one to fifteen. The basal cyclothem is 1 and the uppermost is 15.

A normal cyclothem is composed of a series of beds, called phases which are arranged in a definite order and are designated by decimal numbers from 0.1 to 0.8. The basal member is Phase 0.1 and the uppermost is Phase 0.8.

Nonmarine sandstone forms the basal phase of eight cyclothems, and each basal sandstone is separated from the underlying cyclothem by an erosional unconformity.

Underclays are present at least locally in each cyclothem except Cyclothem 3. The physical properties of most underclays appear to be about the same. Carbonaceous matter and fragments of plant fossils are abundant in Phase 5.3.

A coal bed is present at least locally in twelve of the fifteen cyclothems. Five of the coal beds are mined, although two of them produce more than 90 per cent of all of the coal mined in the district. The coal beds are remarkably persistent in distribution and uniform in thickness.

Black shale phases are present in fourteen of the fifteen cyclothems. They contain abundant fossils in six cyclothems.

Limestone beds are thicker and more numerous in the upper portion of the Cherokee. Limestone phases are present in five cyclothems, and each phase is fossiliferous.

Marine fossils are abundant in eight of the cyclothems. The greatest number of individuals from one cyclothem was collected from Cyclothem 9. The greatest number of species collected from one cyclothem was 16, from Cyclothem 8. The total number of species collected was 42. The most common species were *Mesolobus mesolobus var. lioderma*, *Mesolobus mesolobus var. decipiens*, and *Marginifera muricatina*. The species most diagnostic of cyclothems are: *Linoproductus prattenianus*, occurring abundantly only in Cyclothem 9 and rarely in any other cyclothem; *Fusulina* occurring abundantly only in Cyclothem 15 and rarely in Cyclothem 12; and *Domatoceras williamsi*, and *Nuculana arata* occurring only in Cyclothem 8.

## Complete list of Fossils from the Cherokee.

Fusulina sp.
Crinoid stems
Prismopora sp.
Rhombopora sp.
Chaetetes milleporaceus Milne-Edwards and Haime
Orbiculoidea missouriensis (Shumard)
Derbya crassa (Meek and Hayden)
Chonetes granulifer Owen
Mesolobus mesolobus var. lioderma Dunbar and Condra
Mesolobus mesolobus var. decipiens (Girty)
Mesolobus mesolobus var. euampygus (Girty)
Dictyclostus portlockianus var. crassicostatus Dunbar and Condra

Marginifera muricatina Dunbar and Condra
Linoproductus prattenianus (Norwood and Pratten)
Linoproductus magnispinus Dunbar and Condra
Linoproductus missouriensis (Sayre)
Wellerella osagensis (Swallow)
Squamularia perplexa (McChesney)
Neospirifer triplicatus (Hall)
Neospirifer cameratus (Morton)
Ambocoelia planoconvexa (Shumard)
Punctospirifer kentuckyensis (Shumard)
Hustedia mormoni (Marcou)
Cleiothyridina orbicularis (McChesney)
Composita subtilita (Hall)
Composita argentea (Shepard)
Composita ovata (Mather)
Nuculopsis girtyi Schenck
Nuculana arata Hall
Yoldia knoxensis McChesney
Myalina sp.
Aviculopecten sp.
Trepospira sphaerulata Conrad
Pleurotomaria ornatiformis Moringstar
Bellerophon sp.
Euphemites carbonarius Cox
Euphemus nodocarinatus Hall
Naticopsis scintilla Girty
Trackydoma sp.
Meekospira sp.
Orthoceras sp.
Pseudothoceras knoxenses
Bactrites cherokensis Miller and Owen
Metacoceras pottsvillensis Morningstar
Temnocheilus harneri Miller and Owen
Domatoceras williamsi Miller and Owen

Correlations of the beds have been made by these criteria: continuity of beds, lithologic character, sequence of beds, unconformities, and fossils; from the study of more than 700 well logs, fifty measured sections, numerous outcrops and ten deep mines.

# CHAPTER V

## GEOLOGICAL HISTORY

Some of the principal features in the historical geology of the Cherokee time in Kansas are: (1) evidence of erosion of the land before the beginning of Cherokee sedimentation, (2) differential subsidence of the area and the accumulation of nonmarine sediments, (3) formation of narrow and elongated sandstone lenses or channel sands. (4) dominance of continental and coarser sediments in the eastern part of the area, (5) formation of 12 beds of coal, 5 of which are persistent over the district, (6) general subsidence and submergence of the area as a whole at least 15 times and the accumulation of marine sediments during each submergence, (7) erosion unconformities.

At the close of the Mississippian time that part of Kansas known as the outcrop area of the Cherokee was above the sea, while hundreds of feet of sediments were accumulating in the Cherokee seas to the south. Before the Cherokee sea advanced into Kansas, the topography of the outcrop area was of the mature type, not greatly different from the present Ozark topography. It was probably much modified, however, by the effects of solution. In recent times the Cherokee beds have subsided into solution caverns of the Mississippian limestone, forming sink holes on the surface of the ground. These sink holes are common in the district southeast of Pittsburg.

The beds of Cherokee sediments are variable in thickness. Bass[73/] shows a map indicating the thickness of the Cherokee shale in eastern Kansas is thin at some localities. These areas probably stood at a slightly higher elevation than adjacent areas and therefore received less sediment.

The chief diastrophic movement during Cherokee time was one of general subsidence of the region as a whole at a slow but variable rate. This general or regional subsidence which was accompanied by an advance of the sea and the accumulation of marine sediments, was punctuated by intervals of time characterized by the withdrawal of the sea. The retreat of the sea may have been caused by an uplifting of the sea bottom, the silting up of the basin with sediments, or by a differential subsidence causing local areas to be relatively elevated with respect to sea level.

The beginning of the time of each cyclothem was characterized by the accumulation of continental sediments in the basin area. West-flowing streams eroded channels in the newly formed lands of the basin area. Erosion of the higher Ozark lands to the east formed coarse sandy sedi-

73/Bass, N. W., Origin of Bartlesville shoe string sands. Bulletin of the American Association of Petroleum Geologists. vol. 18, p. 1334, 1934.

ments which were transported by surface streams to broad low flats, i.e., the basin areas. The accumulation of these sediments produced the basal beds or nonmarine phases of each cyclothem. The nature of these sediments indicates that they were transported by streams and deposited in channels as thick lens shaped accumulations of sand. Later sediments were spread out by the shifting streams to form rather thin beds of sandy shale. The sandstones have a coarse texture and contain an abundance of land plant fragments, feldspar minerals, and mica. The continued erosion of the uplands and the accumulation of the sediments in the basins resulted in deposits of irregular forms and size. The nonmarine beds of the cyclothems have their greatest thickness in the eastern part of the area, which indicates that these sediments were transported from an area of higher elevation east of the basin, probably the Ozark dome. These nonmarine sediments had probably been previously deposited as shore deposits along the western side of the Ozark dome during times of greater submergence. They were therefore probably derived from the same original source as most of the sediments of the Cherokee, viz., Llanoria.[74]

Deposition of continental sediments in the basin came to an end because erosion had reduced the elevation

74/Powers, Sidney, Age of the Oklahoma Mountains; Geological Society of America. Vol. 39. p. 1052, 1928.

of the lands from which sediments were derived, to base level.

Since the surface of the ground in the basin areas was poorly drained the beds of fine-grained muds lying near the surface were oxidized, leached, and in part kaolinized. These beds are now called underclays.

Swampy lowlands were produced by irregular warping of the basin areas. Vegetation accumulated in these swamps as peat and was later transformed into coal. Coal beds were formed, at least locally, in twelve of the fifteen cyclothems of the Cherokee in southeastern Kansas. Five of these beds are fairly persistent over the district.

Marine division of cyclothems. The marine sediments of the normal cyclothem accumulated in the basin as a result of regional subsidence and the submergence of the region by the Cherokee sea which advanced from the south and west.[75] A paleogeographic map of the early Pennsylvanian time, by Powers[76] shows this seaway extending from Texas through Oklahoma to the outcrop area of the Cherokee in Kansas. Evidence that the marine sediments of the Cherokee came from the south is the increase in the thickness, and the coarsness of the clastic sediments of the beds in

75/Shuchert, Chas., and Dunbar, Carl, O., A textbook of Geology p. 241, 1933.

76/Powers, Sidnes; Age of the Oklahoma Mountains Geological Society of America. vol, 39. p. 1052, 1928.

the southern part of the area. Moore[77] finds that the source of the Pennsylvanian sediments of the western interior basin lay chiefly to the south and perhaps the southeast. During the early stage of the sea transgression, black mud was deposited upon the newly formed coal bed. These muds, mixed with large amounts of carbonaceaus matter washed from the swamp basins, have since been consolidated and are now black shales. Then followed an accumulation of more marine muds containing less carbonaceaus lands. Clastic sediments were no longer supplied, the waters of the sea cleared, and limestone was formed, all of which indicates a time of maximum submergence.

Differential subsidence or an uplift of the bottom of the sea caused fine muds to be deposited in the shallow seas that had not yet retreated from the basins. Marine deposition in the basin ended when the sea withdrew because a differential subsidence produced a relative uplift.

The newly formed surface was then subjected to erosion, with the result that at many places an erosional unconformity was produced. These unconformities separate the beds of one cyclothem from the beds of another and when present occur beneath a bed of sandstone.

77/Moore, Raymond C., Pennsylvanian cycles in the Northern Mid-continent region. Ill. State Geological Survey, Bull. 60, p. 255, 1931.

Three unconformities observed appear fairly persistent over the district; however, erosional unconformities occur at least locally in seven cyclothems. A gravel conglomerate marks the erosion unconformity at the top of Cyclothem 3. Though normally the plane of this unconformity is parallel to the beds of the cyclothem, locally the nearly horizontal gravel conglomerate rests directly upon the upturned edges of the beds of the cyclothem which dip at an angle of 80 degrees.

Summary. The most characteristic feature of Cherokee history in southeastern Kansas is the general subsidence of the region as a whole, interrupted by times of warping or differential subsidence. The regional subsidence was accompanied by an advance of the sea and the accumulation of marine sediments. The times of warping or differential subsidence were characterized by the withdrawal of the sea, development of erosion surfaces, the accumulation of continental sediments, the weathering of the surface of the continental sediments, the development of peat swamps and the formation of coal.

Field evidence of Cherokee history is the evidence of cyclic sedimentation, which consists of a peculiar sequences of beds that is repeated, at least in part, fifteen times. Each normal sequence or cyclothem consists of nonmarine and marine sediments and indicates the alternating presence and absence of a shallow continental sea.

## REGISTER OF LOCALITIES

Locality 1. N.W. $\frac{1}{4}$ of sec. 7, T. 32 S., R. 24 E., In bed of Cherry Creek crossed by State Highway 7 near Scammon. An exposure of Phases 8.3, 8.4, 8.5, and 8.7.

2. N.W. $\frac{1}{4}$ of sec. 35, T. 30 S., R. 24 E., in strip pits of Pittsburg and Midway Coal Mining Company near Chicopee. An excelent exposure of; Phases 9.3, 9.4, 9.5, 9.6.

3. S.E. $\frac{1}{4}$ of sec. 14, T. 31 S., R. 23 E., one mile west of Cherokee. An exposure of Phases 12.4, 12.5, and 13.4.

4. S.W. cor. of S.W. $\frac{1}{4}$ of sec. 23, T. 30 S., R. 24 E., in strip pit of Commercial Fuel Company, 2 miles west of Pittsburg on U.S. Highway 60. Good exposure of Phases 9.3, 9.4, 9.5, 9.6, 9.8, 10.3, 10.4, 10.5, and 10.8.

5. Center of N. line of sec. 32, T. 29 S., R. 25 E., 2 mi. N. of Frontenac. Exposure of Phases 12.3, 12.4, and 12.5.

6. Center of sec. 32, T. 29 S., R. 25 E., in Crawford County State Park. Exposure of Phases 12.3, 12.4, 12.5 and 12.7.

7. Center of S. line of sec. 19, T. 30 S., R. 24 E., two miles S. and one-half mile E. of Beulah. Exposure of Phases 15.2, 15.3, 15.5 and 15.7.

8. Center of S. line of sec. 28, T. 28 S., R. 25 E., one mile N. of Croweburg and one-half mile E. of U. S. Highway 73. Exposure of Phases 12.3, 12.4, 12.5.

9. Center of W. line of Sec. 8, T. 28 S., R. 25 E., two miles S. of Bourbon County line on U. S. Highway 59. Exposure of Phases 14.3, 14.4, 14.5, and 14.6.

10. One quarter of a mile S. of Locality 9. Exposure of Phases 13.7, 13.8, 14.4, 14.5, 14.7, 14.8, 15.1, 15.2, 15.3, 15.4, 15.5 and 15.7.

Locality 11. Center of sec. 24, T. 29 S., R. 25 E., in strip mine of Alston Coal Company on Mo.-Kan. state line. Exposure of Phases 6.3, 6.4, 6.5, 6.6, 7.3, 7.4, 7.5, and 7.8.

12. Center of the N.W. ¼ of sec. 9, T. 32 S., R. 25 E. A sink hole on the farm of Guy Johnson shows an excellent exposure of Phases 3.1, 3.4, 4.1, 4.5, and 4.6 overlain by a gravel conglomerate, Phase 5.1.

13. S.W. ¼ of sec. 17, T. 31 S., R. 25 E., on Crawford-Cherokee County line. Exposures of Phases 4.3, 4.4, 4.5 and 4.8.

14. N.W. ¼ of sec. 34, T. 30 S., R. 24 E. Strip mine of Pittsburg Midway Coal Mining Company. Exposures of Phases 9.3, 9.4, 9.5, 9.6, 10.3, 10.4, 10.5, and 10.8.

15. Sec. 9, T. 31 S., R. 24 E. Strip mine of Apex Coal Company on Country Club road 2 mi. E. of State Highway 7. Exposure of Phases 9.3, 9.4, 9.5, and 9.6.

16. Center of S. line of sec. 7, T. 31 S., R. 24 E., in mine of Kruger Coal Company. Exposure of Phases 6.3, 6.4, and 6.5.

17. N.E. ¼ of sec. 22, T. 30 S., R. 24 E., in mine of DeGasperi Coal Company. Exposure of Cyclothems 6.0, 7.0, 8.0, 9.0, and 10.0; and Phases 6.3, 6.4, 6.5, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 8.2, 8.3, 8.4, 8.5, 8.6, 9.2, 9.3, 9.4, 9.5, 9.6, 10.3, and 10.4.

18. S.W. ¼ of sec. 6, T. 29 S., R. 25 E., in old strip north of section road. Exposure of Phases 15.4, 15.5, and 15.7.

19. N.E. ¼ of sec. 10, T. 29 S., R. 24 E., in bed of creek. Exposure of Phase 15.7.

20. N.W. ¼ of sec. 7, T. 32 S., R. 24 E., in bed of Cherry Creek 500 feet N. of Locality 1. Exposure of Phases 8.3, 8.4, 8.5, 8.7. An excellent collecting locality.

Locality 21. N.E. ¼ of sec. 5, T. 27 S., R. 25 E., in bed of Drywood Creek. Exposure of Phases 12.3, 12.4, 12.5, 13.3, and 13.7.

22. Center of sec. 10, T. 29 S., R. 25 E., in old strip pits. Exposure of Phases 15.3, 15.4, 15.5 and 15.7.

23. N.W. ¼ of sec. 32, T. 31 S., R. 24 E., in strip mine of Commercial Fuel Company on Weir road 1 mile E. of Kansas Highway 7. Exposure of Phases 9.3, 9.4, 9.5, 9.6, 10.3, 10.4 and 10.5.

24. S.W. ¼ of sec. 28, T. 30 S., R. 25 E., in clay pits of W. S. Dickey Company. Exposure of Phases 4.5, 4.6, 4.8, 5.1, 5.2, 5.3, 5.4 and 5.5.

25. Center of sec. 9, T. 32 S., R. 23 E., in strip mine of Pittsburg Midway Coal Mining Company. Exposure of Phases 9.3, 9.4, 9.5, and 9.6.

26. S.W. ¼ of sec. 36. T. 30 S., R. 24 E., on section road one mile E. of Chicopee. Exposure of sandstone member (Phase 7.1.)

27. S.W. ¼ of sec. 16, T. 30 S., R. 25 E., log of deep well at the Kansas City Southern Railroad Shops. Exposure of Phase 7.1.

28. S.W. ¼ of sec. 32, T. 29 S., R. 24 E., five miles W. of Capaldo. Exposure of Phases 15.5, and 15.7.

29. S.W. ¼ of sec. 25, T. 30 S., R. 24 E., 300 feet W. of Georgia street in Pittsburg. Exposure of Phases 6.3, 6.4, and 6.5.

30. S.W. ¼ of sec. 23, T. 34 S., R. 24 E., on banks of Little Shawnee Creek. Exposure of Phases 1.2, 1.5, and 1.6.

31. Center of sec. 27, T. 30 S., 25 E., on banks of Little Cow Creek. Exposure of Phase 3.1.

32. S.W. ¼ of sec. 15, T. 31 S., R. 25 E., in old strip pits. Exposure of Phases 3.3, 3.4, 3.5, and 3.8.

Locality 33. N.E. ¼ of sec. 34, T. 31 S., R. 25 E. Exposure of phases 3.3, 3.4, and 3.5.

34. N.E. ¼ of sec. 16, T. 28 S., R. 25 E., in strip pit of the Jones Coal Company. Exposure of Phases 14.3, 14.4, 14.5 and 14.6.

35. N.E. ¼ of sec. 24, T. 30 S., R. 25 E., on farm of J. J. Stephenson. Exposure of Phases 6.3, 6.4, 6.5, and 6.7.

36. S.W. ¼ of sec. 27, T. 28 S., R. 25 E., in strip mine of Pioneer Fuel Company. Exposure of Phases 12.3, 12.4, 12.5, and 12.6.

37. N.E. ¼ of sec. 33, T. 29 S., R. 25 E. Exposure of Ardmore limestone (Phase 13.7).

38. Center of sec. 19, T. 29 S., R. 24 E., in rock quarry one mile E. of Girard. Exposure of phases 15.5 and 15.7.

39. Center of sec. 19, T. 32 S., R. 25 E. Exposure of phases 3.4, 3.5, and 3.7.

40. S.W. corner of sec. 24, T. 31 S., R. 25 E. Exposure of Phases 4.6 and 4.7.