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BULLETIN 58

STRATIGRAPHY OF THE MARMATON GROUP, PENNSYLVANIAN, IN KANSAS

BY JOHN MARK JEWETT

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STRATIGRAPHY OF THE MARMATON GROUP, PENNSYLVANIAN, IN KANSAS

By John Mark Jewett

ABSTRACT

The Marmaton group comprises four limestones and four shale formations which lie in the upper part of rocks of Desmoinesian age in Kansas. Rocks of this group are underlain by the Cherokee shale; they lie below a regional unconformity that is regarded as separating rocks of Desmoinesian age from those of Missourian age. The outcrop belt of these rocks in Kansas ranges in width from about 10 to 25 miles, and extends from Linn and Bourbon counties on the Kansas-Missouri boundary to Montgomery and Labette counties on the Kansas-Oklahoma boundary.

The rock units are described in detail and 179 stratigraphic sections measured in Kansas are given. A few sections measured in neighboring parts of Missouri and Oklahoma are also included. The rock descriptions are based on studies of these and many other less complete exposures.

Exposures of Marmaton rocks in Kansas offer excellent opportunities for studying cyclic deposits. Both cyclothems and megacyclothems are more or less readily identified in these sediments.

INTRODUCTION

Purpose and Scope of the Investigation

For many years I have felt the need of having in separate covers detailed descriptions of one or more groups of Pennsylvanian rocks in Kansas. In an unpublished manuscript prepared in 1937, Abernathy described the Cherokee rocks occurring in their outcrop area in southeastern Kansas. This paper treats rocks in Kansas belonging to the next younger group, the Marmaton. Inasmuch as the Cherokee is the lowermost of the Pennsylvanian rocks in the state, Abernathy's report and this one may be regarded as the first of unit descriptions of Kansas Pennsylvanian rocks. Field data already at hand will be used in preparing reports on the two next higher groups, Bourbon and Bronson. In the files of the State Geological Survey of Kansas are many data relative to other stratigraphic units; field notes that are sufficient with little additional work for use in preparing detailed descriptions of all the outcropping Paleozoic rocks of the state. Moore

(1936) classified the Pennsylvanian rocks of Kansas, but his descriptions of Marmaton rocks are somewhat less detailed than are those of other groups. Several papers give descriptions of Kansas Paleozoic rocks in smaller specific areas. A recent Geological Survey bulletin (Moore, Frye, and Jewett, 1944) contains a brief tabular description of the outcropping rocks in Kansas.

The chief purpose of this paper is to present descriptions, as detailed as is now possible, of rock strata in Kansas that have been classified as belonging to the Marmaton group, Pennsylvanian system. Based on these detailed descriptions, certain conclusions pertaining to earth history can be drawn, and several questions, as yet unanswered, are raised.

An attempt has been made to present all new available data that are pertinent to the outcropping rocks of the Marmaton group in Kansas. The nomenclature, general and specific character, thickness, distribution, and correlation are described for each unit, and correlated graphic sections of numerous outcrops are shown. It is believed that this report contains comments about these rocks of late Desmoinesian age in Kansas that are of geologic and economic interest. Important fossils of the various units are mentioned, although no attempt has been made to prepare complete faunal or floral lists or to give descriptions of specific fossils. Paleontologic studies, as well as several other types, could logically be guided by the contents of this paper.

It should be noted here that although paleontology is an extremely useful tool in the stratigraphy of Pennsylvanian rocks in the northern Mid-Continent region, guide fossils of the smaller stratigraphic units are nearly lacking or absent. The larger units, notably the series, are somewhat characterized by distinctive animal and plant remains, but, with the exception of fusulines, fossils are not unique to individual formations. Except in the zones of disconformities that mark the various series boundaries as they have been established, the upper and lower limits of the occurrence of species vary from place to place. It is true, however, that the relative abundance of particular species or assemblages as well as the biologic make-up are usable characteristics of individual units. It is believed, also, that the relative abundance and paucity of characteristic faunas and floras are significant criteria useful in interpreting the record of conditions under which the rock units were formed.

Stratigraphy is that branch of geologic science that embraces descriptions and definitions of natural divisions of sedimentary rocks and the interpretation of their significance in geologic history. As stated by Moore (1941, p. 179), it involves determination of the sequence of rocks both locally and in the general time scale, tracing their areal distribution, observation of lateral and vertical changes in their character, correlation of equivalent but possibly widely dissimilar units, and, finally, study of geologic events involved in their genesis. It is obvious that geologic history is a fundamental part of all divisions of earth science. Therefore, all branches of geology are intimately related to stratigraphy which both serves and depends upon them.

All stratigraphic information is of economic importance. The rocks described in this paper are exposed in an area of shallow oil and gas production, and oil and gas are produced from them in several eastern Kansas fields. Coal included in these rocks is mined in eastern Kansas and in western Missouri. Cement is made from some of them. Several of the sandstones are important because of their water-bearing properties. Rock wool has been made from some of the limestones and shales. Asphalt rock is mined from rocks of this group in Missouri. Included limestones have various other uses and the shales are important sources of ceramic materials. All operations that involve penetration below the soils are facilitated by stratigraphic information, and in most of them knowledge of details of stratigraphy is essential for successful operation. Specific engineering projects—dam construction for example—are continuously requiring the services of geologists well acquainted with details of local stratigraphy. The importance of stratigraphy to soil studies is widely gaining recognition.

Surface structure mapping, so extensively practiced in the earlier stages of petroleum geology, requires exact stratigraphic data. Much surface mapping was done 20 or more years ago, at a time when few details of the stratigraphy of many parts of Kansas were known. It is altogether possible that detailed surface mapping may again be an extremely efficient tool in oil discovery. Levorsen (1943) has recently written that "the basis of this work (the 'art of discovery') is a restudy first of all of surface outcrops, most of which will have to be reexamined . . ."

Stratigraphy is necessarily largely compilation of a great amount of data on thicknesses, rock materials, fossil contents, and structural relationships, but this information, which is useful *per se,* is also requisite in making soundly based conclusions pertaining to geologic history. The economic and academic value of such conclusions cannot be overemphasized. Stratigraphy may be looked upon as the foundation of several other types of geologic investigations.

It has been stated (Bucher, 1936) that the essence of all geologic work is:

> to search for the general properties, the "specific laws" in the reality in which we deal, and ultimately for such "general laws" as can be safely formulated. . . to seek understanding of the empirical laws thus found by studying the findings of workers in the nearest level of complexity.

The field work on which this report primarily is based was in progress during parts of several field seasons covering a period from 1928 to the present. I have drawn also upon my studies of Pennsylvanian rocks in several other states. Field studies of this kind should not stop at state or other political boundaries. I have therefore spent much time tracing and studying the rock layers described in this paper beyond the boundaries of Kansas into Oklahoma and into Missouri. In order that these rocks in Kansas may be better understood and that the studies may be extended geographically, descriptions and graphic sections of some outcrops in Oklahoma and Missouri are included in this paper.

In order to appreciate as fully as possible the significance of what one sees in the strata, one should not lose sight of the theories and conclusions of the world's prominent students of earth history. Here it may be mentioned that Grabau (1931, p. 3) wrote that the present is not the key to the past and that the earth in Paleozoic time was so distinct that we cannot visualize its history in the light gained from study of later eras. This does not mean, however, that observations of present phenomena are not vital to the understanding of the processes that operated in forming Paleozoic rocks. It does mean, however, that the probabilities of *Pangea* and *Panthalassa,* of great geosynclines, of an exchange of poles and tropics, and of other unknown features must not be disregarded. It is held as true that in Paleozoic time the earth was unique in its physical conformation and organic history.

Marmaton rocks are included in one of the several groups of the Pennsylvanian system of the North American Mid-Continent

region. Jongmans (1936) has made this significant statement concerning Carboniferous (Pennsylvanian and Mississippian) rocks:

> There is no geologic formation of which the detailed subdivision and correlation have been the subject of longer scrutinizing than the Carboniferous, but at the same time agreement on the formation has been found more difficult to attain than on almost any other.

Previous Work

Many geologists have contributed to knowledge of the rocks of southeastern Kansas. Specific reference to several of these is omitted here because detailed citations are given subsequently.

The first annual report on the geology of Kansas was published by Mudge in 1866. In 1878 Mudge published the first geologic map of the state. G. C. Swallow, appointed State Geologist in 1865, gave his attention to the stratigraphy of eastern and central Kansas and in 1866 issued a preliminary report on the geology of Kansas (Swallow, 1866). Swallow and his assistant, Major Frederick Hawn, may be regarded as the first important stratigraphic workers in southeastern Kansas.

G. C. Broadhead should perhaps rank first among those of the pioneer students of Pennsylvanian rocks in eastern Kansas and western Missouri. His interests were largely centered in the coal-bearing rocks and his field studies were carried out in great detail. He numbered various zones from 1 to 224 and, although subsequent workers have recognized more rock units in the same section, most of his numbered beds can be identified.

During a period of 50 years Charles R. Keyes contributed many papers to Pennsylvanian stratigraphy; several of his papers contain reports on Marmaton rocks. The paleontologic works of Keyes are important among the early faunal studies of Pennsylvanian rocks.

Erasmus Haworth and his co-workers, especially John Bennett and M. Z. Kirk, made important contributions to eastern Kansas stratigraphy. In the same period J. W. Beede and Austin F. Rogers made important paleontologic studies that included Marmaton and other faunas. In 1915 Henry Hinds and Frank C. Greene published an important work on the Pennsylvanian stratigraphy of Missouri. Their report contains a chapter on invertebrate paleontology by G. H. Girty. Greene has continued his interest and ac-

tivity in studies of Pennsylvanian sediments and is an authority on Marmaton and other rocks in Missouri.

A great deal of credit is due to Raymond C. Moore for the advancement of Mid-Continent stratigraphy and paleontology. His publications on Pennsylvanian rocks and fossils are numerous.

Numerous geologists who have studied oil and gas fields of eastern Kansas, eastern Oklahoma, and western Missouri have added to the knowledge of Marmaton stratigraphy. In Oklahoma the studies of Malcolm C. Oakes and Robert H. Dott have been important contributions to the stratigraphy of Marmaton and other rocks in that state. Previously D. W. Ohern (1910) studied and mapped Marmaton and other formations in northeastern Oklahoma.

Marmaton rocks in Missouri and Iowa were described by L. M. Cline (1941), and interbasinal correlations of Marmaton and other Pennsylvanian formations were indicated in a recent paper by J. M. Weller, H. R. Wanless, L. M. Cline, and D. G. Stookey (1942).

In addition to the studies made by Keyes, Beede, Rogers, and Girty, descriptions of fossils from Marmaton rocks are included in the works of several specialists in specific biologic fields. Carl O. Dunbar and George E. Condra pioneered fusuline studies. Several other paleontologists later contributed to the studies of these fossils. Dunbar and Condra's work on Pennsylvanian brachiopods includes descriptions of Marmaton forms. J. Brookes Knight's work on gastropods, A. K. Miller, Carl O. Dunbar, and George E. Condra's work on cephalopods, and Norman D. Newell's studies of Late Paleozoic pelecypods include descriptions of Marmaton fossils.

This paper is the first to describe in detail Marmaton rocks in Kansas. In a previous paper (Jewett, 1941) I offered a classification of the Marmaton group in Kansas.

Acknowledgments

I have studied Kansas rocks for several years and in doing so have been associated with many geologists, all of whom have been my teachers. I have learned from all of them. To Professor, now Major, Raymond C. Moore I am especially indebted for guidance in this and other stratigraphic studies. Thanks are extended also to John C. Frye who has critically read the manuscript and to Edith Lewis and Betty Hagerman who edited it.

GENERAL CONSIDERATIONS OF THE MARMATON ROCKS IN KANSAS

Marmaton rocks are partly marine and partly nonmarine in origin. Like probably all known sedimentary rocks, they are of continental origin. That is, although some of them were formed in submarine environments, they were formed on the floors of shallow epicontinental seas and not in deep ocean basins. The present northern Mid-Continent outcrop area of these rocks was a part of a relatively stable platform at the time of their genesis. There were deeper basins of accumulation to the south, as shown by the vastly thicker sections of rocks of equivalent age in the Pennsylvanian basins in Oklahoma and Arkansas. Still farther south was a land that was undergoing erosion and that perhaps furnished the greater part of the rock material. The sediments that are now incorporated in these rocks, however, very probably came in part from other directions. To the north of the Kansas outcrop area were also regions that were undergoing erosion. To the east was the Ozark uplift, and, although the Ozark area was now and then the site of deposition, there is evidence that some of these sediments came from there.

Marmaton rocks crop out in Kansas in a belt ranging in width from about 10 miles to about 25 miles. The outcrop belt extends from Linn and Bourbon counties on the Kansas-Missouri boundary to Montgomery and Labette counties on the Kansas-Oklahoma boundary. The general strike is about 30° east of north and the dip is westerly. The average dip is about 20 feet to the mile. The prevalent dip locally is interrupted by minor flexures. Because of variations in thickness of individual layers, the dip measured on any one horizon is different from that measured on another. The total thickness of the rocks of the group is about 250 feet.

The Marmaton group comprises the upper and more calcareous part of the stratigraphic section assigned to the Desmoinesian series. In Kansas the Marmaton rocks are dominantly shale. Limestone is second in quantitive importance and sandstone is third. There is a minor amount of coal. The Cherokee shale, comprising the lower part of the Desmoinesian series, is chiefly shale and sandstone. Desmoinesian limestones especially differ in lithologic characteristics from those of the younger Pennsylvanian section. The most noticeable difference is the absence of certain lithologies that are common in the higher section. Flinty limestone

is plentiful in higher groups, especially the Bronson and Kansas City. Marmaton limestones are only locally and very sparsely flint bearing. Massive cross-bedded "oölitic" limestone which is mostly a mass of algal pellets is characteristic of the Bronson and Kansas City groups, but is absent from Marmaton rocks. Fusulines, although present in several Desmoinesian limestones, were not important rock makers in Desmoinesian time. In the Shawnee and Wabaunsee groups there are limestones that are little more than cemented masses of fusulines. Dark, bluish-gray, impure limestone that shows little or no bedding within individual units and that also is common higher in the section is sparsely present in the Marmaton group.

Most of the limestone in these rocks is light gray and weathers into a rock of even lighter color. This more or less contrasts with most of the limestone of younger groups which develops a rusty brown coating when exposed for a few years. Brown-weathering limestone beds are not absent from the Marmaton group, however. One type of finely crystalline brownish-gray limestone characteristically weathers into a deep-brown-coated rock. The most common limestone type in the Marmaton group is light gray, rather coarsely crystalline, and has the appearance of being a breccia. Small limestone fragments of irregular outline seem to be imbedded in a matrix of slightly different color and texture. This type of limestone is also common in younger groups.

Coralline limestone, which is dominantly composed of *Chaetetes* but contains plentiful "*Aulopora*" and some algal remains, is the most distinctive rock type in the Marmaton group. The coral *Chaetetes* was important as a rock builder in Late Desmoinesian time as were fusulines later. *Chaetetes* was a colonial tabulate coral that formed large coralla resembling heads of cauliflower.

The thicker shale units that are called formations include sandstones which are classified in two general types on the basis of their relationships to the shale. One type of sandstone can be sharply differentiated from the nonarenaceous clay shale below and in lateral directions. The other type is gradational from shale through sandy shale. This difference is based more upon the kind of contact than upon the rock itself, although the first type is generally less clayey than the type with gradational contacts. Clay and sand were being deposited at about the same time and some cutting and filling took place. One sees the first type of

contact in those outcrops where a sand-filled channel cuts clay shale. In general, channel filling seems to be not more than 25 feet in depth.

Shales that separate the limestone members in the limestone formations are partly if not wholly marine. They contain fossil brachiopods, bryozoans, crinoid remains, and locally mollusks and corals. Black carbonaceous shale and small amounts of coal are characteristic of some of the thinner shale units. Where fossiliferous, the black shales contain a sparse fauna in which brachiopods are the most conspicuous and conodonts are locally present. Small dark phosphatic concretions are common in the black shales. The thin fossiliferous shales are thinner bedded than the thicker nonmarine shales. Thin coal beds in these thinner shales may have been deposited locally below sea level.

All of eastern Kansas shows evidence of the presence of a Late Tertiary (?) peneplain truncating the gently westward-dipping rocks. The peneplain dips gently to the east and is now being destroyed by erosion. The truncated edges of more resistant strata form steep east-facing escarpments ranging in height from a few feet to approximately 150 feet. The physiographic history of eastern Kansas is probably complex and certainly has not been sufficiently studied. Evidence of peneplanation is found chiefly in the nearly accordant escarpment crests, in enclosed river meanders, and in the presence on the high divides of bedded gravel deposits which in the northern part underlie glacial drift.

The outcrop area of Marmaton rocks in Kansas is drained by the Marais des Cygnes and Verdigris rivers. Most of the region is under cultivation, but the economic use of the land is largely determined by the nature of the underlying rock. The dip slopes held by some limestones and sandstones are mainly unplowed grasslands and woodlands. The presence of generally deep residual soil and other surficial deposits and the tendency of limestone blocks to slump over less resistant beds cause the study of natural outcrops to be somewhat difficult. There are, however, many artificial and some natural cuts in which the rocks are well exposed.

SEQUENCE OF STRATA AND DISCONFORMITIES IN THE OLDER PENNSYLVANIAN SECTION IN OKLAHOMA AND KANSAS

Following is a brief discussion of the rock sequence that embraces the beds of the Marmaton group. Table 1 shows the classification of the Pennsylvanian rocks in the northern Mid-Continent region. Table 2 gives the classification of the Marmaton group.

Disconformity at the Base of Pennsylvanian Rocks

In the northern Mid-Continent area, where these studies are chiefly centered, Pennsylvanian rocks lie upon an eroded surface of other rocks ranging in age from pre-Paleozoic to Late Mississippian. In most of the area Pennsylvanian sediments rest upon various formations of the Mississippian system. Locally, as in the Central Kansas uplift and in the Nemaha uplift, Pennsylvanian beds overlap and overstep older rocks, including those of pre-Paleozoic age. Structural conditions in Mississippian and older rocks indicate an important time break between the Pennsylvanian and Mississippian systems.

The oldest Pennsylvanian rocks, those of Morrowan age, are separated from the overlying Pennsylvanian beds by a structural disconformity in southeastern Oklahoma. Rocks of Lampasan age lie above this disconformity and the Lampasan rocks are overlain by those of Desmoinesian age.

Pennsylvanian Rocks Older Than the Desmoinesian

In the deeper basins, nearer to and in the Appalachian trough (Pennsylvania to Texas), there are Pennsylvanian rocks older than those assigned to the Desmoinesian series. These are the rocks of Morrowan and Lampasan (or Derryan) age. In general, sediments that are assigned to the Lampasan series extend farther west and north from the Appalachian geosyncline than do those of Morrowan age. Rocks of Morrowan age, wherever known, are separated from younger sediments by a structural disconformity, and paleontologic evidence indicates a hiatus between sediments assigned to the Lampasan series and the Desmoinesian series.

Desmoinesian Series

In the Mid-Continent region, rocks assigned to the Desmoinesian series include beds above the McAlester formation in cen-

tral Oklahoma and in the Arkansas river valley; above the Pumpkin Creek beds in the Ardmore basin, Oklahoma; above the Smithwick group in north-central Texas; and below a widespread disconformity that occurs at the base of the Bourbon rocks in Kansas and at the base of the Seminole formation in Oklahoma (Moore and others, 1944, pl. 1, chart 6). In some previous publications the base of the Atoka formation has been designated as the base of the series (Moore, 1936, p. 53). Now, however, the Atoka beds and overlying sediments, including the Hartshorne sandstone and the McAlester shale, are assigned to the Lampasan series (Moore and others, 1944, pl. 1).

In Kansas the Marmaton group and the underlying Cherokee shale commonly are assigned to the Desmoinesian series (Moore, 1932; 1936, p. 51), but from studies in eastern Oklahoma Newell (1937, p. 39) has shown evidence that the Warner sandstone in the McAlester formation is the equivalent of the basal part of the Cherokee shale in southeastern Kansas. If this is true, the base of Desmoinesian rocks, as now defined, occurs a few feet above the base of the Cherokee shale in its type area.

TABLE 1.—*Classification of Pennsylvanian rocks in the northern Mid-Continent region*

Permian system
(unconformity indicated by local channeling)
Pennsylvanian system
Virgilian series
Wabaunsee group
Shawnee group
Douglas group
(regional unconformity)
Missourian series
Pedee group
Lansing group
Kansas City group
Bronson group
Bourbon shale
(regional unconformity)
Desmoinesian series
Marmaton group
Cherokee shale*
(regional unconformity)
Mississippian system

* The lowermost few feet of the Cherokee shale in Kansas probably should be assigned to the Lampasan series.

TABLE 2.—*Classification of rocks of the Marmaton group*

Missourian series

(unconformity)

Desmoinesian series

Marmaton group

Memorial shale

Lenapah limestone

Idenbro limestone member

Perry Farm shale member

Norfleet limestone member

Nowata shale

Includes Walter Johnson sandstone

Altamont limestone

Worland limestone member

Lake Neosho shale member

Tina limestone member

Bandera shale

Includes Bandera Quarry sandstone and Mulberry coal

Pawnee limestone

Laberdie limestone member

Mine Creek shale member

Myrick Station limestone member

Anna shale member*

Labette shale

Includes Warrensburg? sandstone (Englevale sandstone)

Fort Scott limestone

Higginsville limestone member

Little Osage shale member

Includes Houx limestone and Summit coal

Blackjack Creek limestone member

Cherokee shale

* In Kansas a very thin limestone is included in the Anna shale at its base. In neighboring parts of Missouri and Oklahoma, thicker limestone in the same position clearly belongs to the Pawnee formation.

The disconformity at the top of Desmoinesian rocks has been traced for great distances (Jewett, 1941, p. 298). In Oklahoma the disconformity at the top of the series is at the base of the Seminole formation (Moore, 1936, p. 53; Oakes and Jewett, 1943). In Kansas the disconformity occurs at the base of the Hepler sandstone which is the basal part of the Bourbon deposits and is correlated with the upper part of the Seminole formation. That is, Missourian rocks overlap Desmoinesian strata from the south or rocks lying on the disconformable surface in Kansas are slightly younger than those that lie on the same surface farther south. The Chariton

conglomerate in Iowa is believed to be the northward extension of the Hepler sandstone and to be of about the same age.

The type section of Desmoinesian rocks is along Des Moines river in central Iowa, but it seems that the lower part of the Des Moines river section, the "lower Cherokee," should be assigned to the Lampasan series.

It should be noted that the term Desmoinesian is now restricted to include only the upper part of the rock-time unit that commonly has been called the Desmoinesian series. Moore (Moore and others, 1944, pp. 671, 673, 675-677) has presented criteria for the separation of another series, the Lampasan, to which older post-Morrowan rocks are assigned. Hence, the Desmoinesian rocks comprise a unit that is third from the base of the Pennsylvanian system. The older series are the Morrowan and the Lampasan.

Sediments of Lampasan and Desmoinesian age were deposited in the Appalachian trough from Pennsylvania to New Mexico. This area was seemingly a part of a great depression west and north of a positive segment that is designated as Appalachia-Llanoria. The border of this old land area probably traced a line that crossed eastern Pennsylvania, western Virginia, eastern Tennessee, northwestern Georgia, central Alabama, central Mississippi, southern Arkansas, and Texas to about the middle point of the Texas-Mexico boundary. Deposition of Pennsylvanian sediments is believed to have taken place in the form of transgressive overlap away from the eastern and southern positive area, Appalachia-Llanoria. By the close of Desmoinesian time and probably earlier, transgression was met by similar transgression from other directions and from other positive areas that were being eroded. Diastrophic movements within the basins were of differential nature. The presence of many local hiatuses and the occurrences of overlap are probable.

CHEROKEE SHALE

The Cherokee shale is defined to include strata from the base of the Pennsylvanian north of the Kansas-Oklahoma line upward to the base of the Fort Scott limestone (Moore, 1936, p. 55). This definition is the same as the original definition of Haworth and Kirk (1894, p. 105).

In writing of Pennsylvanian rocks in eastern Oklahoma, numerous geologists have used the term Cherokee to include strata

above the disconformity at the top of rocks of Morrowan age and below the Fort Scott limestone. As explained elsewhere in this paper, it is evident that some of the post-Morrowan beds in eastern Oklahoma are older than the oldest strata included in the type Cherokee section in southeastern Kansas. It is well established that the Lampasan rocks overlap older rocks northward from the deeper basins of southeastern Oklahoma and that the basal sediments in southeastern Kansas are equivalent in age to rocks well above the base of the post-Morrowan Pennsylvanian section in eastern Oklahoma.

Cherokee rocks are chiefly clastic. Shale is strongly predominant. Gray clayey and silty micaceous shale is most common but there is also much sandy shale and sandstone. Very dark or black carbonaceous shale occurs at several horizons. Fifteen coal beds have been identified in the Kansas Cherokee section. The amount of limestone is very minor. Sandstones in the Cherokee rocks commonly occur in lenticular bodies but the lenses are arranged in definite stratigraphic zones. "Shoestring sands," long narrow channel fillings or bar deposits, are numerous and many of them are important oil and gas reservoirs.

The maximum known thickness of Cherokee rocks north of Oklahoma is in the Forest City basin in northeastern Kansas and in northwestern Missouri. The thickness there slightly exceeds 700 feet. The average thickness in southeastern Kansas is about 400 feet. The thickest section in southeastern Kansas is in Labette county where about 500 feet has been measured. On the low structural arch between the Forest City basin and the Cherokee basin the thickness is about 350 feet. Rocks of the Cherokee group overlap older beds on the Ozark uplift giving rise to a much smaller thickness of Cherokee rocks in several Missouri counties.

Cherokee rocks are generally absent or are very thin in Kansas west of the Nemaha ridge. However, basal Pennsylvanian rocks in the Sedgwick basin in south-central Kansas and a part of the "Sooy" conglomerate in much of western Kansas are believed to be equivalent to the upper part of the Cherokee shale of eastern Kansas.

Whether or not the Cherokee rocks in eastern Kansas and neighboring places are dominantly marine is a debatable question. Limestones and other rocks containing marine fossils are rare. Fossil land plants are plentiful. All detailed descriptions of Chero-

kee deposits in southern Iowa, western and northern Missouri, eastern Kansas, and eastern Oklahoma indicate that they were laid down under cyclical conditions. Abernathy (1937a, p. 19) identified 15 successive cyclic deposits in the type locality. A characteristic cyclothem includes in ascending order: (1) sandstone, (2) sandy shale, (3) underclay, (4) coal, (5) black shale, (6) gray shale, (7) limestone, and (8) calcareous shale.

The Ardmore limestone, about 100 feet below the top of the Cherokee shale, is the most prominent limestone in the Kansas and Missouri Cherokee section. It has been correlated by several geologists with the Verdigris limestone of eastern Oklahoma. Abernathy (1937a) stated that the Ardmore limestone lies in the second cyclothem below the Fort Scott cyclothem, but observations in the type locality of the Verdigris limestone indicate that it is separated from the Fort Scott limestone by several cyclical units.

Certain notations concerning the nature of the probable northward overlap of Pennsylvanian rocks should be made here. (1) Although geologists are not in accord with the theory that such overlap occurs, northward overlap of these basal rocks is fairly evident. (2) Studies sufficient to show evidence of continuously progressive overlap have not been made. (3) Observations indicate, on the other hand, that now and then regressive overlap or offlap took place. That is, each successively younger deposit does not extend farther to the north than do all the preceding ones. If one assumes that generally the strata overlap northward but that now and then, in the course of their deposition, some sedimentary units were not as far-reaching as others, one can then account for the discrepancy in the number of cyclical units between the Verdigris limestone (Ardmore) and the Fort Scott limestone in the two places.

MARMATON GROUP

The Marmaton is the upper of two rock units in Kansas recognized as being of Desmoinesian age. The lower unit is the Cherokee shale. In 1932 and 1936 Moore (1936, p. 57) defined the Marmaton group as including beds between the base of the Fort Scott limestone and the upper limit of the Desmoinesian series. The disconformity at the base of the Hepler sandstone seems to be the upper limit of the Desmoinesian series in Kansas. This pre-Missourian disconformity and overlying sandstone and conglom-

erate are rather definitely identified from southern Oklahoma to Iowa, Illinois, and Indiana (Oakes and Jewett, 1943; Jewett, 1940a, pp. 8, 9; Jewett, 1941, pp. 299, 300; Weller, Wanless, Cline, and Stookey, 1942, p. 1592). The Marmaton group is set apart from the underlying Cherokee shale because the former is more dominantly calcareous. It includes four limestone formations and four shale formations. These formations are identified along their line of outcrop from Arkansas river valley in Oklahoma to Iowa and Illinois.

The Marmaton group comprises, in ascending order (1) Fort Scott limestone, (2) Labette shale, (3) Pawnee limestone, (4) Bandera shale, (5) Altamont limestone, (6) Nowata shale, (7) Lenapah limestone, and (8) Memorial shale. The combined thickness in Kansas is about 250 feet. The type locality of the Marmaton group is along Marmaton river, from Uniontown to Fort Scott, Bourbon county, Kansas. All beds can be seen along the river bluff between the two places and most of them are exposed along U.S. highway 54 between Uniontown and Fort Scott.

Disconformity Between Desmoinesian and Missourian Rocks

A widespread and important disconformity occurs between rocks assigned to the Desmoinesian series and those assigned to the Missourian series. This is indicated by biologic evidence as well as by evidence of a physical break. For a number of years it has been known that an important faunal and floral break occurs somewhere within the section that had commonly been assigned to the Pleasanton formation (Memorial shale and Bourbon shale). More recently it has been shown that in Kansas and eastern Missouri there is an erosional disconformity at the base of the Bourbon shale and that a thin sandstone in that zone rests upon an eroded surface that ranges from a position almost as low as the top of the Altamont limestone (and, in the shallow subsurface, locally lower) to 30 or more feet above the Lenapah limestone (Jewett, 1941, p. 299). Recent studies indicate, also, that rocks of Missourian age were deposited with structural overlap from the south on Desmoinesian beds (Jewett, 1941, p. 300; Oakes and Jewett, 1943). Evidence indicating that the pre-Missourian disconformity can be traced across Missouri into Iowa and is present in Illinois is accumulating. The Chariton conglomerate in Iowa

seems to be equivalent to the basal Missourian sandstone of eastern Kansas and western Missouri (Weller, Wanless, Cline, and Stookey, 1942, p. 1592).

STRATIGRAPHY OF THE MARMATON GROUP IN KANSAS

Fort Scott Limestone (Swallow, 1866) Bennett, 1896

Three members, two limestones and a separating shale, have for a long time been recognized as comprising the Fort Scott limestone formation. For many years the lower limestone has been known as the "Cement rock" and the upper limestone has sometimes been called the "Lexington bottom rock." Recently the three members have been given formal geographic names. Named in ascending order the members are (1) Blackjack Creek limestone, (2) Little Osage shale, and (3) Higginsville limestone. The Houx limestone and Summit coal are names of beds in the Little Osage shale. The members in Kansas are described separately below.

A few years ago it was found that a lenticular limestone occurs a few feet below the Blackjack Creek limestone. This is the Breezy Hill limestone (Pierce and Courtier, 1938, p. 33), which seems to correspond cyclically to higher limestones that are included in the base of other Marmaton limestone formations. Where present it lies below black shale and coal which for many years have been regarded as being in the Cherokee shale. Because the "Cement rock" has for so long been regarded as the basal part of the Fort Scott limestone formation, because the black shale below it has for a long time been used to mark the top of the Cherokee shale, and because the Breezy Hill limestone is lenticular, it seems best not to amend the definition. However, observations in Craig and Rogers counties, Oklahoma (pl. 1, secs. 186, 188, 191, and 198), indicate that the Breezy Hill limestone may actually occur in a zone that is several cyclical deposits below the Fort Scott assemblage.

The top of the Fort Scott limestone is well defined and easily identified at the top of the Higginsville limestone. The top of the Fort Scott limestone is readily identified in the subsurface in eastern Kansas, but because of the local occurrence of the Breezy Hill limestone the base of the formation is not so easily detected in well records. The Fort Scott limestone has been identified along its outcrop line from Arkansas river valley in Oklahoma to south-

ern Iowa. Equivalent beds are recognized in Illinois (Weller, Wanless, Cline, and Stookey, 1942, p. 1586, fig. 1).

In 1941, I (Jewett, 1941, p. 304) suggested that quarry exposures in the NE¼ sec. 19, T. 25 S., R. 25 E., Bourbon county, Kansas, a short distance northeast of Fort Scott, be regarded as the type exposure of the Fort Scott formation. The exposure there is shown graphically in plate 1, section 72.

Graphic representations of outcrops of the Fort Scott limestone and adjacent rocks in Kansas and neighboring parts of Missouri and Oklahoma are shown in plate 1. Index numbers of sections in plates 1, 2, 3 and 4 correspond to numbers of stratigraphic sections at the end of this paper.

FORT SCOTT LIMESTONE

BLACKJACK CREEK LIMESTONE MEMBER Cline, 1941

The Blackjack Creek limestone is the lower member of the Fort Scott limestone. It lies above black shale, which, according to present classification, is in the upper part of the Cherokee shale. The name Blackjack Creek was introduced by Cline (1941, p. 36). According to Cline, the type exposure of the Blackjack Creek limestone is in Johnson county, Missouri, "four miles southeast of Fayetteville and along Blackjack Creek."

Distribution.—In Kansas the Blackjack Creek limestone crops out from northeastern Bourbon county to south-central Labette county (pl. 1).

Description.—Where studied at the outcrops in Kansas, the Blackjack Creek limestone ranges in thickness from about 4 feet to 17.5 feet. In general it consists of two distinct limestones. The upper limestone has not been observed by me north of southern Bourbon county (pl. 1, secs. 74 and 101). The lower part of the Blackjack Creek limestone is the rock that has been called "Cement rock." This part generally weathers brown but it displays tan, brownish, and dark dove-gray colors when freshly exposed. It is generally earthy but in some exposures the rock is finely crystalline. Conchoidal fracture is rather common. The "Cement rock" is massive and its bedding is more regular than that of the upper part of the Blackjack Creek limestone. It contains few fossils. In northeastern Bourbon county the lower part of the Blackjack Creek limestone is divided by about one foot of calcareous shale (pl. 1, sec. 49). The measured thicknesses of the "Cement rock" part range from 1.55 feet in the NW¼ sec. 11, T.

28 S., R. 24 E., Crawford county, to about 10 feet in the SE¼ sec. 9, T. 34 S., R. 19 E., Labette county (pl. 1, sec. 172).

In many exposures the upper part of the Blackjack Creek limestone is easily distinguished from the lower part. The upper part, where present, is lighter gray, more coarsely crystalline, and more irregularly bedded. It is locally a mass of *Chaetetes* in the upper part (pl. 1, secs. 111, 117, and 149). This upper wavy-bedded *Chaetetes*-bearing part of the Blackjack Creek limestone is locally separated from the "Cement rock" by a thin shale parting (pl. 1, sec. 108).

The "Cement rock" is less pure limestone than the remainder of the Blackjack Creek limestone. A small amount of flint has been observed in the "Cement rock" in Labette county (pl. 1, sec. 172) and there is some flint in the upper part of the Blackjack Creek limestone in Rogers county, Oklahoma (pl. 1, sec. 186).

I have not seen the upper part of the Blackjack Creek limestone north of exposures in southern Bourbon county, Kansas; in many places in northern Bourbon county, in Linn county, and in eastern Missouri the Little Osage shale is in contact with the upper surface of the "Cement rock." Similar conditions prevail locally in northeastern Oklahoma. In many exposures in Oklahoma, however, the upper part is well developed. It is believed that the local absence of the upper part is due to nondeposition rather than to intraformational erosion. Measured thicknesses of the upper portion of the Blackjack Creek limestone range from about 7 to 13 feet.

With the exception of the rock-building corals, *Chaetetes*, which are almost if not entirely confined to the upper part, fossils are not especially abundant in the Blackjack Creek limestone. Fusulines are more commonly present in the upper part, but have been seen in the "Cement rock" in northeastern Oklahoma. Mollusks are plentiful in the "Cement rock" portion of this member in Oklahoma.

FORT SCOTT LIMESTONE

LITTLE OSAGE SHALE MEMBER Jewett, 1941

The Little Osage shale separates the upper and lower limestones of the Fort Scott formation. The Houx limestone (Cline, 1941, p. 36) occurs in the Little Osage shale above the Summit coal. The type exposure of the Little Osage shale is in the NE¼ SE¼ sec. 2, T. 24 S., R. 25 E., Bourbon county, Kansas. A graphic sec-

tion of that exposure is shown in section 49, plate 1. The type exposure of the Houx limestone is on the Houx ranch, Johnson county, Missouri (Cline, 1941, p. 36). The name Summit was introduced as the name for this coal in Macon county, Missouri (McGee, 1892, p. 331).

Distribution.—In general, outcrops of the Little Osage shale are near exposures of the limestone members of the Fort Scott formation. Locally, however, the Blackjack Creek limestone holds rather wide dip slopes, and the Little Osage shale and the Higginsville limestone occur a few miles west of the outcrop line of the lower member.

Description.—In Kansas the thickness of the Little Osage shale at its outcrops ranges from about 4 to 12 feet. The thickest sections that I have measured are in Bourbon county. This member is generally thicker in northeastern Missouri than it is in Kansas.

In the northern part of the Kansas outcrop area and in eastern Missouri the Little Osage shale consists of five distinct units: (1) the lowermost part, light to dark-gray shale, locally calcareous, and about 3 feet thick; (2) the Summit coal bed, having a maximum thickness of about 1 foot; (3) shale, black and fissile, or gray in the lower part and black in the upper part, the black shale commonly containing coaly concretion-like masses; (4) the Houx limestone bed, about 1 foot thick in eastern Missouri and thinner in Kansas; (5) the uppermost part, gray calcareous shale, ranging in thickness from about 1 foot to 4.5 feet, the greatest known thickness being in Missouri. The Summit coal and Houx limestone beds have been identified as far south as the vicinity of Fort Scott, in Bourbon county. In northern Crawford county there is 2 feet of gray shale overlain by about 3 feet of black fissile shale, which in turn is overlain by about 1 foot of gray shale. Very probably these rocks are equivalent respectively to the lower, middle, and upper shale units (1, 3, and 5) as they are known farther north (pl. 1, secs. 72 and 108). Locally in southeastern Kansas and in northeastern Oklahoma the Little Osage shale is all or nearly all black fissile shale. Generally a few inches of gray shale occurs in the uppermost part. Black shale in this member commonly contains small black more or less spherical phosphatic concretions. In one place in Craig county, Oklahoma, cen. W. line sec. 36, T. 28 N., R. 19 E. (pl. 1, sec. 202), black limestone concretions are present in black shale. At the same place there is a thin

limestone in the upper part of the Little Osage shale. This limestone probably is equivalent to the Houx limestone.

Large hard black limestone concretions which are common in black shale in the Cherokee rocks a short distance below the Blackjack Creek limestone have not been observed in the Little Osage shale. The Little Osage shale is not conspicuously fossiliferous. Cup corals occur in the upper few inches in some exposures in eastern Missouri, and conodonts are rather abundant in black shale portions.

FORT SCOTT LIMESTONE

HIGGINSVILLE LIMESTONE MEMBER Cline, 1941

The upper member of the Fort Scott limestone is the Higginsville limestone. The name was introduced by Cline (1941, p. 36). According to Cline, the Higginsville limestone is well exposed east of Higginsville in Lafayette county, Missouri. No exact location of the type exposure has been published.

Distribution.—At most points on the line of outcrop of the Fort Scott limestone the three members are exposed at the same place. Locally, however, the lower member, the Blackjack Creek limestone, holds dip slopes a few miles wide; hence the outcrops of the Higginsville limestone are west of those of the lower limestone. The line of outcrop of the base of the Fort Scott formation is shown in plate 1.

Description.—The maximum measured thickness of an outcrop of Higginsville limestone in Kansas is about 15 feet. Its thickness across the state in the belt of its outcrop is seemingly rather constant (pl. 1). In many exposures the upper part has been removed by recent erosion or the lower part is covered by recent deposits. In isolated partial exposures of the Fort Scott limestone, the Higginsville member is distinguished with difficulty from the Blackjack Creek limestone. In its outcrop area low structural undulations cause topography to be of little value in correlation.

The Higginsville limestone is light to medium dark gray. It is commonly granular and crystalline. Much of it displays a brecciated appearance. Locally both the upper and lower parts are earthy in texture. In many places the upper part is a mass of fossil corals, *Chaetetes*. The beds in the lower part are generally massive, but as a rule the whole unit displays irregular wavy beds which are usually thinner in the middle part.

Giant fusulines are rather characteristic and are seen in many exposures. In places where the upper part of the rock is composed principally of *Chaetetes*, fusulines are entirely or almost entirely restricted to rock below the coral biostrome. Elsewhere fusulines are often seen in the upper part and project from the slightly weathered upper surface of the Higginsville limestone. Large crinoid stems and other fragments also are common. Brachiopods, including the common Marmaton genera, are more abundant in exposures in Oklahoma than in Kansas. Very minute fusulines are extremely abundant in the upper part of the Higginsville limestone in some exposures in Labette and Crawford counties.

Labette Shale Haworth, 1898

The Labette shale includes beds between the Fort Scott and Pawnee limestones. It was named by Haworth and defined as occurring between the Oswego (Fort Scott) limestone and the Pawnee limestone (Haworth, 1898, p. 36).

The name "Peru sand" is commonly applied to sandstone bodies that occur in the Labette shale in the subsurface. The name Englevale was introduced by Pierce and Courtier (1935, pp. 1061-1064) for a sandstone in the Labette shale. Observations at numerous exposures along the outcrop line of the Labette shale from northeastern Oklahoma across Kansas and eastern Missouri indicate that the thick sandstone deposits in the vicinity of Warrensburg occur in the Labette shale. The name Warrensburg sandstone was introduced by Hinds and Greene (1915, p. 91) for the channel-filling sand body.

For a distance of a few hundred miles there is much sandstone in the Labette shale. The sand bodies are lenticular and at least in part are channel fillings. The disconformities at the bases of the sandstone lenses are not indicative of long periods of erosion. Mud, sand, and a very minor amount of coal and limestone were deposited in the areas of present outcrops. The several thin coal beds and limestone lenses indicate several cyclic deposits. Two massive sandstones separated by a limestone bed and shale occur in some exposures in eastern Oklahoma. Studies between eastern Kansas and Warrensburg, Mo., indicate that the Englevale and Warrensburg sandstones occur at about the same stratigraphic horizon.

The village of Labette in Labette county, Kansas, was designated as the type locality for the Labette shale (Haworth, 1898,

p. 36). I designated the somewhat poor exposure beginning near the center of the north line and extending to a point near the northeast corner of sec. 22, T. 32 S., R. 20 E., near the town of Labette, as a *pro tempore* type exposure. There are at present no good exposures of the Labette shale known near Labette.

Distribution.—The outcrop line of the Labette shale in Kansas is between the sinuous outcrop of the bounding limestones. The belt ranges in width from a small fraction of a mile to a few miles. The lines of outcrop of the bases of the two limestones are shown in plates 1 and 2. The line shown in plate 2 as the outcrop line of the base of the Pawnee limestone is also the outcrop line of the top of the Labette shale.

Description.—Changes in thickness of the Labette shale along its line of outcrop in Kansas are rather abrupt. According to measured sections, the thickness range is between about 30 and 100 feet. Sections measured at locations about 1 mile apart in northeastern Bourbon county show a difference of 20 feet in thickness. According to measurements I have made at outcrops and to logs of wells drilled a short distance west of the outcrops, the Labette shale is thickest in Labette county and thinnest in Bourbon county. Thus, the thickness increases southward.

The Labette shale includes clay and silt shale, sandstone, and minor amounts of limestone and coal. There is a persistent limestone in the upper-middle part in southeastern Kansas. This is very probably the same limestone that occurs in the same part of the Labette shale over a wide area in northeastern Oklahoma. It is especially well developed in Craig county. Although the formation contains much sandstone in Kansas, sandstone is not as important quantitively in the Kansas outcrop sections as in exposures in Oklahoma and Missouri. There are several coal beds in the Labette shale. All are of more or less local occurrence, but it is believed that they represent coal phases of definite cyclothems. One coal bed occurs near the base in a zone that is more commonly occupied by black shale alone or by black shale and a very thin coal bed. The black shale zone in the basal part of the Labette shale is especially well developed in southeastern Rogers county, Oklahoma, near the place where the underlying Fort Scott limestone pinches out or grades laterally into clastic deposits (pl. 1, sec. 187). This facies is rather persistent and has been observed in several Kansas exposures. Another coal bed near the middle

part is seemingly less persistent. A black shale and coal zone occurs in the upper part of the Labette shale next below the persistent thin limestone that marks the base of the Pawnee limestone. This coal in the upper part has been seen at several places along the line of outcrop from Labette to Linn county. Locally, however, black shale in this zone does not contain a bed of coal, and in a few places the black shale facies is absent.

Sandstone lenses, perhaps in part channel fillings, are common in the Labette shale although less common in Kansas than in Missouri and Oklahoma. Limestone conglomerates occur in the basal part of some of the sand bodies in Missouri but they have not been observed in Kansas. In Missouri the Warrensburg channel sandstone is believed to occur in the Labette shale. It fills a channel that locally is cut below the Fort Scott limestone. The top of the channel fill in the vicinity of Warrensburg seems to be in the lower middle part of the Labette shale at approximately the same horizon that marks the top of sandstone bodies in Kansas. A few inches of sandstone occurs about 25 or 30 feet above the base of the formation in several exposures in Kansas. There are two very important sandstone horizons in the Labette shale in Oklahoma. It is believed that the lower of the two sandstones occupies the same stratigraphic position as the Warrensburg sandstone. The Englevale sandstone in Crawford county, Kansas, lies in the same position.

A nearly complete Labette shale section is exposed near the center of the north line of sec. 16, T. 25 S., R. 24 E., Bourbon county, Kansas. There the lower coal bed lies about 2 feet above the Higginsville limestone, the upper member of the Fort Scott formation. A zone of thin sandy limestone and sandstone is present about 12 feet from the base of the Labette shale, which there is about 39 feet thick. The upper part of the section is chiefly gray and yellow shale. At an exposure about 1 mile distant, in the SW cor. sec. 15, T. 25 S., R. 24 E., the formation is about 54 feet thick and no sandstone was seen. A thin and impure limestone occurs in the upper middle part.

The sections described above are rather characteristic of the less sandy facies of the Labette shale. In northeastern Bourbon county there are three thin limestones in the middle part of the formation. The lower two are separated by about 7 feet of shale and the upper one is about 18 feet higher than the middle lime-

stone. The lower limestone is a brachiopod-bearing rock about 1 foot thick. It lies on a thin coal bed, below which is 6 feet of carbonaceous shale resting on the Warrensburg sandstone. The upper two limestones are very thin and are cross-bedded. They seem to be detrital limestones, but are believed to have been formed from wave or current-washed shell fragments and precipitated masses rather than from fragments of a pre-existing rock.

The top of the Warrensburg or Englevale sandstone lies in a zone about 20 or 30 feet above the base of the Labette shale. The thicknesses of these sand bodies in Kansas range from a feather-edge to about 30 feet.

Pawnee Limestone (Swallow, 1866) Moore, 1936

The Pawnee limestone lies between the Labette and Bandera shales; hence it is the first prominent limestone assemblage above the Fort Scott limestone. It generally has been described as comprising a single ledge, and Swallow (1866) applied the name Pawnee to "heavy bedded, porous and compact, coarse and fine, drab, brown and bluish-gray, cherty, concretionary and mottled (limestone), 20 to 25 feet thick." It is now known that the Pawnee limestone is divisible into members (Jewett, 1941, p. 315). The following members, named in ascending order, are recognized: (1) Anna shale, (2) Myrick Station limestone, (3) Mine Creek shale, and (4) Laberdie limestone.

The inclusion of a shale member at the base of a limestone formation is rather unusual. There is a thin slabby and locally lenticular limestone at the base of the Anna shale over a very wide area. This limestone is so thin in Kansas, nowhere more than 2 or 3 inches, that it does not seem deserving of a name and designation as a member. In Missouri and Oklahoma, however, limestone at the base of the persistent black shale that comprises most of the Anna member is much thicker. In Oklahoma, this limestone probably comprises the greater part of the thick Oologah limestone (Jewett, 1941, p. 290). It is clear that this basal limestone and the overlying shale belong in the Pawnee limestone assemblage. In 1936 Moore (1936, p. 62) amended the definition of the Pawnee limestone to include the thin limestone bed discussed above (Jewett, 1941, pp. 312-315).

The Pawnee limestone is easily identified in well logs in all of eastern Kansas. It is identified in Oklahoma (pl. 2) and com-

prises all, or at least the main part, of the Oologah limestone that crops out a few miles east of Tulsa. It has been traced across Missouri into Iowa (Cline, 1941, p. 37; Jewett, 1941, p. 312) and its equivalent is recognized in Illinois (Weller, Wanless, Cline, and Stookey, 1942, pp. 1591, 1592).

Because the type exposure of the Pawnee limestone had not been definitely located, I (Jewett, 1941, p. 315) designated an exposure along state highway 7, slightly north of the center of sec. 7, T. 27 S., R. 24 E., Bourbon county, Kansas, as the type. The exposure there is shown graphically in plate 2, sec. 97.

Graphic sections of outcrops of the Pawnee limestone and adjacent rocks in Kansas and in neighboring parts of Missouri and Oklahoma are shown in plate 2.

PAWNEE LIMESTONE

ANNA SHALE MEMBER Jewett, 1941

The Anna shale is the lower member of the Pawnee limestone formation. It lies below the Myrick Station limestone and in Kansas includes at its base a thin bed of dark limestone. The commercially important Lexington coal of Missouri occurs in the Anna shale. The type exposure of the Anna shale is the same as that of the Pawnee limestone; that is, a little north of the center of sec. 7, T. 27 S., R. 24 E., Bourbon county, Kansas, on Kansas highway 7.

Distribution.—The outcrop of the base of the Pawnee limestone or the base of the Anna shale is shown in plate 2. The line of outcrop is a sinuous line from eastern Linn county to Labette county.

Description.—Along its line of outcrop in Kansas, the Anna shale member of the Pawnee limestone ranges in thickness from about 2 feet to approximately 12 or 13 feet. Changes in thickness are rather abrupt. It must be remembered, however, that the Anna shale comprises black shale and thin-bedded limestone facies of strata below the more strictly defined Myrick Station limestone and hence its lower boundary does not mark a definite stratigraphic horizon.

In Kansas the Anna shale consists chiefly of black and generally fissile shale. It commonly contains small black nearly spherical phosphatic concretions imbedded in black shale. In nearly all exposures the upper few inches consists of gray shale.

This upper gray shale zone ranges in thickness from a few inches to approximately 2 feet. Locally the upper gray zone is absent (pl. 2, secs. 116 and 119). With few exceptions, careful searching in places where the basal part of the Pawnee limestone is well exposed reveals a thin bed of slabby black crystalline or earthy limestone below the thicker black shale part of the Anna member. This limestone is in the closing part of the marine phase of a lower Pawnee cyclothem which is rather fully developed in Nowata county, Oklahoma (pl. 2, sec. 193). There the Pawnee limestone assemblage includes limestone lower than this lower Anna bed of Kansas and eastern Missouri.

The Lexington coal, economically important in Lafayette county, Missouri, occurs in the Anna shale. The basal black limestone described above is present over wide areas in Missouri and has been identified in Missouri below the Lexington coal. Locally in Crawford county, Kansas, the upper middle part of the Anna shale is very coaly and may be described as nearly coal (pl. 2, sec. 119). Elsewhere in Crawford county, concretionary-like masses of coaly material occur in the upper part of the Anna shale (pl. 2, sec. 67). A coal bed 0.1 feet thick in Craig county, Oklahoma (pl. 2, sec. 203), is approximately at the horizon of the Lexington coal bed. The Lexington coal has been seen in Missouri in several Anna shale exposures between the type locality of the coal, near Lexington, Mo., and eastern Kansas.

The Anna shale is not conspicuously fossiliferous. Fragments of crinoids and other fossils occur in the basal limestone, and flattened brachiopod shells occur locally in the black shale.

PAWNEE LIMESTONE

MYRICK STATION LIMESTONE MEMBER Cline, 1941

The Myrick Station limestone is the second member from the base in the Pawnee limestone in Kansas. The name was applied by Cline (1941, p. 37) to the "Lexington cap-rock" in its exposure near Myrick Station on Missouri river in Lafayette county, Missouri. The same limestone is easily identified in numerous exposures in Lafayette, Johnson, Cass, and Bates counties, Missouri, and Linn county, Kansas. Cline (1941, p. 37) designated the exposures in ravines in the south bluff of Missouri river near Myrick Station, Lafayette county, Missouri, as the type exposure of the Myrick Station limestone.

Distribution.—The distribution of the outcrops of Myrick Station limestone in Kansas is almost exactly the same as that of the underlying Anna shale (pl. 2).

Description.—At outcrops in Kansas, the Myrick Station limestone ranges in thickness from less than 1 foot to approximately 8.5 feet. The greater thicknesses are due to the presence locally of *Chaetetes* biostromes which occur more commonly in the upper part.

The lower part of the Myrick Station limestone has a rather uniform thickness ranging between approximately 3 and 4 feet. This lower part is characteristically dark brownish-gray or dove-gray limestone that weathers tan or brown. This part is massive and is regularly bedded. Locally a large portion is composed of *Chaetetes* colonies, but these corals are not characteristic.

Generally where in excess of approximately 4 feet in thickness, the upper part of the Myrick Station limestone is a *Chaetetes* biostrome. Algal limestone is also abundant. In sec. 11, T. 25 S., R. 24 E., Bourbon county, a *Chaetetes* mass is separated from the lower massive part of the Myrick Station limestone by a thin shale bed. The coral mass there is overlain by 0.5 foot of slabby non-coralline limestone. Crinoid fragments, brachiopods (notably *Squamularia*), and sparse fusulines are other plentiful fossils in the Myrick Station limestone.

PAWNEE LIMESTONE
MINE CREEK SHALE MEMBER Jewett, 1941

North of Marmaton river in Kansas, and in Missouri, the Pawnee limestone includes a definite shale unit between the Myrick Station and Laberdie members. This is the Mine Creek shale (Jewett, 1941, p. 318). South of Marmaton river the Mine Creek shale is thin, but it can be identified in many exposures. The type exposure of the Mine Creek shale is near the middle of the south side of sec. 23, T. 21 S., R. 25 E., on a tributary of Mine creek in Linn county, Kansas. The type exposure is represented graphically in plate 2, section 10.

Distribution.—Because the overlying Laberdie limestone generally lies next below the soil in extensive dip slopes bordered on the east by the Pawnee limestone escarpment, the line of outcrop of the Mine Creek shale is almost exactly the same as that of the basal members of the Pawnee formation (pl. 2).

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Description.—Measured thicknesses of the Mine Creek shale in Kansas range from a featheredge to about 17 feet. The thickest Kansas outcrop sections are in the northern part of the outcrop belt. In eastern Missouri this member of the Pawnee limestone has a thickness comparable to that in near-by Kansas counties. In northeastern Oklahoma the thickness is commonly less than 1 foot (pl. 2).

The Mine Creek shale consists of gray, black, and greenish-gray and yellow shale and a minor amount of limestone. In one exposure in Johnson county, Missouri, a thin sandstone bed occurs in the middle part (pl. 2, sec. 185). Locally in Bates county, Missouri, the Myrick Station limestone, which normally underlies the Mine Creek shale, seemingly is absent, but the upper part of the Mine Creek shale is readily identifiable there because of its fauna consisting chiefly of numerous brachiopods. In the shallow subsurface in central Bates county, this member has a thickness ranging from 8 to 11 feet, of which locally 7 feet is fine-grained sandstone. At several exposures in Linn and Bourbon counties, Kansas, the Mine Creek shale is divisible into three parts—two shale deposits separated by a thin bed of limestone. Where thickest and where better exposed, the lower shale unit is yellowish and greenish-gray and is limonitic. Limonite occurs in small concretions and stringers. The upper shale is highly fossiliferous. It contains an extensive fossil zone that allows identification of the unit in areas where the underlying limestone is not seen. This brachiopod zone in the upper part of the Mine Creek shale is exposed in numerous places in Bates, Cass, and Johnson counties, Missouri, as well as in Linn county, Kansas. The upper fossiliferous part is calcareous and contains small limestone nodules. It is probable that the limestone in the middle part of the Mine Creek shale is not the same bed in various exposures. Locally in Linn county, Kansas, this limestone is a coquina of brachiopods.

In the southern part of Bourbon county and in Crawford and Labette counties the Mine Creek shale is merely a thin shale bed between the Myrick Station and Laberdie limestones, which, however, are distinguishable one from the other because of lithologic differences. Locally in Crawford county the Mine Creek shale is about 1.5 feet thick; the upper part is gray and blocky and the lower part is black and platy shale. As noted above, in the northern part of the outcrop belt in Kansas the upper part of the Mine

Creek shale is abundantly fossiliferous. Chonetids are the most plentiful fossils.

PAWNEE LIMESTONE

LABERDIE LIMESTONE MEMBER Jewett, 1941

The uppermost member of the Pawnee limestone is the Laberdie limestone (Jewett, 1941, p. 320). North of Marmaton river in Kansas, it is distinctly separated from the Myrick Station limestone by several feet of shale. The same condition exists in Missouri. Farther south in Kansas and in Oklahoma, the separating shale (Mine Creek) is thinner and may be locally absent, but in many exposures the underlying darker more massive Myrick Station limestone can be differentiated from the lighter colored more crystalline and thinner bedded Laberdie limestone. The type exposure of the Laberdie limestone is mostly artificial. It is in a quarry in the southwestern part of sec. 6, T. 23 S., R. 25 E., 1 mile west of Prescott, Linn county, Kansas. Laberdie creek is a short distance west of the quarry.

Distribution.—The Laberdie limestone underlies dip slopes ranging up to a few miles in width. Outcrops of at least the basal part of the limestone generally occur with the lower Pawnee members along the line shown in plate 2.

Description.—It is difficult to make accurate measurements of the thickness of the Laberdie limestone at many of the outcrops. In the northern part of the outcrop area in Kansas the thickness is approximately 10 feet. In the southern part it is much greater, the average being perhaps 20 or more feet.

In general the Laberdie limestone is light gray, crystalline, and brecciated. It occurs in rather thin wavy beds or beds of irregular thickness. Commonly the lower part is somewhat more massive. Locally it is in part a *Chaetetes* biostrome. Coralline limestone is more plentiful in the upper part. Fossils, particularly the abundant corals, are frequently partly or wholly silicified, but flint nodules are rare or entirely absent. This statement is contrary to a more or less prevalent belief that the Pawnee limestone is a flinty rock. Commonly large fragments of weathered flint from higher strata have accumulated on the escarpments of the Pawnee limestone and other rocks, giving the erroneous impression that the scarp-making rock is flint bearing.

In much of the Kansas outcrop area the Laberdie limestone lies below extensive dip slopes. In such areas the soil mantle is

thin, and bare outcrops are common in places of small relief as well as along drainage channels. A large part of the area underlain by the Laberdie limestone is unplowed grassland. Terrain of this kind is characteristic in Bourbon county.

The upper part of the Laberdie limestone weathers into a mass having an irregular hummocky upper surface. The whole unit consists of limestone that generally becomes lighter in color upon weathering. This rock is often called the "cotton rock." Weathered surfaces are pitted and flecked with brown. Sparse fusulines, crinoid and echinoid fragments, and brachiopods, in addition to abundant *Chaetetes,* are somewhat characteristic of the Laberdie limestone. With the exception of the coralline facies, however, it is not a highly fossiliferous rock. Exposures of the Laberdie limestone in Oklahoma are more fossiliferous than those in Kansas. Silicified specimens of *Cystauletes mammilosus* King, a cylindrical sponge, are locally abundant.

Bandera Shale Adams, 1903

The Bandera shale is a relatively thick clastic deposit that lies above the Pawnee limestone and below the Altamont limestone. It was named by Adams (1903, p. 32) from exposures near the former railroad station of Bandera, in Bourbon county, Kansas.

The Bandera formation includes a definite zone of sandstone to which the name Bandera Quarry sandstone has been applied (Jewett, 1941, p. 292). Near the base of the formation is a bed of coal which is persistent from the southern part of Bourbon county, Kansas, northward into Missouri. Coal is found in the same position in the subsurface in eastern Nebraska (Condra and Reed, 1943, p. 55). This is the Mulberry coal, named by Hinds (1912, p. 75) from exposures along Mulberry creek in Bates county, Missouri, not far east of Linn county, Kansas.

A continuous and complete section of the Bandera shale is not exposed in the vicinity of old Bandera station, in sec. 29, T. 25 S., R. 23 E., Bourbon county, Kansas. The upper approximate 20 feet of the Bandera shale and the overlying Altamont limestone are exposed in the NW¼ SW¼ of the section, and nearly all the local occurrence of the Bandera Quarry sandstone is exposed in the flagstone quarries in the vicinity of the center of the north line of the southwest quarter of the section (pl. 3, secs. 60 and 61). The exact type exposure of the Mulberry coal has not been des-

ignated, but it is assumed to be in the mining district along Mulberry creek southeast of Amoret, Bates county, Missouri.

Distribution.—The Bandera shale and sandstone underlie a belt of varying width between the outcrops of the Pawnee and Altamont limestones extending in Kansas from Labette county to Linn county. A prominent anticlinal dome in the vicinity of Mound City, Linn county, has given rise to an inlier of Bandera shale and the bounding limestones there.

Description.—The Bandera shale is variable in thickness. It is similar in this respect to the Labette and Nowata shales. Along the outcrop line in Kansas the thickness ranges from about 35 to about 75 feet. Available records of some rather closely spaced bore holes a short distance down dip from the outcrops show variations in thickness that are of interest because of their probable relationship to the present drainage pattern of the area. In northeastern Linn county and in Bates county, Missouri, there seems to be an abrupt change in thickness of the Bandera shale at about the present position of Marais des Cygnes river. North of the river the average thickness is about 22 feet and is as little as 8 feet in central Bates county. For a few miles south of the river the common thickness is about 45 feet and the known maximum is 52 feet. South of Little Osage river in northern Bourbon county, measured subsurface thicknesses range from about 47 to 96 feet.

The Bandera shale includes clayey and sandy shale, sandstone, and a minor amount of coal and limestone. The shale is mostly light in color. There is a very persistent zone of rather bright purplish or maroon shale in the upper part. Concretions and small lenses of limonite are characteristic of this facies. Septarian limestone concretions occur locally in the same facies.

The Mulberry coal bed is in the lower part of the Bandera shale at a position that ranges from a few inches to about 6 feet above the base of the formation. This coal bed has not been identified south of a point in southern Bourbon county, Kansas, but it extends far to the north. Locally in Linn county, Kansas, and in Bates county, Missouri, the Mulberry coal is more than 2 feet thick. It is extensively mined in these places. Recently Condra and Reed (1943, p. 55, fig. 19) have noted the presence of a coal bed in the lower part of the Bandera shale in the subsurface in eastern Nebraska. A very local coal bed occurs near the top of the Bandera shale in Labette county, Kansas.

Shale that separates the Mulberry coal from the underlying Laberdie limestone is distinct lithologically from the remainder of the Labette shale. This shale is not sandy, is less limonitic, and is slightly carbonaceous. It has some of the characteristics of an underclay and is often called "fire clay." Chemical analyses made in the Survey laboratories show that this shale has an alumina (Al_2O_3) content of 20.02 percent.

Sandstone and sandy shale are plentiful in the Labette formation. A part of the sandstone occurs as channel fillings. In some places clean cut lateral contacts between clay shale and sandstone have been studied. Elsewhere the sandstone grades laterally through sandy shale into clay shale without sand. The tops of sand bodies, at least a part of which are channel fillings, are in the upper and middle part of the formation. Locally in Kansas and in eastern Missouri, sand bodies occur next below the Altamont limestone, and locally the entire Bandera section is sandstone. In Kansas channel fillings are not known to extend into strata below the top of the Pawnee limestone. Locally in Missouri, filled channels reach downward into the Pawnee rocks. At one place, in the NW¼ sec. 2, T. 15 N., R. 28 W., Johnson county, Missouri, a channel filled with sandstone and limestone conglomerate is cut to a level about 5 feet above the top of the Myrick Station limestone. The Laberdie limestone and the upper part of the Mine Creek shale can be seen at a place a few feet away from the wall of the filled channel. The top of this coarse clastic channel filling was not observed there, but the channel filling is believed to be a part of the Bandera formation. In the same vicinity the base of the Hepler sandstone (basal Missourian) rests on shale in the upper part of the Bandera formation and a few feet above the top of a Bandera sandstone body.

Sandstone bodies that collectively are called Bandera Quarry sandstone occur in the Bandera shale in Kansas. This sandstone is commonly well bedded and is fine and micaceous. Locally it is cemented with siliceous material. Locally the Bandera Quarry sandstone occupies the entire Bandera section. Where present, it is generally separated by shale ranging in thickness from a few to 20 or more feet. The Bandera Quarry sandstone has been quarried for a long time in Bourbon county. Beautiful flagstones and building stone are produced. In the exposures in a quarry in the SW¼ sec. 29, T. 25 S., R. 23 E., this sandstone is about 30 feet

thick. For the most part, it is well bedded and contains an abundance of fossil worms.

A thin bed of nearly black limestone occurs locally in the lower part of the Bandera shale just above the Mulberry coal. This limestone and the underlying coal are exposed in sec. 1, T. 26 S., R. 23 E., Bourbon county, Kansas. Limestone has been noted in well records at the same stratigraphic horizon in northern Linn county and in eastern Missouri.

The Bandera shale contains few invertebrate fossils. Annelid worms in the Bandera Quarry sandstone have been noted above. Fragments of land plants are abundant in sandy shale and sandstone, especially in the lower part of the formation, but above the Mulberry coal. Carbonaceous masses in the shale below the Mulberry coal probably are the partly coalified fragments of plants.

Graphic representations of several Bandera shale outcrops in Kansas are shown in plate 3.

Altamont Limestone Adams, 1896

The Altamont limestone lies next above the Bandera shale; it comprises limestone and shale beds. These are best developed in Kansas in southeastern Neosho and Labette counties, and they are equally well developed locally in Bates county, Missouri.

For a long time the Altamont limestone, like the Pawnee and Lenapah limestones, was described and represented in diagrams as a single limestone ledge. Seemingly one limestone member and then another had been seen at outcrops, but two had not been noticed at one outcrop or the very persistent midde shale member had perhaps been assumed to be of local occurrence. Observations have shown, however, that the separating shale is very widespread and that the three members can be identified from northeastern Oklahoma to southern Iowa and into Illinois (Cline, 1941, pp. 26, 27; Jewett, 1941, p. 326; Weller, Wanless, Cline, and Stookey, 1942, p. 1586). They can be recognized in the subsurface in much of eastern Kansas. I have used the persistent and easily recognized Lake Neosho shale as the basis of division into members (Jewett, 1941, p. 326). All limestone within the formation and above the Lake Neosho shale is called Worland, and the limestone below, locally composed of as many as four distinct beds, is assigned to the Tina member.

No exposures in the vicinity of Altamont that show the whole Altamont formation are known. The Lake Neosho shale, a part

of the overlying Worland limestone, and a part of the underlying Tina limestone are exposed near the center of the west line of sec. 5, T. 33 S., R. 19 E., about 3.5 miles west of Altamont, Labette county, Kansas. This exposure has been designated as the type exposure (Jewett, 1941, p. 326). The exposure there is shown graphically in plate 3, section 160.

Graphic sections of outcrops of the Altamont limestone and adjacent rocks in Kansas and in neighboring parts of Missouri and Oklahoma are shown in plate 3.

ALTAMONT LIMESTONE

TINA LIMESTONE MEMBER Cline, 1941

Tina limestone is the name of the lowest member of the Altamont limestone. The name was introduced by Cline (1941, p. 43), and I (Jewett, 1941, p. 329) proposed that it be used for all limestone in the Altamont formation below the Lake Neosho shale. Cline designated exposures in the west-central part of sec. 7, T. 54 N., R. 22 W., Carroll county, Missouri, as the type of the Tina limestone.

Distribution.—The Tina limestone is locally absent in some exposures of the Altamont formation in Linn and Bourbon counties. The upper part, however, is present almost continuously along the line shown in the map of southeastern Kansas in plate 3. All phases of the member are well developed in Labette and southeastern Neosho counties.

Description.—According to measurements made at a great many outcrops, the Tina limestone in Kansas ranges in thickness from a featheredge to slightly more than 10 feet. Like several other Marmaton limestones, it is locally largely a *Chaetetes* biostrome, and its thicker developments locally are due to the presence of the remains of these Desmoinesian rock-building corals. In general, the lower member of the Altamont limestone is more fully developed in the southern part of its outcrop belt than in the northern part, but changes in thickness are somewhat abrupt (pl. 3). Locally the Tina limestone is absent (pl. 3, secs. 25, 36, 43, 82, and 95). In some exposures it is seen to pinch out or to grade laterally into sandstone (pl. 3, secs. 10 and 35).

In places where it is more fully developed, the Tina limestone is composed of two or three limestones separated by thin shale beds (pl. 3, secs. 127, 128, 129, 132). The exposure in the SW¼

sec. 23, T. 30 S., R. 20 E., Neosho county, shows clearly its full development. There the basal part consists of 0.75 foot of gray mottled wavy-bedded limestone containing *Mesolobus*. This is overlain by a thin shale bed. The second limestone from the base is really two rocks. The lower one is gray, nodular, and brecciated. In its upper part are pelecypods and "*Fistulipora*." Fusulines are rather abundant in its lower part and crinoid fragments are plentiful throughout. This lower part is a little more than 2 feet thick. The upper rock of this second limestone unit is massive and contains crinoid remains and brachiopods. Next above is a thin shale overlain by 1.5 feet of bluish-gray to purplish-brown limestone which occurs in thin irregular beds and contains many crinoid fragments.

The upper unit described above is the most persistent part of the Tina limestone, and it extends far northward across Missouri into Iowa. Along most of this distance the other parts are absent but are developed locally. Where this persistent part alone is present in Kansas it is generally less than 1.5 feet thick, is granular, and contains a molluscan fauna and plentiful algal remains. Locally it is almost entirely an algal limestone. Cross-bedding is common. At some places it is a mass of fossil fragments that have seemingly suffered much abrasion by waves or currents. Locally it grades laterally and vertically into sandstone. Ostracodes are abundant in this rock in Bates county, Missouri.

Although one or more of the units of the Tina limestone that are described above can be recognized in many exposures, nearly the entire member is a *Chaetetes* biostrome in Labette county. The coral mass, however, wherever seen, lies on at least a few inches of noncoralline limestone. Evidently *Chaetetes* did not thrive on mud bottoms.

ALTAMONT LIMESTONE
LAKE NEOSHO SHALE MEMBER Jewett, 1941

The Lake Neosho shale is the middle member of the Altamont limestone. It is very persistent and is identified in exposures where the underlying Tina limestone is absent. Because of its easily recognized characteristics, particularly the presence of rough irregular phosphatic concretions, it is conveniently used as the basis of subdivision of the Altamont limestone into members. The type exposure of the Lake Neosho shale is southeast of Neosho

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County State Park, in the SE¼ sec. 23, T. 30 S., R. 20 E., Neosho county, Kansas (pl. 3, sec. 132).

Distribution.—The Lake Neosho shale is present with the overlying Worland limestone and, except in a very few places, with the underlying Tina limestone along the line shown in the map of southeastern Kansas in plate 3.

Description.—The thickness of the Lake Neosho shale is rather uniform over wide areas. The characteristic thickness is about 2 feet. Locally, however, it is nearly 6 feet thick. The Lake Neosho shale is the most easily recognized member of the Altamont limestone. It can be differentiated from the underlying Bandera shale in outcrops where the Tina limestone, which normally separates the two shales, is absent. The Lake Neosho shale chiefly includes yellowish-gray and black shale. Where the unit is rather thin, it is dominantly light in color but black shale is found almost without exception in the lower or middle part. Irregularly shaped slightly elongated rough dark phosphatic concretion-like nodules are invariably present in the dark-gray or black shale beds. These nodules are the most characteristic feature of the unit. They commonly contain teeth and bone fragments, and probably are coprolites.

ALTAMONT LIMESTONE

WORLAND LIMESTONE MEMBER (Greene, 1933) Cline, 1941

The Worland limestone is the upper member of the Altamont limestone. It is known from Oklahoma to Iowa, and an equivalent limestone seems to be present in Illinois. The name Worland has been used for several years but only recently has a definition been offered (Cline, 1941, p. 29; Jewett, 1941, p. 334). I have designated as the type exposure of the Worland limestone the exposure along the Kansas City Southern railway just north of a grade crossing northeast of Worland, Bates county, Missouri (Jewett, 1941, p. 334).

Distribution.—In Kansas the Worland limestone makes a somewhat prominent outcrop and escarpment from eastern Linn county to southwestern Labette county.

Description.—The Worland limestone in Kansas has a rather uniform thickness of about 8 feet, although it is generally somewhat thinner in the northern part of its outcrop area. This upper member of the Altamont limestone is somewhat less easily divided

into parts based on lithologic differences than are several of the other Marmaton limestones. In general it is rather light bluish-gray in color and is massive; it is finer grained than are other limestones of the Marmaton group. Specimens from many exposures have the characteristics of lithographic limestone. In some places the lower part is brecciated. Chemically, the Worland limestone is usually purer calcium carbonate than other rocks of this group. Samples are frequently found to be approximately 97 percent pure. In one exposure, in the SW¼ sec. 23, T. 30 S., R. 20 E., Neosho county, Kansas (pl. 3, sec. 132), the rock consists of light bluish-gray limestone and thin lenses of nearly white flint.

One of the most comprehensive exposures of the Worland limestone in Kansas is in a small quarry in the SE¼ sec. 24, T. 25 S., R. 22 E., a short distance east of Uniontown, Bourbon county. There the lower 7 feet includes slightly nodular dense and slightly crystalline gray limestone containing fossil brachiopods. This is the part of the Worland limestone that is persistent over wide areas. Next above is about 2 feet of bluish-gray, nodular, rather thin-bedded limestone, in which are enclosed domelike masses of well-bedded shale. Some of the shale-filled "cavities" are 6 feet long and 1.8 feet high. The shale filling rests on the underlying limestone unit described above. The included shale masses are calcareous and contain many small limestone nodules and fusulines. The rock containing the shale-filled cavities is overlain by about 2 feet of interbedded nodular limestone and calcareous shale. The exposure described here is represented in plate 3, section 52.

The Worland limestone holds a prominent escarpment and extensive dip slope in southeastern Kansas. Because it is the only relatively thick limestone in a belt several miles wide, it is extensively quarried for road material and other uses.

Chonetids, *Squamularia, Composita,* and other brachiopods, and fusulines are characteristic of the Worland limestone. In many exposures fusulines are rather uniformly distributed throughout the persistent part of the rock, and they are abundant in the locally occurring upper part.

Nowata Shale Ohern, 1910

Shale and sandstone that lie between the Altamont and the Lenapah limestones were called Nowata shale by Ohern (1910,

p. 23). I have suggested the name Walter Johnson sandstone for included sand bodies (Jewett, 1941, p. 335). The Nowata derives its name from the city of Nowata, Nowata county, Oklahoma. The type exposure of the Walter Johnson sandstone is in sec. 10, T. 35 S., R. 17 E., Montgomery county, Kansas.

Distribution.—In general the band of outcrop of the Nowata shale is narrow, but because of the rather wide dip slope held by the Worland limestone the line of outcrop is commonly a few miles west of the outcrop of the basal part of the Altamont formation.

Description.—Along its line of outcrop in Kansas, the Nowata shale ranges from almost nothing to approximately 50 feet in thickness. Measured sections indicate rather abrupt thickness changes.

The Nowata shale includes light and dark clay shale, sandy shale, and sandstone. Unlike the Labette and Bandera shales, no coal beds are known in the Nowata in Kansas. It seems that genetically the dark and black shale (pl. 4, secs. 180, 92, and 143) between the Worland limestone and the Norfleet limestone belong with the Lenapah rock assemblage rather than with the lighter colored and locally sandy Nowata strata, but because of the continuity of the bounding limestones it seems hardly expedient to exclude these darker beds from the Nowata formation.

In general the Nowata shale is light gray, yellow, and limonitic. Locally it is almost or entirely free from sand. At places it is sandy shale or contains massive sandstone bodies. The sandstone and sandy shale are abundantly micaceous. Dark and black shale in the formation commonly contains small smooth dark phosphatic concretions which are quite unlike the phosphatic nodules that occur so abundantly in the Lake Neosho shale but similar to those in black shales in the Fort Scott and Pawnee formations. Generally the Nowata shale is almost free from fossils, but brachiopods are common in places where the dark shale facies is developed. In Bates county, Missouri, *Mesolobus* sp., other chonetids, and large productids are abundant.

Lenapah Limestone Ohern, 1910

The Lenapah limestone overlies the Nowata shale. It was named by Ohern (1910, p. 23) from the town of Lenapah in Nowata county, Oklahoma. Like other Marmaton limestone formations, the Lenapah is divisible into members. The upper member is the

Idenbro limestone; the middle member is the Perry Farm shale; and the lower member is the Norfleet limestone. The type exposure of the Lenapah limestone is in an old quarry in the NW¼ NE¼ sec. 30, T. 28 N., R. 16 E., Nowata county, Oklahoma. This is at Bell Spur, a short distance north of Lenapah. Newer quarries a short distance southeast of Bell Spur now offer better exposures (pl. 4, sec. 200).

Weller, Wanless, Cline, and Stookey (1942, fig. 1) recognized the equivalent of the Lenapah limestone in southern Iowa and western Illinois. According to their correlation in Illinois, the Lonsdale limestone and overlying beds, including strata that are correlated with Exline limestone of northern Missouri, are equivalent to the Lenapah limestone. In Iowa, the Cooper Creek limestone, the Exline limestone, and separating shale beds are correlated with the Lenapah beds. The Exline limestone has commonly been called the "*Trepospira* zone." Thus it seems that the correlation of the Exline limestone or "*Trepospira* zone" and the upper part of the Lenapah limestone (Idenbro limestone) is well founded (Weller, Wanless, Cline, and Stookey, 1942, p. 1592). In Bates county, Missouri, *Trepospira* sp. occurs rather abundantly in the upper part of the Perry Farm shale.

Graphic sections of 46 outcrops of the Lenapah limestone and adjacent rocks are shown in plate 4.

LENAPAH LIMESTONE
NORFLEET LIMESTONE MEMBER Jewett, 1941

The lower part of the Lenapah limestone, below the nodular and locally fossiliferous shale in the middle part, is the Norfleet limestone. Its definition (Jewett, 1941, p. 338) is such as to include all limestone and shale beds of the Lenapah formation below the easily defined Perry Farm shale. From the definition it follows that the Norfleet limestone is absent or is very poorly developed in much of the outcrop area in southeastern Kansas, but wherever limestone underlies the nodular Perry Farm shale it is assigned to the Norfleet member. The type exposure of the Norfleet limestone is in the SE¼ sec. 35. T. 32 S., R. 18 E., Labette county, Kansas. The section there is shown graphically in plate 4, section 143.

Distribution.—The Norfleet limestone is a less persistent part of the Lenapah formation and hence it is not everywhere present

along the line of outcrop of the formation shown on plate 4. It is best developed in the southern part of the area of outcrop and is rather poorly developed locally in the northern part (pl. 4).

Description.—The Norfleet limestone, although not persistent, is a zone that can be readily identified along a line that extends from northeastern Oklahoma at least as far northeast as Bates county, Missouri; it is seemingly represented in Iowa by the Cooper Creek limestone and in Illinois by the Lonsdale limestone. Throughout the northern part of the Kansas outcrop area, except where it is locally absent, it is a thin bed of limestone about 0.5 foot thick. In Labette county it varies from slabby to massive limestone and has a maximum known thickness of 3 feet (pl. 4, sec. 143). In northeastern Oklahoma the Norfleet limestone comprises the lower part of the thick Lenapah limestone section. Near Lenapah it is 14 feet thick (pl. 4, sec. 199).

The Norfleet limestone is extremely variable in lithology. It is for the most part identified as limestone immediately below the Perry Farm shale, which has more definite characteristics. In northeastern Oklahoma the Norfleet limestone is light gray, sandy, hard, and massive, and contains few fossils. In Labette county, Kansas, it varies from massive limestone bearing an abundance of *Dictyoclostus* to slabby crinoidal limestone and slabby limestone containing abundant plant remains (pl. 4, secs. 143 and 159). In Neosho county (pl. 4, sec. 126) it consists locally of interbedded dark-gray sandy limestone and calcareous shale. The Norfleet limestone is seemingly absent from nearly all the outcrop belt in Bourbon county, but it occurs locally there and in Linn county (pl. 4). In its northern known exposures it is characteristically marked by small tubular and irregular limonitic inclusions in dark and purplish-gray limestone.

LENAPAH LIMESTONE

PERRY FARM SHALE MEMBER Jewett, 1941

The Perry Farm shale is the middle member of the Lenapah formation. It includes calcareous fossiliferous shale above the Norfleet limestone and below the Idenbro limestone (Jewett, 1941, p. 339). In general it is characterized by irregular limestone nodules in gray shale, and locally in northeastern Oklahoma it becomes mottled massive limestone. At its upper boundary the Perry Farm shale is somewhat gradational into the overlying

Idenbro limestone. The type exposure of the Perry Farm shale is in the NW¼ NE¼ sec. 7, T. 34 S., R. 18 E., Labette county, Kansas. The section there is shown graphically in plate 4, section 169.

Distribution.—The Norfleet limestone is only locally present in the northern part of the Lenapah outcrop area in Kansas. However, because of the presence of the bounding limestones and because of its characteristics, the Perry Farm shale generally can be identified along the line of outcrop of the Lenapah formation.

Description.—In its Kansas outcrop belt, the Perry Farm shale ranges in thickness from a featheredge to perhaps as much as 20 feet. Locally in Linn and Bourbon counties this member of the Lenapah limestone has not been identified, and at some exposures it seems proper to classify beds next below the Idenbro limestone as belonging to the Nowata shale (pl. 4, secs. 1, 3, 16, 33, 47, 53, and 85). In other places, however, even though the Norfleet limestone is absent, the Perry Farm shale can be identified (pl. 4, secs. 9, 122, and 123).

The Perry Farm shale includes chiefly gray and yellow shale and nodular or concretionary limestone. The limestone is generally light to medium gray and is dense in texture. It occurs in discontinuous nodular lenses. The greatest dimensions of individual limestone masses range from a small fraction of an inch to a few inches. Locally in Neosho county thin beds of limestone continue laterally for at least 50 feet and are probably much more extensive. A short distance south of the Kansas-Oklahoma boundary, concretionary shale of the Perry Farm member grades laterally into limestone which is nodular in appearance and is mottled. The limestone occurring in thin beds in Neosho county is very similar in lithology to the solid limestone in this part of the section in Nowata county, Oklahoma (pl. 4, secs. 199 and 200). Locally in Bourbon county, Kansas, and in eastern Missouri, the Perry Farm shale displays a nearly black shale facies (pl. 4, secs. 92 and 180). In Bates county, Missouri, limestone nodules occur in black shale near the base of the member.

Locally the Perry farm shale is abundantly fossiliferous. In Labette county it carries a mixed coral, molluscan, and brachiopod fauna, a facies fauna similar to that of the Wewoka shale in Oklahoma (Girty, 1915). In Nowata county, Oklahoma, and in neighboring parts of Kansas, *Marginifera* are extremely abundant in the upper part of the Perry Farm shale.

LENAPAH LIMESTONE

IDENBRO LIMESTONE MEMBER Jewett, 1941

The Idenbro limestone is the upper and most prominent member of the Lenapah limestone. It is the part of the formation that forms a low escarpment and lies below a somewhat extensive dip slope in Labette and Montgomery counties, Kansas; it is believed to extend far to the north and east where it is correlative with the Exline limestone in Missouri and Iowa. The type exposure of the Idenbro limestone is in the SW¼ sec. 2, T. 32 S., R. 18 E., Labette county, Kansas. The section there is shown graphically in plate 4, section 144.

Distribution.—The Idenbro limestone is present across Kansas from Linn to Montgomery counties and has been identified as far south in Oklahoma as the vicinity of Tulsa. It has also been identified in several places in Missouri. The line of outcrop of the Lenapah formation in Kansas is shown in plate 4. The outcrop of the Idenbro member is practically the same.

Description.—Measured sections of the Idenbro limestone in Kansas range from about 1 to 7 feet in thickness. It is probable that along the outcrop line in Labette and Montgomery counties the Idenbro is everywhere about 7 feet thick, but the full thickness is seldom seen at outcrops. It is thin and inconspicuous north of Labette county. It forms a low escarpment in places where it is a few feet thick.

The Idenbro limestone is generally light gray. It is commonly nodular, but, as shown on weathered and freshly exposed surfaces, it is not uniform in color and texture. The nodular structure of the Idenbro limestone is less pronounced than that of the limestone facies of the Perry Farm shale, however. The rock is impure limestone. Chemical analyses of some samples show a silica content of 35 percent. The mottled nodular appearance is probably due to its being largely of algal origin.

The Idenbro limestone varies from massive to thin-bedded limestone. Exposure to weathering, however, generally brings out rather thin and irregular bedding. The basal part is more massive than the upper. In the northern part of the Kansas outcrop belt, the Idenbro limestone is more sandy, darker in color, and generally more limonitic than in the southern part. Although it is a thin ledge in Linn and Bourbon counties, the rock is massive, showing no tendency to weather into thin slabs as it does else-

where. In this facies it is granular, purplish-brown, and contains tubular masses of limonite. The limonite masses are roughly about one-half inch by 2 or 3 inches; the greatest dimension is more or less parallel with the bedding of the rock.

Fossils are somewhat plentiful in the Idenbro limestone. Algal remains, corals, and bryozoans are common. Fossil corals include "*Aulopora*" and individual cup corals. *Chaetetes* has not been observed. Brachiopods, including *Mesolobus*, are rather generally distributed vertically and laterally. Fragments of crinoids, *Prismopora*, "*Fistulipora*," and brachiopods, interspersed with algal remains, stand out in relief on weathered slabs of rock in the upper part.

Memorial Shale Dott, 1936

The Memorial shale formation includes all the Desmoinesian beds in the northern Mid-Continent region above the Lenapah limestone. In Kansas and western Missouri, it embraces shale between the Idenbro limestone and the Hepler sandstone (Jewett, 1941, p. 340). The Hepler sandstone is the basal Missourian deposit of the area. The name Memorial shale is from Memorial Park cemetery near Tulsa, Okla. It was originally described (Dott, 1936) from exposures along the west line of the SW¼ sec. 36, T. 19 N., R. 13 E., Tulsa county, Oklahoma.

Distribution.—The Memorial shale is present above the Lenapah limestone in Kansas except locally where it has been removed by pre-Missourian erosion. In a few exposures in Linn county the basal Missourian deposits lie upon the eroded surface of the Lenapah limestone or lower beds. Elsewhere along the line of outcrop of these rocks, a few feet of Memorial shale separates the Lenapah limestone from the Hepler sandstone, which lies next above the post-Desmoinesian disconformity.

Description.—In Kansas, the Memorial shale ranges from a featheredge to about 30 feet in thickness. The thickness, however, is generally less. In northeastern Linn county it is locally absent owing to post-Desmoinesian and pre-Missourian erosion. The same conditions have been noted in the subsurface in Miami county where the pre-Missourian disconformity locally is as low stratigraphically as a horizon in the Bandera shale.

In most of its outcrops the Memorial shale consists of well-bedded slightly blocky clay shale. The color is commonly various shades of gray. Greenish and yellowish-grays predominate.

Some red shale is present in the lower part in Linn county. Small lenses and stringers of limonite are often seen. In a few places the Memorial shale is slightly sandy but almost nowhere is it so sandy as to be distinguished with difficulty from the overlying Hepler sandstone. Small lenses of brown fine-grained sandstone similar to the Hepler sandstone occur in the upper part of the Memorial shale in southwestern Bourbon county (pl. 4, sec. 76).

A coal bed occupies a position near the base of the Memorial shale in Labette county (pl. 4, secs. 135 and 156). The coal is underlain by about an equal thickness of black shale. In the same vicinity another coal, seemingly very local in lateral extent, lies at the top of the Memorial shale or at the base of the Hepler sandstone. It is impossible to determine whether the disconformity there lies above or below the coal bed (pl. 4, sec. 156).

The Memorial shale is barren of fossils in most of its outcrop area in Kansas. However, corals and brachiopods are abundant in the vicinity of Mound Valley in Labette county. In sections 2 and 11, T. 32 S., R. 18 E., the coral *"Trachypora" austini* Worthen occurs very abundantly. These corals were actually rock builders there, comprising practically all the rock in a thin zone. The fossils weather freely from the shale. In the same place the coral *"Aulopora"* is abundant, and the brachiopod *Mesolobus* ranges upward nearly to the base of the Hepler sandstone.

According to Oakes (Oakes and Jewett, 1943, p. 633), the Memorial shale is absent from most of the outcrop area of Marmaton rocks in northeastern Oklahoma. The pre-Missourian disconformity there is in contact with the Lenapah limestone, a condition that is known only very locally in Kansas. Because the Lenapah limestone and the basal Missourian sandstone, the Hepler sandstone, can be readily traced into Missouri and very probably across the state into Iowa, it follows that the Memorial shale is present in Missouri (pl. 4, sec. 180). Thick surficial deposits in Missouri cause poor outcrops of these weak rocks that occur a few feet above the more resistant scarp-making Marmaton limestones.

CYCLIC DEPOSITS

General Review of Present Concepts of Cyclic Deposition

For a little more than a decade nearly all students of Pennsylvanian and Permian rocks have been cognizant of cyclic sedimentation that occurred on scales intermediate between that of very short time repetitions, such as are represented by varves, and those represented by the great transgressive and regressive phases that characterize time-rock units, the series or larger divisions. These cyclic deposits are commonly called cyclothems, but after the introduction of the term megacyclothem (Moore, 1936, pp. 21-38) it has been plain that depositional cycles of two or more magnitudes can be recognized in some rock sections. Megacyclothems as recognized in Mid-Continent Pennsylvanian strata consist of several smaller cyclic units. Attention has been called to the probability that megacyclothems may be recognized in areas where cyclothems already are known and that some "cyclothems" may be identified as megacyclothems (Jewett, 1941, p. 343). Partly because of looseness of definitions and partly because of progress in detailed knowledge of the rocks, clarification of terms seems to be essential. It is very probable, however, that systematic classification of these intermediate cyclic deposits must await still more detailed stratigraphic and sedimentary studies.

Wanless and Weller (1932, p. 1003) defined cyclothem as a series of beds deposited during a single sedimentary cycle. Weller (1930, p. 99) previously defined cycle as a recurrence, repetition, or return to the starting point. This definition of cyclothem could, perhaps, be applied to varves, annual deposits recording the march of the seasons, or to large transgressive and regressive units having the magnitude of geologic series or even systems. Obviously, however, the intention was not to include such extremes of sedimentary cyclic units. Elias (1937, p. 408) in discussing cyclic deposits in the Big Blue (Wolfcampian) series in Kansas, stated that the cyclic units are intermediate between the minute seasonal rhythms of varved clays and the great cycles of geologic periods. Such statements are not especially helpful because it is evident that rock units called series are in many cases cyclic units and it is commonly agreed that these units are larger —that is to say, are thicker—and represent a greater amount of

time than the units commonly called cyclothems. Weller regards cyclothems as roughly having the magnitude of formations, and Moore has identified megacyclothems that roughly correspond to formations in Kansas. Of course the classification of rock units into formations has come about because of the more or less obvious differences in lithology in successive beds; in places like Illinois and Kansas, where Pennsylvanian rocks have been studied in great detail, the formations are the easily differentiated, mappable units, and are of about the same time span.

As an example of the use of terms in an important recent stratigraphic paper, it is noted that McKee (1938, p. 130) stated that both the Toroweap and Kaibab (Permian) formations in northern Arizona and southern Utah are thought to be true cyclothems, and that the members they include are equivalent to "phases" as the term is used by Moore. Moore (1936, pp. 28, 30) used the term phase to indicate one of the units making a cyclothem. McKee (1936, p. 132) recognized numerous "minor cycles" in the Kaibab formation.

The classificatory system including (1) varve, (2) phase, (3) cyclothem, and (4) megacyclothem is well established. It is, of course, understood that cyclothems are not commonly divisible into varves, but it is recognized that varves are cyclic deposits and it is probable that varves will be recognized in Paleozoic rocks. According to usage, megacyclothems consist of two or more cyclothems of different character that occur in regular sequence; phases are units within cyclothems. Hence, the term cyclothem seems properly used to designate in any area the smallest recognizable cyclic units except varves. It is held that if the term cyclothem is used it should be in this sense and that the term megacyclothem should be used to indicate a unit, cyclic in itself, but composed of two or more cyclothems.

Moore (1936, p. 23) has proposed that cyclic deposits of the northern Mid-Continent region be designated by the names of the limestones that each contains. This practice can be followed when working in most parts of the Pennsylvanian section, but it is necessary to use the names of some other kinds of rock in the Cherokee shale. Abernathy (1937), who identified and named 15 cyclothems in the Cherokee shale, used principally the names of coal beds to designate cyclothems.

Fifteen cyclothems are known in Cherokee rocks in Kansas. It is believed that there are four well-developed megacyclothems of four or more cyclothems each in the Marmaton group in Kansas. Moore (1936, p. 23, fig. 10) has identified four megacyclothems in the Shawnee group. Cyclic deposits in rocks between the Marmaton group and the Shawnee group seemingly are not so distinctly developed in the outcrop belt, and exact numbers can not be given so definitely. It is to be noted, however, that cyclic deposits are clearly discernible and are very obvious in several parts of the section. The Wabaunsee group, overlying the Shawnee rocks, is divisible into several cyclothems, but there the grouping of cyclothems into megacyclothems is not evident.

Wanless and Shepard (1936) reviewed the literature on Pennsylvanian and Permian cyclic deposits. They found that cyclic sediments of Pennsylvanian age had been described from Illinois, Kansas, Iowa, West Virginia, Michigan, Texas, Colorado, British Isles, and the Silesian basin. They pointed out that described sections of Pennsylvanian rocks in many parts of the world indicate the presence of cyclic deposits.

There are several recent stratigraphic papers, in which cyclic deposition is not discussed, that nevertheless clearly indicate cyclic sedimentation in their descriptions and graphic sections. Here may be noted the Pennsylvanian sections described in (1) the Appalachian valley in Virginia (Butts, 1940); (2) the Muskogee-Porum district of Oklahoma (Newell, 1937); (3) Washington county, Oklahoma (Oakes, 1940); and (4) New Mexico (Thompson, 1942).

It was noted by Wanless and Shepard (1936) that the period of earth history marked by cyclic sediments in the central part of the United States of America seems to extend from about the end of Meramecian, through Chesterian (Late Mississippian) and throughout all of Pennsylvanian and early Permian time. The presence of cyclic deposits in rocks of Chesterian age was noted by Wanless and Shepard (1936, p. 1180) and Permian cyclic deposits have been noted by McKee (1938), by Elias (1937), and by me (Jewett, 1933). The compilation of the number of cyclothems in Pennsylvanian rocks by Wanless and Shepard seems too small, however, in the light of present knowledge. They assigned 38 to the Pennsylvanian. We now know of more than 30 in the

Desmoinesian rocks alone (Abernathy, 1937a, p. 19; Jewett, 1941, p. 288).

It is commonly believed that these types of cyclic deposits have resulted from fluctuations in relative height of sea level and that cyclothems are widespread. The theories as to the causes of sea-level fluctuations will not be discussed fully here, but attention is called to the hypothesis of Wanless and Shepard (1936) postulating that waxing and waning of glaciers caused the sea-level variations. It has been pointed out that four cyclothems in Illinois are recorded in a certain section of rock and that the same number of megacyclothems are known in Kansas rocks which are believed to be of approximately equivalent time span. It must follow, then, that these Kansas megacyclothems are equivalent (if they resulted from the same casual factors) to the Illinois cyclothems. In spite of this seeming misuse of terms in one place or the other, it is held that the usage is good. In both places the term cyclothem is used for the smallest cyclic unit that has been recognized.

It is evident that more minute changes in the elevation of sea level could not have been equally well recorded by changes in rock material in all places where sediments were accumulating. Marmaton rocks in their outcrop area in southeastern Kansas are more dominantly calcareous and a greater part is of marine origin than rocks of the same age in Illinois. The relatively short time and seemingly shallower sea invasions of eastern Kansas did not reach as far eastward as Illinois. Rocks of Missourian age are divisible into cyclothems and megacyclothems in eastern Kansas but equivalent rocks form a nearly solid limestone section farther west in the state. Minor changes in sea-level elevation were not so effective there.

Knowledge of cyclic sedimentation is not new. More than 120 years ago Conybeare and W. Phillips remarked on the rhythmic manner in which clay is followed by sand and sand by limestone in the Oölitic sequence of Britain. This principle of cyclic sedimentation, which was established at about the same time that William Smith was laying the foundations of stratigraphy, has been used by several subsequent European students of Mesozoic rocks. A rather casual survey of European stratigraphic literature shows that the principle of cyclic deposits was a commonly accepted tool in stratigraphy during the first two decades of the

present century and that much earlier cyclic deposits, as least in the Jurassic, were known to be widespread. The first modern stratigraphers to recognize the really important bearing of cyclic deposits on problems of stratigraphy are Andrée (1908), Klüpfel (1916), and Frebold (1924). Arkell (1933) was fully cognizant of their bearing on studies of the Jurassic of Great Britain.

Although cyclic sediments in American Paleozoic rocks were recognized earlier, it was only a few years ago that their significance and usefulness in Pennsylvanian stratigraphy were emphasized. The recent advancement of studies of cyclothems and stratigraphy based on cyclic units is due chiefly to the researches of J. M. Weller, H. R. Wanless, and their associates in Illinois, and of R. C. Moore and his co-workers in Kansas. It is now evident that numerous stratigraphic problems can best be solved through the study of cyclic units. An example that may be cited here is the question of the true relationships of beds in the Cherokee shale in eastern Oklahoma and eastern Kansas. It does not seem to be out of place to remark that the principle of cyclic deposition ranks with paleontology in usefulness in studies of many parts of the Pennsylvanian rock section.

Modern students of British Carboniferous rocks seem to be fully aware of the significance of cyclic sedimentation. Richey (1937, pp. 96-99) described rhythmic cycles in the Carboniferous limestone and oil shales of Scotland. Tonks and Jones (1931, pp. 10-13) described sedimentation cycles in the Carboniferous of Manchester; Robertson (1932, pp. 87-89) described cyclic sediments in the South Wales coal-field; and Trotter and Hollingsworth (1932, pp. 17-19) discussed the same features in the Brampton district.

Three principal types of hypotheses to explain cyclic deposits have been advanced. They are (1) that cyclic sedimentation recorded intermittent subsidence, contemporaneous with and followed by sedimentation, and then renewed subsidence; (2) that it recorded diastrophic movements alternating between subsidence and uplift; and (3) that it recorded sea-level fluctuations caused by storing of ocean water on land in the form of continental glaciers or as interior seas or lakes.

An hypothesis of the first type was advanced as early as 1871 by J. Phillips. Much later Stout (1931) and Cady (1934) sought to explain Pennsylvanian cyclic deposits in the same way. Weller

(1930) formulated an hypothesis of alternating subsidence and uplift, and Wanless and Shepard (1936) are the authors of the theory of fluctuating sea level brought about by storing of ocean waters on the land. They placed special emphasis on the probability that Late Paleozoic glaciation caused cyclothems. Richey (1937, p. 96), in writing of cyclic sedimentation in the Lower Carboniferous of Scotland, stated that the strata were lain down over a gradually sinking area, that the strata repeatedly raised the surface within reach of the growth of vegetation, and that the rhythmic sequence may all be explained by supposing that subsidence took place spasmodically.

Evidence of Cyclic Sedimentation in Marmaton Rocks

The presence of four large cyclic units in the Marmaton group is obvious. There are four limestone formations, each underlain and overlain by clastic formations which consist principally of clay and sandy shale but contain a relatively large amount of sandstone, a part of which fills definite channels whose walls are of clay shale and limestone. A more or less persistent deposit of "underclay" and coal lies above each limestone formation. Thus it seems that the Fort Scott limestone, a part of the underlying Cherokee shale, and the lower part of the overlying Labette shale are a cyclic unit. The Pawnee limestone and a part of the overlying Bandera shale constitute another megacyclothem next above the upper part of the Labette shale. Still higher the Altamont limestone is underlain and overlain by clastic deposits, and especially the Bandera Quarry sandstone below the Altamont formation records the beginning of sedimentation after channeling took place. The fourth large cyclic deposit, near the top of the Marmaton group, consists of the upper part of the Nowata shale, the Lenapah limestone, and the overlying Memorial shale or at least the lower part of it. Thus it is convenient to speak of four megacyclothems: (1) the Fort Scott, (2) the Pawnee, (3) the Altamont, and (4) the Lenapah.

These four well-defined and relatively large cyclic units in the Marmaton rocks are called megacyclothems chiefly because the thinner shale units included within the limestone formations may be only partly marine and they certainly record an approach of the shore line. Each of the thinner shales contains in the middle part either black shale or black shale, coal, and underclay. Thus

each of the thinner shale units contains a phase that marks the end or beginning of a cycle.

Typical cyclothems in the Wabaunsee group (Moore, 1936, p. 23, fig. 2) are similar to those in the Marmaton group, and it is reasonable to suppose that the Wabaunsee rocks when they were exposed farther east, before erosional beveling had placed their outcrops in the present geographic position, may have contained more phases of nonmarine shale, for example in "phases .4 and .6." At their present outcrops these phases of Wabaunsee cycles bear a molluscoid fauna and are regarded as phases of cyclothems, as are their homologies in outcropping Marmaton rocks.

The four limestone formations of the Marmaton group generally contain four or more distinct cyclothems that represent marine invasions. The shale formations include several cyclothems which seem to be dominantly nonmarine, but minor and somewhat local marine invasions are recorded in some of the cyclothems included in the shale formations. Each of the larger cyclic units (roughly the four limestone formations) presents evidence of three, four, or more distinct marine invasions of a large area. Thus the Marmaton rocks in their Kansas outcrop belt contain at least 15 well-developed cyclothems and several poorly developed ones. The latter are included in the shale formations.

In spite of the voluminous literature dealing with sedimentation and interpretation of fossil sediments, little can be said with exactness concerning the conditions under which sedimentary rocks were formed. In some cases, perhaps in many, marine and nonmarine sediments cannot certainly be distinguished. Nevertheless in studies of this kind it is well to call attention to the significance of various rock types. There are some deductions that seem to be sound. Because of their repeated occurrence as cyclic phases, the probable origin of several rock types is briefly discussed here.

In discussing the sequence of major events during a typical megacycle of Pennsylvanian rocks, Wanless and Shepard (1936, p. 1202) denied that the sandstone that fills channels is material derived locally because the sandstones are composed largely of micaceous sands and the walls of the channels are of clay shale and limestone. However, in eastern Kansas and in western Missouri only locally have the channels been cut into limestone and in eastern Missouri, where the channels more commonly are cut

into limestone beds, the basal parts of the channels are frequently filled with locally derived limestone fragments. It is likewise true that in these rocks the occurrence of sandstone as channel fillings is the exception rather than the rule and that great quantities of micaceous sandstone grade laterally into clayey shale. Locally channels were cut into sandy shale and sandstone. Because of the absence of sufficiently large areas of near-by quartzose rock that were exposed in Late Desmoinesian time and because of the fineness and the degree of sorting of the quartz grains, it is evident that the primary source of the micaceous quartz sandstone was not near by. Igneous rock mineral species other than mica and quartz are practically absent from these Marmaton sandstones. At least some of the mica may be of secondary origin, although there may be little basis for that assumption. The primary source of the quartz sand, like the clay in the shale beds, must have been a distant terrain.

Sandstone is abundant in the Pennsylvanian section farther south and east, and sandy sediments including sandstone form a part of the conformable sequence of these rocks throughout the Mid-Continent region. It is reasonable to believe that the sandstone that now fills the channels is reworked material from near-by sources.

The channels themselves require explanation. The large and deep channel that contains the Warrensburg channel sandstone in Missouri seems to extend northward off the Ozark dome. At the present time little can be definitely said about the direction or pattern of other channels, although it is probable that several radiate from the Ozark region. This is suggested by the facts that several channels are deeper in places near the Ozarks and that the basal part of the fillings there are limestone conglomerates. It is suggested here that the channels were probably cut by water draining from or across slightly uplifted or tilted areas. It is postulated that large areas were essentially flat and were near sea level immediately before channeling. Sand and silt ranked high in quantitive importance in sediments that were accumulating. Either because of differential subsidence or subsidence and uplift, comparatively small areas were placed in such a position that surface water drained across them with sufficient velocity to cut channels a few feet deep in the soft sediments. Abrupt lateral changes in thickness of shales suggest local intraformational move-

ments. While cutting the channels the flowing water carried sand, silt, and clay beyond the channels into more depressed areas where it was deposited in conformable beds. Later the channels were filled with sand and silt while clay was probably being carried farther from the source. After the channels were filled, sandy deposits were spread with apparent conformity on the slightly older clays and sands in which the channels had been cut.

Bass (1936) has presented convincing evidence that Cherokee shoestring sand bodies in Greenwood and Butler counties, Kansas, were formed as offshore bars in a shallow sea. It is entirely probable that some of the Marmaton sandstone lenses had a similar origin. However observations show that at least some of them fill definite channels cut in beds of shale and limestone.

Cross-bedding in Marmaton sandstones in eastern Kansas is comparatively rare. Both the sandstones that occur in more or less lens-like masses, which are seemingly conformable with clay shale, and those that fill definite channels are thin bedded. Ripple marks are plentiful. Fossils are almost nonexistent except for remains of land plants which occur locally. One exception is the local occurrence of myriads of fossil annelids in the Bandera Quarry sandstone at a place where it seems to fill a channel. The presence of land-plant remains indicates that now and then deposition built up near-by terrains to within the reach of the growth of vegetation, but the plant remains, consisting mostly of stem fragments, are not now in the places in which they grew. Fossil fern leaves, found abundantly in some other Pennsylvanian sandstones, are rare in Marmaton rocks.

In summary it is pointed out that Marmaton sandstones occur in large lenses but that the lower part of the masses locally occupy channels and that the lower parts of the channels locally are filled with limestone breccia or conglomerate. The sand is fine, indicating that it was carried a great distance from its primary source or that it has been shifted by waves for a long time. In the channels, and locally elsewhere, the sand is remarkably free from clay, which indicates that here and there are deposits of reworked quartz grains and mica flakes. In general, the primary structure of the sand deposits indicates deposition under quiet conditions.

Thick beds of gray shale in the Marmaton group generally are more or less sandy, but locally they are almost entirely without

sand grains. These shales are seemingly nonfossiliferous. They grade vertically and laterally into sandy shales and, like the sandy shales, they are evenly and well bedded. However, the gray shale that occurs in thick beds as a part of the shale formations occurs in "blocky" beds which contrast with thinner bedded, fissile, or platy shale. Stringers and small lenses of limonite are common in these gray shales, and at the outcrops the rocks are locally yellow or yellowish-gray in color.

It is believed that the thicker gray shale beds were deposited at a position near sea level—probably generally slightly below sea level. They record events that took place near the beginning and end of the large cycles of deposition and are in part contemporaneous with sandy shales and sandstones. Locally this type of gray shale embraces other kinds of rock, such as thin-bedded fossiliferous gray shale, black platy or fissile shale, coal, and limestone, which seems to record local and short-time incursions of the sea or deepening of sea water between periods of greater elevation. These sequences within thick shale formations are local and incomplete cyclothems. In the Kansas outcrop belt of Marmaton rocks they are best developed in the Labette shale.

Thinner deposits, consisting of gray and commonly greenish-gray shale, thin-bedded or even fissile, and commonly bearing marine fossils, brachiopods, crinoid fragments, and locally corals, are distinguished from the more blocky gray shale that is predominant in the shale formations. These thinner shales commonly lie next below and above limestones. Shales of this kind, where separating limestones within the limestone formations, at least locally are themselves divided in their approximate middle parts by black shale or by black shale and coal. These calcareous fossiliferous thin-bedded shales seem to record transgressions and regressions of sea water, whose maximum stages of invasion were marked by limestone deposition. Although any of the cyclothem phases may be absent locally, they occur normally above black shale or black shale and coal and below limestone.

Much of the black shale in Kansas Marmaton rocks is platy rather than fissile. The bedding, which is always well pronounced at the outcrop, ranges from paper-thin to one-fourth inch or more. In underground workings or as seen in cores taken from wells, black shale of this kind displays little or no bedding and has the appearance of black massive rock. Bedding in these shales

probably is partly slaty cleavage which becomes apparent after weathering. The layman's term "slate" for this rock is probably not altogether inappropriate. Where coal is associated with black shale, the coal commonly underlies the carbonaceous shale. A few exceptions to this have been noted, but thin coal beds, coaly concretions, and shale that is nearly coal occurring in black shale evidently are detrital. Small phosphatic concretions which are roughly spherical and generally smooth commonly occur in black shale deposits. Linguloid and orbiculoid brachiopod shells, generally believed to have lived in brackish muddy waters, are more or less commonly present. It is believed that this type of black shale was formed through deposition of muds which were black partly because of underlying peat beds in their source area and partly because of shallowness of the water which produced stagnant conditions. In the cyclothem record, black shale indicates the former presence of shallow near-shore water, free from sand. The source areas were low and covered by vegetation.

Coals in Marmaton rocks commonly underlie black shales. In some places they are underlain by "underclays." One of the most persistent coal beds is the Mulberry coal which occupies a position near the base of the Bandera shale. The Mulberry coal is one of the thicker beds and whenever present it seems to be underlain by "underclay." This coal deposit is believed to be typical of Marmaton coal beds that were formed through accumulation of plant material at the place in which it grew. Evidence of such deposition includes the facts that the coal lies above an "underclay," is relatively free from ash, and is of widespread occurrence.

The presence of the Summit coal, which occupies a position in the Little Osage shale, indicates that the sea withdrew completely from a part of eastern Kansas during the closing stages of the Blackjack Creek cycle (lower cyclothem of the Fort Scott megacyclothem). This coal is underlain by gray shale which has some of the characteristics of an underclay. The coal is laterally persistent for many miles, and it is relatively free from ash. The Summit coal is believed not to have been of detrital origin. There are several similar coals in the Marmaton rocks, particularly a short distance above each limestone formation.

It is evident that limestone records the former presence of marine water relatively free from land-derived detrital material. No limestone beds in the Marmaton group in the northern Mid-

Continent region are recognized as fresh-water limestones. The several different types of limestone, however, present special problems of origin. In Marmaton time in eastern Kansas, calcareous sediments deposited in places relatively near the shore commonly developed thin slabby-bedded structures or developed into a massive layer of impure limestone with little or no bedding. Calcareous nodules not sufficiently plentiful to form continuous beds but enclosed in clay were formed in places where the accumulation of clay greatly exceeded the precipitation of lime.

Thin-bedded wavy-bedded limestone, common in the Pennsylvanian section in this part of the world, was developed in places which at the time were covered by clear sea water and probably were relatively far from shore. In late Desmoinesian time *Chaetetes* colonies flourished under similar conditions, seemingly crowding out most of the other bottom-dwelling invertebrates. Pseudobrecciated limestone commonly occurs in thin beds and is relatively free from land-derived detritus. The brecciated appearance is probably of secondary origin; its significance is not certainly known. Algal remains are plentiful in both impure and purer limestone in the Marmaton group. Fusulines occur in the thicker limestones and do not seem to be restricted within the thicker beds. Brachiopods range through black shales, gray shales, and limestones of varying degrees of purity, but mollusks are confined to what seems to be shallow water limestones and marine shales which commonly are nearly black.

The Fort Scott Megacyclothem

The Fort Scott limestone, including the underlying coal and clastic deposits and the overlying coal and clastic deposits, records a relatively large cycle of deposition, a megacyclothem. Smaller cycles within the larger one are detectable.

Several Kansas outcrops, for example the ones represented by sections 108 and 111 of plate 1, give the impression that the limestone bed in the upper part of the Cherokee shale lies in the lowermost cyclothem of the larger Fort Scott cycle. Observations in Craig and Rogers counties, Oklahoma, however, indicate that this limestone in Kansas, the Breezy Hill, may lie in the third or fourth cyclothem below the Fort Scott limestone. It is believed that cyclic deposits between that of the Breezy Hill limestone and the Blackjack Creek limestone are confined to a narrow zone in northeast-

ern Oklahoma and that in southeastern Kansas and at some places in eastern Oklahoma there is a hiatus in the upper part of the Cherokee shale. This is not conclusive, however; the problem is one of several similar ones that may be solved through detailed study of Cherokee cyclothems.

The Mulky coal, the "underclay" below it, and the overlying black shale, which locally contains giant black concretions, are believed to belong in a cyclothem with the overlying Blackjack Creek limestone rather than with the Breezy Hill limestone. The "underclay" and coal record nonmarine deposition. Advancement of the sea over peat beds seems to be recorded by the black shale; calcareous shale, next below the Blackjack Creek limstone, recorded slightly deeper and clearer waters. The Blackjack Creek limestone records the maximum sea invasion of the lowermost Fort Scott cycle. The basal part, massive impure limestone called the "Cement rock," is characteristic of the basal part of several thicker Marmaton limestones. It represents the beginning phase of limestone deposition in cyclothems containing relatively thick limestones. It is the kind of limestone that locally was succeeded by purer thin-bedded and commonly coralline limestone deposition. *Chaetetes* biostromes were deposited locally on the "Cement rock" substratum, while the clearing of the water promoted the deposition of purer calcium carbonate, commonly in thin and wavy beds. Locally a few inches of slabby impure limestone occurs as the uppermost part of the Blackjack Creek limestone. Faunal phases in the Blackjack Creek limestone are not very well defined, but the following succession with some vertical overlap can be detected: (1) mollusks and crinoids, (2) *Chaetetes* and brachiopods, and (3) brachiopods and fusulines.

Local calcareous shale breaks in the "Cement rock" part of the Blackjack Creek limestone are found in places that are believed to have been relatively near the shore line at the time of deposition. Higher in the section an homologous limestone, the basal part of the Tina limestone, grades laterally into sandstone and shale. Calcareous fossiliferous gray shale overlain by the Summit coal is the closing phase of the Blackjack Creek cyclothem.

Shale, commonly black and slaty but paradoxically calcareous and containing marine fossils locally in the lower part, followed by the Houx limestone records the second sea invasion of the Fort Scott megacyclothem. In parts of eastern Oklahoma and southeast-

ern Kansas the Houx limestone seems to be included in the Higginsville limestone as its lower part. In that area, which is believed to be a slightly deeper part of the depositional basin, the Houx and Higginsville cyclothems are not readily divisible.

The Higginsville cyclothem contains black shale, gray fossiliferous shale, and the overlying Higginsville limestone, which in turn is overlain by extensive black shale deposits and a relatively persistent coal bed. The Higginsville limestone displays faunal zones, more or less distinct and somewhat similar to those of the Blackjack Creek limestone. *Chaetetes,* however, was an important rock builder during the closing stages of this limestone phase, and algal remains are also plentiful in the upper part of the phase. It seems reasonable to believe that *Chaetetes* and algal deposits accumulated in shallow but clear waters. Molluscoid faunas, found in the earlier and later marine phases of several Pennsylvanian cyclothems, are associated with less pure limestone and with calcareous shale. These faunas indicate muddy waters.

The Pawnee Megacyclothem

Cyclothems in the Labette shale, the clastic formation that separates the Fort Scott and Pawnee limestones, are locally and poorly developed in Kansas. The scarcity of good exposures has prevented detailed study of these beds. Seemingly there are several poorly developed cyclothems above the Higginsville limestone in the Fort Scott megacycle. It is believed that a rather persistent unnamed coal bed in the lower-middle part of the Labette shale was deposited during the closing stages of the Fort Scott megacycle, and it is probable that a large part of the sandstone that collectively is called Englevale sandstone belongs in the upper part of the Fort Scott megacyclothem. Detailed study of cyclic deposits in such thick clastic deposits as the Labette shale will undoubtedly shed much light on Pennsylvanian paleogeography.

The Pawnee megacyclothem in Kansas contains four well-developed cyclothems. They are, in ascending order, (1) the Anna (lower ? Oologah) cyclothem, (2) the Myrick Station cyclothem, (3) the Mine Creek cyclothem, and (4) the Laberdie cyclothem. All contain at least black shale, gray shale, and limestone phases. Actually there are more cyclothems, but only these four are sufficiently developed in Kansas to warrant names. There are several partly developed cyclothems in the upper part of the Labette

shale; locally these are divisible into coal, black shale, and limestone phases (pl. 2, sec. 181).

A rather persistent coal bed a few inches below the thin limestone that in Kansas is classified as the basal part of the Anna shale is believed to belong with this limestone in the Anna cyclothem. This relationship is not conclusively established because it is possible that lower Pawnee cyclothems, represented at least in part in eastern Missouri and northeastern Oklahoma (pl. 2, secs. 181 and 193), are absent in eastern Kansas. It is clear, however, that the Anna cyclothem is well developed in northern Oklahoma and that there is one and perhaps two cyclothems between it and the overlying Myrick Station cyclic unit. Black shale and the Lexington coal bed in the Anna shale mark the beginning of the Myrick Station cyclothem. Coal in the Anna shale in Kansas is probably detrital; hence, it is not correlated exactly with the Lexington coal of Missouri. The Lexington coal is believed to occur in Oklahoma (pl. 2, sec 203) where it is underlain by shale having some of the characteristics of an underclay.

The Myrick Station cyclothem starts with black shale or coal and black shale, which is overlain by a bed of gray marine shale. The black shale phase is also at least in part marine. Locally it contains sparse orbiculoid and linguloid brachiopods. A prolonged and widespread invasion of clearer sea water is recorded by the Myrick Station limestone. Brown massive impure limestone, similar to the Fort Scott "Cement rock," was formed over a great area in the beginning. It is believed that this is the part of the Myrick Station limestone that extends into Iowa and Illinois. This basal limestone was succeeded by purer thinner bedded limestone deposits. *Chaetetes* colonies became established early during Myrick Station deposition, but were more plentiful during the later stages. Abrupt clearing of the water seemingly permitted *Chaetetes* to start colonies on mud bottoms. This condition is more or less uncommon. Noncoralline limestone commonly underlies *Chaetetes* biostromes.

In general the Myrick Station limestone is divisible into faunal and lithologic zones or phases. In ascending order they are: (1) massive earthy brownish-gray limestone with mixed molluscan, crinoid, and brachiopod faunas, (2) thinner bedded limestone with fusulines, brachiopods, and crinoid remains, or locally *Chaetetes* colonies, and (3) slabby impure limestone. In northern Oklahoma

and southern Kansas the Myrick Station limestone is overlain by gray marine shale or locally by black shale, or again locally there is no shale between it and the overlying Laberdie limestone. Obviously the sea did not withdraw from this area at the end of the cyclothem (pl. 2). In western Missouri and neighboring parts of Kansas the lower part of the Mine Creek shale may be in part nonmarine and certainly records near-shore conditions. Locally in western Missouri the lower part of the Pawnee limestone is well developed (pl. 2, secs. 181, 182, and 185). Elsewhere, for example in several exposures in Bates county, the Myrick Station limestone and the black shale and the thin limestone of the Anna shale seem to be completely absent. The lowermost Pawnee beds in those exposures are those in the upper part of the Mine Creek shale, which consist of calcareous fossiliferous shale and limestone nodules and are widespread over western Missouri and eastern Kansas.

The Mine Creek cyclothem is aberrant and somewhat local. In eastern Kansas it consists of the lower part of black or gray marine shale, then thin limestone and brachiopod coquinas that are overlain by black or gray shale beds (pl. 2).

The Laberdie cyclothem begins with black shale or with fossiliferous gray shale which is classified as the upper part of the Mine Creek shale. Phases in the Laberdie limestone are not readily differentiated. *Chaetetes* colonies were established locally almost at the beginning of limestone deposition. They became more numerous and larger as limestone deposition proceeded. Fusulines, brachiopods, and crinoid remains are, it seems, not confined to definite zones.

The sea withdrew from a large area including much of eastern Kansas and western Missouri soon after the end of Laberdie deposition. The persistence of the Mulberry coal bed and its "underclay" offers the strongest evidence for this statement. It is significant that the Mulberry coal has been identified in the subsurface in eastern Nebraska. Locally, however, the absence of the sea was of short duration, for in some places in eastern Kansas and neighboring parts of Missouri a thin limestone bed was deposited a few inches above the Mulberry coal. Thus it seems that the Mulberry cyclothem should be grouped with other cyclothems in the Pawnee megacyclothem. The end of the megacyclothem is

marked by erosion that preceded deposition of the channel sandstone of the Bandera Quarry sandstone.

The Altamont Megacyclothem

The Altamont megacyclothem is somewhat unique. Its chief characteristic is the great lateral persistency of carbonaceous shale containing phosphatic nodules that are unlike the small smooth nearly spherical nodules found in other dark shales in Marmaton rocks. These nodules are in the Lake Neosho shale. They are rough, irregular in form, and gray in color. They contain teeth and other remains of vertebrate animals. They may be coprolites.

The Altamont megacyclothem (pl. 3) begins with the Bandera Quarry sandstone, a part of which fills channels cut in clay shale of the lower part of the Bandera shale. Throughout a large area there is a maroon band in the upper part of the Bandera shales above the sandstone phase. Locally in Labette county, a thin coal bed that has characteristics of coal formed at the place in which the plant material grew occurs in the upper part of the Bandera shale. This coal is above the maroon zone and a few inches below the Altamont limestone. There is a coal bed in the same stratigraphic position in northern Missouri and southern Iowa (Cline, 1941, pp. 26, 27, fig. 2). It is believed that in Kansas a large amount of the clay and sandy shale in the upper part of the Bandera formation is nonmarine. The Altamont limestone comprises the dominantly calcareous part of the megacyclothem, which closes with coarse clastic deposits or with shale beds next below sandstone in the Nowata shale. Cyclothems that are locally detectable and compose the larger cycle, named in upward order, are: (1) the Lower Tina cyclothem, (2) the Middle Tina cyclothem, (3) the Upper Tina cyclothem, and (4) the Worland cyclothem. In most parts of the Altamont limestone outcrop area, the Tina limestone comprises the limestone phase of a single cyclothem. Cline (1941, p. 60) recognized the "Tina cyclothem" as far north as Adair county, Missouri. However, in accordance with the use of the term cyclothem adopted in this paper, locally three cyclothems can be detected in the lower part of the Altamont rocks.

The Lower Tina cyclothem begins with coal and other nonmarine rocks in the upper part of the Bandera shale. Locally the upper part of the Bandera shale is undoubtedly marine, showing that the sea was present in certain places before limestone deposi-

tion started (pl. 3, sec. 171). Limestone was deposited only locally during the Lower Tina cycle. This limestone is darkish-gray, mottled, and contains chonetid brachiopods including plentiful *Mesolobus*. It is easily distinguished from other parts of the Tina limestone. The closing stages of the cycle are represented by very thin beds of marine shale. The Lower Tina cyclothem has been seen in Bates county, Missouri, and in Neosho county, Kansas.

The Middle Tina cycle, like the Lower, is local in occurrence. The two can be seen in the same places. The Middle cyclothem, however, contains the thickest bed of limestone in the Tina deposits. The opening phase of this cycle is not divided from the closing phase of the underlying cycle, but marine shale is followed by fusuline-bearing limestone. This limestone is overlain by limestone containing a mixed molluscan and bryozoan fauna. This is followed by less pure limestone bearing brachiopods and crinoids. The cycle ends and the next higher one begins with thin beds of marine shale.

The limestone phase of the Upper Tina cyclothem is extremely widespread. This is believed to be the part of the Tina limestone that persists, with only a few local areas of nondeposition, from northeastern Oklahoma to northern Missouri. Throughout most of the outcrop area it shows evidence of having been deposited in very shallow water. It is sandy and locally grades into siltstone and sandstone. In many Kansas outcrops it is brecciated and cross-bedded as though loose limy pellets and animal remains were shifted by waves or currents before being cemented into a compact bed. This facies commonly bears a gastropod fauna mixed with algal remains, or in some places it is a mass of ostracodes, brachiopods, and algae. Attention is called to the analogy of this persistent limestone to "super" limestone of the Shawnee (Virgilian) cyclic deposits (Moore, 1936, p. 27) and to the "battlefield-beds" of Mesozoic cycles (Arkell, 1933, p. 57). Frebold (1927, p. 240) believed that each bed of this kind represents a shallowing of the sea and a prolonged pause.

Chaetetes were important rock builders throughout most of the time of Tina deposition. In southern Kansas, immediately south of the area in which Tina cycles can best be differentiated, most of the Tina section is composed of *Chaetetes* masses. The colonies seem to have gained a footing soon after the beginning of deposition of the limestone phase of the Lower Tina cyclothem,

and the corals continued to flourish in areas that were protected from incoming clays during the waning and waxing of Tina cycles. Thus aided by accumulations of calcareous algae they continued to build up limestone masses until covered by muds that now form the Lake Neosho shale.

Black shale containing coprolites (?), underlain and overlain by gray shale, marks the transition from the Upper Tina cyclothem into the Worland cycle. The zone of phosphatic nodules extends far to the north and, as can be detected from Cline's sections (1941 pp. 33, 40, and 52), it actually belongs to the Worland cycle rather than to the Tina cycle. In northern Missouri Cline found a widespread coal smut between the Tina limestone and the zone of phosphatic nodules.

The Worland limestone in Kansas is not readily divisible into phases. Fusulines and brachiopods are dispersed throughout its thickness. *Chaetetes* colonies to my knowledge do not occur in the Worland limestone in Kansas, but they are plentiful in this rock in Missouri (Cline, 1941, p. 43), where Cline found cyclic phases to be more easily differentiated.

The Altamont megacyclothem closes with clastic deposits in the lower part of the Nowata shale. As already explained, it is probable that in eastern Kansas there is a hiatus above the Altamont limestone and that dark shale, for convenience classed in the Nowata formation, actually represents early phases of the Lenapah cycle. Coal is not known to occur in the lower part of the Nowata shale in Kansas but Cline found coal underlain by underclay in this part of the stratigraphic section rather generally in Missouri (Cline, 1941, pp. 26-27, fig. 2).

The Lenapah Megacyclothem

Although the Lenapah limestone is inconspicuous throughout its line of outcrop north of Labette county, Kansas, and it was only recently known to extend across the state into Missouri, its cyclic elements can be identified along a line extending many miles. The Lenapah formation, like the older Marmaton limestone formations, contains the more calcareous part of a megacyclothem. In the southern part of the Kansas outcrop area it is separated here and there from the Altamont limestone by a thick clastic deposit, much of which is sandstone (pl. 4, sec. 178); part of the sandstone probably occurs as channel fillings. Abrupt changes in thickness of the

clastic deposits between the two limestones suggest that there was erosion of Nowata shale beds before the advent of the Lenapah cycle, that there was considerable differential subsidence prior to Lenapah deposition, or both (pl. 4). The megacycle began with deposition of clastic material, much of which is sandstone. It passes into a more calcareous phase, then into one of clastic deposition, and the cycle closes with erosion that marked the end of Desmoinesian time. Like other Marmaton limestones, the Lenapah is overlain closely by "underclay" and coal (pl. 4, secs. 135 and 156).

The Lenapah formation, when studied in detail, shows evidence of cyclic deposition within the formation and hence, with underlying and overlying beds, it is regarded as composing a megacyclothem. The included cyclothems, named in ascending order, are: (1) the Norfleet cyclothem, (2) the Perry Farm cyclothem, and (3) the Idenbro cyclothem. All of the cyclothems are more or less aberrant and the phases are of rather local occurrence. The cyclothems are not readily detectable in northern Oklahoma. The Norfleet cyclothem begins with sandstone and shale, overlain by black shale. Locally gray shale overlies black shale and underlies the Norfleet limestone. The Norfleet limestone, which has several facies varying from massive brachiopod-bearing dark-brown limestone through slabby limestone containing land-plant fossils into alternating beds of impure limestone and shale, records a variety of conditions, differing probably in part because of configuration of the shore line which must have been near the locations of some of the present outcrops. Gray and black shale overlying the Norfleet limestone records the closing stages of the cycle.

The Perry Farm cyclothem is similar to the Mine Creek cyclothem in the Pawnee megacycle. Its middle phase is poorly developed, being represented by thin limestone beds, by limestone nodules, and by shale with many marine fossils. Its opening and closing stages are locally represented by black and gray shale, but commonly one or more phases are absent from any one outcrop.

The Idenbro cyclothem records the most prolonged period of deepened water in the megacycle, and the Idenbro limestone is the member of the Lenapah formation that extends far to the northeast. The cycle began with the deposition of black shale which is overlain by calcareous fossiliferous shale. This in turn is overlain by the Idenbro limestone, whose base is generally transitional

from the shale below. Throughout large areas in southeastern Kansas and in neighboring parts of Oklahoma, the Idenbro limestone shows evidence of having been formed in clear water, although locally the basal part is argillaceous and the whole limestone is more siliceous than are the other Marmaton limestones. The argillaceous limestone phase is overlain by thin wavy-bedded purer limestone. Cup corals and brachiopods are dispersed throughout the thickness of the rock, but algal remains are confined largely to the upper and lower parts.

In northern Oklahoma limestone deposition continued from the Norfleet cycle to about the close of the Perry Farm cycle (pl. 4, secs. 199 and 200). In eastern Missouri all Lenapah cyclothems are detectable but the limestone phases are very thin (pl. 4, secs. 180 and 181a).

The closing phases of the Idenbro cyclothem are not well recorded. A succession of "underclay," coal, and black shale occurring next above the Idenbro limestone (pl. 4, sec. 156) probably belongs in the Idenbro cyclothem. Cyclic deposits higher in the Memorial shale have not been detected. It is probable that in eastern Kansas the Idenbro cycle was the last in Desmoinesian time.

DETAILED STRATIGRAPHIC SECTIONS

The following stratigraphic sections of Marmaton rocks are arranged in consecutive land sections and ranges in each township in Linn county (stratigraphic sections 1-31), Bourbon county (stratigraphic sections 32-101), Crawford county (stratigraphic sections 102-121), Neosho county (stratigraphic sections 122-132), Labette county (stratigraphic sections 133-177), Montgomery county (stratigraphic sections 178 and 179), Missouri (stratigraphic sections 180-185), and Oklahoma (stratigraphic sections 186-203). Measured thicknesses are given in feet.

Stratigraphic Sections in Linn County, Kansas (1-31)

(1) SW cor. sec. 3, T. 20 S., R. 25 E.

Bourbon shale
Hepler sandstone
Sandstone, brown, fine-grained **2.0-3.0**
Unconformity

Marmaton group
  Memorial shale (25.6 feet)
    Shale, yellow, and clay, blocky 4.0
    Shale, gray and yellow, more or less blocky; limestone nodules in lower part 21.6
  Lenapah limestone
    Idenbro limestone member
      Limestone and sandstone, sandy limestone, locally sandstone; large productids ..... 1.1±
  Nowata shale
    Shale, gray and yellow, and clay ..... exposed 10.8

(2) NW¼ SE¼ sec. 8, T. 20 S., R. 25 E.

Bandera shale (10± feet exposed)
    Sandstone or sandy shale, gray and brown, hard ..... exposed 4.0
    Shale, contains large limy nodules 4.0
    Coal (Mulberry) ..... 2.0±

(3) Near cen. E line sec. 9, T. 20 S., R. 25 E.

Bourbon shale
  Hepler sandstone
    Sandstone, brown ..... exposed 2.0

Unconformity

Marmaton group
  Memorial shale
    Shale, gray and yellow, blocky; contains sparse limonite concretions and vein fillings in lower part 32.4
  Lenapah limestone
    Idenbro limestone member
      Limestone, gray, sandy; contains large productids, *Mesolobus* sp., and other brachiopods 0.6
  Nowata shale (7± feet exposed)
    Shale, gray, sandy, fossiliferous ..... 3.0±
    Shale, gray, blocky ..... exposed 4.0

(4) SW¼ sec. 19, T. 21 S., R. 24 E.

Bourbon shale
  Hepler sandstone
    Sandstone, mostly covered; about 16 feet exposed in quarry a short distance southwest 10.0

Unconformity

Marmaton group
  Lenapah limestone (4.5± feet)
    Idenbro limestone member?
      Limestone, brown, sandy; contains large productids, orbiculoids, and *Schizopora* sp. 1.5

Perry Farm shale member?
Shale and thin limestone beds ..... 3.0±
Nowata shale
Covered ..... 10.0±
Altamont limestone
Worland limestone member
Limestone, light to medium gray, massive, uneven top, a slight thickness exposed in drainage

(5) NW cor. sec. 33, T. 21 S., R. 24 E.

Altamont limestone (8.5 feet)
Worland limestone member
Limestone, gray with splotches of brown iron oxide, lower part slightly darker dove gray; in two beds of equal thickness, locally a thin shale bed between limestones; upper surface uneven; abundant fragments of brachiopods and other fossils 4.0
Lake Neosho shale member
Shale, gray, with thin limestone layers in upper part; contains phosphatic concretions 1.3
Tina limestone member (3.2 feet)
Limestone, gray, hard, nodular; contains crinoid stems; grades into unit below 0.4
Shale and shaly limestone 0.8
Limestone, nodular, and sandstone, fine and micaceous 2.0
Bandera shale
Shale ..... exposed 4.0±

(6) Near cen. sec. 5, T. 21 S., R. 25 E. Section in bank of Marais des Cygnes river and above

Bronson group
Hertha limestone
Critzer limestone member
Limestone, brown, massive; contains *"Osagia"* and many cephalopods ..... 10.0 ±
Bourbon shale
Covered, wooded, grass slope ..... 85.0 ±
Shale, yellow and gray, carbonaceous, weathered ..... exposed 0.66
Coal ..... 0.25±
Shale, yellow and gray, weathered; contains abundant small limestone nodules 5.0
Hepler sandstone (11± feet)
Sandstone, gray and yellow, very calcareous; contains sticklike and plumose casts of "seaweeds" 1.0
Sandstone and sandy shale, gray and yellow ..... 2.0 ±
Sandstone, gray and yellow, fine-grained, ripple marked ..... 1.0 ±

Sandstone or siltstone, massive to thin-bedded, shaly in places, cuts down into post-hole like depressions 2 to 3 feet deep; definite lower contact 7.0

Unconformity

Marmaton group
Memorial shale (10.25 feet exposed)
Shale, dark to medium gray; contains limonitic stringers and nodules 6.75
Shale, medium gray with maroon bands, irregular 3.5
Lenapah limestone (5.67 feet)
Idenbro limestone member
Limestone, chiefly as nodules in shale (previous to present position of bank a hard nodular bed 0.5 to 1 foot thick was exposed), dark gray to bluish-gray, impure, very earthy, nodules are oxidized into hematite to depth of one-eighth inch; found only after digging 0.55
Perry Farm shale member (4.9 feet)
Shale, very dark gray to black, not hard and platy as unit below, weathers into flakes, blocky when fresh, very smooth to touch 4.15
Shale, black, thin-bedded, platy; contains small phosphatic concretions; vertical joints filled with impure limonite strands in vertical cliff in river bank 0.75
Norfleet limestone member
Limestone, local occurrence, pinches out into shale, dark gray to very black, weathers brownish gray; contains scattered minute calcite crystals, sparse vugs of calcite, few fossil fragments; sharp lower contact 0.22
Nowata shale
Shale, dark bluish-gray, upper part weathers into flakes, flecked with iron oxide, seems to be iron-stained when comparatively freshly exposed ..... exposed 4.33
Covered to water of Marais des Cygnes river 0.75

Note: Worland limestone is exposed in river bed at low water stage a short distance south of this exposure, and is only a few feet below lowest beds exposed in this section.

(7) Near cen. sec. 16, T. 21 S., R. 25 E.

Lenapah limestone
Idenbro limestone member
Limestone, blue, dense ..... 3.0±
Nowata shale
Covered 10-15.0
Altamont limestone (15.2 feet)
Worland limestone member (11 feet)
Limestone ..... 3.0±
Covered interval ..... 5.0±

Limestone, bluish-gray, dense, hard, irregular bedding 3.0
Lake Neosho shale member
Shale, gray, not well exposed; contains phosphatic concretions 2.2
Tina limestone member
Limestone, brown and gray, brown nodules stand out on weathered faces, granular, cross-bedded; contains algal remains, gastropods, many invertebrate fragments, and shark teeth 2.0
Bandera shale
Clay shale and sandstone, fine, beds dip about 30°, lenticular mass of sandstone in lower part ..... 20.0±

(8) Near cen. sec. 19, T. 21 S., R. 25 E.

Bourbon shale
Hepler sandstone
Sandstone, gray and brown, fine-grained ..... 20.0±
Unconformity
Marmaton group
Nowata shale (21.5 feet)
Shale, gray, and clay, limonitic 11.5
Covered interval; seems to contain some sandstone or sandy shale ..... 10.0±
Altamont limestone (12 feet exposed)
Worland limestone member
Limestone, bluish-gray, dense, flaggy, locally becomes sandy; contains *Derbyia* sp. 2.0
Covered interval 8.0
Limestone, light bluish-gray, massive ..... exposed 2.0±

(9) SW cor. sec. 19, T. 21 S., R. 25 E.

Bourbon shale
Sandstone, poorly exposed, well-exposed in asphalt rock mine a short distance southwest .....
Unconformity
Covered interval ..... 8.0±
Marmaton group
Lenapah limestone (4.5 feet exposed)
Idenbro limestone member
Limestone, very sandy; contains large productids, *Orbiculoidea* sp., and *Schizopora* sp. 1.5
Perry Farm shale member
Limestone, shaly, thin-bedded ..... 3.0±
Covered interval ..... 10.0±
Altamont limestone
Worland limestone member
Limestone, gray, uneven top of ledge exposed

(10) Near cen. S line sec. 26 and near cen. N line sec. 35, T. 21 S., R. 25 E.

Altamont limestone (5 feet exposed)
- Worland limestone member
  - Limestone, light gray, dense, nodular in upper part ..... 2.0±
- Lake Neosho shale member
  - Shale, mostly covered; contains phosphatic concretions ..... 2.0±
- Tina limestone member
  - Sandstone, gray, limy, micaceous, massive, shaly in lower part 1.0

Bandera shale (42.4 feet)
- Sandstone or sandy shale, gray, micaceous 5.0
- Shale, gray, calcareous, limonitic 3.0
- Sandstone, gray, micaceous 2.0
- Shale, gray and yellow, limonitic, especially in upper part; one thin sandstone bed 3 feet from top; contains large septarian concretions in lower part, which is more blocky than upper part. Mulberry coal about 2 feet from base 32.4

Pawnee limestone (32.8-34.3 feet)
- Laberdie limestone member (11 feet)
  - Limestone, light gray, crystalline, thin-bedded; formerly exposed in quarry south of road, later covered by mine workings ..... 8.0±
  - Limestone, blue-gray to light gray; contains sparse fossils 2.5
  - Limestone and calcareous shale, gray; contains abundant fossils 0.5
- Mine Creek shale member (14.5-16 feet)
  - Shale, gray 2.0-3.0
  - Limestone, gray; contains abundant brachiopods 0.5-1.0
  - Shale, greenish-gray, slightly carbonaceous in lower part; contains limonitic zones and concretions ..... 12.0±
- Myrick Station limestone member
  - Limestone, brown, massive 3.8
- Anna shale member (3.5 feet exposed)
  - Shale, gray 0.5
  - Shale, black, platy 1.0
  - Limestone, dark, crystalline, slabby 0.2
  - Shale, gray 0.5
  - Coal ..... 0.3±
  - Shale, gray ..... exposed 1.0±

(11) Near SW cor. sec. 29, T. 21 S., R. 25 E.

Covered interval, with Bourbon beds exposed above

Altamont limestone (4.5 feet)
- Worland limestone member
  - Limestone, light gray, hard, massive 3.0
- Lake Neosho shale member
  - Shale, gray 0.8
- Tina limestone member
  - Limestone, dark gray, cross-bedded 0.7

Bandera shale
Shale, gray, limonitic especially in lower part, somewhat sandy about 8 feet from top ..... exposed 21.6

(12) Cen. S line sec. 34, T. 21 S., R. 25 E.

Bourbon shale
Hepler sandstone
Sandstone and sandy shale 6.0
Unconformity
Marmaton group
Lenapah limestone (11.3 feet)
Idenbro limestone member
Limestone, gray, crystalline; contains limonitic inclusions and *Composita* ..... 1.0±
Perry Farm shale member
Shale, mostly covered 9.8
Norfleet limestone member
Limestone, dark gray, crystalline, nodular; contains few limonitic inclusions 0.5
Nowata shale
Shale, partly covered, dark gray 5.0
Altamont limestone
Worland limestone member

(13) Near cen. W line sec. 5, T. 22 S., R. 24 E.

Bandera shale (4 feet)
Coal (Mulberry) ..... 1.0±
Shale, weathered ..... 3.0±
Pawnee limestone
Laberdie limestone member
Limestone, brownish-gray, earthy; contains sparse flint nodules ..... exposed 0.5±

(14) Near cen. sec. 7, T. 22 S., R. 24 E.

Altamont limestone (12.1 feet)
Worland limestone member (8.9 feet)
Limestone, bluish-gray, soft, sandy appearing 1.5
Shale and limestone, thin-bedded; limy shale alternates with limestone; fossiliferous 2.3
Shale, limy, and small lenses of powdery limestone 2.1
Limestone, gray, hard, dense to slightly crystalline 3.0
Lake Neosho shale member
Shale, gray 1.2
Tina limestone member
Limestone, dark gray 2.0

Bandera shale
Shale, gray 0.3
Sandstone

Note: Worland limestone and lower beds were exposed when excavations were made for a dam; higher beds are exposed a short distance northeast of the dam.

(15) NE¼ sec. 8, T. 22 S., R. 24 E. Coal mine

Altamont limestone
Bandera shale (44.5 feet)
Shale, clayey, somewhat sandy, limonitic; contains plant fossils ..... 43.0±
Coal (Mulberry) 1.5

(16) Near cen. S line NE¼ sec. 8, T. 22 S., R. 24 E.

Bourbon shale
Hepler sandstone
Sandstone, brown, ferruginous ..... 3.0±
Unconformity
Marmaton group
Memorial shale
Covered interval ..... 4.0±
Lenapah limestone
Idenbro limestone member
Limestone, brown, sandy appearing, abundantly fossiliferous; contains pelecypods and *Mesolobus* and other brachiopods 3.7
Nowata shale
Shale, yellow and gray 10.0
Covered 14.3
Altamont limestone (6.5 feet exposed)
Worland limestone member
Limestone, light gray, dense ..... exposed 2.0±
Lake Neosho shale member
Shale, mostly covered ..... 2.0±
Tina limestone member
Limestone, brownish-gray, granular ..... 2.5±
Bandera shale
Shale, gray and yellow ..... exposed 9.0

(17) NE cor. sec. 8, T. 22 S., R. 24 E.

Altamont limestone (5.2 feet)
Worland limestone member
Limestone, dove-gray, hard, brittle, sparsely fossiliferous 1.7
Lake Neosho shale member
Shale, gray; contains many phosphatic concretions ..... 2.0±

Tina limestone member
Limestone, brownish-gray, granular 1.5
Bandera shale
Shale, gray and yellow ..... exposed 3.0±

(18) NW cor. sec. 8, T. 22 S., R. 24 E.

Bourbon shale
Hepler sandstone
Sandstone, brown and gray, fine-grained, micaceous 5.0
Unconformity
Marmaton group
Lenapah limestone
Idenbro limestone member
Limestone, brownish-gray, crystalline, hard, fossiliferous ..... 1.5±
Nowata shale
Covered interval, may include part of Worland limestone 22.0
Altamont limestone
Worland limestone member
Limestone, light gray, shaly and sandy ..... exposed 1.0±

(19) Near cen. N line, sec. 3, T. 22 S., R. 25 E.

Bourbon shale
Sandstone, brown and gray, massive 3.0
Shale, sandy, and sandstone, mostly covered 22.0
Hepler sandstone (?) (21.6 feet)
Sandstone, deeply weathered, not well exposed 10.8
Covered interval 5.4
Shale and sandstone, more sandy in upper part 5.4
Unconformity
Marmaton group
Nowata shale (?)
Shale, gray and yellow, blocky, limonitic in lower part 10.8
Altamont limestone (10.9 feet)
Worland limestone member (7 feet)
Limestone, dark gray, carbonaceous, crystalline 0.5
Shale, gray, limy 3.4
Limestone, medium gray, dense, hard 3.1
Lake Neosho shale member
Shale, covered 1.7
Tina limestone member
Limestone, dove-gray, hard, crystalline, nodular in lower part 2.2
Bandera shale (33.4 feet exposed)
Shale, yellow and gray 2.0
Sandstone, gray 1.0
Shale, dark gray in upper part, lighter gray in lower part 2.5
Shale, yellow; contains limestone concretions 5.4
Shale, partly sandy, not well exposed 22.5

(20) From near the SW cor. to cen. N side sec. 3, T. 22 S., R. 25 E.

Bourbon shale
  Hepler sandstone
    Sandstone ..... 3.0±

Unconformity

Marmaton group
  Memorial shale
    Shale, mostly covered ..... 10.0±
  Lenapah limestone
    Idenbro limestone member
      Limestone, bluish-gray, slabby, slightly asphaltic 0.7
  Nowata shale
    Shale, yellow; contains sparse limestone nodules ..... 7.0±
  Altamont limestone (8 feet)
    Worland limestone member
      Limestone, light bluish-gray, dense to slightly crystalline ..... 3.0±
    Lake Neosho shale
      Shale, covered ..... 3.0±
    Tina limestone member
      Limestone, brownish-gray, brecciated appearing 2.0
  Bandera shale (54.4 feet)
    Shale, sandy 6.0
    Shale, gray and yellow, blocky, limonitic 5.4
    Covered interval 43.0
  Pawnee limestone
    Laberdie limestone member
      Limestone, bluish-gray, earthy to crystalline ..... exposed 2.6

(21) SW¼ sec. 12, T. 23 S., R. 23 E.

Altamont limestone (10.6 feet)
  Worland limestone member
    Limestone, dove-gray with splotches of darker gray, rather dense, rather massive, brecciated appearing in middle and upper middle parts, crystal faces scarcely visible without magnification; contains sparse brachiopods; maximum thickness at the location is in quarry; natural exposures near by are thinner 5.1
  Lake Neosho shale member
    Shale; contains masses of *Chaetetes* in upper part and phosphatic concretions ..... 4.0±
  Tina limestone member
    Limestone, dark gray, weathers brown, nodular, weathering produces a pitted mass; contains sparse *Chaetetes* 1.5
  Bandera shale
    Shale, bluish-gray, limonitic, sandy and micaceous in lower part ..... exposed 10.0

(22) SW¼ sec. 4, T. 23 S., R. 24 E.

Bourbon shale
  Hepler sandstone
    Sandstone, gray and brown, fine-grained, micaceous ..... exposed 4.0
Unconformity
Marmaton group
  Lenapah limestone
    Idenbro limestone member
      Limestone, brown; contains abundant white crinoid fragments in brown matrix ..... 1.0±

(23) NE¼ sec. 7, T. 23 S., R. 24 E.

Lenapah limestone (4.9 feet)
  Idenbro limestone member
    Limestone, brown; fossil fragments weather white in brown matrix; contains crinoid remains and brachiopods 1.4
  Perry Farm shale member
    Shale, gray; contains limestone nodules ..... 3.0±
  Norfleet limestone member
    Limestone, brown, sandy appearing ..... 0.5±
Nowata shale
    Shale, gray, blocky ..... exposed 12.0

(24) NE¼ NE¼ sec. 12, T. 23 S., R. 24 E.

Altamont limestone (9 feet exposed)
  Worland limestone member
    Limestone, gray, dense, somewhat irregular bedding ..... exposed 3.0
  Lake Neosho shale member
    Shale, dark gray; contains phosphatic nodules 4.0
  Tina limestone member
    Limestone, brownish-gray; contains *Chaetetes* 2.0
Bandera shale (28.5 feet exposed)
    Shale, sandy 4.0
    Sandstone, thin-bedded 2.5
    Shale, gray and yellow, thin-bedded 7.0
    Shale, gray, blocky ..... exposed 15.0

(25) Near the SW cor. SE¼ SW¼ sec. 12, T. 23 S., R. 24 E.

Altamont limestone (4 feet exposed)
  Worland limestone member
    Limestone, light gray, hard, massive ..... exposed 2.0±
  Lake Neosho shale member
    Covered by slumping of the overlying limestone ..... 1.0±
  Tina limestone member
    Limestone nodules in shale, gray and yellow ..... 2.0±

Bandera shale
Shale, yellow and gray; contains flat limestone concretions in upper part ..... exposed 37.8
Note: Base of section is about 15 feet above the Pawnee limestone.

(26) Near cen. E. line sec. 13, T. 23 S., R. 24 E.

Pawnee limestone (5 feet)
Myrick Station limestone member
Limestone, brown, massive; overlain by deposits of loose flint and clay ..... 2.0±
Anna shale member (3 feet)
Shale, gray ..... 1.0±
Shale, black, fissile to platy ..... 2.0±
Bandera shale (23.5 feet exposed)
Shale, gray 13.0
Limestone, brown, sandy ..... 0.5±
Shale, gray ..... exposed 10.0

(27) SW¼ sec. 15, T. 23 S., R. 24 E.

Altamont limestone (5 feet exposed)
Worland limestone member
Limestone, light gray, dense, massive ..... exposed 2.0±
Lake Neosho shale member
Shale, not well exposed; contains abundant phosphatic nodules 2.0±
Tina limestone member
Limestone, gray and brown, brecciated, nodular ..... 1.0±
Bandera shale (21 feet exposed)
Shale, gray and yellow, limy; contains septarian concretions ..... 8.0±
Sandstone, gray and brown, massive 1.0
Shale, gray and yellow, somewhat sandy ..... exposed 12.0

(28) SW cor. sec. 6, T. 23 S., R. 25 E.

Pawnee limestone
Laberdie limestone member
Limestone, light gray, weathers somewhat lighter in color, thin wavy beds, somewhat more massive in lower part 6.0
Mine Creek shale member
Shale and thin beds of limestone, not well exposed, but cropping out with myriads of fossils below quarry in road ditch and east of Laberdie creek ..... exposed 6.0
Note: The Myrick Station member is partly exposed when water in Laberdie creek is low.

(29) SE cor. sec. 8, T. 23 S., R. 25 E.

Pawnee limestone (4 feet)
Myrick Station limestone member
Limestone, brown, massive ..... 3.0±

Anna shale member
Shale, black, platy 1.0
Labette shale (31 feet exposed)
Shale, gray and yellow, lower 5 feet not well exposed 9.8
Shale, gray, blocky 10.8
Limestone, sandy, micaceous 0.4
Shale, gray and yellow, blocky ..... exposed 10.0

(30) Slightly south of NE cor. SE¼ sec. 8, T. 23 S., R. 25 E.

Pawnee limestone (3.2 feet exposed)
Myrick Station limestone member
Limestone, brown, massive, slightly flinty ..... exposed 2.0±
Anna shale member
Shale, black, platy 1.2
Labette shale
Shale, gray ..... exposed 3.0±

(31) SW¼ sec. 11, T. 23 S., R. 25 E.

Pawnee limestone (15.1-16.1 feet exposed)
Laberdie limestone member
Limestone, gray, weathers lighter in color; thin irregular beds in upper part; lower part more massive 8.4
Mine Creek shale member (5.7 feet exposed)
Covered interval 1.0-2.0
Shale, very black, thin-bedded, flaky ..... 0.5±
Shale, light gray; contains abundant fossils, chiefly brachiopods 3.0±
Limestone, gray, weathers rusty brown, upper part slightly bluish, nodular and concretionary; contains algal remains and other fossils 0.7
Shale, dark gray, extremely flaky; contains abundant chonetids ..... exposed 1.5

Stratigraphic Sections in Bourbon County, Kansas (32-101)

(32) NE¼ SE¼ sec. 29, T. 23 S., R. 23 E.

Lenapah limestone (5.15 feet exposed)
Idenbro limestone member
Limestone, light gray, cross-bedded in upper part ..... exposed 1.5
Perry Farm shale member
Shale, gray, calcareous; contains limestone nodules 3.0
Norfleet limestone member
Limestone, medium to dark gray, massive 0.65
Nowata shale
Shale, gray ..... exposed 12.0

(33) Near SE cor. sec. 35, T. 23 S., R. 23 E.

Bronson group
  Hertha limestone
    Critzer limestone member
      Limestone (upper part may include part of Sniabar member), granular ..... 10.0±
Bourbon shale
      Covered 43.0
      Shale, gray, flaky, not well exposed 16.0
      Shale, mostly covered 10.8
      Shale, mostly covered, may include a thin limestone bed in middle part 16.0
  Hepler sandstone
      Sandstone, gray and brown, fine-grained, grades into sandy shale above 5.4

Unconformity

Marmaton group
  Memorial shale
      Shale, gray, flaky, partly covered 4.5-5.5
  Lenapah limestone
    Idenbro limestone member
      Limestone, gray and yellow, impure, nodular ..... 1.0±
  Nowata shale (14.8 feet)
      Shale, yellow and gray, thin-bedded 10.8
      Covered ..... 4.0±
  Altamont limestone
    Worland limestone member
      Limestone, light gray, dense, earthy, not well exposed 3.0

(34) Near NW cor. sec. 7, T. 23 S., R. 24 E.

Altamont limestone (8 feet exposed)
  Worland limestone member
    Limestone, light gray, dense ..... exposed 3.0±
  Lake Neosho shale member
    Shale, mostly gray; contains phosphatic concretions ..... 4.0±
  Tina limestone member
    Limestone, brown, nodular ..... 1.0±
Bandera shale (43 feet exposed)
    Shale and sandstone ..... 16.0±
    Shale, gray and yellow ..... 27.0±

(35) Near SW cor. sec. 19, T. 23 S., R. 24 E.

Altamont limestone (5-5.5 feet exposed)
  Worland limestone member
    Limestone, light gray, not well seen ..... exposed 3.0±

Lake Neosho shale member
Shale, mostly gray, not well exposed; contains phosphatic concretions ..... 2.0±
Tina limestone member
Limestone, gray and brown, nodular, pinches out laterally 0-0.5
Bandera shale (70.8 feet)
Shale, sandy ..... 1.0±
Sandstone, yellow and gray 0.8
Shale and sandstone, more sand in upper part 2.4
Shale; contains limonitic lenses and concretions 16.2
Shale, gray; contains limonitic concretions 16.2
Sandstone, cross-bedded, definite contact with shale below; contains plant fossils 2.3
Shale, yellow, limonitic and calcareous in upper part 5.7
Shale, yellow, limonitic, weathered 10.8
Covered interval ..... 10.0±
Coal (Mulberry) ..... 0.4±
Covered interval ..... 5.0±
Pawnee limestone
Laberdie limestone member
Limestone, in creek bed

(36) Near cen. W line sec. 30, T. 23 S., R. 24 E.

Altamont limestone (4 feet)
Worland limestone member
Limestone, light gray; contains crinoid remains and *Composita* sp. ..... 2.0±
Lake Neosho shale member
Shale, gray, flaky; contains phosphatic nodules in upper part ..... 2.0±
Bandera shale (16.2 exposed)
Shale, gray and yellow, sandy 5.4
Shale, gray and yellow, more sandy than unit above; contains layers of limonite ..... exposed 10.8

(37) Near cen. W line SW¼ sec. 29, T. 23 S., R. 24 E.

Pawnee limestone (11.2 feet exposed)
Laberdie limestone member
Limestone, light gray, thin-bedded, poorly exposed
Mine Creek shale member
Covered (may include parts of Laberdie and Myrick Station limestones) ..... 3.0±
Myrick Station limestone member
Limestone, brown and gray; contains flint in upper part; contains few fossils 4.0
Anna shale member (7.2 feet)
Shale, black to dark gray 0.6
Shale, black 2.8

Limestone, dark in upper part, remainder gray, granular, sandy appearing 1.5
Shale, gray 1.7
Limestone, bluish-gray, thin-bedded 0.6
Labette shale
Shale, mostly covered ..... exposed 2.0±
Note: Compare with sections 190 and 193, Nowata county, Oklahoma

(38) Near cen. W line sec. 31, T. 23 S., R. 24 E.

Pawnee limestone (5.9 feet exposed)
Laberdie limestone member
Limestone, dove gray, thin-bedded, brecciated appearing exposed 3.5
Mine Creek shale (2.4 feet)
Shale, upper part black, lower part gray, fissile; contains abundant fossil fragments ..... 1.1±
Limestone, bluish-gray, shaly, fossiliferous 0.6
Limestone, bluish-gray, earthy; contains *Mesolobus* sp. and *Neospirifer* sp. 0.7

(39) Near SE cor. sec. 8, T. 23 S., R. 25 E.

Pawnee limestone (4 feet exposed)
Myrick Station limestone member
Limestone, brown and gray, weathers brown ..... exposed 3.0±
Anna shale member
Shale, black, may be slight thickness of gray in upper part, platy 1.0
Labette shale (31 feet exposed)
Shale, gray, not well exposed in lower part 9.8
Shale, gray, blocky 10.8
Limestone, sandy, micaceous 0.4
Shale, gray, blocky ..... exposed 10.0

(40) NE cor. sec. 21, T. 23 S., R. 25 E.

Pawnee limestone (12.5 feet)
Myrick Station limestone member
Limestone, gray, weathers brown, massive 6.7
Anna shale member (5.8 feet)
Shale, gray 0.2
Shale, black, fissile; contains orbiculoids 0.9
Shale, gray 3.8
Limestone, dark gray, earthy, thin-bedded, slabby 0.9
Labette shale (32.8 feet)
Shale, gray 6.5
Sandstone, massive in upper part, shaly in lower part 1.3
Shale, gray, sandy, upper part less sandy and blocky 6.6
Shale and sandstone; sandstone micaceous, thin-bedded, and confined to middle part 5.4

Covered interval ..... 13.0±
Fort Scott limestone
Higginsville limestone member
Limestone, in drainage

(41) Near SE cor. sec. 26, T. 23 S., R. 25 E.

Labette shale (37.6 feet exposed)
Sandstone, fine-grained, massive 27.3
Shale, gray 6.0
Limestone, sandy 1.3
Shale, gray ..... exposed 3.0±

(42) Near cen. W line sec. 32, T. 23 S., R. 25 E.

Labette shale
Covered interval to near base of Pawnee limestone 54.0
Limestone, gray, weathers in part brown, shaly, sandy appearing 1.5
Shale, gray, thin-bedded 7.0
Shale, gray, not well exposed especially in lower part 10.8
Shale, blue, dense, concretionary ..... 0.4±
Shale, gray, beds thin to blocky ..... 5.0±
Limestone, shaly; contains *Mesolobus* sp. 0.7
Limestone; contains *Derbyia* sp. and *Composita* sp. 0.4
Coal 0.3
Shale, gray, carbonaceous especially in upper part 6.0
Sandstone, fine-grained, micaceous ..... 4.0±
Shale, gray, sandy in upper part ..... exposed 10.0±

(43) Near cen. E line sec. 1, T. 24 S., R. 23 E.

Altamont limestone
Worland limestone member
Limestone, weathered, not well exposed
Lake Neosho shale member
Shale, yellow and gray, flaky; contains phosphatic concretions .... 2.0±
Bandera shale (59.6 feet)
Shale, yellow and gray, limonitic, grades into Lake Neosho shale 4.0±
Covered interval 27.0
Sandstone, yellow, fine-grained, micaceous ..... 2.0±
Shale, not well exposed 26.6
Note: Base of section is not far above the Pawnee limestone.

(44) SW¼ NE¼ sec. 8, T. 24 S., R. 23 E.

Lenapah limestone
Idenbro limestone member
Limestone, gray, earthy ..... exposed 1.0±

(45) Slightly north of SW cor. sec. 34, T. 24 S., R. 23 E.

Altamont limestone (4 feet exposed)
  Worland limestone member
    Limestone, light gray, thin-bedded, weathered into flaky mass ..... exposed 3.0±
  Lake Neosho shale member (1 foot)
    Shale, gray 0.7
    Shale, dark gray; contains phosphatic concretions 0.3
Bandera shale
  Shale, yellow, blocky; contains limonitic concretions .... exposed 11.0

(46) SE¼ SE¼ sec. 4, T. 24 S., R. 24 E.

Labette shale
  Sandstone, weathered ..... exposed 6.0
  Covered interval 8.0
Fort Scott limestone
  Higginsville limestone member
    Limestone, gray, crystalline, not well exposed; contains large fusulines ..... exposed 6.0

(47) Near cen. sec. 30, T. 24 S., R. 24 E.

Bourbon shale
  Hepler sandstone
    Sandstone, shaly ..... exposed 6.0±

Unconformity

Marmaton group
  Lenapah limestone
    Idenbro limestone member
      Limestone, gray, crystalline, slabby 0.5
  Nowata shale
    Shale, gray, limonitic in upper and upper middle parts ..... 30.0±
  Altamont limestone
    Worland limestone member
      Limestone, light gray, dense ..... exposed 6.0±

(48) Slightly east of cen. S. line sec. 33, T. 24 S., R. 24 E.

Altamont limestone (5 feet exposed)
  Worland limestone member
    Limestone, light gray, somewhat slabby ..... exposed 2.0±
  Lake Neosho shale member
    Shale, mostly dark gray; contains phosphatic concretions ..... 2.0±
  Tina limestone member
    Limestone, brownish-gray, granular, nodular ..... 1.0±
Bandera shale (29 feet exposed)
  Shale, gray in upper part, purple to maroon in middle and lower parts ..... 16.0±

Covered interval	5.0
Covered interval with the upper surface of a sandstone at top	20.0±
Sandstone, gray and brown; contains pockets of coarser sand in finer matrix	7.0±
Sandstone and sandy shale, very fine-grained, well bedded	exposed 6.0

(49) Slightly south of cen. E. line sec. 2, T. 24 S., R. 25 E.

Marmaton group

Labette shale (47.6 feet)

Covered to near base of Pawnee limestone	12.0
Shale, mostly covered	5.5
Shale, gray and yellow	5.5
Sandstone and sandy shale, yellow and gray	5.5
Sandstone	0.3
Shale, sandy	2.3
Shale, sandy in part	5.5
Covered interval	5.5
Sandstone and shale, partly covered	5.5

Fort Scott limestone (27.5 feet)

Higginsville limestone member (10.8 feet)

Limestone, brown, dense to earthy, brittle	2.3
Limestone, mostly covered	5.5
Limestone, bluish-gray, irregular thin beds; contains brachiopods	3.0±

Little Osage shale member (12 feet)

Shale, gray, calcareous, not all well seen	3.0±
Limestone (Houx?), tan, dense to earthy	0.4
Shale, black	2.7
Shale, gray, calcareous, fossiliferous	2.6
Coal (Summit)	0.7
Shale, mostly covered	2.6

Blackjack Creek limestone member (4.7 feet)

Limestone, brown, weathers buff, massive	2.4
Shale, yellow and gray, calcareous	1.1
Limestone, tan, earthy	1.2

Cherokee shale

Shale, dark gray, nearly black	3.8
Coal (Mulky)	1.8
Underclay	0.9
Shale, not well seen	exposed 16.0

(50) Near cen. W line sec. 11, T. 24 S., R. 25 E.

Pawnee limestone

Laberdie limestone member (16 feet)

Limestone, gray, brecciated appearing, not well exposed	10.0±
Limestone, thinner beds than in unit above	6.0±

Myrick Station limestone member
Limestone, brown and gray, crystalline, massive 4.0
Anna shale member
Shale, black, platy ..... exposed 2.0±

(51) Near cen. N line sec. 23, T. 25 S., R. 22 E.

Bourbon shale
Sandstone and sandy shale ..... exposed 2.0±
Shale, gray and yellow; contains limonitic concretions 6.5
Limestone, very nodular or concretionary; contains rhombporids and *Composita* sp. ..... 2.0±
Shale, yellow and gray, slightly sandy 2.0
Hepler sandstone
Sandstone, weathered brown, massive ..... 4.0±

Unconformity

Marmaton group
Memorial shale
Shale, gray ..... 3.0±
Lenapah limestone member
Limestone, light bluish-gray, uneven upper surface; contains crinoids and mollusks ..... exposed 1.0

(52) SE¼ SE¼ sec. 24 and NE¼ NE¼ sec. 25, T. 25 S., R. 22 E.

Altamont limestone (17.7 feet)
Worland limestone member (11 feet)
Limestone, light gray, thin-bedded, nodular 2.0
Limestone and shale; shale cavities domelike, 6 feet in diameter and 1.75 feet high, filled with fusuline-bearing gray shale; limestone gray and thin-bedded 2.0
Limestone, gray and brown, dense, crystalline, nodular 7.0
Lake Neosho shale member
Shale, chiefly gray, black in middle part; contains phosphatic nodules ..... 1.0±
Tina limestone member (5.7 feet)
Limestone, algal 2.5
Shale, yellow 0.2
Limestone, brown and gray, nodular, rough-weathering; top irregular 3.0
Bandera shale
Sandstone and shale, micaceous ..... exposed 5.0

(53) NW¼ sec. 26, T. 25 S., R. 22 E.

Lenapah limestone (6.35 feet exposed)
Idenbro limestone member (2.35 feet exposed)
Limestone, brownish-gray, crinoidal ..... exposed 0.25

Limestone, brownish-blue, granular, well bedded, crinoidal; contains echinoid remains 2.1
Perry Farm shale member (?)
Shale, gray; contains *Chonetes* sp. ..... exposed 4.0

(54) S½ SE¼ sec. 26, T. 25 S., R. 22 E.

Bourbon shale
Hepler sandstone
Sandstone, brown, massive ..... exposed 2.0
Unconformity
Marmaton group
Memorial shale (7 feet)
Shale, gray, sandy ..... 4.0±
Shale, gray 3.0
Lenapah limestone
Idenbro limestone member
Limestone, light gray, finely crystalline, crinoidal ..... exposed 2.0
Covered interval ..... 6.0±
Altamont limestone (8.5 feet exposed)
Worland limestone member
Limestone, gray, dense, semilithographic in upper part; contains brachiopods and crinoid fragments in lower part 7.5
Lake Neosho shale member
Shale, chiefly gray; contains phosphatic nodules ..... exposed 1.5

(55) Near cen. S line sec. 36, T. 25 S., R. 22 E.

Lenapah limestone
Idenbro limestone member
Limestone, brownish-blue, crinoidal ..... exposed 1.0±
Nowata shale
Covered interval ..... 3.0±
Altamont limestone (10.75 feet exposed)
Worland limestone member (10.25 feet)
Limestone, gray, dense ..... 3.0±
Limestone, not well exposed 2.75
Limestone, gray, dense; contains crinoid remains and brachiopods 4.5
Lake Neosho shale member
Shale, drab in upper part, mostly greenish-gray; contains phosphatic nodules ..... exposed 0.5

(56) Near cen. S line SE¼ SW¼ sec. 2, T. 25 S., R. 23 E.

Altamont limestone (8.8 feet exposed)
Worland limestone member
Limestone, light gray, crystalline ..... 5.0±
Lake Neosho shale member
Shale, gray, flaky; contains phosphatic concretions 2.0

Tina limestone member
Limestone, gray, earthy, weathers as breccia 1.8
Bandera shale
Shale, gray and yellow; contains small limestone nodules in upper part; contains limonitic concretions ..... exposed 17.0±

(57) SW¼ NW¼ NW¼ sec. 13, T. 25 S., R. 23 E.

Altamont limestone (6-8 feet exposed)
Worland limestone member
Limestone, deeply weathered
Limestone, light gray ..... exposed 2.0-3.0
Lake Neosho shale member
Shale, gray, flaky; contains phosphatic concretions 2.0-3.0
Tina limestone member
Limestone, dove gray, earthy; appears somewhat brecciated in upper part when weathered 2.0
Bandera shale (23 feet exposed)
Shale, yellow, limonitic ..... 3.0±
Shale, yellow ..... 7.0±
Shale, yellow; contains calcareous nodules ..... 11.0±
Sandstone, brown and gray, massive ..... exposed 2.0±

(58) Near the SE cor. sec. 19, T. 25 S., R. 23 E.

Altamont limestone (6.3 feet)
Worland limestone member
Limestone, light gray, crystalline, thin-bedded 3.0
Lake Neosho shale member
Shale, yellow and gray, flaky; contains phosphatic nodules 0.9
Tina limestone member (2.4 feet)
Limestone, thin-bedded; contains abundant brachiopods, *Squamularia* sp., and *Composita* sp. 1.0
Limestone, gray, crystalline, earthy, weathers as single brecciated ledge 1.4
Bandera shale
Shale, gray and yellow, limonitic, slightly sandy, blocky ..... exposed 21.0

(59) NE cor. sec. 20, T. 25 S., R. 23 E.

Altamont limestone (4.2 feet exposed)
Worland limestone member
Limestone, dove gray, massive, upper surface irregular .. exposed 2.0
Lake Neosho shale member
Shale, gray; contains phosphatic nodules 0.7
Tina limestone member
Limestone, brownish-gray, brecciated appearing 1.5
Bandera shale
Long shale slope

(60) N½ SW¼ sec. 29, T. 25 S., R. 23 E.

Bandera shale (21.6 feet)
- Sandstone, light gray and buff, fine-grained, massive, slightly irregular bedding, thinner bedded in basal part, ripple marked 5.4
- Sandstone, gray and buff, beds paper-thin to 0.5 feet, small ripple marks, films of "mud" on bedding planes, carbonaceous coating between beds 6.2
- Sandstone, gray and buff, beds 0.2 to 0.3 feet thick, small ripple marks, film of "mud" on bedding planes; contains fossil "worms" 10.0

(61) NW¼ SW¼ sec. 29, T. 25 S., R. 23 E.

Altamont limestone member (6.3-6.4 feet)
- Worland limestone member
  - Limestone, light gray ..... 3.0±
- Lake Neosho shale member
  - Shale, not well exposed; contains phosphatic concretions ..... 3.0±
- Tina limestone member
  - Limestone, grades locally into sandstone 0.3-0.4

Bandera shale (25.3 feet exposed)
- Shale, gray and yellow, limonitic 4.5
- Shale, gray, yellow, and maroon, blocky 5.4
- Shale, gray, yellow, and maroon 5.4
- Shale, gray and yellow ..... exposed 10.0±

(62) SE¼ sec. 31, T. 25 S., R. 23 E.

Lenapah limestone
- Idenbro limestone member
  - Limestone, gray, finely crystalline, slight thickness exposed

Nowata shale
- Shale, gray and yellow 3.0

Altamont limestone
- Worland limestone member
  - Limestone, light gray, crystalline 3.0-4.0
- Lake Neosho shale member
  - Shale, deeply weathered; contains dark phosphatic nodules; slight thickness exposed in road ditch

(63) SW¼ sec. 31, T. 25 S., R. 23 E.

Bourbon shale
- Hepler sandstone
  - Sandstone, brown, massive ..... exposed 3.0±

Unconformity

Marmaton group
- Memorial shale
  - Shale, yellow, slightly micaceous ..... 6.0±

Lenapah limestone (5 feet)
  Idenbro limestone member
    Limestone, red to brown 0.5
  Perry Farm shale member
    Shale, mostly covered ..... 3.0±
  Norfleet limestone member
    Limestone, gray to brown, nodular 1.5
Nowata shale
    Shale, gray; contains limestone lenses and *Chonetes* sp. in upper part ..... exposed 8.0

(64) Near cen. W line sec. 3, T. 25 S., R. 24 E.

Altamont limestone
  Worland limestone member
    Limestone, mostly weathered float blocks
  Lake Neosho shale member
    Covered ..... 4.0±
  Tina limestone member
    Limestone, brownish-gray, nodular ..... 2.0±
Bandera shale
    Shale, gray 5.0
    Shale, purple and small amount of green ..... exposed 6.0
    Long shale slope to exposure of Pawnee limestone

(65) NE¼ sec. 4, T. 25 S., R. 24 E.

Altamont limestone (5 feet exposed)
  Worland limestone member
    Limestone, light gray, dense; contains crinoid fragments and brachiopods ..... exposed 2.0±
  Lake Neosho shale member
    Shale, gray; contains phosphatic concretions 2.0
  Tina limestone member
    Limestone; contains "breccia" and *Mesolobus* sp. ..... 1.0±
Bandera shale
    Shale, blue-gray, flaky in upper part, blocky in lower part ..... exposed 10.0±

(66) Near cen. N line sec. 11, T. 25 S., R. 24 E.

Altamont limestone (5.6 feet exposed)
  Worland limestone member
    Limestone, poorly exposed ..... exposed 2.0
  Lake Neosho shale member
    Shale, gray, poorly exposed; contains phosphatic nodules ..... 3.0±
  Tina limestone member
    Limestone, gray to brown, cross-bedded, nodular 0.6
Bandera shale (42.3 feet)
    Shale, yellow and maroon 11.5

Sandstone, brown, thin-bedded 10.8
Covered interval ..... 20.0±
Pawnee limestone (25.1 feet)
Laberdie limestone member (9.4 feet)
Limestone, covered 5.4
Limestone, dove gray, thin-bedded ..... 4.0±
Mine Creek shale member (2.5 feet)
Shale, black, fissile to blocky 1.5
Limestone, dark gray 0.2–0.3
Shale, gray, fissile 0.7
Myrick Station limestone member (8.7 feet)
Limestone, brown, nodular 0.8
Limestone, gray, weathers brown, massive; contains *Chaetetes* 3.8
Shale, dark and light gray, fissile 0.4
Limestone, brown, massive; contains carbonaceous streaks in upper part 3.7
Anna shale member (4.5 feet)
Shale, gray 0.5
Shale, black, mostly fissile, more blocky in upper part; contains coal nodules in upper part 3.7
Limestone, dark gray; contains *Squamularia* sp. 0.3
Labette shale

(67) Near cen. N line NW¼ NE¼ sec. 11, T. 25 S., R. 24 E.

Pawnee limestone (11.1 feet exposed)
Myrick Station limestone member (6.6 feet exposed)
Limestone, medium gray, crystalline, irregular bedding; contains *Chaetetes* in upper part ..... exposed 2.5
Shale, yellow and gray, thin-bedded 0.4
Limestone, brown, massive, thinner bedded in upper part 3.7
Anna shale member (4.5 feet)
Shale, gray 0.5
Shale, black, fissile in lower part, blocky in upper part; contains coaly concretions in upper part 3.7
Limestone, dark gray, carbonaceous; contains small *Squamularia* sp. 0.3
Labette shale
Shale, gray ..... exposed 4.0

(68) NW cor. sec. 15, T. 25 S., R. 24 E.

Pawnee limestone (17 feet exposed)
Laberdie limestone member
Limestone, bluish-gray, weathers light gray, fossiliferous ..... exposed 5.0±
Mine Creek shale member
Shale, gray, black in middle part, fissile 3.5
Myrick Station limestone member (6.5 feet)

Limestone, gray, weathers brown; contains large fusulines and echinoid spines 3.4
Shale, gray ..... 0.1±
Limestone, gray, weathers brown; contains fusulines 3.0
Anna shale member
Shale, black with some gray in upper part ..... 2.0±
Labette shale
Shale, gray ..... 6.0±

(69) SE cor. sec. 15, T. 25 S., R. 24 E.

Pawnee limestone (16.4 feet exposed)
Laberdie limestone member
Limestone, blue-gray, weathers to lighter color, thin wavy bedding, fossiliferous ..... exposed 2.0
Mine Creek shale member
Shale, black and gray 3.5
Myrick Station limestone member (6.5 feet)
Limestone, brown and gray; contains fusulines and echinoid spines 3.4
Shale ..... 0.1±
Limestone, brown and gray; contains fusulines 3.0
Anna shale member (7.4 feet)
Shale, gray ..... 1.0±
Shale, black; contains small black concretions ..... 2.0±
Shale, dark gray and yellow, blocky 4.1
Limestone, dark gray, slabby 0.3
Labette shale (51.2 feet)
Shale, gray and yellow ..... 8.0±
Limestone, brown, dense, earthy 0.4
Shale, yellow and gray 37.8
Covered interval ..... 5.0±
Fort Scott limestone
Higginsville limestone member
Limestone, light gray

(70) Near cen. N line sec. 16, T. 25 S., R. 24 E.

Pawnee limestone (4.3 feet exposed)
Myrick Station limestone member
Limestone, brown, massive; contains corals and brachiopods ..... exposed 2.5
Anna shale member (1.8 feet)
Shale, gray 0.8
Shale, black; contains small black concretions 1.0
Labette shale (37.7 feet)
Shale, gray and yellow, somewhat carbonaceous 15.2
Covered interval 10.0
Sandstone or sandy limestone 1.0
Shale, yellow 9.0

Coal 0.5
Covered interval 2.0
Fort Scott limestone
Higginsville limestone member
Limestone, gray and brown, crystalline; contains crinoid fragments and brachiopods

(71) NW¼ NW¼ sec. 24, T. 25 S., R. 24 E.

Pawnee limestone (5 feet exposed)
Myrick Station limestone member
Limestone, brown, massive ..... exposed 2.0±
Anna shale member
Shale, black, blocky 2.0-3.0
Labette shale (40.25 feet exposed)
Shale, not well exposed; may include basal limestone of Anna shale ..... 10.8±
Shale, gray and yellow; contains lenses of dark blue and brown limestone in upper 4 feet 16.0
Limestone, dark gray, thin-bedded, carbonaceous 0.2
Shale, gray 0.3
Coal 0.45
Shale, gray, well bedded ..... 1.0±
Sandstone, gray and brown, calcareous, resembles limestone in weathered outcrop ..... 2.0±
Shale, light gray, sandy, micaceous ..... 3.5±
Shale, partly covered ..... exposed 6.0±

(72) W½ NE¼ sec. 19, T. 25 S., R. 25 E.

Marmaton group
Labette shale
Shale, dark gray and black; contains a thin coal; deeply weathered ..... exposed 3.0±
Fort Scott limestone (27.9 feet)
Higginsville limestone member (14 feet)
Limestone, light gray, more massive in upper part, weathered surface does not show distinct bedding; contains *Chaetetes* in upper part; giant crinoid fragments and an abundance of various fossil fragments on upper surface 13.0
Limestone, yellow-gray 1.0
Little Osage shale member (8.7 feet)
Shale, yellow and gray 0.9
Limestone (Houx), blue-gray in lower part, brown in upper part 0.6
Shale, black, mostly fissile; contains small phosphatic concretions, coaly concretions in lower part 4.0
Coal (Summit) 0.2
Shale, dark gray, fissile in upper 0.5 foot, slakes into small blocks 3.0

Blackjack Creek limestone member
Limestone, bluish-gray, massive, conchoidal fracture 5.2
Cherokee shale
Shale, black, blocky, not fissile; contains small black concretions, giant black limestone concretions in lower part 5.2
Coal (Mulky) 1.4

(73) NE¼ NW¼ sec. 21, T. 25 S., R. 25 E.

Fort Scott limestone (21.0 feet)
Higginsville limestone member
Limestone, medium light gray, weathers mottled brown and gray, slightly crystalline, irregular bedding, little flint in upper few inches; contains cup corals, crinoid fragments, and brachiopods 9.0
Mine Creek shale member
Shale, mostly covered by stone wall, gray in upper part ..... 8.0±
Blackjack Creek limestone member
Limestone, brown, massive 4.0

(74) NW¼ NW¼ sec. 26, T. 25 S., R. 25 E. (Measured by R. C. Moore)

Fort Scott limestone (13.5 feet exposed)
Higginsville limestone member
Limestone, light gray, irregular thin bedding ..... exposed 2.0±
Mine Creek shale member (6 feet)
Shale, black, fissile, lower 0.6 foot very soft 3.0
Shale, gray, weathers into fine fragments 3.0
Blackjack Creek limestone member
Limestone, light drab gray, hard, impure, a single massive bed; contains scattered productids 5.5
Cherokee shale
Shale, gray, calcareous, grades into shaly limestone, fossiliferous 1.5
Shale, black, blocky; contains irregular small concretions 2.5
Shale, black, fissile, hard, joints prominent; contains large concretions, pyritized fossils, and abundant *Marginifera* and *Mesolobus* 2.0
Coal 1.2
Shale, gray ..... exposed 1.0

(75) NW cor. sec. 1, T. 26 S., R. 22 E.

Bourbon shale
Hepler sandstone
Sandstone, brown, micaceous ..... exposed 4.0±
Unconformity
Marmaton group
Memorial shale
Shale, yellow and gray; contains few calcareous nodules ..... 6.0±

Lenapah limestone
Idenbro limestone member
Limestone, bluish-gray, nodular, top uneven ..... exposed 2.0±

(76) NW¼ sec. 11, T. 26 S., R. 22 E.

Bourbon shale
Hepler sandstone
Sandstone, brown and gray, fine-grained ..... 5.0±
Unconformity
Marmaton group
Memorial shale (16 feet)
Shale with few pockets of sand ..... 4.5±
Limestone, nodular 0.0-0.5
Shale, gray 11.0
Lenapah limestone
Idenbro limestone member
Limestone, gray, somewhat nodular ..... 1.0±
Nowata shale (9 feet exposed)
Shale, gray 3.0
Sandstone, micaceous ..... exposed 6.0

(77) Near NW cor. sec. 12, T. 26 S., R. 22 E.

Bourbon shale
Shale, not well seen ..... exposed 6.0±
Hepler sandstone
Sandstone, mostly gray, some brown, massive in upper part; contains large mica flakes 7.8
Unconformity
Marmaton group
Memorial shale
Shale, greenish-gray, micaceous, platy ..... exposed 6.0

(78) Near cen. W½ sec. 13, T. 26 S., R. 22 E.

Bourbon shale
Hepler sandstone
Sandstone, brown and gray, fine-grained ..... exposed 2.0±
Unconformity
Marmaton group
Memorial shale
Shale, gray ..... 0.5±
Lenapah limestone
Idenbro limestone member
Limestone, bluish-gray, crinoidal ..... 1.0±
Perry Farm shale member
Shale, gray; contains limestone nodules ..... exposed 2.0±

(79) Near SE cor. sec. 14, T. 26 S., R. 22 E.

Altamont limestone (13.7 feet exposed)
- Worland limestone member (6 feet exposed)
  - Limestone, dove gray, dense; contains algal pellets in upper part and crinoid stems ..... exposed 4.0±
  - Limestone, dove gray, oölitic appearing; contains algal pellets, crinoid stems, and sparse *Composita* sp. 2.0
- Lake Neosho shale member
  - Shale, calcareous, nodular; contains few phosphatic concretions 1.7
- Tina limestone member
  - Limestone, dove gray, dense, earthy; contains algal (?) pellets ..... exposed 6.0±

(80) Cen. W line sec. 1, T. 26 S., R. 23 E.

Bandera shale (25.3 feet exposed)
- Sandstone (Bandera Quarry) ..... exposed 4.0
- Shale, gray, limonitic and carbonaceous, blocky 15.0
- Limestone, nearly black, crystalline, slabby 0.3
- Limestone, nearly black, crystalline, massive 1.4
- Limestone, nearly black, massive 0.7
- Limestone, slabby, in shale 0.09
- Coal (Mulberry) 0.55
- Shale and underclay ..... 2.0±

Pawnee limestone
- Laberdie limestone member (16 feet exposed)
  - Limestone, mostly a mass of *Chaetetes*, not well exposed ..... 4.0±
  - Limestone, light gray mottled, crystalline, thin irregular bedding ..... exposed 12.0±

(81) Near cen. N line sec. 2, T. 26 S., R. 23 E.

Bandera shale (26 feet exposed)
- Shale, gray and yellow, limonitic, blocky ..... exposed 20.0±
- Limestone, black, slabby ..... 2.0±
- Covered interval ..... 4.0±

Pawnee limestone
- Laberdie limestone member
  - Limestone, mostly *Chaetetes* masses ..... exposed 1.0±

(82) Near cen. NE¼ sec. 3, T. 26 S., R. 23 E.

Altamont limestone (5 feet exposed)
- Worland limestone member
  - Limestone, light gray, dense ..... exposed 3.0±
- Lake Neosho shale member
  - Shale, mostly gray, not well seen; contains phosphatic concretions ..... exposed 2.0±

(83) Near the NW cor. sec. 12, T. 26 S., R. 23 E.

Bandera shale (8-36 feet exposed)
- Sandstone (Bandera Quarry), brown, mostly gray when fresh, micaceous, fine-grained, ferruginous, in channel .... exposed 3.0-20.0
- Shale, gray and yellow, cut by channel filled with sandstone ..... exposed 5.0-16.0

(84) SW¼ sec. 12, T. 26 S., R. 23 E.

Pawnee limestone (34.3 feet exposed)
- Laberdie limestone member (24.5 feet exposed)
  - Limestone, light gray, dense to crystalline, weathers as rough breccia, holds dip-slope in wide area ..... exposed 1.5
  - Limestone, light gray, thin irregular bedding; contains brachiopods 21.0
  - Limestone, dove gray, crystalline, in thin limy shale (may be part of Mine Creek member) ..... 2.0±
- Mine Creek shale member
  - Shale, not well seen ..... 1.0±
- Myrick Station limestone member (7.3 feet)
  - Limestone, brown and gray, shale break in upper part 3.0
  - Limestone, brown and gray 4.3
- Anna shale member
  - Shale, black with little gray shale at top, blocky ..... exposed 1.5

(85) Near cen. S½ sec. 19, T. 26 S., R. 23 E.

Bourbon shale
- Hepler sandstone
  - Sandstone and sandy shale, not well seen; may include Memorial shale ..... exposed 10.8

Unconformity (may occur a few feet higher)

Marmaton group
- Lenapah limestone (1.2 feet)
  - Idenbro limestone member (1.2 feet)
    - Limestone, gray, nodular ..... 1.0±
    - Limestone, brown, earthy 0.2
- Nowata shale (21.6 feet)
  - Shale, yellow and gray, blocky 10.8
  - Covered interval 10.8
- Altamont limestone (15.83 feet exposed)
  - Worland limestone member
    - Limestone, bluish-gray, dense to partly granular, algal (?), not well seen ..... 6.0±
  - Lake Neosho shale member (2.33 feet)
    - Shale, mostly gray; contains abundance of phosphatic nodules .... 1.0±
    - Limestone 0.33
    - Shale and limestone nodules ..... 1.0±
  - Tina limestone member (7.5 feet exposed)

Limestone, dove gray, granular, earthy ..... 1.0±
Limestone, brownish-gray, earthy; contains concretionary-like masses of hard finely crystalline rock ..... exposed 6.5

(86) NE¼ sec. 27, T. 26 S., R. 23 E.

Bandera shale (43.0 feet exposed)
Sandstone (Bandera Quarry), massive ..... exposed 5.0
Shale, yellow and gray 38.0
Covered interval 17.0
Pawnee limestone
Laberdie limestone
Limestone, upper part exposed in drainage

(87) SW¼ sec. 34, T. 26 S., R. 23 E.

Altamont limestone (5.15 feet exposed)
Worland limestone member
Limestone, light gray, crystalline, thin-bedded ..... exposed 4.0
Lake Neosho shale member
Shale, gray, fissile; contains phosphatic concretions 1.0
Tina limestone member
Limestone, gray, earthy, nodular 0.15
Bandera shale (56 feet exposed)
Shale, yellow and gray, blocky ..... 27.0±
Sandstone, platy, thin-bedded 6.0
Shale, yellow and gray, limonitic, carbonaceous, blocky ..... exposed 23.0±

(88) Near cen. S line sec. 8, T. 26 S., R. 24 E.

Pawnee limestone (19.36 feet exposed)
Laberdie limestone member
Limestone, light gray, wavy-bedded; contains fusulines and sponges and *Chaetetes* in lower part ..... exposed 10.0±
Mine Creek shale member
Shale, yellow 0.33
Myrick Station limestone member
Limestone, gray to brown, somewhat earthy 3.55
Anna shale member (5.48 feet)
Shale, gray and yellow 0.33
Shale, black, platy, nearly coal in lower part 1.65
Shale, black and gray 3.0
Limestone, black, slabby 0.5
Labette shale (8.73 feet exposed)
Shale, yellow and gray, pockets of black 1.5
Shale, dark blue, platy, grades into unit below 2.33
Sandstone or sandy limestone ..... 0.2±
Shale, yellow, silty, micaceous 2.2
Limestone, blue, dense, hard 0.5
Shale, yellow and gray, blocky ..... exposed 2.0±

(89) Near cen. S line SE¼ sec. 10, T. 26 S., R. 24 E.

Pawnee limestone (32.6 feet)
- Laberdie limestone member (15.4 feet exposed)
  - Limestone, light gray, highly crystalline, wavy-bedded, brecciated appearing 4.6
  - Limestone, light gray, wavy-bedded, not all well exposed 5.4
  - Limestone, light gray, mostly dense; contains abundant "marklets"; not all well seen 5.4
  - Covered interval, seemingly all limestone; may include Mine Creek shale and part of the Myrick Station limestone ..... 3.0±
- Myrick Station limestone member (3.2 feet)
  - Limestone, gray, very slightly crystalline to earthy, massive in upper part, thinner bedded in lower part 1.9
  - Limestone, gray and partly brown, weathers brown, massive; contains crinoid fragments 1.3
- Anna shale member (11 feet)
  - Shale, gray 0.2
  - Shale, black, fissile ..... 1.0±
  - Shale, gray; contains lenses of calcareous sandstone 9.0
  - Limestone, dark bluish-gray, massive 0.8

Labette shale
- Shale, not well seen ..... exposed 4.0

(90) SW¼ SE¼ sec. 12, T. 26 S., R. 24 E.

Pawnee limestone (13 feet exposed)
- Laberdie and Myrick Station limestone members
  - Limestone, light gray in upper part, brown in lower part, more massive in lower part, not well exposed; may include a slight thickness of Mine Creek shale ..... exposed 10.0±
- Anna shale member (3.0 feet)
  - Shale, yellow and gray 1.0
  - Shale; contains small black concretions ..... 2.0±

Labette shale (22.8 feet exposed)
- Shale, yellow and gray 14.2
- Limestone, blue, hard, sandy in upper part 0.6
- Shale, gray and yellow ..... exposed 8.0±

(91) Near cen. sec. 6, T. 26 S., R. 25 E.

Pawnee limestone (15.93 feet exposed)
- Laberdie limestone member (14.53 feet)
  - Limestone, light and darker gray mottled, lighter parts are more crystalline than darker, irregular massive to medium thin beds, fossils stand out on weathered surfaces; contains large crinoid stems, few cup corals, and brachiopods 8.2
  - Limestone and shale, carbonaceous and silty, irregular beds, shale breaks more plentiful in lower part 3.0

Limestone, gray, carbonaceous; contains bands of *Chaetetes* and wavy bands of carbonaceous limestone with plentiful fusulines; irregular upper and lower surfaces 3.0-3.33
Mine Creek shale member
Shale, nearly black, fissile 0.3
Myrick Station limestone member
Limestone, dark gray, earthy ..... exposed 1.1

(92) Near cen. sec. 14, T. 27 S., R. 22 E.

Bourbon shale
Hepler sandstone
Sandstone

Unconformity

Marmaton group
Memorial shale (29 feet)
Shale, covered 21.0
Shale, light gray, limonitic 8.0
Lenapah limestone (14 feet exposed)
Idenbro limestone member
Limestone, gray, weathers lighter color, somewhat sandy appearing; contains brachiopods and crinoid fragments ..... 3.0±
Perry Farm shale member (5 feet)
Limestone and shale, light gray, dense; limestone nodules in shale 2.0
Shale, gray and yellow, slightly micaceous; contains sparse limestone nodules 2.0
Limestone and shale; light gray nodular limestone in shale ..... 1.0±
Norfleet limestone member
Limestone, dark gray, granular, alternating with limy shale ..... exposed 6.0

(93) Near NE cor. sec. 13, T. 27 S., R. 23 E.

Pawnee limestone (6 feet exposed)
Myrick Station limestone member (3.4 feet exposed)
Limestone, gray, weathers brown, granular, irregular beds ..... exposed 2.5
Limestone, brownish-gray, earthy, massive 0.9
Anna shale member (2.6 feet)
Shale, gray, flaky 0.6
Shale, black, paper-thin beds; contains small black concretions, orbiculoids, and plant impressions 1.4
Shale, dark gray, silty 0.2
Limestone, dark gray, slightly crystalline, impregnated with carbonaceous material 0.4
Labette shale
Shale, not well seen ..... exposed 15.0

(94) Near cen. S line sec. 14, T. 27 S., R. 23 E.

Altamont limestone
Bandera shale (30 feet exposed)
- Covered interval 20.0
- Sandstone, brown, ferruginous, micaceous, well cemented 3.0
- Sandstone, gray and yellow, limonitic, shaly in upper part 10.8
- Sandstone, gray and yellow, thin-bedded, limonitic 5.4
- Shale, gray and yellow, carbonaceous, limonitic 5.4
- Shale, gray, weathers red, limonitic, slightly carbonaceous ..... exposed 5.4

(95) NW cor. sec. 24, T. 27 S., R. 23 E.

Altamont limestone (5 feet exposed)
- Worland limestone member
  - Limestone, light gray, poorly seen ..... exposed 2.0±
- Lake Neosho shale member
  - Shale, gray; contains phosphatic concretions ..... 3.0±

Bandera shale (43 feet exposed)
- Sandstone, weathered, not well exposed 27.0
- Shale, micaceous, sandy in lower part ..... exposed 16.0

(96) Cen. E line sec. 2, T. 27 S., R. 24 E.

Pawnee limestone (24.6 feet exposed)
- Laberdie limestone member (12.5 feet exposed)
  - Limestone, light gray, brecciated appearance, not all well seen ..... exposed 8.0±
  - Limestone, light gray, brecciated appearance, thinner beds than unit above, not all well exposed 4.5
- Myrick Station limestone member (8.4 feet)
  - Limestone, gray, massive 5.0
  - Covered interval 2.0
  - Limestone, brown, massive 1.4
- Anna shale member (3.7 feet exposed)
  - Shale, gray 0.6
  - Shale, black, platy 1.1
  - Shale, gray ..... exposed 2.0

(97) Near cen. E line NE¼ SW¼ sec. 7, T. 27 S., R. 24 E.

Pawnee limestone (34.95 feet)
- Laberdie limestone member (30.4 feet)
  - Limestone, mostly covered 20.0-25.0
  - Limestone, light gray, slightly crystalline, irregular wavy beds, slightly more massive in lower part; contains *Chaetetes* in lower part 5.4
- Mine Creek shale member
  - Shale, gray, slightly carbonaceous 0.25

Myrick Station limestone member
Limestone, brown and gray, very slightly crystalline, more massive in lower part; contains "worm borings" and large fusulines ..... 1.5±
Anna shale member (1.8 feet)
Shale, gray 0.3
Shale, black, fissile; contains small black concretions 1.1
Shale, gray; contains oblong phosphatic concretions 0.1
Limestone, dark, slabby, weathers light gray and rough with fossil fragments 0.0-0.3

(98) Near the NE cor. sec. 13, T. 27 S., R. 24 E.

Pawnee limestone (8.83 feet)
Myrick Station limestone member
Limestone, brown and gray, massive ..... 5.0±
Anna shale member (3.83 feet)
Shale, gray ..... 2.0±
Shale, black, fissile; contains few small black concretions 1.25
Shale, gray, silty 0.25
Limestone, dark gray, nearly black, weathers rusty brown, earthy 0.33
Labette shale (47.65 feet exposed)
Underclay, gray, locally darker shade, shaly in upper part 1.45
Shale, dark gray, scattered lighter bands 12.8
Shale, light gray, blocky, grades into unit above 6.4
Shale, light to dark gray, not well seen ..... exposed 27.0

(99) SE cor. sec. 18, T. 27 S., R. 24 E.

Pawnee limestone (11.5 feet exposed)
Laberdie and Myrick Station limestone members
Limestone, mostly massive; contains "worm burrows" in lower part (Myrick Station) and large fusulines ..... exposed 10.0±
Anna shale member (1.5 feet)
Shale, gray 0.2-0.5
Shale, black ..... 1.0±
Labette shale (8 feet exposed)
Shale, gray and yellow; contains zone of hard limonitic concretions in basal part 5.0
Shale, gray and yellow ..... exposed 3.0

(100) Near NW cor. sec. 19, T. 27 S., R. 24 E.

Bandera shale (46.1 feet)
Shale, gray and yellow, sandy; interval reaches nearly to base of Altamont limestone ..... 6.0±
Sandstone, gray and brown, shaly in lower part; contains "worm borings" 10.4
Shale, gray and yellow, calcareous, blocky 5.4

Shale, gray, blocky 2.0
Shale, gray and yellow; contains limonitic concretions 5.4
Shale, partly covered 5.4
Shale, carbonaceous material in lower part, not all well seen 5.4
Coal (Mulberry) ..... 0.5±
Shale, weathered, base not well exposed ..... 6.0±
Pawnee limestone
Laberdie limestone member
Limestone ..... exposed 0.5±

(101) Near cen. E line sec. 16, T. 27 S., R. 25 E.

Marmaton group
Fort Scott limestone
Blackjack Creek limestone member (6.5 feet exposed)
Limestone, gray, massive to thin-bedded; contains fusulines, echinoid and crinoid fragments, and "*Aulopora*" sp.; *Chaetetes* masses scattered throughout ..... exposed 5.5
Limestone, gray, weathers brown, dense to earthy 0.9-1.0
Cherokee shale
Shale, black, platy; contains small black oblong concretions and in lower part black impure hard limestone concretions up to 1 foot in diameter ..... exposed 3.6

Stratigraphic Sections in Crawford County, Kansas (102-121)

(102) Near SW cor. sec. 25, T. 28 S., R. 21 E.

Altamont limestone (6 feet)
Tina limestone member (6 feet)
Limestone, dark bluish-gray, dense to slightly granular, massive but wavy-bedded 1.5
Shale, gray; contains *Rhombopora* sp. 0.25
Limestone, dark bluish-gray, "Osagite" (granular algal) in upper part; contains abundant crinoid fragments, horn corals, and large rhomboporids; small brachiopods especially prominent on upper weathered surface 1.0
Limestone, dark dove-gray; contains dense "cryptozoans" in upper part 0.75
Shale and nodular limestone 0.2
Shale and limestone nodules, shale yellow, limy; limestone nodules up to 1 foot long 2.2
Limestone, impure 0.1

(103) Near cen. sec. 26, T. 28 S., R. 21 E.

Altamont limestone
Tina limestone member
Limestone, dark blue, cross-bedded, top hummocky, crinoidal; contains brachiopods and large echinoid spines 2.0

Bandera shale (12.5 feet exposed)
- Shale, gray to slightly yellowish 6.5
- Shale, black, fissile 3.0
- Shale, black, blocky ..... exposed 3.0

(104) Near cen. E line sec. 36, T. 28 S., R. 21 E.

Altamont limestone (5.8 feet exposed)
- Worland limestone member
  - Limestone, dove-gray, brecciated appearing, nodular in lower part 4.0
- Lake Neosho shale member
  - Shale, yellow ..... exposed 1.8

(105) Slightly (0.2 mile) south of cen. N. line sec. 14, T. 28 S., R. 22 E.

Altamont limestone (4 feet exposed)
- Worland limestone member
  - Limestone, dove-gray, crystalline, massive 2.0
- Lake Neosho shale member
  - Shale, yellow, limonitic, slightly sandy, poorly exposed; contains phosphatic concretions ..... exposed 2.0±

(106) Slightly south of cen. sec. 14, T. 28 S., R. 22 E.

Bandera shale
- Sandstone, brown, fine-grained, slightly coarser in upper part, ripple-marked, definite contact at base ..... exposed 3.0
- Shale, gray; contains scattered thin layers of sandy shale and lenses of fine yellow sand 7.7
- Covered to water in creek 3.0

(107) Near cen. S½ SE¼ sec. 23, T. 28 S., R. 22 E.

Altamont limestone
- Tina limestone member
  - Limestone, gray to brown, cross-bedded, crinoidal 0.5

Bandera shale
- Shale, clayey, gray and partly black ..... exposed 7.0

(108) Near SW cor. sec. 11, T. 28 S., R. 24 E.

Marmaton group
- Fort Scott limestone (35.21 feet)
  - Higginsville limestone member
    - Limestone, medium dark gray, dense to slightly crystalline, well bedded; contains wavy bands of crystalline calcite, *Chaetetes* in upper part, large crinoid stems, and fusulines .... 10.0±
  - Little Osage shale member (6.25 feet)
    - Shale, gray 1.25
    - Shale, black, fissile 3.0

Shale, gray 2.0
Blackjack Creek limestone member (18.96 feet)
Limestone, medium gray, wavy thin beds 14.0
Limestone, light gray, crystalline; contains *Chaetetes* and many crinoid stems 2.75
Shale 0-0.66
Limestone, dove-gray, weathers tan, massive 1.55
Cherokee shale
Shale, black 3.0
Coal (Mulky) 1.0
Shale, light gray, mostly covered 2.0
Limestone (Breezy Hill), light gray, nodular, impure 1.25
Shale, gray, calcareous 3.0
Sandstone, forms pavement in creek

(109) NW¼ sec. 15, T. 28 S., R. 24 E.

Fort Scott limestone (8 feet exposed)
Higginsville limestone member
Limestone, light gray, wavy-bedded, more massive in lower part ..... exposed 5.0
Little Osage shale member (3.0 feet exposed)
Shale, gray 0.5
Shale, black, platy ..... exposed 2.5

(110) Near cen. S line sec. 33, T. 28 S., R. 24 E.

Pawnee limestone (17 feet)
Laberdie limestone member
Limestone, light gray, medium thin wavy beds 15.0
Myrick Station limestone member
Limestone, dark gray, weathers tan, massive 2.0

(111) Near cen. W line sec. 5, T. 28 S., R. 25 E.

Marmaton group
Fort Scott limestone (10.4 feet)
Blackjack Creek limestone member
Limestone, light gray, slightly crystalline, mostly massive appearing, weathers into comparatively thin-bedded rock; contains *Chaetetes* occurring as lumpy masses up to 1 foot in diameter 6.5
Shale, light gray to dark, irregular upper and lower contacts with limestone; contains large crinoid stems 0.2-0.3
Limestone, medium gray, granular, massive, wavy carbonaceous zones at bedding contacts, locally nearly all carbonaceous; contains *Chaetetes* 1.5
Shale, yellow, clay 0.2
Limestone, dark bluish-gray, dense, upper part thinner bedded, lower part massive 1.9

Cherokee shale
- Shale, gray 0.1
- Shale, black, platy 3.0
- Coal (Mulky) 0.8
- Underclay 1.0
- Shale, gray 1.9
- Limestone (Breezy Hill), light gray, earthy, impure, nodular 1.5
- Sandstone and shale, gray; sandstone, fine-grained, micaceous, part massive and part lenticular ..... exposed 8.0±

(112) SW¼ sec. 2, T. 29 S., R. 21 E.

Altamont limestone
- Tina limestone member
  - Limestone, poorly exposed

Bandera shale
- Covered 1.0
- Sandstone, massive 3.0
- Shale, distorted and cut out by limonitic concretions 0.5-1.5
- Sandstone, massive ..... exposed 1.0

(113) Near cen. E line NE¼ sec. 27, T. 29 S., R. 21 E.

Altamont limestone (2 feet exposed)
- Tina limestone member (2 feet exposed)
  - Limestone, poorly exposed
  - Limestone, dove-gray, dense, irregular rusty splotches ..... 1.0±
  - Limestone, gray, granular; contains abundant crinoid fragments 0.35-1.0

Bandera shale
- Shale, gray and yellow, flaky; contains thin lenses of siltstone ..... exposed 10.0±

(114) Near SW cor. SE¼ sec. 35, T. 29 S., R. 22 E.

Pawnee limestone (6.2 feet exposed)
- Laberdie limestone member (3.5 feet exposed)
  - Limestone, gray, slightly crystalline, wavy beds; contains "cryptozoans" and "*Osagia*" in upper part ..... exposed 1.2
  - Limestone, dove-gray, weathers lighter color, crystalline, massive; contains large crinoid stems 2.3
- Myrick Station limestone member
  - Limestone, gray, weathers brown, earthy, massive; contains abundant crinoid fragments, brachiopods, and small derbyoids 1.5
- Anna shale member (1.2 feet exposed)
  - Shale, gray 0.2
  - Shale, black, fissile ..... exposed 1.0±

(115) NW¼ sec. 9, T. 29 S., R. 23 E.

Pawnee limestone (10.6 feet exposed)
- Laberdie limestone member
  - Limestone, light dove-gray, crystalline, fairly massive, wavy-bedded; contains large cup corals ..... exposed 6.0
- Mine Creek shale member
  - Shale ..... 0.1±
- Myrick Station limestone member
  - Limestone, brown and dark gray, massive 2.0
- Anna shale member (2.5 feet exposed)
  - Shale, gray ..... 0.5±
  - Shale, black ..... exposed 2.0±

(116) Near SE cor. sec. 11, T. 29 S., R. 23 E.

Pawnee limestone (5.4 feet exposed)
- Laberdie limestone member
  - Limestone, light gray, thin wavy-bedded ..... exposed 3.0±
- Myrick Station limestone member
  - Limestone, dark gray and brown, weathers brown 1.4
- Anna shale member
  - Shale, black, platy ..... exposed 1.0±

(117) SW¼ SE¼ sec. 16, T. 29 S., R. 24 E.

Fort Scott limestone (8.75 feet exposed)
- Higginsville limestone member
  - Limestone, light gray, carbonaceous coatings on wavy bedding planes ..... exposed 2.0
- Little Osage shale member
  - Shale, black, platy 4.75
- Blackjack Creek limestone member
  - Limestone; contains masses of *Chaetetes* ..... exposed 2.0±

(118) Near cen. N line sec. 19, T. 29 S., R. 24 E.

Fort Scott limestone (11.8 feet exposed)
- Higginsville limestone member
  - Limestone, light gray mottled, brecciated appearing; contains *Chaetetes* ..... exposed 5.0
  - Limestone, medium to light gray, darker than unit above, carbonaceous material on wavy bedding planes; contains fusulines 4.5
  - Shale, highly carbonaceous 0.1-0.2
  - Limestone, dark gray, earthy 2.1
- Mine Creek shale member
  - Shale, black, platy, small thickness exposed in quarry floor.

(119) Near cen. N line sec. 23, T. 30 S., R. 21 E.

Pawnee limestone (31.46 feet exposed)
- Laberdie limestone member (19.75 feet)
  - Limestone, partly exposed along road west and north of exposure in lower beds 15.0
  - Limestone, light gray, wavy-bedded, massive in lower part, crinoid stems 4.0
  - Limestone, dark gray, earthy, slabby in lower part; contains many small brachiopods 0.75
- Mine Creek shale member
  - Shale, gray and blocky in upper part, black and platy in lower part, hard concretionary-like zone in middle part; contains few brachiopods 1.56
- Myrick Station limestone member
  - Limestone, medium light gray, upper surface hummocky, base even; contains calcite crystals in ashy matrix; contains large "cryptozoans" in upper part, few crinoid fragments, and *Squamularia* sp. 4.2-4.4
- Anna shale member (5.75 feet exposed)
  - Shale, black, thin-bedded; contains flattened thin-shelled brachiopods 1.35
  - Shale, very black, nearly coal, paper thin in upper part; contains hard small pyritic concretions 1.4
  - Shale, very black, thin-bedded, flaky ..... exposed 3.0

(120) NW¼ sec. 30, T. 30 S., R. 23 E.

Marmaton group
- Fort Scott limestone (9.5 feet exposed)
  - Blackjack Creek limestone (9.5 feet exposed)
    - Limestone, light gray, wavy-bedded; contains *Chaetetes* ..... 6.0±
    - Limestone, gray, dense; contains algal remains ..... 2.5±
    - Limestone, dark gray 1.0

Cherokee shale
- Shale, black, platy ..... 4.0±
- Limestone (Breezy Hill) ..... 2.0±

(121) SW¼ sec. 19, T. 30 S., R. 24 E.

- Fort Scott limestone (17.5 feet exposed)
  - Higginsville limestone member
    - Limestone, light gray, brecciated, thin-bedded in upper 10 feet and in lower 2 feet ..... exposed 15.0
  - Little Osage shale member (2.5 feet exposed)
    - Shale, gray 0.5
    - Shale, black, platy ..... exposed 2.0

Stratigraphic Sections in Neosho County, Kansas (122-132)

(122) Near SW cor. sec. 29, T. 28 S., R. 21 E.

Lenapah limestone (20.9 feet exposed)
- Idenbro limestone member
  - Limestone, light dove-gray, finely crystalline, nodular, top surface irregular ..... 2.0±
- Perry Farm shale member (18.9 feet)
  - Shale, yellow, and small limestone nodules ..... 3.5±
  - Shale, yellow, micaceous, slightly silty 5.4
  - Shale, yellow, micaceous; contains small limestone nodules, more numerous in lower part 10.0
  - Covered interval ..... 15.0±

Altamont limestone
- Worland limestone member
  - Limestone, small thickness exposed in creek.

(123) SE¼ sec. 30, T. 28 S., R. 21 E.

Lenapah limestone (5.38 feet exposed)
- Idenbro limestone member and upper part of Perry Farm shale member
  - Nearly all covered ..... 6.0±
- Perry Farm shale member (5.38 feet)
  - Limestone and shale, great mass of small limestone nodules in shale; thin lenticular limestone beds in lower part ..... 4.0±
  - Limestone, dark, crystalline 0-0.2
  - Shale, yellow 0.85
  - Limestone, dark gray, dense to slightly crystalline 0-0.33

Nowata shale
- Shale, gray and yellow, slightly silty ..... exposed 2.0

(124) Slightly east of cen. N line sec. 31, T. 28 S., R. 21 E.

Bourbon shale
- Hepler sandstone
  - Sandstone, gray, weathers brown, fine-grained, well bedded ..... exposed 3.0

Unconformity

Marmaton group
- Memorial shale
  - Shale, gray, clayey; contains small lenses of sandstone .. exposed 5.0

(125) Near cen. W. line sec. 33, T. 28 S., R. 21 E.

Altamont limestone (6.5 feet exposed)
- Worland limestone member
  - Limestone, gray, weathers brown, crystalline 1.0
- Lake Neosho shale member
  - Shale, not well exposed; contains phosphatic concretions ..... 3.0±

Tina limestone member
Limestone, dove-gray, earthy, top irregular; contains few fossil fragments 2.5
Bandera shale (5 feet)
Covered 1.0
Sandstone ..... 4.0±

(126) Near cen. S½ SW¼ sec. 28, T. 29 S., R. 20 E.

Bourbon shale
Hepler sandstone
Sandstone, poorly exposed ..... (?)
Unconformity
Marmaton group
Memorial shale (18 feet)
Covered 10.0
Shale, gray, limonitic, base irregular 8.0
Lenapah limestone (18 feet)
Idenbro limestone member
Limestone, gray, weathers lighter shade, ashy to earthy, irregular bedding; contains pelecypods in upper part and large productids 3.0
Perry Farm shale member (9 feet)
Shale, gray; contains light-gray dense limestone nodules 2.0
Shale, slightly micaceous; contains few limestone nodules 2.0
Shale and nodular limestone 1.0
Covered 4.0
Norfleet limestone member
Shale, limy, and limestone, dark gray, nodular ..... exposed 6.0

(127) Slightly south of NW cor. SW¼ sec. 36, T. 29 S., R. 20 E.

Altamont limestone (12.8 feet exposed)
Worland limestone member
Limestone, light gray, crystalline; contains brachiopods .. exposed 1.5
Lake Neosho shale member (5 feet)
Shale, gray to yellow, somewhat flaky 3.0
Shale, black, fissile; contains phosphatic nodules with shark teeth and bones 1.0
Shale, light gray 1.0
Tina limestone member (6.3 feet)
Limestone, medium gray, weathers slightly brown, nodular, algal in upper part, upper surface irregular; contains few brachiopods, mostly as fragments 1.3
Shale, black 2.0
Limestone, medium gray, slightly darker than first limestone above, slightly crystalline, few crystal faces, mostly dense, nodular; upper surface irregular, base slightly irregular 3.0
Bandera shale
Shale, gray, slightly limonitic ..... exposed 3.0

(128) Near cen. W line sec. 30, T. 29 S., R. 21 E.

Altamont limestone (18.51 feet)
- Worland limestone member (8 feet)
  - Limestone, gray, weathers nearly white, semilithographic, thin beds 1.15
  - Limestone, gray, slightly crystalline to dense, massive, weathers into corrugated surfaces; contains large horn corals, crinoid stems, and few brachiopods; also many *Ambocoelia* sp. in lower part 6.85
- Lake Neosho shale member (4.71 feet)
  - Shale, gray, flaky to blocky 1.6–1.75
  - Shale, very black, blocky, slightly thinner bedded in upper part; contains phosphatic concretions in lower and middle parts 2.3
  - Shale, gray, slightly carbonaceous, silty, flaky; contains many flattened brachiopods in lower part 0.66
- Tina limestone member (5.8 feet)
  - Limestone, dark gray, earthy, nodular 0.2
  - Shale; contains nodular limestone 0.5
  - Limestone, gray, weathers light tan, earthy, no bedding; contains many fossil fragments 1.5
  - Shale, gray, darker in upper part; contains small hard limestone nodules in lower part 1.8
  - Limestone, dark dove-gray, dense to very slightly crystalline, weathers as one bed with faint indication of bedding in lower part; contains *Composita* sp., mostly as fragments 1.8

Bandera shale (6.3 feet exposed)
- Shale and finely crystalline limestone nodules 1.3
- Shale, gray; contains small limestone lenses 5.0

(129) Near NE cor. SE¼ NE¼ sec. 11, T. 30 S., R. 20 E.

Altamont limestone (7+ feet exposed)
- Worland limestone member
  - Limestone, poorly exposed, weathered ..... ?
- Lake Neosho shale member
  - Shale, poorly exposed; contains phosphatic nodules ..... ?
- Tina limestone member (7 feet)
  - Limestone, gray, granular, top irregular; contains fossil fragments 1.0
  - Shale, gray, flaky 0.9
  - Limestone, light gray, slightly crystalline, massive, weathers into a rock of brecciated and nodular appearance; contains many crinoid fragments in upper part 4.0
  - Shale, gray 0.1
  - Limestone, light gray, crystalline, shaly, thin beds; irregular contact at base 1.0

Bandera shale (10 feet exposed)

Shale, gray and yellow, limonitic 4.0
Sandstone, buff, fine-grained, micaceous, laminated, part massive, part shaly and thin-bedded ..... exposed 6.0

(130) Near SW cor. SE¼ SE¼ sec. 12, T. 30 S., R. 20 E.

Altamont limestone
Topographic bench
Bandera shale (57 feet)
Covered 16.0
Sandstone, gray and tan, somewhat massive, ripple-marked 6.0
Sandstone, in thin beds, and shale, gray and yellow, containing rounded sandstone pellets 12.0
Shale, dark gray; contains concretionary-like slightly limonitic clay masses up to 1 foot in diameter ..... exposed 7.0
Covered interval to flood plain of Neosho river 16.0

(131) SE¼ SE¼ sec. 22, T. 30 S., R. 20 E.

Lenapah limestone
Idenbro limestone member
Limestone, light gray, nodular, somewhat brecciated ..... exposed 2.5±
Perry Farm shale member
Shale and limestone nodules ..... exposed 10.0±
(Continuous downward through covered interval into section no. 132)

(132) NW¼ sec. 23, T. 30 S., R. 20 E.

Altamont limestone (15.35 feet exposed)
Worland limestone member
Limestone, light gray, weathers lighter shade, brittle; contains thin lenses of flint ..... exposed 2.5
Lake Neosho shale member
Shale, upper part gray and yellow, flaky; lower part black, fissile; contains phosphatic concretions 5.4
Tina limestone member (7.45 feet)
Limestone, bluish-gray and brown mottled, thin-bedded; contains crinoid stems and other fossil fragments 1.5
Shale, gray 0.5-0.6
Limestone, gray, somewhat crystalline, mostly granular to earthy, massive; contains crinoid fragments and brachiopods 1.3
Limestone, gray, weathered surfaces splotched with iron rust, nodular and brecciated, largely algal; contains abundant fusulines in lower part, "*Fistulipora*" sp., crinoid remains, and pelecypod fragments 2.0-2.3
Shale, gray, flaky; top surface irregular 0.25
Limestone, dove-gray, slightly mottled, dense, irregular bedding; contains *Mesolobus* sp. 1.5
Bandera shale (39+ feet exposed)
Shale, gray, flaky, sandy in lower part 7.0

Sandstone 4.0
Shale, gray 11.0
Shale, sandy 17.0
Sandstone ..... ?

Stratigraphic Sections in Labette County, Kansas (133-177)

(133) Near NE cor. sec. 25, T. 31 S., R. 19 E.

Altamont limestone (4.7 feet exposed)
  Worland limestone member
    Limestone, light gray, somewhat crystalline, irregular bedded; contains large fusulines ..... exposed 2.0
  Lake Neosho shale member (2.7 feet exposed)
    Shale, gray 1.7
    Shale, black, weathered; contains phosphatic nodules ..... exposed 1.0

(134) Near cen. W line sec. 26, T. 31 S., R. 19 E.

Memorial shale (2.75 feet exposed)
    Shale, black, fissile 0.5
    Coal 0.25
    Shale, greenish-gray, limonitic, carbonaceous near top, well bedded 2.0
Lenapah limestone (3.2 feet)
  Idenbro limestone member
    Limestone, gray to slightly yellow, earthy, blocky 1.0
  Perry Farm shale
    Shale, olive-colored, thin to flaky-bedded, and limestone nodules slightly more than 1 inch in diameter, hard, dense, weather rusty brown 2.2

(135) Near cen. E line sec. 27, T. 31 S., R. 19 E.

Bourbon shale
  Hepler sandstone
    Sandstone, gray and brown, irregular contact at base 4.0
Unconformity
Marmaton group
  Memorial shale (18.6 feet)
    Shale, gray, partly covered 5.4
    Shale, gray, clayey 5.4
    Shale, gray, clayey, slightly sandy 5.4
    Coal; contains coalified logs 0.4
    Shale, gray 2.0
  Lenapah limestone (7.9 feet exposed)
    Idenbro limestone member
      Limestone, gray, dense, nodular especially in upper part 1.9
    Perry Farm shale member
      Shale, gray; contains limestone nodules ..... exposed 6.0

(136) NE cor. sec. 20, T. 31 S., R. 20 E.

Bourbon shale
  Hepler sandstone
    Sandstone, brown, fine-grained, micaceous, well bedded, definite contact with shale below ..... exposed 1.0

Unconformity

Marmaton group
  Memorial shale
    Shale, yellow and gray, blocky; contains thin lenses of sand ..... exposed 3.0

(137) NW¼ sec. 30, T. 31 S., R. 20 E.

  Nowata shale
    Shale, gray, weathered 2.0
  Altamont limestone (14.6 feet exposed)
    Worland limestone member (14.6 feet exposed)
      Limestone, gray, crystalline to earthy, thin nodular beds; contains *Mesolobus* and rhomboporids 0.5
      Shale, gray, clayey, flaky 3.2
      Limestone, dark gray to bluish-brown, nodular in upper part 3.0
      Limestone, light gray, dense, semilithographic, especially in the upper part, lower part weathers as nodular breccia; contains large fusulines and few brachiopods ..... exposed 7.9

(138) Near cen. sec. 30, T. 31 S., R. 20 E.

  Altamont limestone
    Worland limestone member
      Limestone, light gray, dense, massive; contains sparse flint nodules, fusulines, and brachiopods ..... exposed 12.0
    Lake Neosho shale member
      Shale, black, small amount exposed in drainage ditch in quarry floor ..... reported by quarry foreman 4.0
    Tina limestone member
      Limestone ..... reported by quarry foreman 8.0

(139) Near NW cor. sec. 31, T. 31 S., R. 20 E.

  Altamont limestone (8.3 feet exposed)
    Worland limestone member
      Limestone, gray splotched with brown in upper part and brownish-gray, weathers yellow, dense; base uneven; contains crinoid fragments ..... exposed 1.5
    Lake Neosho shale member (5.8 feet)
      Shale, gray; contains *Ambocoelia* sp. and *Marginifera* sp. 4.0
      Shale, black; contains sparse phosphatic concretions 1.0
      Shale, gray 0.8
    Tina limestone member
      Limestone, gray, granular; upper surface uneven ..... exposed 1.0

(140) Slightly west of cen. N line sec. 19, T. 31 S., R. 21 E.

Pawnee limestone (10 feet exposed)
Laberdie limestone member
Limestone, debris
Limestone, light gray, crystalline 0.5
Mine Creek shale member (?)
Covered 1.5
Myrick Station limestone member
Limestone, brown, earthy 5.0
Anna shale member (3 feet exposed)
Shale, gray, flaky 1.0
Shale, black ..... exposed 2.0±

(141) Near SW cor. sec. 26, T. 31 S., R. 21 E.

Marmaton group
Fort Scott limestone
Blackjack Creek limestone member
Limestone, brownish-gray, weathers brown, earthy, massive ..... exposed 4.0±
Cherokee shale
Shale, black ..... 10.0±
Sandstone ..... exposed 4.0

(142) Near cen. sec. 35, T. 32 S., R. 18 E.

Bourbon shale
Shale, not well exposed
Coal 0.6
Hepler sandstone
Limestone, bluish-brown, sandy, massive 0-1.35
Unconformity
Marmaton group
Memorial shale (25-35 feet)
Shale, contains *Mesolobus* and *"Trachypora"* 10-15.0
Covered interval 15-20.0
Lenapah limestone

(143) SW¼ sec. 35, T. 32 S., R. 18 E.

Lenapah limestone (18-23 feet)
Idenbro limestone member
Limestone, light dove-gray, slightly crystalline, nodular; contains brachiopods ..... 5.0±
Perry Farm shale member
Shale, gray, partly covered 10.-15.0
Norfleet limestone member
Limestone, dove-gray, massive; contains abundant *Dictyoclostus* sp.; becomes hummocky mass of slabby granular

impure limestone containing plant fossils within a short distance 3.0
Nowata shale
Shale, mostly black, platy; contains dark limestone nodules in lower part ..... 5.0±
Altamont limestone
Worland limestone member
Limestone, light gray, dense ..... exposed 1.0±

(144) SW¼ SW¼ sec. 2, T. 32 S., R. 19 E.

Lenapah limestone (19 feet)
Idenbro limestone member
Limestone, gray, dense, nodular, weathers into flaky mass; contains algal remains ..... 7.0±
Perry Farm shale member
Shale, calcareous; contains many limestone nodules ..... 10.0±
Norfleet limestone member
Limestone, gray, nodular, shaly; contains *Marginifera* sp. and *Squamularia* sp. ..... 2.0±
Nowata shale
Shale, gray, calcareous ..... exposed 2.0

(145) Near cen. S line sec. 17, T. 32 S., R. 19 E.

Bourbon shale
Shale, gray; contains fragments of coal and fossil wood .... exposed 2.0
Hepler sandstone
Sandstone or sandy limestone, more calcareous and less sandy in lower part; contains "worm borings" in upper part 2.0
Unconformity
Marmaton group
Memorial shale
Shale, bluish-gray, fossiliferous ..... exposed 2.0

(146) Near cen. N line sec. 20, T. 32 S., R. 19 E.

Bourbon shale
Hepler sandstone
Sandstone, gray and brown, blocky ..... exposed 2.0±
Unconformity
Marmaton group
Memorial shale
Shale, gray ..... exposed 6.0±

(147) Near cen. W line sec. 20, T. 32 S., R. 19 E.

Bourbon shale
Hepler sandstone
Sandstone, brown, weathered ..... exposed 2.0±
Unconformity

Marmaton group
Memorial shale
Shale, gray, flaky ..... 7.0±
Lenapah limestone (6 feet exposed)
Idenbro limestone member
Limestone, gray, nodular, distinctly bedded in upper part, lower part transitional into nodular limestone and shale in unit below ..... 2.0±
Perry Farm shale member
Shale, gray; contains many limestone nodules ..... 4.0±
Covered interval, including Norfleet limestone (?) and Nowata shale 20.0±
Altamont limestone
Worland limestone member
Limestone, light gray ..... exposed 1.0±

(147a) Near SE cor. NW¼ NW¼ sec. 26, T. 32 S., R. 19 E.

Altamont limestone
Tina limestone member
Limestone, dove-gray to white; chiefly great masses of *Chaetetes* colonies, black carbonaceous films along irregular bedding surfaces; contains vugs of crystalline calcite and spare *Dictyoclostus* sp. 7.5
Bandera shale
Shale, dark gray ..... few inches exposed

(148) Near NE cor. sec. 3, T. 32 S., R. 21 E.

Fort Scott limestone
Blackjack Creek limestone member (10.5 feet exposed)
Limestone, gray, brecciated appearing; contains sparse flint, abundant small fusulines, and abundant *Chaetetes* .... exposed 6.0
Limestone, gray, crystalline; contains cup corals 4.5

(149) Near NE cor. sec. 8, T. 32 S., R. 21 E.

Fort Scott limestone (17.5 feet exposed)
Higginsville limestone member
Limestone, light dove-gray, irregular beds 0.3-0.6 foot thick; contains brachiopods ..... exposed 2.5
Little Osage shale member
Shale, black except small amount of gray in upper part, fissile 5.0
Blackjack Creek limestone member
Limestone, gray, granular; contains *Chaetetes* ..... exposed 10.0

(150) Cen. E line sec. 24, T. 32 S., R. 21 E.

Marmaton group
Fort Scott limestone (4 feet exposed)
Blackjack Creek limestone member (4 feet exposed)

Limestone, light gray, weathers lighter shade, granular to slightly crystalline ..... exposed 3.0
Limestone, brown, earthy ("Cement rock") ..... 1.0±
Cherokee shale
Shale, black, with small thickness of gray at top, fissile; contains flattened phosphatic concretions 4.0
Limestone (Breezy Hill) sandy, earthy, nodular, more sand in lower part 1.6
Shale, sandy 0.5
Sandstone, massive, and sandy shale ..... exposed 6.0

(151) SE¼ NE¼ sec. 29, T. 32 S., R. 21 E.

Marmaton group
Fort Scott limestone (4 feet exposed)
Blackjack Creek limestone member
Limestone, light gray, weathers somewhat lighter in color, granular to slightly crystalline ..... 3.0±
Limestone, brown, earthy, massive ("Cement rock") ..... 1.0±
Cherokee shale
Shale, small thickness of gray in upper part, mostly black, fissile; contains flattened phosphatic concretions 4.0
Limestone (Breezy Hill), sandy, earthy, nodular, more sand in lower part 1.6
Shale, sandy 5.0
Sandstone, massive, and sandy shale 6.0

(152) Near cen. W line sec. 1, T. 33 S., R. 18 E., along Pumpkin creek, north, below, and south of highway bridge

Lenapah limestone (10.2 feet exposed)
Idenbro limestone member
Limestone, light gray in upper part, slightly darker gray in lower part, slightly crystalline to earthy; contains *Dictyoclostus* sp. and other brachiopods ..... exposed 1.5
Perry Farm shale member
Shale and nodular limestone, gray, weathers yellow in upper part and dark gray to nearly black in lower part; upper part locally weathers as nodular limestone in shale 7.5
Norfleet limestone member
Limestone, nearly black, slabby, locally massive; locally a mass of fossil fragments, *Marginifera* sp., *Dictyoclostus* sp., and *Neospirifer* sp. 1.2
Nowata shale
Shale, not all well exposed, nearly black in part 6.0
Altamont limestone
Worland limestone member
Limestone, dove-gray, dense, small thickness exposed in creek .. 0.5
Note: Rocks here dip at relatively steep angles in several directions, probably owing to intraformational slumping.

(153) NE¼ sec. 2, T. 33 S., R. 18 E.

Lenapah limestone (5.5 feet exposed)
Idenbro limestone member
Limestone, light gray, thin uneven bedding; contains sparse flint nodules in upper part, large horn corals, organ pipe corals, crinoid fragments, and *Dictyoclostus* sp. ..... exposed 3.0
Perry Farm shale member
Shale; contains abundant limestone nodules ..... exposed 2.5

(154) Near cen. NW¼ sec. 2, T. 33 S., R. 18 E.

Bourbon shale
Limestone (upper part of Checkerboard), bluish-gray, cross-bedded, crinoidal 0.7
Shale, buff, silty 0.7
Limestone (lower part of Checkerboard), ferruginous, fossiliferous 0.2
Shale, gray; contains crinoid fragments, *Derbyia* sp., *Composita* sp., and gastropods 6.5
Coal 0.3
Shale or underclay; contains silicified wood 1.0
Hepler sandstone (2 feet)
Limestone, sandy, nodular 1.0
Sandstone, buff, calcareous; contains brachiopods 1.0
Unconformity
Marmaton group
Memorial shale
Shale, gray in upper part, dark gray in lower part; contains *Mesolobus* sp. and large productids in upper part, a thin zone packed with "*Trachypora*" *austini* about 3 feet from base, and abundant "*Aulopora*" sp. and *Lophophyllum* sp. in lower part ..... exposed 13.7

(155) Near cen. S line sec. 2, T. 33 S., R. 18 E.

Lenapah limestone (11.5 feet exposed)
Idenbro limestone member (3 feet exposed)
Limestone, dove-gray, thin irregular-bedded; contains many fossil fragments 2.0
Limestone, dove-gray, massive; upper part largely a mass of organ pipe corals 1.0
Perry Farm shale (8.5 feet exposed)
Shale and nodular limestone; contains abundant *Marginifera* sp. 4.0
Shale, dark gray, somewhat flaky; contains local thin limestone lenses, abundant gastropods, *Ambocoelia* sp., and *Mesolobus* sp. ..... exposed 4.5

Note: Large numbers of specimens of "*Trachypora*" *austini* which have been weathered from the overlying Memorial shale,

carried downstream, and deposited at the natural dam formed by the Idenbro limestone occur here.

(156) NE¼ sec. 11, T. 33 S., R. 18 E.

Bourbon shale
- Limestone (Checkerboard), cross-bedded; a coquina composed chiefly of spired gastropods 0.5
- Shale, gray and yellow, limonitic 24.0
- Coal 0.3
- Underclay 1.0
- Shale 2.0

Hepler sandstone
- Limestone, sandy 1.0

Unconformity

Marmaton group

Memorial shale (18.4 feet)
- Coal 0.2
- Shale, gray, silty; contains crinoid fragments, *Mesolobus* sp., *Chonetes* sp., and productids 14.0
- Shale, black 1.4
- Coal 0.8
- Underclay 2.0

Lenapah limestone

Idenbro limestone member
- Limestone, light gray, upper surface hummocky, slight thickness exposed in drainage

Note: The unconformity between the Marmaton and Bourbon groups (Desmoinesian-Missourian series) may be below the next coal below the Hepler sandstone.

(157) Near NW cor. sec. 21, T. 33 S., R. 18 E.

Bourbon shale
- Sandstone, brown and gray ..... exposed 3.0±

Unconformity

Marmaton group

Memorial shale
- Shale, gray and yellow, concretionary ..... 10.0±
- Shale, gray and partly black ..... 20.0±
- Coal ..... 0.3±
- Shale, black ..... 15.0±

Lenapah limestone

Idenbro limestone member
- Limestone, gray, nodular, few inches exposed

(158) NW¼ NW¼ sec. 23, T. 33 S., R. 18 E.

Lenapah limestone (7.9 feet exposed)

Idenbro limestone member (3.8 feet exposed)

Limestone, gray, slabby; contains large solitary corals .... exposed 2.0±
Limestone, light gray, irregular-bedded, massive ..... 1.8±
Perry Farm shale member (4.1 feet exposed)
Shale and nodular limestone 1.6
Limestone, dove-gray, nodular, irregular upper and lower surfaces; contains *Marginifera* sp. and fucoids 0.5
Shale and nodular limestone; contains *Marginifera* sp. and *Chonetes* sp. ..... exposed 2.0±

(159) NW¼ NW¼ and SW¼ sec. 35, T. 33 S., R. 18 E.

Lenapah limestone (12 feet exposed)
Idenbro limestone member
Limestone, light gray, weathered ..... exposed 1.0±
Perry Farm shale member
Shale, gray, and limestone nodules ranging from a fraction of an inch to several inches in diameter; brachiopods, gastropods, and pelecypods abundant 10.0
Norfleet limestone member
Limestone, dark gray, weathers brown, slabby ..... 1.0±
Nowata shale
Shale, gray and black in upper part, lower part covered 5.5
Altamont limestone (14.7 feet exposed)
Worland limestone member (12.2 feet)
Limestone, medium dark dove-gray, thin-bedded 0.33
Limestone, dove-gray, dense, semilithographic, somewhat more granular in lower part, even-bedded, massive, irregular contact with unit below 5.67
Shale, gray 0.0-0.2
Limestone, dove-gray, dense; contains brachiopods ..... 6.0±
Lake Neosho shale member (2.5 feet exposed)
Shale, bluish-gray, calcareous; contains brachiopods 0.5
Shale, black, platy ..... exposed 2.0±

(160) Near cen. W line sec. 5, T. 33 S., R. 19 E.

Altamont limestone (11 feet exposed)
Worland limestone member
Limestone, light gray, crystalline, somewhat massive .... exposed 3.0
Lake Neosho shale member
Shale, mostly covered, partly black, fissile; contains phosphatic concretions 2.0
Tina limestone member (6 feet exposed)
Limestone, mostly a mass of *Chaetetes*; contains few brachiopods 5.0
Limestone, brownish-gray, crystalline to earthy ..... exposed 1.0

(161) Near SE cor. sec. 18, T. 33 S., R. 19 E.

Lenapah limestone (3.7 feet exposed)
Idenbro limestone member

Limestone, light gray, crystalline, thin-bedded ..... exposed 1.5
Perry Farm shale member
Shale, gray and yellow, calcareous 2.0
Norfleet limestone member
Limestone, nodular 0.2
Nowata shale
Shale, gray ..... exposed 4.0±

(162) Near NE cor. SE¼ SE¼ sec. 19, T. 33 S., R. 19 E.

Altamont limestone
Tina limestone member
Limestone; large blocks of *Chaetetes* limestone, mostly covered
Limestone, brownish-gray, crystalline; contains abundant fossil fragments 1.0
Bandera shale
Shale, yellow, limonitic, blocky ..... exposed 6.0

(163) Near SW cor. sec. 3, T. 33 S., R. 20 E.

Pawnee limestone (10.2 feet exposed)
Myrick Station limestone member (5.3 feet exposed)
Limestone, dark brownish-gray, grayer in lower part, weathers brown, crystalline to slightly earthy ..... exposed 4.0
Limestone, dove-gray, crystalline, base irregular 1.2-1.3
Anna shale member (4.9 feet)
Shale, gray, calcareous; contains *Ambocoelia* sp. and crinoid fragments 1.4
Shale, black, fissile, basal part not well exposed 3.0
Limestone, dark gray, nearly black, crystalline, slabby, shaly in lower part; contains fossil fragments 0.5
Labette shale (2.7 feet exposed)
Shale, dark gray 2.0
Coal 0.2
Shale, dark gray, carbonaceous 0.5
Shale, in covered slope .....

(164) NW¼ NW¼ sec. 22, T. 33 S., R. 20 E.

Pawnee limestone (9.25 feet exposed)
Laberdie limestone member (4 feet exposed)
Limestone, weathered blocks; contains *Chaetetes* and fusulines ..... exposed 2.0±
Limestone, light gray, earthy to crystalline, hard, somewhat wavy-bedded ..... 2.0±
Mine Creek shale member
Shale, gray, flaky; contains *Hustedia* sp. and *Punctospirifer* sp 0.55
Myrick Station limestone member
Limestone, weathered to light tan, earthy; contains wavy laminations and crinoid fragments 0.25-0.5

Anna shale member (4.2 feet)
Shale, gray with black splotches, flaky 2.2
Shale, black; contains small black concretions ..... 2.0±
Labette shale
Shale, gray ..... exposed 1.0±

(165) SW¼ NW¼ sec. 16, T. 33 S., R. 21 E.

Marmaton group
Fort Scott limestone
Blackjack Creek limestone member
Limestone, covered
Limestone, gray, earthy to crystalline ..... exposed 0.4
Cherokee shale
Shale, gray 0.4
Shale, black; contains small black crystalline concretions 2.6
Shale, gray, silty 0.4
Limestone (Breezy Hill), brown and gray, nodular, irregular upper and lower surfaces ..... 1.0±
Shale, sandy 15.0
Sandstone ..... exposed 5.0±

(166) Near NE cor. sec. 23, T. 34 S., R. 17 E.

Lenapah limestone (11.7 feet exposed)
Idenbro limestone member (4.4 feet exposed)
Limestone, gray, crystalline, thinner bedded in upper part, nodular throughout but more nodular in upper part, fossiliferous 3.0
Shale, gray, fossiliferous 0.4
Limestone, medium light gray, crystalline 1.0
Perry Farm shale member (6.3 feet)
Shale and limestone nodules; contains gastropods, *Amboco-elia* sp., and *Marginifera* sp. 3.0-4.0
Limestone, dark gray, dense, hard, concretionary 0.3
Shale, calcareous 2.0
Norfleet limestone member
Limestone, dark gray, impure, slabby, grades into shale above .. 1.0
Nowata shale
Covered 18.0
Altamont limestone
Worland limestone member
Limestone, a few inches exposed in drainage.

(167) Near cen. S line sec. 26, T. 34 S., R. 17 E.

Altamont limestone (17.6 feet exposed)
Worland limestone member
Limestone, light gray, earthy to crystalline, wavy-bedded; contains sparse flint ..... exposed 4.0

Lake Neosho shale member
Shale, not well exposed, mostly black 2.0
Tina limestone member (11.6 feet)
Limestone, light gray, chiefly a mass of *Chaetetes* 4.0
Limestone, light gray, massive, pitted from weathering 2.0
Limestone, light gray; contains *Chaetetes* in upper part, brecciated in lower part 4.7
Limestone, light gray, massive; contains fusulines in upper part 0.9
Bandera shale (9.4 feet exposed)
Shale, covered 5.4
Sandstone, fine-grained, micaceous, cross-bedded, ripple-marked ..... exposed 4.0

(168) Near cen. E line sec. 5, T. 34 S., R. 18 E.

Lenapah limestone (6.2 feet exposed)
Idenbro limestone member
Limestone, dove-gray, thin wavy beds; contains abundant brachiopods ..... exposed 1.5
Perry Farm shale member (4.7 feet exposed)
Shale, gray and yellow, slightly limonitic, fossiliferous; contains limestone lenses in upper part 1.5
Limestone, nodular ..... 0.2±
Shale, gray, fissile ..... exposed 3.0

(169) Slightly east of cen. N line sec. 7, T. 34 S., R. 18 E.

Lenapah limestone (22.9 feet exposed)
Idenbro limestone member
Limestone, light dove-gray, somewhat crystalline, fossiliferous ..... exposed 1.0±
Perry Farm shale member (21.9 feet)
Shale, gray, fossiliferous; contains limestone nodules ..... 16.0±
Limestone, impure, nodular ..... 0.5±
Shale, gray, mostly covered 5.4
Norfleet limestone member
Limestone, a few inches exposed
Note: Worland limestone member of Altamont limestone is exposed in creek at low water stage.

(170) Near NE cor. sec. 20, T. 34 S., R. 18 E.

Lenapah limestone (13.5 feet exposed)
Idenbro limestone member
Limestone, light to dove-gray, holds extensive dip slope .. exposed 3.0
Perry Farm shale member
Shale; contains limestone nodules, abundant mollusks, and *Mesolobus* sp. 10.0

Norfleet limestone member
Limestone, dark gray, slabby ..... exposed 0.5
Note: Worland limestone member of Altamont limestone is exposed in drainage about 20 feet below this section.

(171) Near cen. W line sec. 23, T. 34 S., R. 18 E.

Altamont limestone (20 feet exposed)
Worland limestone member
Limestone, light dove-gray ..... exposed 2.0-3.0
Lake Neosho shale member
Shale, covered; contains abundant phosphatic concretions 2.0-3.0
Tina limestone member (14.9 feet)
Limestone, light gray, crystalline 3.0
Limestone, somewhat earthy; contains *Chaetetes* 1.2
Limestone, largely masses of *Chaetetes*; contains *Dictyoclostus* sp. 2.0
Limestone, chiefly masses of *Chaetetes* 2.5
Limestone, medium gray, crystalline; contains abundant *Chaetetes* in upper and middle parts and abundant small fusulines in lowest 2 feet 5.4
Limestone, dark gray, massive, somewhat indefinite contact with shale below 0.8
Bandera shale
Shale, gray and yellow; contains thin lenses of limestone in upper few inches and a few large limonitic concretions in lower half ..... exposed 10.0

(172) SE¼ sec. 9, T. 34 S., R. 20 E.

Marmaton group
Fort Scott limestone (28.2 feet exposed)
Higginsville limestone member (6.2 feet exposed)
Limestone, dove-gray, somewhat wavy-bedded; contains many "marklets" in upper part and echinoid fragments ..... exposed 3.7
Limestone, covered 2.0
Limestone, light gray, slightly granular 0.5
Little Osage shale member
Shale, black, fissile 4.5
Blackjack Creek limestone member (17.5 feet)
Limestone, light gray, weathers slightly buff, powdery, massive; contains fusulines 7.5
Limestone, gray, slightly darker than unit above, irregular bedding; contains sparse flint and carbonaceous streaks; irregular contact with unit above 10.0
Cherokee shale
Shale, black, a slight thickness exposed in quarry floor

(173) Near SW cor. sec. 1, T. 35 S., R. 17 E.

Lenapah limestone (6.4 feet exposed)
- Idenbro limestone member
  - Limestone, light gray; contains brachiopods ..... exposed 3.0
- Perry Farm shale member (3.4 feet exposed)
  - Shale and limestone nodules ..... 3.0±
  - Limestone, gray, concretionary ..... 0-0.4±

Nowata shale
- Shale, gray ..... exposed 6.0±

(174) Near cen. W side sec. 12, T. 35 S., R. 17 E.

Lenapah limestone (12.8 feet exposed)
- Idenbro limestone member
  - Limestone, light gray to medium dark gray, darker in lower part, deeply weathered, holds low escarpments ..... exposed 2.0
- Perry Farm shale member
  - Shale, gray, calcareous, fossiliferous, and limestone nodules; contains abundant gastropods and less abundant brachiopods 5.0
- Norfleet limestone member (5.8 feet exposed)
  - Shale and impure limestone, dark gray 1.7
  - Limestone, impure 0.3
  - Shale and impure limestone, bluish-gray 1.9
  - Limestone, tan, impure, massive 1.9

Nowata shale
- Shale, dark bluish-gray, blocky ..... exposed 3.0

(175) Near SE cor. sec. 11, T. 35 S., R. 18 E.

Altamont limestone
- Tina limestone member
  - Limestone, gray, weathers brown 1.5
- Bandera shale (8.55 feet exposed)
  - Shale, gray, calcareous in upper part 3.5
  - Coal ..... 0.05±
  - Shale, gray and yellow ..... 5.0 ±

(176) SW¼ SE¼ sec. 12, T. 35 S., R. 18 E.

Altamont limestone (18 feet exposed)
- Tina limestone member
  - Limestone, light gray; contains abundant *Chaetetes* ..... exposed 15.0±
  - Limestone, dark gray, weathers tan ..... 3.0±

Bandera shale (37 feet exposed)

Shale, gray and yellow, somewhat sandy throughout, sandier in lower part ..... 34.0±
Sandstone, massive ..... exposed 3.0±

(177) SW¼ SW¼ sec. 5, T. 35 S., R. 20 E.

Fort Scott limestone (11 feet exposed)
Higginsville limestone member
Limestone, gray, lighter than unit below, thin irregular beds; contains veinlets of calcite ..... exposed 5.0
Limestone, dove to dark gray, brecciated appearing, dense to crystalline, slightly wavy-bedded, carbonaceous film at bedding contacts, in four beds; contains brachiopods and crinoid stems 6.0
Note: Black shale in the Little Osage member is exposed in creek.

Stratigraphic Sections in Montgomery County, Kansas (178 and 179)

(178) NW¼ sec. 12, T. 35 S., R. 16 E.

Lenapah limestone (13 feet exposed)
Idenbro limestone member
Limestone, light gray, blotched with brown, brecciated appearance, massive, top uneven; contains few fossils, large fucoids at base, large cyathophylloid corals, "*Aulopora*" sp., *Zaphrentis* sp., *Prismopora* sp., *Chonetes* sp., *Mesolobus* sp., *Squamularia* sp., and *Echinoconchus semipunctatus* ..... exposed 7.0
Perry Farm shale member (6.0 feet)
Shale, abundant *Marginifera* sp. 2.0
Shale and limestone nodules 4.0
Nowata shale
Shale, dark gray, a few lenses and beds of tan sandstone ..... exposed 24.0

(179) NW¼ sec. 10, T. 35 S., R. 17 E.

Lenapah limestone
Idenbro limestone member
Limestone, poorly exposed
Perry Farm shale member
Shale and limestone nodules ..... exposed 4.0±
Nowata shale
Covered interval; may conceal part of Perry Farm shale and Norfleet limestone members of Lenapah limestone ..... 10.0±
Sandstone (Walter Johnson), tan, fine-grained, micaceous, distinctly bedded ..... 5.0±
Shale, gray and yellow ..... exposed 4.0±

Stratigraphic Sections in Missouri (180-185)

(180) SW¼ sec. 33, T. 40 N., R. 33 W., Bates county

Memorial shale
Shale, yellow ..... exposed 6.0±
Lenapah limestone (5.1 feet)
Idenbro limestone member (0.75 feet)
Limestone, blue to dark gray, carbonaceous, granular to earthy, slabby; contains horn corals 0.25
Limestone, blue to dark gray, carbonaceous, granular and earthy to dense; contains limonitic inclusions 0.50
Perry Farm shale member (3.9 feet)
Shale, yellow and gray; contains *Trepospira* sp., horn corals, and chonetids 0.66
Shale, nearly black; contains calcareous and limestone nodules and brachiopods in upper part 1.79
Shale, nearly black, somewhat fissile; contains limestone nodules in upper part 1.45
Norfleet limestone member
Limestone, dark bluish-gray, sandy, dense 0.45
Nowata shale (8.4 feet)
Shale, dark gray, nearly black, somewhat fissile; contains scattered phosphatic zones, abundant large productids, *Mesolobus*, other chonetids, and horn corals 6.9
Shale, light yellow and gray to green 1.5
Altamont limestone (11.11 feet)
Worland limestone member
Limestone, bright bluish-gray, weathers rusty brown, two massive beds, irregular fracture, irregular upper surface; contains fusulines, crinoid and brachiopod fragments 3.66
Lake Neosho shale member
Shale, not well exposed, upper part light gray; contains many phosphatic nodules ..... 2.0±
Tina limestone member (5.45 feet)
Limestone, salt and pepper gray, "oatmeal" rock; contains brachiopods and algae in upper part, few crinoid fragments, and ostracodes 0.85
Shale, greenish-gray, thin-bedded; contains small limestone nodules 0.45-0.5
Limestone, bluish-gray to slightly green, dense to finely crystalline; contains nodules up to 3 inches in diameter 2.15
Shale and limestone nodules 0.45
Limestone, dark to greenish-gray, dense, nodular; contains many brachiopods and large derbyoids 1.5
Bandera shale
Shale, yellow and gray ..... exposed 4.5

(181) SW¼ NW¼ sec. 29, T. 43 N., R. 29 W., Cass county

Pawnee limestone (6.33 feet exposed)
- Myrick Station limestone member
  - Limestone, gray, massive ..... 3.0±
- Anna shale member (3.33 feet)
  - Shale, gray 1.5
  - Shale, black, platy; contains small black concretions 1.0
  - Shale, gray, limy near top 0.5
  - Limestone, dark gray, nearly black, earthy 0.33

Labette shale (16.05 feet exposed)
- Shale, gray ..... 5.0±
- Limestone; contains concretions or nodular lenses 0.0-0.25
- Shale, gray; contains abundant *Mesolobus* sp. and a few other fossils 1.6
- Limestone, tan to gray, dense, hard 0.6
- Shale, gray 0.8
- Shale, black 1.1
- Coal 0.1-0.2
- Underclay 0.5
- Shale, clay ..... exposed 6.0

Note: Underclay and overlying beds, assigned to the Labette shale, belong in the Pawnee megacyclothem.

(181a) NW¼ SW¼ sec. 21, T. 43 N., R. 31 W., Cass county

Bourbon shale
- Hepler sandstone
  - Sandstone, gray and yellowish-brown, fine-grained, cross-bedded, definite contact along sides and base of channels cut into Memorial shale ..... exposed 7.0±

Marmaton group
- Memorial shale (8.15 feet)
  - Shale, gray and yellow, some maroon, blocky, very slick; contains limonitic concretions near contact with Hepler sandstone 1.33-6.0
  - Shale, nearly black, slightly silty, weathers somewhat flaky 2.15
- Lenapah limestone (5.8 feet)
  - Idenbro limestone member
    - Limestone, dark gray to nearly black, weathers yellowish, earthy, locally a continuous ledge, usually lenses; locally a featheredge to 0.9 foot in 1.5 feet lateral distance 0-0.9
  - Perry Farm shale member (4.35 feet)
    - Shale, nearly black, blocky, weathers into steep flake-covered slope; upper 0.66 foot bears *Trepospira* sp., pelecypods, and chonetids 2.25
    - Shale, black, paper-thin laminae, appears platy, very resistant to weathering; contains scattered small pyrite crystals, small smooth phosphatic concretions, and sparse brachiopods (chiefly orbiculoids). 2.1

Norfleet limestone member
Limestone, shiny black, weathers rusty brown, fine-grained, mostly large flat concretions, locally continuous bed for 6 feet or more; masses of dark cone-in-cone between and overlying concretions; contains large cephalopods 0-0.55
Nowata shale (7.56 feet exposed)
Sandstone, gray, weathers brown, fine-grained, pyritiferous, carbonaceous, micaceous 1.5
Shale, dark gray, laminated; contains thin lenses of pyritiferous fine-grained sandstone 0.8
Siltstone and fine sandstone, gray and brown, shaly; contains cone-in-cone sandstone lenses in upper few inches 0.95
Sandstone and shale, gray, micaceous; chiefly shale in upper part, fine-grained sandstone in lower part 0.75
Shale, gray, limy, silty, carbonaceous, crinkled; bed of fine-grained micaceous sandstone in upper 1.6 feet; contains abundant casts of plant fragments 2.15
Sandstone, gray, weathers brown, fine-grained, micaceous, massive 0.25
Shale, medium dark gray, weathers light bluish-gray, slightly micaceous; contains sparse hard sandy layers 0.66
Shale, dark gray, silty, micaceous, ripple-marked; contains small casts of plant fragments
....exposed above water of Grand river 0.5

(182) Near cen. W line NE¼ sec. 6, T. 44 N., R. 29 W., Cass county

Altamont limestone (3.66 feet exposed)
Lake Neosho shale member
Shale, gray ..... exposed 2.0±
Tina limestone member
Limestone, gray, dense; contains algal (?) pellets in earthy matrix 1.66
Bandera shale (23.8 feet)
Shale, gray and maroon ..... 3.0±
Shale, yellow and gray; contains limestone nodules in lower part 5.4
Shale, gray 5.4
Covered interval ..... 10.0±
Pawnee limestone (12.16 feet exposed)
Laberdie limestone member
Limestone, light gray, weathers slightly brown; contains few *Chaetetes* and abundant echinoid remains ..... exposed 5.0
Mine Creek shale member, covered 10.0
Myrick Station limestone member
Limestone, medium gray, weathers brown; contains numerous brachiopods in upper part and *Chaetetes* 3.66
Anna shale member (3.5 feet)
Covered interval 3.0

Shale, black ..... exposed 0.5

Note: Thickness of the Bandera shale may be incorrect because the lower part was measured over some distance and possible dip of beds was disregarded.

(183) Near cen. E line sec. 11, T. 44 N., R. 30 W., Cass county

Bourbon shale (?)
Hepler sandstone (?)
Sandstone fragments
Marmaton group
Memorial shale
Covered interval ..... 20.0±
Lenapah limestone (3 feet)
Idenbro limestone member
Limestone, gray, earthy 1.0
Perry Farm shale member
Shale, gray, black in middle part 2.0
Nowata shale
Shale, gray and yellow, limonitic ..... exposed 3.0

(184) Near cen. W line sec. 31, T. 46 N., R. 25 W., Johnson county

Marmaton group
Fort Scott limestone (32.6 feet)
Higginsville limestone member
Limestone, gray, crystalline, thin wavy beds in middle part, more massive in upper and lower parts; contains *Chaetetes* in upper part 12.0
Little Osage shale member (16.5 feet)
Shale, gray, calcareous; contains cup corals ..... exposed 0.5
Covered interval with Houx limestone, 1 foot thick, 4 feet from top (drill record) ..... 13.0±
Shale, gray, calcareous, nodular; contains few fossils ..... 3.0±
Blackjack Creek limestone member
Limestone, brown, earthy to slightly crystalline, one bed 4.1
Cherokee shale
Shale, gray, darker in lower part, flaky 2.0
Shale, black 1.25
Shale, gray 0.1
Coal 0.05
Covered slope .....

(185) NE cor. sec. 27, T. 46 N., R. 28 W., Johnson county

Pawnee limestone (18.2 feet exposed)
Laberdie limestone member
Limestone, light gray, massive; contains *Chaetetes* throughout, more abundant in upper part ..... exposed 4.0

Mine Creek shale member (13.5 feet)
- Shale and limestone, indefinite base 1.35
- Shale, gray, fossiliferous in upper part, sandy in lower part 4.5
- Sandstone, gray, weathers brown 0.65
- Shale, dark gray, carbonaceous, thin-bedded, micaceous in upper part 7.0

Myrick Station limestone member
- Limestone, dove-gray, finely crystalline, irregular beds ..... exposed 0.7

Stratigraphic Sections in Oklahoma (186-203)

(186) Near cen. S line sec. 11, T. 21 N., R. 15 E., Rogers county

Marmaton group

Fort Scott limestone (22.53 feet)

Higginsville limestone member (7.75 feet exposed)
- Limestone, light dove-gray, brecciated appearance; contains *Composita* sp. and *Squamularia* sp. ..... 3.0±
- Limestone, light dove-gray, more massive beds than unit above; contains *Composita* sp. and *Squamularia* sp. 4.75

Little Osage shale member (5 feet)
- Shale, gray 0.5
- Shale, black, fissile ..... 4.5±

Blackjack Creek limestone member (9.78 feet)
- Limestone, gray and yellow, soft, slabby 0.33
- Limestone, dove-gray, dense, wavy-bedded, massive; contains sparse flint nodules, fusulines, and *Rhombopora* sp. 4.8
- Limestone, light gray, granular to earthy, massive; contains brachiopods 1.45
- Limestone, gray, granular to earthy, three massive beds; contains few brachiopods and crinoid fragments 3.2

Cherokee shale
- Shale, yellow 1.1
- Coal 1.66
- Underclay ..... 1.0±

(187) Near cen. N line sec. 31, and NW cor. sec. 29, T. 20 N., R. 15 E., Rogers county

Marmaton group

Labette shale
- Shale, black, platy ..... exposed 6.0±

Fort Scott limestone (19.35 feet)

Higginsville limestone member
- Limestone, dark bluish-gray in upper part, lighter near base, granular; contains "cryptozoans" 5.4

Little Osage shale member (6.95 feet)
- Shale, gray, clay 0.3

Shale, black, fissile; contains phosphatic concretions	2.15
Limestone (Houx?), dark blue, dense, conchoidal fracture; contains sparse brachiopods	1.5
Shale, gray, clay	3.0
Blackjack Creek limestone member	
Limestone, brown to bluish-gray, somewhat earthy, massive but distinctly bedded; contains chonetids and *Neospirifer* sp.	7.0
Cherokee shale	
Shale and coal, thin alternating beds; contains varves	0.33
Coal	1.15
Coal and shale, thin alternating beds; contains varves	0.66
Shale and sandstone, somewhat massive sandstone in lower part	5.0±
Covered interval	2.0±
Limestone (Breezy Hill?), dark bluish-gray, slabby; contains productids	2.0±
Shale, gray, partly covered ..... exposed	5.0±

(188) SE cor. sec. 36, T. 23 N., R. 16 E., Rogers county

Marmaton group	
Fort Scott limestone	
Higginsville limestone member (8 feet)	
Limestone, covered	2.0±
Limestone, light to medium dark gray, finely crystalline; contains *Composita* sp.	6.0±
Little Osage shale member	
Shale, black, fissile	3.0±
Blackjack Creek limestone member	
Limestone, light dove-gray, weathers lighter in color; contains productids and fusulines in upper part, cephalopods and gastropods in lower part	5.4
Cherokee shale	
Shale, gray, clay, poorly exposed	2.5
Coal	1.0±
Shale, light gray and yellow, limonitic, and sandstone, blue-gray	17.0
Shale, gray and yellow, limonitic, sandy	5.4
Sandstone, massive in upper part, and shale, sandy in lower part	4.4
Sandstone, brown, fine-grained, massive	2.0±
Partly covered interval, little gray shale exposed	12.0±
Limestone (Breezy Hill?), dark bluish-gray, weathers tan, massive	3.0±
Covered interval	1.0
Shale, black; contains phosphatic nodules	1.5
Limestone and shale, fossiliferous	0.1
Shale, light yellow and gray ..... exposed	5.0±

(189) SE¼ SE¼ sec. 17, T. 24 N., R. 16 E., Rogers county

Pawnee limestone (10.81 feet exposed)
- Myrick Station limestone member
  - Limestone, dove-gray ..... exposed 2.0±
- Anna shale member (8.81 feet)
  - Shale, black; contains phosphatic concretions ..... 2.0±
  - Limestone, poorly exposed ..... 0.3±
  - Covered ..... 1.0±
  - Limestone, dark gray, algal and crinoidal 0.85
  - Limestone, dark dove-gray, weathers brown, granular, slightly cross-bedded 1.0-2.0
  - Shale, gray 0.66
  - Limestone, dove-gray, weathers brown, granular, massive; contains large crinoid fragments and *Composita* sp. 1.25
  - Shale, sandy 0.5
  - Limestone, sandy 0.25

Labette shale
- Shale and sandstone ..... exposed 40.0

(190) SW cor. sec. 30, T. 24 N., R. 16 E., Rogers county

Pawnee limestone (9.6 feet)
- Laberdie limestone member
  - Limestone, medium to dark bluish-gray, brecciated ..... exposed 3.0
- Mine Creek shale member (1 foot)
  - Shale, with limestone nodules 0.55
  - Limestone 0.25
  - Shale, limy 0.2
- Myrick Station limestone member
  - Limestone, gray to brown, massive ..... 1.3±
- Anna shale member (4.3 feet)
  - Shale, gray in upper part, mostly black; contains phosphatic nodules 1.75
  - Limestone, dark gray 0.3
  - Shale, gray and yellow 0.35
  - Limestone, dark in upper part, medium gray in lower, slabby, granular, crystalline, irregular beds, nodular in upper part 1.9

Labette shale (40.4 feet exposed)
- Shale, gray, sandy 7.4
- Shale, gray ..... 3.0±
- Sandstone ..... 30.0±

(191) East of cen. N line sec. 20, T. 24 N., R. 17 E., Rogers county

Cherokee shale
- Sandstone, brown, medium to fine-grained 5.0
- Shale, gray, sandy 6.0
- Coal, very thin beds, alternating with thin beds of sandstone, light gray, fine-grained; contains varves 2.5

Sandstone	2.15
Sandstone and sandy shale	3.0
Coal, very thin beds, alternating with thin beds of sandstone, light gray, fine grained; contains varves	1.9
Coal, impure	0.15
Shale, dark, silty	4.5
Shale, dark, carbonaceous, partly covered	4.5
Limestone (Breezy Hill?) dark dove-gray, semilithographic, nodular in upper part	3.0±
Shale, black, fissile	2.5±
Shale, light yellow and gray, limonitic ....exposed	5.0±

(192) Near cen. S line sec. 26, T. 26 N., R. 16 E., Nowata county

Pawnee limestone

Limestone, basal part of Anna shale member, poorly exposed

Labette shale

Shale, yellow and gray, micaceous, slightly silty; contains limonitic concretions	21.6
Shale, yellow and gray, silty and sandy; grades into shaly sandstone in lower part	16.0
Shale, gray, blocky, limonitic, slightly micaceous; contains sandstone lenses in upper part	5.4
Shale, gray, blocky, slightly micaceous	10.8

(193) NW cor. sec. 35, T. 26 N., R. 16 E., Nowata county

Pawnee limestone (26.07 feet)

Laberdie limestone member (12.15 feet)

Limestone, light gray, weathers slightly tan, semilithographic in upper part, grades into crystalline brecciated facies below	6.0
Limestone, light gray, crystalline, brecciated, wavy-bedded; contains silicified fossils and *Cystauletes mammilosus*	4.0±
Limestone, crystalline, wavy-bedded	2.15

Mine Creek shale member

Shale, yellow and gray, flaky; contains crinoid remains	0.45

Myrick Station limestone member (4.57 feet)

Limestone, light dove-gray, granular	0.33
Limestone, dove-gray, slightly crystalline, massive; contains few crinoid remains	1.33
Limestone, bluish-gray, dense to slightly crystalline; contains brachiopods and crinoid remains	1.66
Limestone, dove-gray, dense to slightly crystalline; contains gastropods, crinoid remains, and *Hustedia* sp.	1.25

Anna shale member (8.9 feet)

Shale, mostly gray, some black, flaky	0.8
Shale, black, slightly fissile; contains few smooth black concretions	2.5
Shale, gray, silty	0.5

Limestone, dark gray, slabby; contains plant fossils 0.3-0.4
Shale, black, platy to fissile 0.1
Limestone, dark gray 0.6
Shale, gray, calcareous 1.0
Limestone, light to dark gray, earthy to locally crystalline; contains fusulines near base and productids 3.0
Labette shale
Shale, gray ..... exposed 6.0±

(194) Slightly south of cen. N. line sec. 6, T. 26 N., R. 17 E., Nowata county

Pawnee limestone (31.01 feet)
Laberdie limestone member (18 feet)
Limestone, light gray, weathered, slumped ..... 15.0±
Limestone, light gray, crystalline; contains crinoid remains and other fossils 3.0
Myrick Station limestone member
Limestone, ashy gray in upper part, yellowish-gray in lower part, granular to nearly dense, more massive in lower part 2.5
Anna shale member (10.51 feet)
Shale, black, mostly fissile; contains small smooth black concretions ..... 3.0±
Limestone, bluish-gray; contains gastropods, pelecypods, and brachiopods 1.0-1.33
Shale, light gray, flaky 3.33
Sandstone, gray, micaceous, medium fine-grained 2.0
Limestone, gray, finely crystalline; contains fossil fragments and abundant *"Osagia"* 0.85
Bandera shale
Shale, not well exposed ..... exposed 4.0

(195) SW¼ sec. 6, T. 26 N., R. 17 E., Nowata county

Pawnee limestone (14.91 feet)
Anna shale member
Covered; contains small phosphatic concretions ..... exposed 3.0±
Limestone, dark bluish-gray, granular; contains large bellerophontids, *Neospirifer* sp., and *Composita* sp. 1.33
Shale, sandy, micaceous, and sandstone, nearly white in middle part 2.25
Sandstone, calcareous 1.33
Shale, gray, sandy 1.9
Sandstone, slightly cross-bedded 0.33-0.5
Shale, blocky, micaceous 2.5
Limestone, gray, granular, in four beds, thin shale partings along bedding places; contains crinoid stems and *Composita* sp. 2.1

Labette shale (22 feet exposed)
- Shale, gray, calcareous, fossiliferous 0.75
- Sandstone, thin-bedded 1.25
- Shale, gray and yellow, blocky, slightly micaceous; grades into sandstone above ..... exposed 20.0

(196) SW¼ sec. 29, T. 26 N., R. 17 E., Nowata county

Pawnee limestone (14.05 feet)
- Myrick Station limestone member
  - Limestone, light gray, crystalline, and brecciated in upper part; brown, crystalline in lower part 2.0-3.0
- Anna shale member (11.05 feet)
  - Shale, yellow and gray; contains small limestone nodules 3.0
  - Shale, black, fissile; contains small phosphatic concretions 1.85
  - Limestone, slabby, crinoidal; contains brachiopods 0.55
  - Limestone, medium dark gray, granular, semi-oölitic, nodular in lower part, irregular base; contains few brachiopods in upper part 2.5
  - Shale, light bluish-gray, slightly carbonaceous, blocky; contains limestone nodules in upper part 2.0
  - Limestone, brown, massive, sandy 1.15

Labette shale (24.1 feet exposed)
- Sandstone, limy ..... 1.05±
- Sandstone, medium to fine-grained, cross-bedded in upper part 11.25
- Shale, medium dark gray in upper part, light gray in lower part, flaky, sandy in upper part, grades into unit above ....exposed 11.8

(197) Near cen. N line NE¼ NW¼ sec. 33, T. 26 N., R. 17 E., Nowata county

Pawnee limestone
- Anna shale member
  - Limestone, bluish-gray, sandy ..... exposed 1.0±

Labette shale (91.77 feet)
- Shale, light gray, blocky, flaky; contains sparse limestone nodules 5.0
- Limestone, brown, earthy 0.66
- Sandstone, gray and yellow, thin-bedded 3.33
- Shale, sandy, gray, darker and less sandy in lower part 16.0
- Shale, gray, limonitic 10.8
- Covered interval 5.4
- Limestone, medium dark gray, somewhat crystalline, wavy-bedded 3.0
- Shale and limestone 0.5
- Limestone, gray, massive 0.75
- Shale, yellow and gray, sandy in lower part 3.33
- Sandstone and sandy shale 43.0

(198) NE cor. sec. 36, T. 26 N., R. 13 E., Craig county

Marmaton group
- Fort Scott limestone
  - Blackjack Creek limestone member
    - Limestone, brown, massive
- Cherokee shale
  - Shale, gray, partly covered — 4.0±
  - Coal — 1.0
  - Shale, gray, limonitic, silty in lower part — 10.8
  - Coal — 0.55
  - Shale, sandy, and coal; paper-thin beds — 0.66
  - Shale, gray, limonitic — 10.15
  - Sandstone, fine-grained — 2.0±
  - Shale, medium gray, silty in upper part — 4.9
  - Shale, dark gray, blocky — 5.4
  - Limestone (Breezy Hill?), gray to brown, granular to crystalline; contains flint nodules in upper part and fusulines — 4.33
  - Shale, black; contains phosphatic nodules — 2.2
  - Shale, gray to blue, silty — exposed 10.0

(199) Near cen. sec. 4, T. 27 N., R. 16 E., Nowata county

Lenapah limestone (12 feet exposed)
- Perry Farm shale member
  - Limestone, nodular, cancellous — exposed 4.0±
- Norfleet limestone member
  - Limestone, yellowish-gray, sandy appearing, hard, dense — 8.0

Nowata shale
- Shale, yellow, clayey — 14.0

Note: Limestone in the upper part of this section is assigned to the Perry Farm shale member because it is a limestone facies of the member, which in Kansas is chiefly calcareous shale.

(200) Slightly east of cen. W line E½ SE¼ sec. 30, T. 28 N., R. 16 E., Nowata county

Lenapah limestone (18.01 feet exposed)
- Idenbro limestone member (5.26 feet exposed)
  - Limestone, gray, weathers bluish-tan, slightly crystalline, somewhat porous, massive to thin wavy-bedded — exposed 3.5±
  - Shale, gray — 0.1±
  - Limestone, light gray, dense to slightly granular, algal; contains few brachiopods — 1.66
- Perry Farm shale member (12.75 feet exposed)
  - Shale, greenish-gray; contains nodules of limestone in upper part and abundant *Marginifera* sp. — 0.75
  - Limestone, dense, mottled, apparently nonfossiliferous — exposed 12.0

Note: Limestone in the lower part of this section is assigned to the Perry Farm shale member because it is a limestone facies of the member, which in Kansas is chiefly calcareous shale.

(201) Slightly east of cen. N line NW¼ sec. 24, T. 28 N., R. 17 E., Nowata county

Altamont limestone (25.9 feet)
Tina limestone member
Limestone, light gray; contains *"Osagia"* and *Chaetetes*, partly silicified ..... exposed 2.0
Limestone, light gray, dense, thinner bedded in upper part; contains sparse dark steel-gray flint and *Squamularia* sp. 22.0±
Limestone, dark bluish-gray, crystalline; contains horn corals, few *Cryptozoon*, and echinoid fragments 1.9
Bandera shale (13.85 feet exposed)
Shale, carbonaceous, blocky and laminated ..... 0.2±
Shale, nearly black, silty 3.15
Sandstone, gray, hard 0.5
Sandstone, bluish-gray, fine 5.0
Shale, gray and yellow, blocky ..... exposed 5.0

(202) Near cen. W line sec. 36, T. 28 N., R. 19 E., Craig county

Marmaton group
Fort Scott limestone (17.45 feet)
Higginsville limestone member
Limestone, gray, crystalline, irregularly bedded ..... 5.5±
Little Osage shale member (8.8 feet)
Shale, nearly black ..... 2.0±
Limestone (Houx?), dark brown, earthy 0.75
Shale, black, platy; contains scattered limestone concretions 6.05
Blackjack Creek limestone member
Limestone, brown, earthy, massive 3.15
Cherokee shale
Shale, gray; contains limonitic concretions 5.5
Limestone (Breezy Hill?), dark gray, crinoidal 0.0-0.75
Covered interval 0.5
Coal 1.0
Shale, gray, limonitic 0.66
Sandstone, brown, massive 2.1
Shale, gray, limonitic ..... 5.0±
Coal 0.5
Shale, gray, limonitic ..... 5.0±
Sandstone ..... 0.8±
Shale, gray, limonitic ..... exposed 4.0

(203) SE¼ sec. 27, T. 29 N., R. 18 E., Craig county

Pawnee limestone (14.18 feet)
Myrick Station limestone member
Limestone, massive, weathers brown ..... exposed 4.0±
Anna shale member (10.18 feet)
Shale, gray 0.5

Shale, mostly covered, silty limestone in upper part	1.0±
Shale, black, platy; contains phosphatic nodules	3.0±
Shale, black, fissile	2.25
Coal (Lexington)	0.1
Shale, dark gray	1.5
Shale, gray	1.5±
Limestone, dark gray, earthy, nodular	0.25-0.33

Labette shale

Shale, gray exposed	2.0±

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