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Stratigraphy, sedimentation and structure of the upper Cherokee and lower Marmaton (Pennsylvanian) rocks of Bates County, and portions of Henry and Vernon Counties, Missouri

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STRATIGRAPHY, SEDIMENTATION AND STRUCTURE OF THE UPPER CHEROKEE AND LOWER MARMATON (PENNSYLVANIAN) ROCKS OF BATES COUNTY, AND PORTIONS OF HENRY AND VERNON COUNTIES, MISSOURI

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Kurzfassung

Die Formationen der obercherokeen und untermarmatonen Gruppen (Pennsylvanian System) in Kreis Bates und in Teilen der Kreise Vernon und Henry, Missouri, sind hier ausführlich beschrieben. Die Untersuchung schliesst ein jenen Teil des angesteztes Gebietes das von Kansas-Missouri Grenze östlich zu dem Kreis Henry, Missouri, bis auf einen Abstand von ungefähr 72,5 Kilometer hinreicht.

Diese Pennsylvanian Schichten kommen in zyklischen Folgen oder "cyclothems" vor und bestehen aus verhältnismassig dünnen Schichten von Kalkstein, Tonschiefer, Sandstein und etwas Kohle, Unterton und Konglomerat. Die meisten Geologen betrachten die Mehrheit der Schichten, besonders die Kalksteine, die Kohle, die Untertone und einige der Tonschiefer, als weitverbreitete Ablagerungen, die in "Mid-Continent" und in "Eastern Interior" der Vereinigten Staaten vorkommen. Jedoch einige bedeutende zyklische Schichten in westlichen Missouri sind abwesend. Andere Ablagerungen sind durch seitlichen Abänderungen der Lithologie und Machtigkeit charakterisiert.

Der Verfasser schlägt vor dass der ungleichförmige Boden des damaligen Sees durch Anschwemmung die Ablagerungen geändert und so die Lithologie and die Machtigkeit der Lagerung beeinflusst hat.

Die geologische Kartierung hat mehrere nordwestlich streichende Strukturen konstatiert. Die bedeutendeste Struktur ist als die "Schell City-Rich Hill" Schwelle bezeichnet worden. Bedeutende Änderungen des physikalischen Karakters von einigen Ablagerungen in der Nähe der Struktur sind erörtert und ausführlich diskutiert. Der Verfasser schlägt vor das die Schell City-Rich Hill Schwelle während der pennsylvanianischen Periode am wenigsten sich in Bewegung gesetzt hat und diese Bewegung die Anschwemmung der Sedimente beeinflusst hat.

Verschiedene Paläosedimentologische Karten, die die Paläogeographie des Gebeites während der Anschwemmung der Formation Verdigris und einen Teil der Bandera und Altamont Formationen erläutern, sind hier eingeschlossen.

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INTRODUCTION

Purpose of Investigation

The major purpose of this dissertation is to describe in detail the stratigraphy of the upper Cherokee and lower Marmaton groups of the Middle Pennsylvanian, Desmoinesian Series in a portion of western Missouri.

The stratigraphy of the upper Cherokee and lower Marmaton groups in areas of Kansas west of the project area has been studied by several workers. The most recent contributions have been by Jewett in 1941 and 1945, and by Howe in 1956.

Detailed geological mapping also has been completed under the direction of the Missouri Geological Survey in areas to the east of the project area. Most of the work in this area has been in Henry and Johnson Counties and was done by students from the State Universities of Iowa and Missouri (Henderson, 1956; Smart, 1957; Hover, 1958; Carver, 1959; and Kinsley, 1960).

By comparison, very little detailed stratigraphic work has been done in the intervening area of western Missouri where this study is centered.

Minor objectives in the order of decreasing importance are (1) to correlate units across the area (2) to describe briefly the major structural features (3) to attempt to determine to what degree, if any, structure has affected sedimentation. This investigation may serve as an example of the feasibility of combining three somewhat complimentary approaches to the study of Pennsylvanian strata -

stratigraphy, sedimentation and structure.

Location and Extent of the Area

Rocks belonging to the upper Cherokee and lower Marmaton groups are exposed in a belt which crosses western Missouri in a northeast-southwest direction. The outcrop belt of these rocks ranges in width from 15 to 20 miles. That portion of the belt from the Kansas-Missouri line to a few miles east of the Bates - Henry County line, an outcrop distance of 45 miles, will be discussed in this report (Figure 1). It includes most of Bates County, northwestern Vernon County and a small portion of western Henry County. This region will be called the Bates County area in this dissertation.

Method of Study

This investigation is primarily a study of outcrops and artificial exposures in coal strip mines. Subsurface data was used to a lesser extent particularly where cores were made available by the construction of a complex system of Minuteman missile sites by the United States Air Force.

The area was geologically mapped on a formational basis using 7½ minute topographic maps as a base. This information was transferred to a map scale of 1 inch = 1 mile (Plate 1).

The major part of the field work was done during the summers of 1960 and 1961, but field work was begun in May, 1960 and carried on intermittently until its completion in November, 1963.

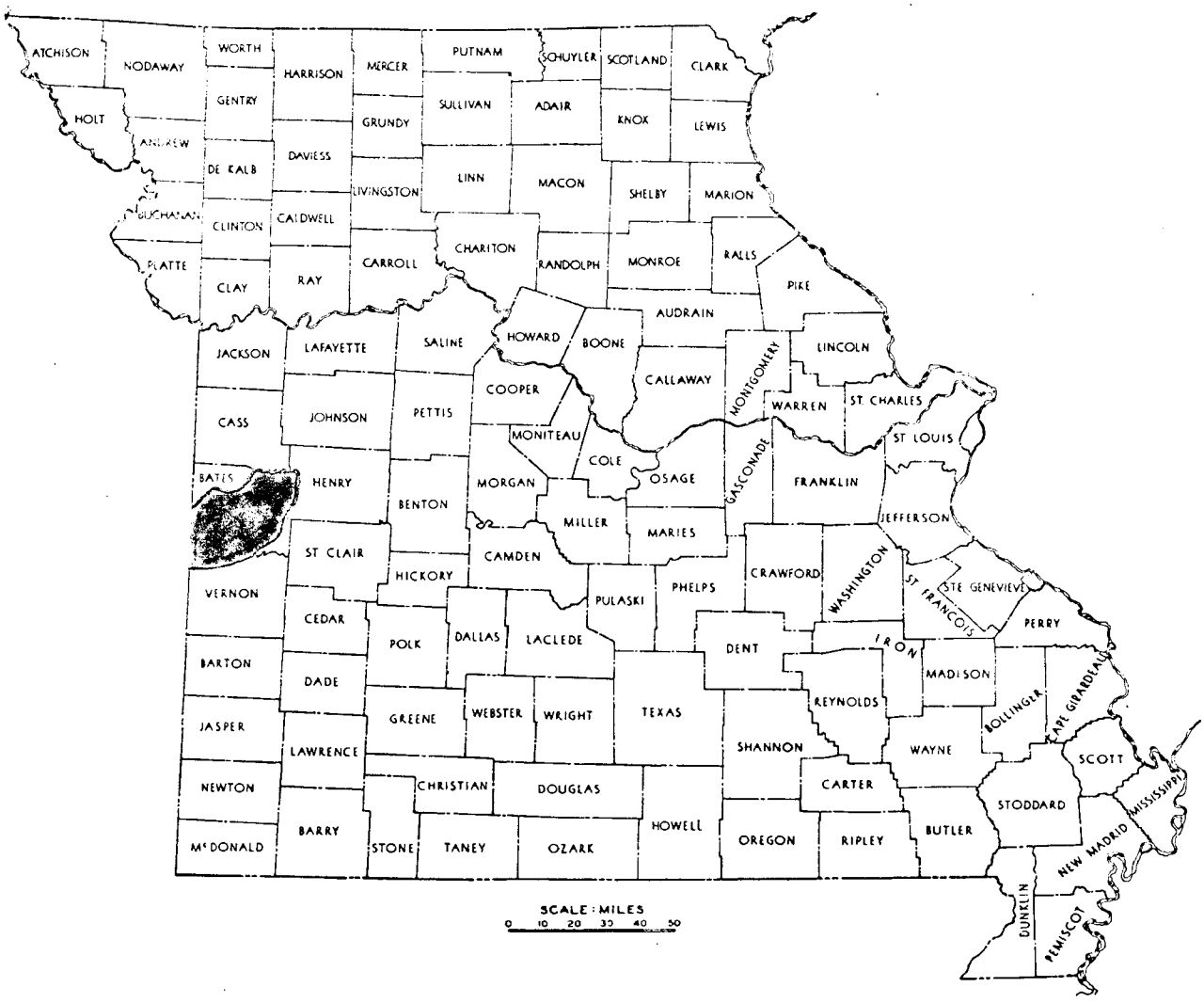

Figure 1. Index map of Missouri. Location of project area shown by shading.

ACKNOWLEDGMENTS

The writer is indebted to numerous individuals and organizations whose help guidance and understanding has made possible this dissertation.

Dr. Alfred C. Spreng, Professor of Geology at the University of Missouri at Rolla served as major adviser. He supervised the field work and the writing of the manuscript.

Dr. A. G. Unklesbay, Chairman of the Department of Geology, University of Missouri at Columbia critically read the manuscript and offered many helpful suggestions.

Special thanks are owed to Dr. Spreng and to Dr. Unklesbay, for teaching me the basic principles and the modern concepts of stratigraphy. The reader will notice that many of the stratigraphic concepts taught in their classrooms are incorporated in this dissertation. Their help and guidance is herewith acknowledged and appreciated.

Dr. D. L. Frizzell, Professor of Geology, University of Missouri at Rolla is acknowledged for his help in solving problems concerning zoological nomenclature.

Dr. Walter V. Searight, Principal Geologist of the Missouri Geological Survey and Water Resources, suggested the project area and visited the writer in the field. Dr. Wallace B. Howe also of the Survey gave freely and generously the knowledge that he possessed concerning the project area.

I am deeply indebted to Professor Thomas R. Beveridge, former

Director of the Missouri Geological Survey and Water Resources and to Dr. William C. Hayes, the present Director, for providing the financial assistance and for making available the personnel and facilities of the Survey. I am especially grateful to Douglas R. Stark for drafting the illustrations and to Glenda Otis for typing the manuscript.

Also acknowledged are the numerous people of western Missouri who allowed the writer access to mining operations or rock outcrops on their property.

I also wish to thank the United States Air Force for permitting me to study the excavations during construction of Minuteman missile sites and for releasing to the Missouri Geological Survey and Water Resources the test cores drilled at these sites. The information obtained from a study of these cores has proved invaluable.

PREVIOUS WORK

The earliest systematized geological reconnaissance of western Missouri was completed in 1873 by G. C. Broadhead and C. J. Norwood of the Missouri Bureau of Geology and Mines, now the Missouri Geological Survey and Water Resources. These early workers were primarily interested in determining the rock succession and in evaluating the mineral wealth of the region. The necessity of working out the rock succession which enabled them to calculate reserve tonnages of coal, limestone, etc. was fully realized by Broadhead, Norwood and other early workers.

Broadhead and Norwood gave special attention to the thick beds of coal which underlie western Missouri. These they placed in the Lower and Middle Coal Measures. The Rich Hill area of southern Bates and northern Vernon counties became, a few years later, the major coal producing field in the state. The thick coal beds of this area were named the Marais des Cygnes coal by Broadhead (1873, p. 124). The name was later abandoned partly because it had been applied indescriminately to more than one coal bed of the Lower Coal Measures.

Broadhead also named the Mulberry coal bed which is exposed along Mulberry Creek in western Bates County (1873-1874, p. 156). Nevertheless, Broadhead and other early workers proposed very few names. Beds were designated by numbers that referred them to various generalized sections. Broadhead numbered the stratigraphic units of the Pennsylvanian from 1 to 284. In 1898, Broadhead revised this

section and renumbered the units 1 to 224, but very few units were given geographic names.

The application of names to various rock units has been a matter of gradual development. The most prominent scarp forming limestones were among the first units to receive geographic names, examples being the Fort Scott, named in 1866, and the Pawnee, also named in 1866. In many instances limestones were named after towns where the stone was quarried for commercial uses. With the development in the latter half of the 19th century of the coal mining industry in southeastern Kansas and western Missouri mineable coals were given names. Some coal beds were named after towns or other geographic features which were well known. Nevertheless, most of the names applied to coal beds were non-geographic descriptive terms which are not recognized in formal stratigraphic classification; examples are "one-foot" coal, "pilot" coal and "ten-inch" coal.

During the 1890's and early 1900's work concerning the stratigraphic classification of the Pennsylvanian rocks of Kansas were accelerated by members of the newly reorganized Kansas University Geological Survey. Several reports were published which dealt with the Pennsylvanian stratigraphy of eastern Kansas. The work of Erasmus Haworth who was assisted by Bennett, Kirk, and others is of outstanding importance. Under Haworth's guidance a number of east-west cross sections of the Pennsylvanian strata of eastern Kansas were constructed and many stratigraphic units were traced in reconnaissance mapping. This work led to the introduction of many new

stratigraphic terms and resulted in a classification in which all Pennsylvanian deposits were assigned to subdivisions. (Haworth 1894, 1895, 1896, 1898; Haworth and Kirk, 1894; Haworth and Bennett, 1908). Several formational or group names now used in western Missouri were introduced by Haworth and associates at this time. By the turn of the century most of the names of the major divisions of the Pennsylvanian had been introduced.

Between the years 1910 and 1915 the State Geological Survey of Missouri and the United States Geological Survey cooperated to publish two important contributions to the knowledge of Pennsylvanian deposits. Hinds, in 1912, published an economic report on the coal resources of Missouri which included detailed information on the coal fields of Bates and Vernon Counties. Hinds and Greene in 1915 published on the Pennsylvanian stratigraphy of Missouri. The major objective of this work was to trace the Pennsylvanian outcrops across Missouri and to correlate them with sections in Iowa and Kansas. The classification developed in Kansas and published by Haworth and Bennett in 1908 was used but certain major rock units were subdivided and names adopted from Missouri localities. The work of Hinds and Greene was accompanied by paleontological discussions on invertebrates by Girty and plants by White.

Greene and Pond in 1926, described the geology and economic resources of Vernon County. A detailed study was made of the Cherokee and Marmaton groups. Names were tentatively proposed for several widely-present stratigraphic units of the Cherokee shale but the

names proposed by Greene and Pond have been abandoned in formal stratigraphic classification because previously named equivalents have been recognized in other areas.

The concept of cyclical deposition, introduced by Weller in 1930, has strongly influenced the stratigraphic classification of Pennsylvanian rocks in at least two ways: (1) The introduction of this concept made geologists realize as never before that many of the units were persistent over wide areas of the Mid-Continent and the Eastern Interior regions of the United States. The widespread extent of many thin but significant units has resulted in the introduction of many new names. (2) The concept of cyclical deposition has led to the grouping of similar sequences of cycles of beds. Many of the cycles have received formal names.

The leading student of cyclical deposition for many years in Kansas was R. C. Moore. The results of his work established the difference between sedimentary cycles in Kansas and Illinois (1932, 1936).

Pierce and Courtier in 1937, reported on the geology and coal resources of the Southeastern Kansas coal field. The major stratigraphic units, particularly the coal beds, were correlated between southeastern Kansas and the section as recognized by Greene and Pond in Vernon County. Pierce and Courtier formally named several widespread units of the Cherokee shale, among them the Mineral coal, Croweburg coal, Fleming coal and the Breezy Hill limestone. A section on the invertebrate fauna of southeastern Kansas by James Williams

was included in the report.

In the five-year period from 1940 to 1945, three important papers were published which dealt with the Marmaton group of Kansas and Missouri. Jewett in 1941, traced individual lithologic units of the Marmaton group from the Oklahoma-Kansas border into Bates County, Missouri. Formal names were proposed for several of the units and included among others the Little Osage shale member, Anna shale member, Mine Creek shale member and the Lake Neosho shale member. Jewett also designated as the type section of the Worland limestone exposures near the town of Worland in western Bates County. In a report published in 1945, Jewett discusses in detail the stratigraphy of the Marmaton group.

Cline in 1941, traced the beds of the upper Desmoinesian and lower Missourian Series from western Missouri into Iowa. He proposed formal names for several limestone units of the Marmaton group. Among the names proposed by Cline are the Blackjack Creek, Higginsville, Myrick Station, and the Coal City limestone.

The work of Cline and Jewett described in detail the stratigraphy of the Marmaton group and helped to establish correlation between Kansas and Missouri of the individual limestone and shale members of this group.

Geologists from the states of Kansas, Oklahoma, Nebraska, Missouri, and Iowa have recognized for years the need for a uniform system of nomenclature and classification of the Pennsylvanian rocks of the Mid-Continent area. Nevertheless, until 1947, meetings be-

tween the geologists of the Mid-Continent states to establish uniformity of classification were of limited nature. On May 5-7, 1947, representatives of the Iowa, Kansas, Missouri, and Nebraska Geological Surveys met at Lawrence, Kansas for the purpose of establishing interstate correlation of the major and minor divisions of Pennsylvanian rocks of the Mid-Continent region. At this meeting the name Marmaton was officially adopted for the strata from the base of the Blackjack Creek limestone to the disconformity that marks the upper limit of the Desmoinesian Series. Classification of the Marmaton group was based largely on the work of Jewett. The term Henrietta which had been in use in Missouri for rocks of a similar stratigraphic position was abandoned. The classification and nomenclature of the Cherokee group was not reviewed at this meeting.

The results of the Lawrence Conference are contained in a report by Moore (1948). A publication by Greene and Searight in 1949, embodies the classification of the post-Cherokee rocks of Missouri in accordance with this interstate agreement.

Cline in 1950, conducted a stratigraphic and faunal study of the upper Marmaton and lowermost Pleasanton groups from Bates County, Missouri to Appanoose County, Iowa. Cline introduced the name Amoret for exposures of limestone near Amoret in western Bates County.

An interstate meeting similar in purpose to the Lawrence conference was held at Nevada, Missouri on March 31 and April 1, 1953. This meeting was called primarily to reach an agreement on the interstate classification and nomenclature of the Cherokee rocks of the

Mid-Continent area. Representatives from the states of Iowa, Kansas, Missouri, Nebraska, and Oklahoma were in attendance.

The representatives at the Nevada Conference divided the strata composing the Cherokee group into formations. With only a few exceptions, the limits selected included the beds from the top of a coal bed to the top of the next higher coal. Coal beds were selected as a basis for formational division because they are the most persistent units in the succession. Although this type of division does not show the best genetic relationship pertaining to cyclic deposits, it is considered best for classifactory purposes. Formations were named after the previously named lithologic unit in the formation which was judged to be the most prominent, regardless of lithology. The majority of the formations of the Cherokee group are named after coal beds because they are considered to be the most prominent units.

The results of the Nevada Conference are summarized by Searight (1953, p. 2747, 2748; 1955, p. 9).

Howe (1956) described in detail the Cherokee group of southeastern Kansas and correlated the individual strata with those in adjacent areas of Oklahoma and Missouri. The system of classification adopted at the Nevada Conference was followed by Howe with only minor modifications.

Hover in 1958, reported on the geology of the Johnstown-Creighton area in western Henry County, Missouri.

Jefferies in 1958, traced the beds of the Fort Scott and Labette formations from Fort Scott, Kansas to southeastern Iowa.

Jefferies described about 10 stratigraphic sections from the Bates County area.

Hoare, in 1961, studied the brachiopod and molluscan fauna of the Atokan and lower Desmoinesian rocks of southwestern Missouri. Hoare, worked with specimens predominately from the upper Krebs and lower Cabaniss subgroups.

The most recent description and classification of the Cherokee and Marmaton groups in Missouri was by Searight in 1961. Searight in this report subdivides the Marmaton group into the Fort Scott and Appanoose subgroups. The Blackjack Creek, Little Osage and Higginsville members of the Fort Scott are raised to formational rank.

Bebout, in 1963, made a systematic study of the fusulinids of the Desmoinesian Series of Missouri. Bebout's work showed that the upper Cherokee and Marmaton groups could be subdivided on the basis of fusulinid assemblages.

Wanless, in 1963, published the results of paleogeographic studies of selected cyclothems in the Illinois Basin and their correlatives in the upper Cherokee and lower Marmaton groups of Missouri, Kansas and Oklahoma. Regional distribution patterns of the lithologic types composing a cyclothem were reconstructed on sets of environmental maps. The bed by bed environmental mapping of cyclothems by Wanless and others has produced the following results: (1) It has contributed much toward a better understanding between the regional relationships of the various lithologic types;

and (2) it has aided considerably in explaining the conditions of origin of most types of strata involved in cyclic sedimentation.

In conclusion, the nature of Pennsylvanian rocks makes them particularly difficult to classify. The widespread areal extent of extremely thin but significant units has resulted in the introduction of numerous names. Moreover, similar lithologies recur several times at different positions in the stratigraphic column. This has led to numerous miscorrelations particularly between adjacent states where correlations have been made on an individual basis. The geographic proximity of western Missouri to Kansas has made this area particularly susceptible to classifactory problems resulting from the establishment of provincial boundaries.

Comparatively recent conferences between several states of the Mid-Continent have alleviated this problem to a considerable degree but much remains to be done.

PHYSIOGRAPHY

Topographically the Bates County area consists of a series of relatively level plains or platforms. Each plain lies at a successively higher elevation than the underlying plain and has been developed on the relatively soft shales and sandstones which occupy the stratigraphic interval between resistant beds of escarpment-forming limestones.

Marbut (1896, pp. 14-109) was first to name the major physiographic features (Figure 2). Hinds and Greene (1915, p. 4) included the Bates County area in the Scarped Plains region and with only minor modifications adopted the physiographic classification developed by Marbut.

Fenneman (1938, p. 613, plate VI) included most of western Missouri south of the Missouri River in the Prairie Plains of Oklahoma and Kansas. Nevertheless, Fenneman applied the names introduced by Marbut to the major physiographic features.

The lowest surface, or Nevada Plain, has been developed on the less resistant shales and sandstones of the Cherokee group and lies at 700 to 750 feet altitude.

Overlying the Nevada Plain is the Henrietta escarpment which is the major physiographic feature in the Bates County area. It enters northwestern Vernon County from Kansas just north of the Little Osage River and trends irregularly northeastward across Bates County into St. Clair and Henry counties.

The Henrietta escarpment and similar features of this area

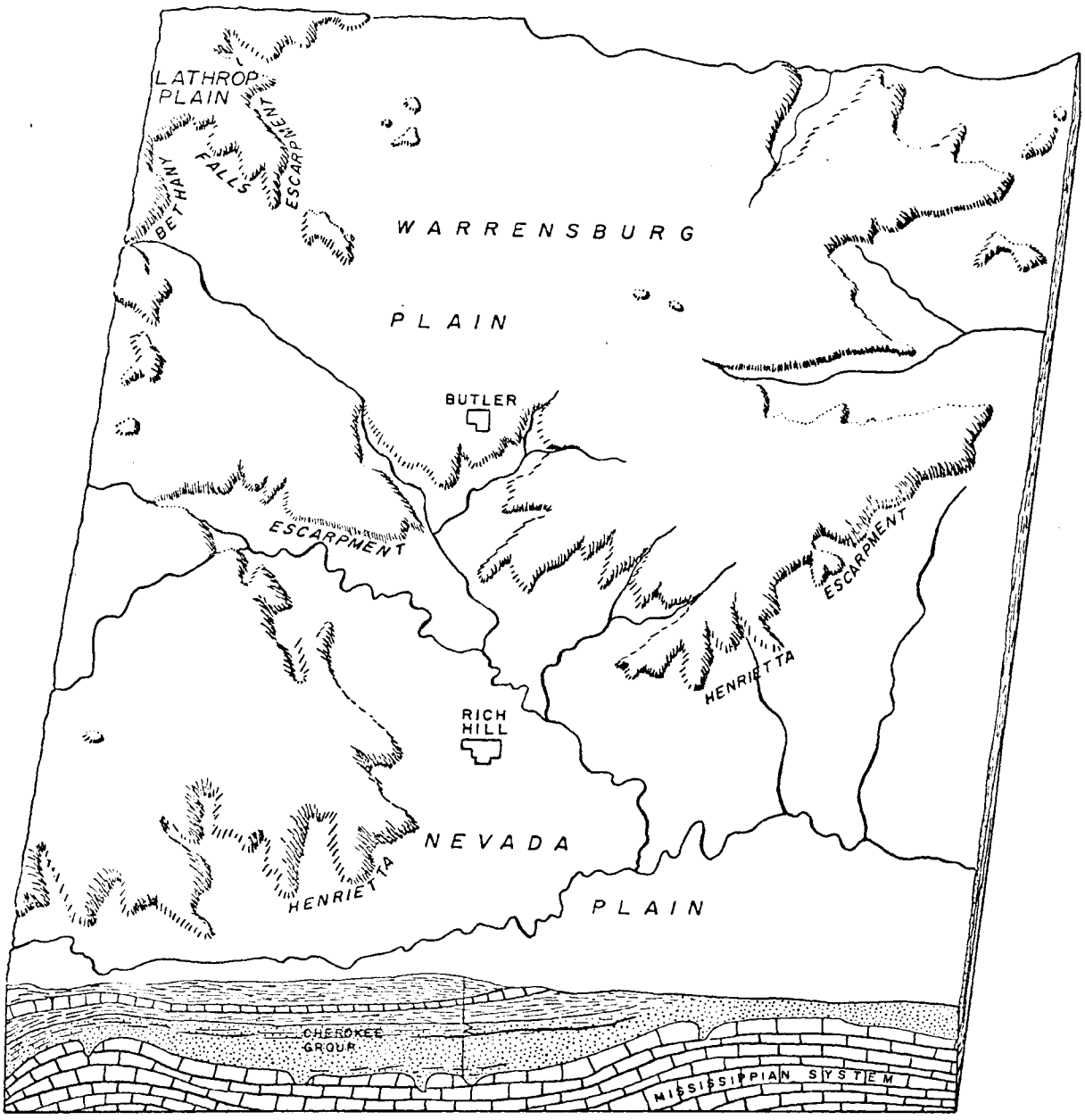

Figure 2. Physiographic divisions of the Bates County area of western Missouri.

have been produced by the erosion of Pennsylvanian strata of unequal resistance. The Henrietta escarpment consists of several relatively thick beds of limestone and interbedded shale that comprise stratigraphically the lower part of the Marmaton group. The Higginsville limestone which attains thicknesses of 20 feet is the major scarp producing limestone; however, in many places the upper part of the escarpment is formed by limestone of the Pawnee and Altamont formations.

The Henrietta escarpment has been modified in some areas of Vernon and Bates County by broad northwestward trending structural folds. The steeply dipping southwestern limb of some of the larger folds are visible along the escarpment as straight northwestward trending ridges (see geologic map Plate 1).

The plain developed on the Henrietta escarpment is gently rolling in contrast to the Henrietta escarpment which is strongly dissected by the deep valleys of streams. This surface has been developed on the soft shales and sandstones of the upper Marmaton and Pleasanton groups. It is known as the Warrensburg plain and lies between 825 and 875 feet altitude.

The Bethany Falls escarpment crosses the northwestern part of Bates County and is formed by the resistant limestones of the Kansas City group.

The Lathrop plain has been developed on the upper surface of the Bethany Falls escarpment. The average altitude of the Lathrop plain is about 1000 feet.

The major part of Bates County is drained by the Marais des Cygnes River. This river and other major streams of the region have features suggestive of late maturity to old age development. The flood plains are several miles wide and are characterized by shifting meander belts and cut off meanders which have formed numerous oxbow lakes.

The volume of water carried by the streams is not in accord with the width of their flood plains. Branson (1944 p. 355) was of the opinion that the downstream portions of the drainage system were rejuvenated during the Ozark uplift. The rejuvenation of this Ozark region would have the same effect as a general rise of base level with the result that aggradation would take place in the upstream portions of the drainage system.

LITHOLOGIC TYPES AND ENVIRONMENTS OF DEPOSITION

The Pennsylvanian strata of western Missouri consist of beds of shale, limestone, sandstone and minor amounts of coal, underclay and conglomerate.

Except in rare instances, beds which contain marine fossils are considered to be marine in origin. These include most limestone and some shale and sandstone beds. The coal, underclay and conglomerate beds are considered to be almost wholly non-marine in origin. A few sandstone, shale and limestone beds are gradational both vertically and horizontally between deposits of marine and non-marine origin. Moreover, the lithologic types composing a particular sequence of beds probably were formed in a variety of marine and non-marine environments which includes lakes, bays, marshes, deltas, lagoons, tidal flats, river channels and shallow marine seas. Heterogeneous lithologies formed under a variety of environments is one of the most characteristic features of Pennsylvanian rocks.

The repetition of similar lithologic types at different stratigraphic position suggests that similar environmental conditions recurred repeatedly throughout Pennsylvanian time.

A brief summary of the physical properties and probably environments of deposition of the major lithologic types is as follows:

Sandstone

The sandstones are variable in appearance and are probably products of several different environments. A few of the sandstones contain marine fossils and are almost certainly representative of a

near shore environment. This is particularly true where the sandstone is calcareous and nodular.

Most of the sandstones contain only plant fragments and are probably of deltaic or continental origin. Some sandstones are channel-filling.

The sandstones are commonly fine-grained, micaceous and slightly ferruginous. The bedding varies from thin and shaly to massive and cross-bedded. The composition is predominately quartz with minor amounts of rock fragments and feldspar. Krumbein and Sloss (1963, p. 134) consider sandstones such as these to be subgraywackes.

Facies changes from shale into sandstone are common. The nature of the gradation from shale into sandstone is revealed best from a study of available test drill cores. In many of the cores the underlying gray shale is interrupted, going upward, by a few thin siltstone or very fine-grained sandstone laminae one-sixteenth to one-fourth inch thick. Higher in the core the laminae become thicker and more abundant until the rock grades into fine-grained sandstone with thin shale interlaminations. Still higher, the rock is more or less a uniform sandstone. Other sandstones show relatively abrupt contact between the sandstone and underlying shale.

Underclay

Underclay is one of the most characteristic members of Pennsylvanian deposits. It commonly lacks bedding and is cut by numerous small slickensides. When struck by the pick it breaks out into angular particles. Many underclays contain compressed carbonized root

markings and small lenses of vitrain. Underclays may be silty or arenaceous and grade into the underlying material which is generally shale or nodular limestone. In places where the underclays are arenaceous they commonly contain well-preserved casts of Stigmaria. Underclays are composed predominately of kaolinite, illite and mixed-layer illite-montmorillonite (Tennissen, 1963, p. 172).

There is no relationship between the thickness of the underclay and the overlying coal beds. Underclay almost always occur with coal beds, but may be present where coal beds are absent.

The origin of underclays is in doubt, but most evidence indicates that they are fossil soils developed in a swampy environment.

Coal

Twelve different coal beds or coal horizons occur in the lower Cherokee and upper Marmaton rocks in the Bates County area of western Missouri. With the probable exception of the Croweburg coal all vary considerably in thickness and some pinch out or otherwise disappear in certain areas. At least one of the coals thickens locally to over 4 feet. The coals vary from bright and blocky to dull and thin-bedded. The thicker coals are sub-bituminous in rank and are composed of interlaminated vitrain, clarain, and fusain. In most places the coal contains pyrite either in the form of lenticular nodules or as fillings along joint planes. A white film of calcium sulphate is frequently observed on the exposed surface of the coal.

Most Pennsylvanian coals are considered to be autochthonous and to have formed in a marshy or swampy environment. Vegetable matter

which accumulated as peat was later transformed into coal.

Conglomerate

Thin beds of conglomerate of very local extent have been observed at several stratigraphic positions. The conglomerate occurs as thin lenses that are from a few inches to 3 feet thick. The particles range in size from granular to pebbles and are held in a sandy matrix. They are composed predominately of rounded to subrounded pieces of limestone and in some places the limestone particles are almost entirely made up of the coral Chaetetes. Minor constituents are coal, shale and sandstone. The lenses of conglomerate occur in the non-marine part of the cyclothem and are considered to have been deposited by streams of fairly high competency. A study of the size of component, sedimentary structures, and limited lateral persistence of any particular conglomerate lens indicates that current action varied greatly in intensity over relatively small areas.

These conglomerates are of particular interest because they occur interbedded in a sequence of strata which was deposited in a low energy environment. The clastic particles forming the overlying and underlying strata are rarely larger than fine sand and are composed predominately of mature sediments derived from distant source areas of the northeastern United States, the Canadian Shield, the Nemaha Structural Belt of Kansas or the Ouachita Mountain area.

The constituents forming the conglomerate are commonly 3 inches in diameter. The immaturity of these conglomerates is indicative of a local source area. A likely supposition is that local positive areas

were active and undergoing erosion during deposition of the non-marine part of the cyclothem.

Shale

Shale is the most abundant lithologic type in the Bates County area of western Missouri and is found in the stratigraphic section at all horizons. It is mostly light to medium-gray and weathers out as small brown chips which cover the slopes of the outcrop. In most localities the shale is arenaceous.

The shale beds or lenses probably were deposited under a variety of environmental conditions. A few of the shale beds contain abundant brachiopods and most certainly were deposited in a marine environment. Most shale beds are non-fossiliferous and grade in some places from shale to silty shale to sandstone. These may have been deposited under marine, near shore, or continental conditions.

Phosphatic Shale

The phosphatic shale beds are in most places black and laminated or fissile in character. The shale splits readily into thin sheets and has been called by miners "paper" shale. These shales contain small phosphatic concretions which are usually flat to irregular-shaped. Frequently the phosphatic concretions are coalesced into lenses. Spheroidal phosphatic concretions as large as 1 1/4 inches in diameter are a common occurrence in the Lake Neosho shale member and occur locally in the Anna shale member. Many of the phosphatic concretions have a hollow center and are presumed to have formed around air bubbles.

Some workers are of the opinion that the phosphatic concretions are the fecal pellets of fish or other organisms. The phosphatic concretions commonly weather out of the black, fissile shale and cover the slopes of the outcrop.

Larger concretions, some of which are 3 feet in diameter, occur in places where the phosphatic shale is well developed. These concretions vary in shape from spheroidal to triradiate. Frequently, two concretions coalesce and form a skull or dumbbell-shaped concretion. These larger concretions are composed of finely crystalline, dark-gray limestone which breaks with a conchoidal fracture. Most of them contain a molluscan fauna but some are unfossiliferous.

Conodonts, crushed gastropods and Orbiculoidea are the fossils most frequently observed in the black, fissile shale beds.

The phosphatic shales, where black and fissile, were probably formed in a restricted marine or lagoonal environment. According to Payton (1959, p. 177) the environment of deposition of the black, fissile shales seems to be most closely allied to tidal flat deposits, the sediments having accumulated in both regressive and transgressive seas.

In much of the Bates County area the black, fissile shales are replaced by greenish-gray shales which contain a few small irregular-shaped phosphatic concretions. It is assumed that these shales were formed under less restricted marine conditions.

Limestone

The physical and faunal characteristics of the limestone beds

vary considerably and indicate that they are products of several different environments. The thin, dark-gray, abundantly fossiliferous limestones which overlie most of the coal beds are known as "cap" limestones. In most outcrops they are separated from the coal by a few inches of dark-gray or black shale but at some exposures the limestone is gradational downward into the coal. The "cap" limestones are argillaceous, ferruginous and have the characteristic of weathering to a deep reddish-brown. Most of the "cap" limestones are abundantly fossiliferous with brachiopods belonging to the genera Desmoinesia[1], Mesolobus, Derbyia, and Crurithyris. Desmoinesia muricatina is particularly abundant in the limestones overlying the Mineral and Robinson Branch coal beds.

Aside from the thin limestones which overlie the coal beds, there are nodular limestones, arenaceous limestones, sideritic limestones, conglomeratic limestones and fairly pure limestones containing abundant fusulinids and Chaetetes. Each lithologic types represents a particular environment. Most are marine but a few unfossiliferous nodular limestones may be non-marine.

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[1]Hoare in 1961, erected the genus Desmoinesia to contain specimens which had previously been included under the genus Marginifera.

DESCRIPTIVE STRATIGRAPHY

Pennsylvanian System

The exposed rocks of the Bates County area of western Missouri belong to the Desmoinesian Series of the Pennsylvanian System. The Cherokee and Marmaton groups are the major rock groups which represent this Series in Missouri. The subdivision of the Desmoinesian Series as recognized by the Missouri Geological Survey (Searight 1961, pp. 81-95) is shown in figure 3[1]. The rocks from the top of the Mineral formation to the top of the Altamont formation are discussed in this report.

Desmoinesian Series

The name Des Moines formation was introduced by Keyes (1893, p. 100) for exposures along the Des Moines River in Iowa. Keyes did not designate precise stratigraphic boundaries but three years later in 1896 (p. 22) he indicated that the term applied to beds between the top of the Mississippian limestone and the base of the Bethany [Hertha] limestone of the Missouri Series.

For many years the name was applied to approximately the same succession of rocks as had been proposed by Keyes; however, later workers realized that in some areas of the Mid-Continent rocks of

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[1] The writer has not capitalized the lithologic part of a rock-stratigraphic name or the words group, formation, member, lens or bed. This procedure is in accordance with the present policy of the Missouri Geological Survey (Koenig, 1961, p. 151).

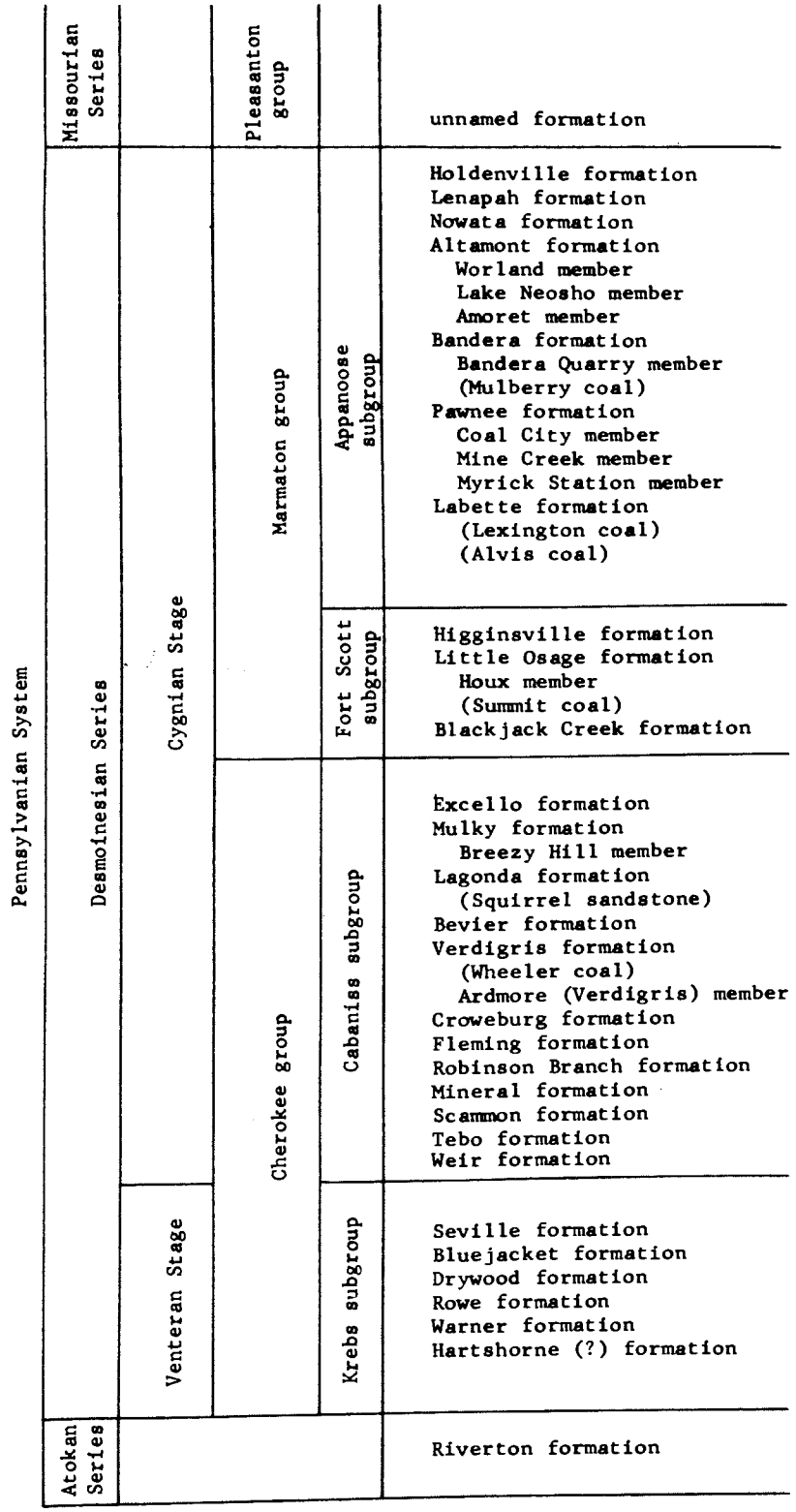


Figure 3. Subdivisions of the Desmoinesian Series in the Mid-Continent area.

Desmoinesian age were not always underlain by rocks belonging to the Mississippian System but (1) rocks of Desmoinesian age lie with angular unconformity on rocks older than Mississippian (Moore 1948, p. 2020) or (2) they rested on older Pennsylvanian rocks belonging to the Atokan Series (Thompson, 1953, p. 321; Searight, 1955, p. 30; Searight and Palmer, 1957, p. 2127). Nevertheless, the Des Moines as used in most areas of Missouri and Kansas until 1932 included rocks from the well-marked unconformity at the top of the Mississippian limestones to the base of the sequence of limestones in the lower part of the Missourian Series. Rocks of this interval are included today in the Cherokee, Marmaton and Pleasanton groups.

Moore (1932, p. 89) lowered the upper boundary of the Desmoinesian Series to the disconformity at the base of the Pleasanton group, thus, removing this group from the Desmoinesian Series.

The term "Des Moines" was changed to "Desmoinesian" by the Lawrence Conference in 1947 (Moore, 1948, p. 2020).

The Desmoinesian series as recognized by the Missouri Geological Survey includes all the rocks from the base of the Cherokee group to the unconformity and faunal break which marks the top of the Marmaton group (Searight, 1961, p. 81).

Cherokee group

Haworth and Kirk (1894, p. 105) gave the name Cherokee shale to the thick shale and sandstone series lying above the Mississippian rocks and below the Oswego (Fort Scott) limestone. The type locality is in Cherokee County, Kansas.

This designation has been retained with the exception of the McAlester basin (Taff and Adams, 1900, p. 273) and parts of southwestern Missouri (Thompson, 1953, p. 321; Searight and Palmer, 1957, p. 2127). In the latter area rock belonging to the Atokan Series fill sinkholes eroded into the limestones of the Mississippian System.

Moore (1949, p. 37,38) raised the Cherokee shale to group status in Kansas. The designation has been followed by other Mid-Continent states.

The present classification of the Missouri Geological Survey places into the Cherokee group all the beds lying below the base of the Blackjack Creek limestone formation and above the base of the Hartshorne(?) formation (Searight, 1961, pp. 81, 82, 84).

The Cherokee group is subdivided into two subgroups the Krebs and Cabaniss. Rocks belonging to the Krebs group crop out southeast of the project area and, consequently, are not discussed in this report.

Cabaniss subgroup

The term Cabaniss was introduced by Oakes (1953, p. 1525, 1526) for exposures between the top of the Krebs subgroup and the base of the Marmaton group in the McAlester basin of southeastern Oklahoma. The name is derived from the town of Cabaniss, Oklahoma.

The Nevada Conference (Searight and others, 1953, p. 2748) divided the Cabaniss subgroup into twelve formations only the top eight of which will be discussed in the report. They are in ascending order the Robinson Branch, Fleming, Croweburg, Verdigris, Bevier,

Lagonda, Mulky, and Excello.

Robinson Branch formation

Name -- The Robinson Branch formation was designated by Searight and others (1953, p. 2748) as including the beds from the top of the Mineral coal to the top of the Robinson Branch coal. The formation derives its name from a coal bed which was formerly strip mined along Robinson Branch, northeast of Walker, Vernon County, Missouri. The type locality is in the SW¼ sec. 2, T. 36 N., R. 30 W. (Searight, 1955, p. 39).

Description -- The Robinson Branch formation averages about 10 feet in thickness but locally in east-central Bates County it thins to a few inches (Plate 2).

The lower part of the Robinson Branch formation is quite variable lithologically from place to place. Four different lithologic types have been recognized directly overlying the Mineral coal and include: (1) black, fissile, non-calcareous shale containing phosphatic concretions (Plate 2, Section 10); (2) black, platy, calcareous shale (Plate 2, Section 1); (3) dark-gray to black, thin-bedded, argillaceous limestone containing abundant Desmoinesia muricatina (Dunbar and Condra) (Plate 2, Sections 7, 12); and (4) dark-gray, non-calcareous, flaky shale (Plate 2, Section 8). Lithologic types designated (2) and (3) have been observed to grade into each other laterally and have the characteristic of grading vertically into the top of the Mineral Coal. The Mineral coal is the top unit of the underlying Mineral formation. It is over 4 feet thick

Figure 4. Jointed limestone bed in the lower part of the Robinson Branch formation at Stratigraphic Section No. 2, northwestern Vernon County. Limestone bed weathers out into large slabs. It is called "cap" limestone by miners in the Rich Hill District because it overlies the Mineral coal; however, beds of slabby limestone which are identical lithologically and faunally to the limestones overlying the Mineral coal are present in many places above the Robinson Branch and Fleming coal beds.

Figure 5. Close-up of the exposed surface of jointed limestone bed shown in Figure 4. Limestone contains abundant Desmoinesia muricatina (Dunbar and Condra).

in the Rich Hill district and was extensively mined before the turn of the century. In former times this coal was known as the lower Rich Hill.

A few inches to several feet of dark-gray, flaky shale overlies one of the four lithologic types previously mentioned. Near the center of this dark-gray, flaky shale is a thin zone of limestone nodules mixed with clay matrix (Plate 2, Section 2). This stratigraphic position is occupied by a sandstone bed in western Henry County, (Plate 2, Section 10) and in the subsurface in the vicinity of Rich Hill (Plate 2, Section 4). It appears that the nodules of limestone when traced laterally grade into the sandstone.

The Robinson Branch coal is the upper unit of the formation. It is underlain by an underclay which is poorly developed locally. The Robinson Branch coal varies considerably in thickness throughout western Missouri. It is 2 feet thick in the Rich Hill district, (Plate 2, Section 3), and is strip mined in tandem with the Mineral coal. The Robinson Branch coal was formerly known as the upper Rich Hill. Variations in thickness from 2 feet to a smut have been observed in a lateral distance of a few feet along the highwall of coal strip mines (Plate 2, Section 1). The Robinson Branch coal commonly is coated with the white fiberous mineral melanterite ($FeSO_4 \cdot 7H_2O$).

Stratigraphic relationships -- The Robinson Branch formation is overlain by the Fleming formation and underlain by the Mineral formation. All three formations are cyclic sequences which are in

Figure 6. Sandstone lens near the middle of the Robinson Branch formation at Stratigraphic Section No. 10, western Henry County. Pick has been placed at the base of the Robinson Branch coal bed.

many ways lithologically and paleontologically similar to each other. The lower boundary of the Robinson Branch formation which has been placed at the top of the Mineral coal is relatively sharp. The Mineral coal has been recognized to persist throughout most of the outcrop distance from Kansas to western Henry County, although the thickness varies considerably from place to place.

The upper boundary of Robinson Branch formation lies at the top of the Robinson Branch coal and below the Fleming formation. Northeastward along the outcrop belt from Rich Hill the Robinson Branch coal thins to a smut or in some places is absent. At these places the stratigraphic boundary must be inferred from the position of the associated strata.

Fleming formation

Name -- The Fleming formation derives its name from the Fleming coal bed (Pierce and Courtier, 1937, p. 73). The Fleming coal and associated coal beds were well exposed in strip mines just north of the village of Fleming in southern Crawford County, Kansas, between the towns of Pittsburg and Cherokee. The formational boundaries were designated by Searight and others (1953, p. 2748) as including beds from the top of the Robinson Branch coal bed to the top of the Fleming coal bed.

Description -- The Fleming formation is about 7 feet thick in northwestern Vernon County but thickens to over 45 feet in the Rich Hill District of south-central Bates County (Plate 2, Section 4). Northeastward from Rich Hill it thins irregularly and is about 5 feet

thick in western Henry County.

The bottom part of the Fleming formation is composed of several inches to 2 or 3 feet of black, platy shale which grades into thin-bedded, argillaceous limestone containing abundant Desmoinesia muricatina (Dunbar and Condra). Other fossils include Lingula, bryozoans, echinoid spines and sparse gastropods. This black, platy shale sometimes grades downward into coal. This characteristic makes it difficult to remove it from the coal during mining operations. The strata of this position are quite similar in places to those overlying the Mineral coal and may be confused with the result that the Robinson Branch coal is miscorrelated with the Mineral.

In northwestern Vernon County a few inches of black shale containing irregular-shaped phosphatic concretions overlies the Robinson Branch coal (Plate 2, Section 1, 2).

The middle part of the Fleming formation consists of soft, dark-gray shale which in north-central Vernon County contains abundant flattened siderite concretions some 6 inches in diameter. A thick, lenticular sandstone bed occupies this interval at Rich Hill (Plate 2, Section 4).

The Fleming coal which is the top of the Fleming formation is poorly developed and is represented in most places in the Bates County area of western Missouri by a coal smut or a thin bed of dark-gray shale. The greatest observed thickness was 3 inches in northwestern Vernon County. The Fleming coal where present is underlain by a few inches of underclay.

Stratigraphic relationships -- The Fleming formation is underlain by the Robinson Branch formation and is overlain by the Croweburg formation. The lower boundary is placed on top of the Robinson Branch coal bed or coal horizon which is present in most areas. The upper boundary is the top of the Fleming coal bed. The Fleming coal bed is not present in many outcrops and where it is absent the upper boundary must be inferred from the position of the associated strata.

Croweburg formation

Name -- The Croweburg formation was designated by Searight and others (1953, p. 2748) as including beds from the top of the Fleming coal to the top of the Croweburg coal.

The formational name is derived from the Croweburg coal which was named for exposures in strip mines about a mile east of Croweburg, Crawford County, Kansas (Pierce and Courtier, 1937, p. 74).

Description -- The Croweburg formation varies in thickness from 7 to 20 feet and averages about 10 feet (Plate 2). It is thickest in south-central Bates County where the formation includes several lenticular sandstone and shale beds (Plate 2, Sections 4, 5).

In most places the lower part of the Croweburg formation consists of dark shales which grades laterally and vertically into thin limestone beds that are similar lithologically and faunally to the limestone beds overlying the Mineral and Robinson Branch coal beds. These limestone beds are dark-gray, thin-bedded, argillaceous and contain abundant Desmoinesia muricatina (Dunbar and Condra). The limestones are ferruginous and weather to a dark reddish-brown. Other

fossils observed in the lower part of the Croweburg formation include Crurithyris, sparse numbers of linoproductids and fragments of other productids.

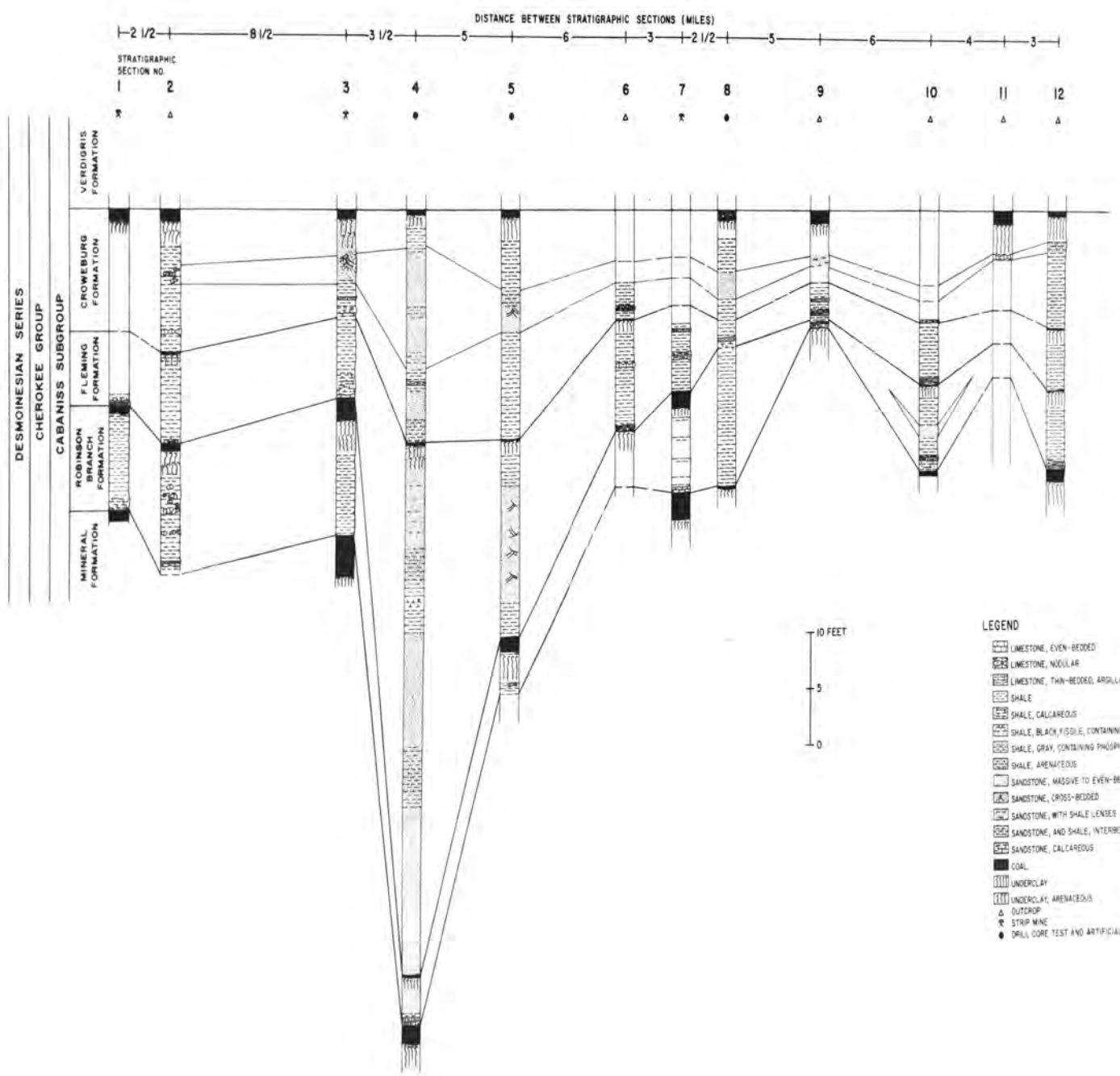
Lenses of light-gray sandstone 2 to 10 feet thick overlie the dark shales and thin limestone beds in the Rich Hill District of south-central Bates County (Plate 2, Sections 3, 4, 5). The contact between the sandstone and underlying shale is sharp in most places. The sandstone is micaceous, cross-bedded, and locally calcareous. The top surface is pitted with holes about one-half inch in diameter and 1 inch deep. These features appear to have contained fossil root material which has been weathered away. When traced along the outcrop belt from the Rich Hill District to western Henry County and northwestern Vernon County the sandstone grades into greenish-gray clay with nodules of limestone. The sandstone grades upward into shale or the underclay of the Croweburg coal bed. The Croweburg coal bed is very persistent and is about 1 foot thick. Because of its uniform thickness it has been informally named by miners the "one-foot" or "ten-inch" coal bed. Nevertheless, in a few isolated outcrops the Croweburg coal is characterized by variations in thickness and may become thin-bedded and contain interbedded shale lenses.

Stratigraphic relationships -- The Croweburg formation is underlain by the Fleming formation and overlain by the Verdigris formation. The upper boundary is placed at the top of the Croweburg coal bed and the lower boundary on top of the Fleming coal bed. In places

Figure 7. Croweburg coal and underclay overlain by gray shales of the Verdigris formation, northeastern Bates County, SE¼ SE¼ sec. 8, T. 42 N., R. 29 W. Because the Croweburg coal bed is remarkably uniform in thickness throughout much of western Missouri, it has been called by miners "the 10-inch seam".

where the Fleming coal is absent the boundary is placed slightly below the lowest thin limestone bed in what is believed to be the approximate stratigraphic position of the Fleming coal bed.

PLATE 2



LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, THIN-BEDDED, ARGILLACEOUS
- SHALE
- SHALE, CALCAREOUS
- SHALE, BLACK, FISSILE, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, GRAY, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, ARENACEOUS
- SANDSTONE, MASSIVE TO EVEN-BEDDED
- SANDSTONE, CROSS-BEDDED
- SANDSTONE, WITH SHALE LENSES
- SANDSTONE, AND SHALE, INTERBEDDED
- SANDSTONE, CALCAREOUS
- COAL
- UNDERCLAY
- UNDERCLAY, ARENACEOUS
- △ OUTCROP
- STRIP MINE
- ● DRILL CORE TEST AND ARTIFICIAL EXCAVATION

CORRELATED STRATIGRAPHIC SECTIONS OF THE ROBINSON BRANCH, FLEMING, AND CROWEBURG FORMATIONS BATES COUNTY AREA, WESTERN MISSOURI

BY
RICHARD J. GENTILE

JULY, 1964

Verdigris formation

Name -- The Verdigris formation was designed by Searight and others, (1953, p. 2748) as including the beds from the top of the Croweburg coal bed to the top of the Wheeler coal bed. The formational name was derived from the Verdigris limestone which was so named for exposures along the Verdigris River in Rogers County, Oklahoma. Although no type section was designated the Verdigris limestone was used as a marker bed by D. W. Ohen and C. D. Smith when compiling a geologic map of Rogers County, Oklahoma. Their map is contained in a report by E. G. Woodruff and C. L. Cooper, 1928.

The Verdigris limestone comprises the beds called Ardmore by Gordon (1893, p. 20-21) in Macon County, Missouri. Although the name Ardmore has precedence, the name Verdigris has had wider usage and for that reason was adopted at the Nevada Conference (Searight, 1953, p. 2748). In the Bates County area of western Missouri the Verdigris limestone has been called the Rich Hill limestone and the "sump" rock.

The Wheeler coal bed is the top unit of the Verdigris formation. It was named by Weller, Wanless, Cline and Stookey (1942, p. 1590) for exposures in southeastern Iowa. The Wheeler coal was called the Williams coal in Vernon and Bates Counties (Greene and Pond, 1926, p. 52).

The Wheeler coal in southwestern Missouri and southeastern Kansas, was for many years considered to be the Bevier coal of northeastern Missouri.

At the Nevada Conference (Searight and others, 1953, p. 2748) the name Bevier was restricted to the upper bench of a thick coal at the type locality in Macon County, Missouri. The name Wheeler was applied to the lower bench which is in most of Macon County separated from the upper bench by a few inches of sandy clay. It is now believed by the Missouri Geological Survey that the lower coal or Wheeler coal is continuous into southwestern Missouri and southeastern Kansas while the Bevier coal pinches out in the vicinity of Henry County, Missouri. This view is not accepted by all members of the Kansas Geological Survey (Hornbacker and Habib 1961, p. 76a).

Description -- The Verdigris formation is 45 feet thick in south-central and southeastern Bates County. It thins along the outcrop belt to about 20 feet in northwestern Vernon County and is less than 15 feet thick in western Henry County (Plate 3).

Lithologically, the Verdigris formation is extremely variable. The lower part is composed of several feet of gray, flaky, shale which when traced northeastward along the outcrop belt from northwestern Vernon County thickens abruptly in the vicinity of Rich Hill and the top part of the shale grades laterally into 6 feet or more of fine-grained, micaceous sandstone (Plate 3, Sections 14, 15). The sandstone grades upward into 2 or 3 inches of sandy to nodular limestone containing abundant fragments of brachiopods of the genera Mesolobus, Desmoinesia, Chonetinella and Eolissochonetes (Plate 3, Sections 5, 14). Traced southwestward and northeastward along the outcrop belt from south-central Bates County and north-central Vernon

County the sandy or nodular limestone unit grades laterally into thin-bedded to blocky, dark-gray limestone containing Mesolobus mesolobus and Desmoinesia. It is overlain by about 2 or 3 feet of black, fissile shale which contains abundant phosphatic concretions (Plate 3, Section 14). The black, fissile shale persists from the vicinity of Rich Hill southwestward to beyond the Kansas State boundary (Plate 3, Section 1). Northeastward from Rich Hill to at least as far as western Henry County this interval is occupied by a few inches of greenish-gray shale with irregular-shaped, phosphatic concretions.

The Verdigris limestone consists of two beds separated by shale from approximately two miles southwest of Rich Hill to the Kansas State boundary (Plate 3, Section 1, 13). The lower bed is dark-gray, jointed and usually occurs as one bed which characteristically weathers to large rectangular-shaped blocks. Locally it has been called the "diamond" rock. The upper bed is light-gray, wavy-bedded and contains Desmoinesia, and other brachiopods. The Verdigris limestone is represented in south-central Bates County and north-central Vernon County by over 5 feet of light-gray, thick-bedded, nodular limestone which in some places contains numerous thin thanatocoenoses of fossil fragments belonging mostly to the genera Mesolobus and Eolissochonetes (Plate 3, Section 15).

The Verdigris limestone thins in northeastern Bates and west-central Henry County and is from 6 inches to 3 feet thick. Locally it is bedded and contains some sand but in most places it is

Figure 8. Phosphatic shale bed underlying Verdigris limestone at Stratigraphic Section No. 15, north-central Vernon County. Head of pick has been placed near the base of the phosphatic shale bed. Phosphate occurs as thin lenses and concretions in a greenish-gray shale. Southwestward from Rich Hill this interval grades abruptly laterally into 2 feet or more of black, fissile shale. Light colored beds below head of pick are composed of sandy shale.

Figure 9. Nodular bedding in the Verdigris limestone at Stratigraphic Section No. 15, north-central Vernon County.

represented by a rubble of nodules of limestone (Plate 3, Sections 11, 18).

The Wheeler coal is separated from the Verdigris limestone by clay and underclay. The coal is 6 inches thick or more approximately 2 miles southwest of Rich Hill (Plate 3, Section 13) and this thickness is believed to persist to the Kansas-Missouri boundary. The Wheeler coal and underclay are not present in many places northeast along the outcrop belt from Rich Hill until western Henry County at which place it again thickens to 6 inches or more (Plate 3, Section 11).

Sandstone cuttings from well borings have been obtained from the interval between the Verdigris limestone and the Wheeler coal in extreme southwestern Bates County. It is assumed that a sandstone bed is present at this position in the area.

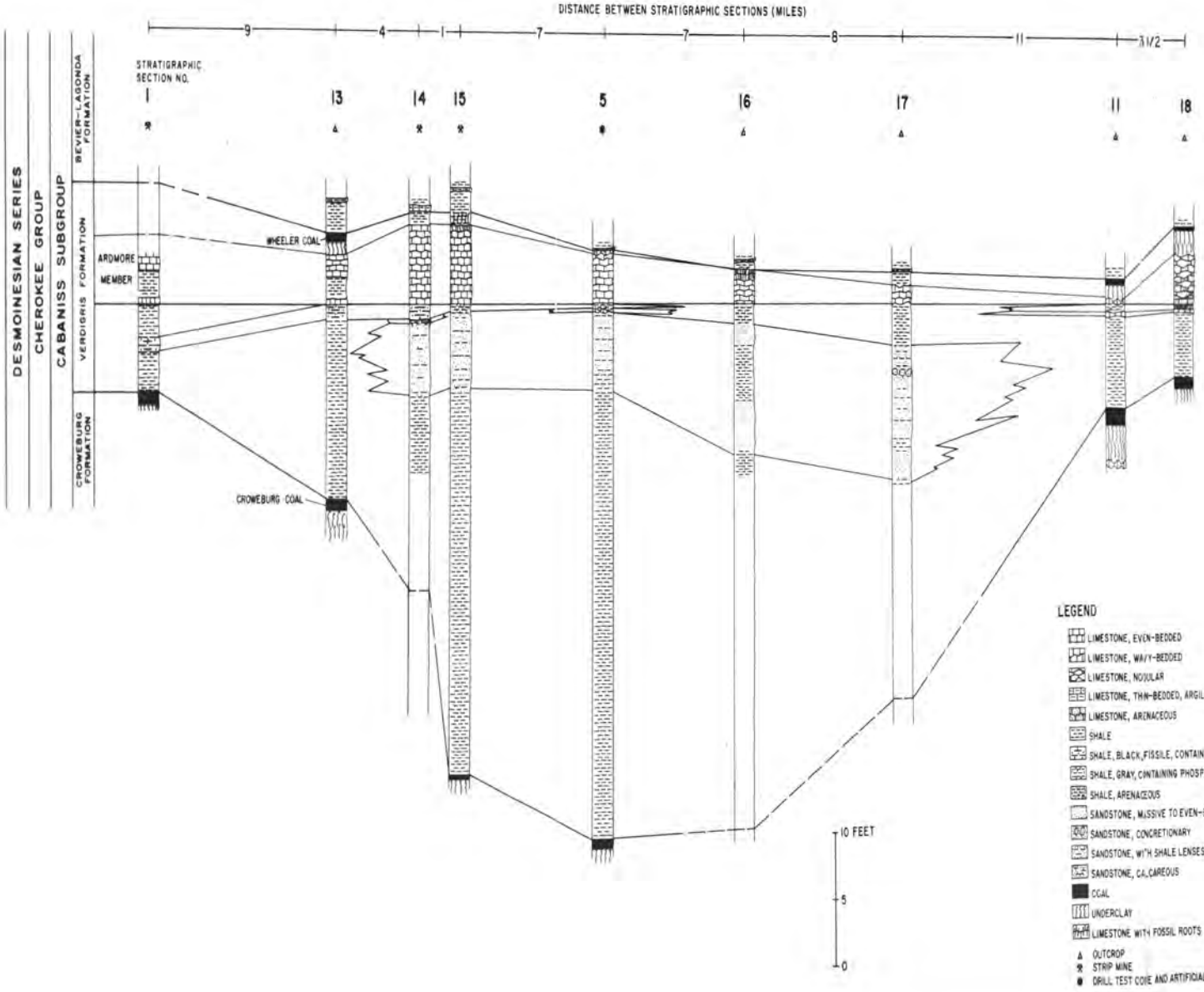
Stratigraphic relationships -- The Verdigris formation includes the strata from the top of the Croweburg coal bed to the top of the Wheeler coal bed. The lower boundary of the Verdigris formation is easily recognized because in surface exposures as well as drill cuttings the Croweburg coal bed is (1) persistent in extend (2) fairly uniform in thickness (3) and most important, it is the first coal bed below the Verdigris limestone.

The upper boundary of the Verdigris formation is difficult to recognize in some areas in south-central Bates County because the Wheeler coal bed with its associated underclay and thin-bedded cap limestone are absent and this interval contains gray shales. At

Figure 10. Wheeler coal bed and associated strata at Stratigraphic Section No. 21, southwestern Bates County. Coal is overlain by approximately 2 feet of dark-gray shale (position of pick handle). A thin abundantly fossiliferous limestone bed overlies the shale. Talus composed of Lagonda shale covers the slope above the thin limestone bed. The Wheeler coal bed is 9 inches thick and is separated from the Verdigris limestone (not shown) by approximately 2 feet of underclay. A few miles east of this location the strata between the Verdigris limestone and the thin limestone bed shown above are considerably reduced in thickness or they are absent.

these places the boundary between the Verdigris and the Bevier formation is placed within the shale sequence at the approximate stratigraphic position of the top of the Wheeler coal. However, at some exposures the thin-bedded cap limestone which overlies the Wheeler coal lies almost directly on the Verdigris limestone and the Wheeler coal and underclay have all but pinched out and the boundary between the Verdigris and Bevier formation is placed for all practical purposes on top of the Verdigris limestone (Plate 3, Sections 5, 16).

PLATE 3



LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, WAVY-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, THIN-BEDDED, ARGILLACEOUS
- LIMESTONE, ARENACEOUS
- SHALE
- SHALE, BLACK, FISSILE, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, GRAY, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, ARENACEOUS
- SANDSTONE, MASSIVE TO EVEN-BEDDED
- SANDSTONE, CONCRETIONARY
- SANDSTONE, WITH SHALE LENSES
- SANDSTONE, CALCAREOUS
- COAL
- UNDERCLAY
- LIMESTONE WITH FOSSIL ROOTS
- ▲ OUTCROP
- ✱ STRIP MINE
- ● DRILL TEST CORE AND ARTIFICIAL EXCAVATION

CORRELATED STRATIGRAPHIC SECTIONS OF THE VERDIGRIS FORMATION BATES COUNTY AREA, WESTERN MISSOURI

BY
RICHARD J. GENTILE

JULY, 1964

Bevier-Lagonda formation

Name -- The name Bevier was originally applied by McGee (1888, pp. 328-336) to a coal bed or beds mined extensively at Bevier, Macon County, Missouri. The formational boundaries were established by Searight and others (1953, p. 2748) and include the beds from the top of the Wheeler coal bed to the top of the Bevier coal bed.

The Lagonda formation was named by Gordon (1893, p. 19 in Areal Reports of 1896) for sandstones and shales overlying the Bevier coal and constituting the uppermost division of the Lower Coal Measures. The name was derived from Lagonda Post Office, Chariton County, Missouri.

In this report the Bevier and Lagonda formation will be discussed as one unit because the Bevier coal bed has not been recognized in the Bates County area of western Missouri and as a result the upper boundary of the Bevier formation could not be established.

In 1951, Howe, (p. 2092) on the basis of work in Kansas and Oklahoma included in the Lagonda formation the beds above the Bevier coal bed extending to the top of the Iron Post coal bed.

Searight and others (1953, p. 2748) placed the formational boundaries at the top of the Bevier coal bed and at the base of the Breezy Hill limestone member. The boundaries recognized by Searight and others were essentially similar to those of Gordon who named the formation in 1893.

According to present usage of the Missouri Geological Survey (Searight, 1961, p. 89) the lower boundary of the Lagonda formation

is placed at the top of the Bevier coal bed and the upper boundary at the top of the lowermost of three thin coal beds or smuts which lie below the Mulky underclay in Henry County. Hover (1958, p. 44) working in west-central Henry County, tentatively correlated the Iron Post Coal of Oklahoma and Kansas with a coal bed which is possibly the lowermost of this sequence in Henry County. These coals appear at approximately the same stratigraphic position in the two areas.

Description -- The exact thickness of the Bevier-Lagonda formation could not be determined in the western part of the area because the upper part of the formation is quite variable lithologically, and consequently the boundary could not be established, (see Plate 4). Nevertheless, it is doubtful if the formation is over 50 feet and less than 25 feet thick.

The Bevier-Lagonda formation is composed predominately of shale and sandstone with minor amounts of coal and thin-bedded, argillaceous limestone.

A few inches of dark-gray, thin-bedded limestone which weathers to reddish-brown, earthy blocks is present at the base of the formation and locally overlies the Wheeler coal bed, or is separated from it by a few inches to a foot or two of dark shale (Plate 4, Sections 5, 21). This limestone contains Desmoinesia and sparse Linoproductus.

A 3-inch bed of black, fissile shale that is surrounded by gray shale lies 10 to 15 feet above the base of the formation in western Henry County and northeastern Bates County (Plate 4, Sections

18, 26). It is assumed that this unit is associated with the Bevier coal but its exact stratigraphic position is not known. A few inches to 2 feet of dark-gray, thin-bedded, arenaceous limestone with abundant Mesolobus occupies the same stratigraphic position throughout most of Bates County and northwestern Vernon County (Plate 4, Sections 5, 21, 22).

A thin bed of coal lies at the top of the Bevier-Lagonda formation in west-central Henry County and northeastern Bates County (Plate 4, Sections 11, 25). As previously mentioned this coal has been tentatively correlated with the Iron Post coal of Oklahoma (Hover, 1958, p. 44). Nevertheless it could not be traced with any degree of certainty southwestward from northeastern Bates County. A coal horizon which is marked by an arenaceous underclay and a thin-bedded limestone is present in south-central Bates County (Plate 4, Section 21). But a correlation between these strata and the coal bed tentatively called the Iron Post by Hover in northeastern Bates County is a matter of conjecture.

Several feet of sandstone and sandy shale underlie the Iron Post(?) coal in northeastern Bates and western Henry Counties (Plate 4, Sections 11, 18, 25). The sandstone has been informally called by drillers the "Squirrel" sandstone because of its tendency to "jump around" from one stratigraphic position to another in the interval between the Ardmore limestone and the Blackjack Creek limestone. This is a valid deduction because the "Squirrel" sandstone grades laterally into shale in comparatively short distances and may occur

at more than one stratigraphic horizon. At most outcrops in the Bates County area of western Missouri two or more sandstones occur in the interval between the Verdigris and Blackjack Creek limestones (Plate 4, Sections 11, 21, 22, 25).

Stratigraphic relationships -- The Bevier-Lagonda formation is underlain by the Verdigris formation and overlain by the Mulky formation. Both boundaries are problematic in most areas.

Mulky formation

Name -- The Mulky formation derives its name from the Mulky coal bed which was named by Broadhead (1872, p. 45-46) for outcrops along Mulky Creek in Lafayette County, Missouri.

Present usage of the Missouri Geological Survey (Searight, 1961, p. 89) places the lower boundary at the top of the lowermost coal (Iron Post(?)) in a succession of three coal beds or horizons lying below the Mulky underclay in Henry County, Missouri. The upper boundary of the formation is placed at the top of the Mulky coal bed.

The Mulky formation includes the Breezy Hill member. The Breezy Hill member was named by Pierce and Courtier (1937, p. 33) for exposures of nodular limestone 6 inches to 2 feet thick lying below the underclay of the Mulky coal and above the "Squirrel" sandstone at Breezy Hill just southwest of Mulberry, Kansas.

Description -- The Mulky formation is 25 to 35 feet thick in northeastern Bates County and western Henry County (Plate 4). Southward along the outcrop from this area to the Kansas line the thick-

ness could not be determined with any degree of accuracy because the lower boundary could not be recognized.

The lower part of the Mulky formation is northeastern Bates and western Henry County is composed of several feet of limestone and interbedded shale. The limestone beds are thin-bedded, argillaceous, medium to dark-gray and contain small amounts of sand (Plate 4, Sections 11, 18). The thickness of the individual limestone beds vary from less than an inch to over 1 foot. The thicker beds have the characteristic of weathering out into large rectangular slabs. Fossils include fusulinids, Mesolobus, Antiquatonia, Kozlowskia abundant small crinoid columnals and coiled gastropods. The shale lying between the limestone beds is medium-gray and slightly sandy. In some places poorly developed underclays are present below one or more of the limestone beds (Plate 4, Section 25). The limestone and interbedded shales are not well developed southwest of northeastern Bates County. At several localities in south-central Bates County (Plate 4, Sections 21, 22) discontinuous thin-bedded limestone with associated underclay has been recognized but it could not be determined which limestone, if any, was its correlative in northeastern Bates County. It is assumed that the well-developed coal horizons at this interval in northeastern Bates and western Henry Counties are localized in areal extent throughout the remainder of the Bates County area.

The lower part of the Mulky formation is not well exposed in northwestern Vernon County.

The "Squirrel" sandstone of drillers terminology is present in the upper part of the formation. It is a fine-grained, micaceous sandstone several feet thick. The top part in some places becomes calcareous and grades into nodular limestone mixed with greenish-gray clay. The term Breezy Hill was formerly restricted to this nodular limestone.

The Mulky coal is the top unit of the Mulky formation. It is 2 feet or more in thickness in western Henry County (Plate 4, Section 18) and has been mined in small operations. Southwestward from the Bates-Henry County boundary the Mulky coal thins to a smut in most areas of Bates County. The Mulky coal in northwestern Vernon County thickens locally to 1 foot or more and contains a well developed underclay (Plate 4, Section 20).

Stratigraphic relationships -- The Mulky formation is underlain by the Lagonda formation and overlain by the Excello formation. The upper boundary is easily determined since the Mulky coal or associated strata are present in most places. The lower boundary is difficult to place because of the variations in lithology at this position in most of the Bates County area.

Excello formation

Name -- The Excello formation consists of a thin shale unit lying between the top of the Mulky coal and the base of the Blackjack Creek limestone (Searight and others, 1953, p. 2748).

The type section was designated by Searight (1955, p. 35) from

exposures in the highwall of a coal strip mine west of Excello in the NW¼ sec. 30, T. 56 N., R. 14 W., Macon County, Missouri about 2.6 miles west of U. S. Highway 63.

Description -- The Excello formation is about 3 feet thick in northwestern Vernon County and thins to less than 1 foot in most areas of Bates County. It increases in thickness to 5 feet or more in western Henry County (Plate 4).

The Excello formation in northwestern Vernon County consists of black, fissile shale overlain by dark-gray shale which grades upward into light-gray shale (Plate 4, Sections 19, 20). The black fissile shale contains small irregular-shaped to round phosphatic concretions. In south-central Bates County the Excello formation thins to less than 1 foot and is composed of black to dark-gray, soft shale which weathers greenish-gray (Plate 4, Section 22). The shale looses its fissility and the phosphatic concretions are smaller and more irregular in shape. Locally in this area less than 1 inch of dark-gray, fossiliferous limestone overlies the Mulky coal or coal smut.

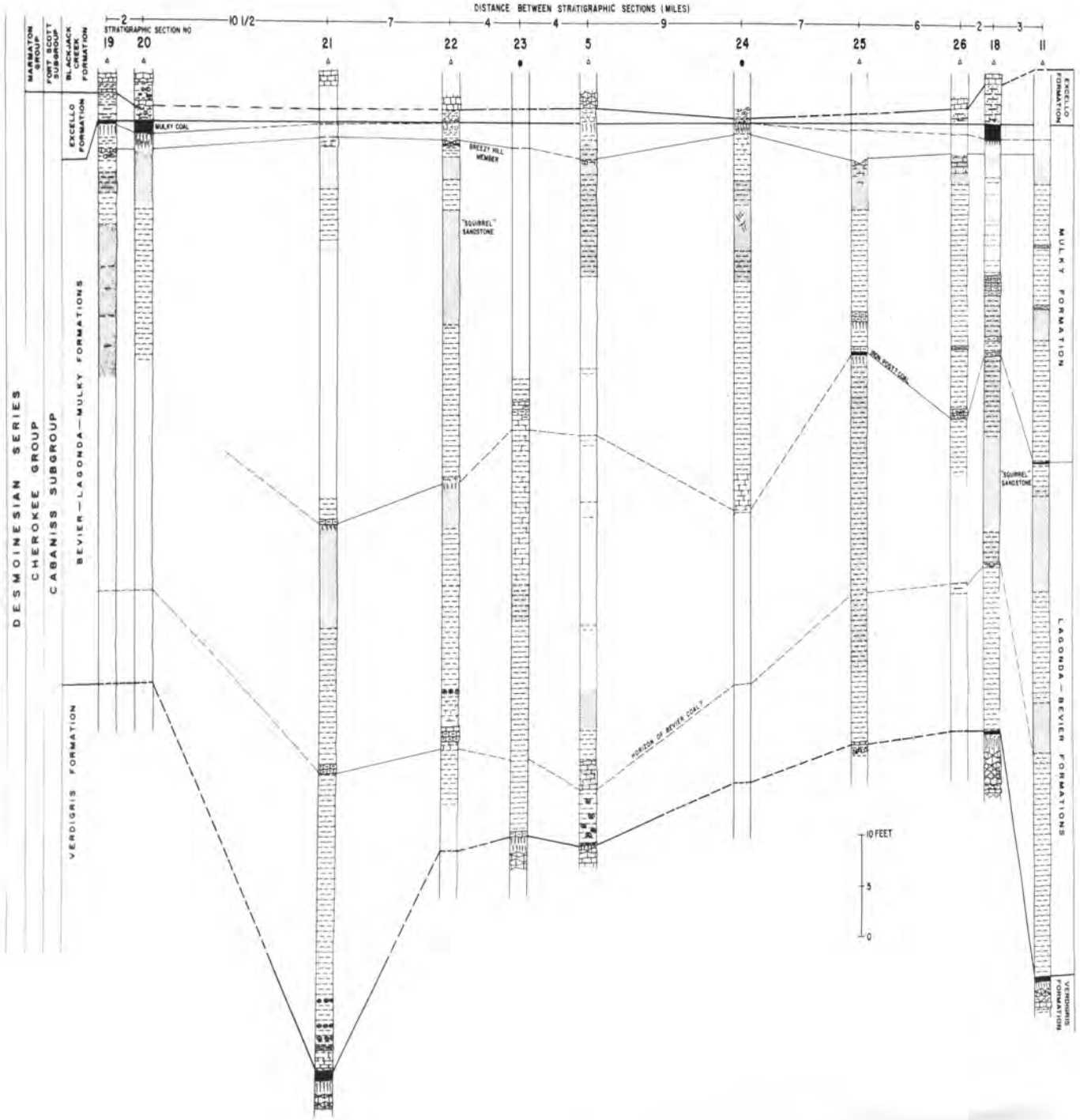
The Excello formation thickens in the vicinity of the Bates-Henry County border and is lithologically similar to its correlative in northwestern Vernon County. It includes 3 feet or more of black, fissile shale overlain by dark-gray shale which grades upward into light-gray shale (Plate 4, Section 18). The black fissile shale contains irregular-shaped to round phosphatic concretions and large, finely crystalline, fossiliferous limestone concretions many of which

are spheroidal and 2 feet or more in diameter.

Conodonts and a few low-spired crushed gastropods have been observed in the black, fissile shales.

Stratigraphic relationships -- The Excello formation is underlain by the Mulky formation and overlain by the Blackjack Creek formation. Both upper and lower boundaries are relatively sharp.

PLATE 4



CORRELATED
STRATIGRAPHIC SECTIONS
OF THE
BEVIER, LAGONDA, MULKY,
AND
EXCELLO FORMATIONS
BATES COUNTY AREA,
WESTERN MISSOURI

BY
RICHARD J. GENTILE

JULY, 1984

LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, WAVY-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, THIN-BEDDED, ARGILLACEOUS
- LIMESTONE, NODULAR, ARENACEOUS
- LIMESTONE NODULES WITH CLAY MATRIX
- SHALE
- SHALE, BLACK, FISSILE, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, BLACK, FISSILE
- SHALE, GRAY, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, CONTAINING CLAY IRONSTONE CONCRETIONS
- SHALE, CALCAREOUS
- SANDSTONE MASSIVE TO EVEN-BEDDED
- SANDSTONE, CROSS-BEDDED
- SANDSTONE WITH SHALE LENSES
- SANDSTONE AND SHALE, INTERBEDDED
- SANDSTONE, CALCAREOUS
- SHALE, ARENACEOUS
- COAL
- UNDERCLAY
- UNDERCLAY, ARENACEOUS
- △ OUTCROP
- ● DRILL TEST CORE AND ARTIFICIAL EXCAVATION

Marmaton group

Keyes (1897, p. 24) first used the term Marmaton for the shale between the Fort Scott and Pawnee limestones in Vernon County, Missouri and Bourbon County, Kansas. One year later this same interval was named the Labette by Haworth (1898, p. 36) who used the name Marmaton for the beds above the base of the Fort Scott limestones and below the top of the Pleasanton shales (1898, p. 92).

Although the term Labette had priority over Marmaton the term Marmaton became established by usage and Labette was restricted to the beds between the Fort Scott and Pawnee limestones.

In 1932, (Moore, p. 89) redefined the Marmaton group as including beds above the base of the Fort Scott limestone and below the unconformity which separates the Desmoinesian and Missourian Series.

Jewett (1940, p. 209) recognized the unconformity mentioned by Moore as occurring below a thin, sandstone bed which he had named Hepler (Jewett 1940a, pp. 8, 9). Acting accordingly he placed the top of the Marmaton group below this sandstone.

The name Henrietta which was previously used for the Marmaton in Missouri was suppressed at the 1947 Lawrence Conference (Moore, 1948, p. 2027) because the type locality is indefinite and the span of beds included is uncertain.

Searight (1961, p. 90) divided the Marmaton group into two subgroups, the Fort Scott below and the Appanoose above.

Fort Scott subgroup

The Fort Scott subgroup consists of two limestone units sepa-

rated by an interval of shale, thin limestone, coal and in some places sandstone.

The name Fort Scott was introduced by Swallow (1866, p. 25) for exposures of limestone at Fort Scott, Kansas. It was the upper limestone which Swallow designated as the Fort Scott. Later workers included all three units.

Cline (1941, p. 36) named the lower limestone the Blackjack Creek and the upper one the Higginsville. Jewett (1941, p. 302) proposed the name Little Osage shale for the beds that lie between the Blackjack and Higginsville limestone.

The Fort Scott limestone was given formational status at the Lawrence Conference (Moore, 1948, p. 2025) and the Blackjack Creek limestone, Little Osage shale and Higginsville limestone were classed as members.

Searight (1961, p. 90) raised the Fort Scott formation to a subgroup and the Blackjack Creek, Little Osage and Higginsville member were raised to the rank of formation. In the same publication Searight (p. 90) raised the Fort Scott formation to a subgroup "chiefly because of the northward expansion in thickness and the northward lithologic differentiation of the Little Osage which contains important named units in Missouri which could not otherwise continue to bear formal names".

Haworth and Kirk (1894, pp. 105, 107, 116) used the term "Oswego" for the beds that are now called the Fort Scott subgroup, however, the term was preoccupied by a Silurian formation in New

York and the term "Oswego" was later abandoned for the old name Fort Scott limestone. Nevertheless, "Oswego" is still used by drillers and some oil company geologists.

Blackjack Creek formation

Name -- The Blackjack Creek formation was named by (Cline, 1941, p. 36) for exposures along Blackjack Creek in Johnson County, Missouri. The name was proposed to Cline by F. C. Greene in a letter dated January 5, 1940. Cline did not propose a type section and as a result Jefferies (1958, p. 32) has proposed as the type section exposures in the north ditch of a gravel road along the south line of the SW¼ SE¼ SW¼ sec. 14, T. 47 N., R. 25 W., Johnson County, Missouri.

The formational limits were established by Searight (1961, p. 90) as including the beds between the top of the Excello formation and the base of the Little Osage formation.

Description -- The Blackjack Creek formation varies irregularly in thickness from 3 to 7 feet (Plate 5).

The Blackjack Creek formation is composed of limestone and shale with limestone predominating. The lower part of the formation commonly consists of finely crystalline, bedded limestone which weathers brown or tan. The limestone in most exposures is jointed with the main joint pattern oriented SW-NE and NW-SE. As a result of the jointing the limestone commonly weathers out in diamond-shaped blocks. Locally the lower part may become unevenly bedded or form a thick, nodular bed (Plate 5, Section 30). Fossils include Composita,

Neospirifer, Mesolobus and other brachiopods, horn corals, fusulinids and abundant crinoid columnals.

The upper part of the Blackjack Creek formation in northwestern Vernon County consists of thick-bedded, blocky limestone which contains abundant Chaetetes colonies near the top (Plate 5, Section 27). When traced northeastward along the outcrop belt from northwestern Vernon County into Bates and Henry County the upper part of the Blackjack Creek formation becomes nodular bedded and in most places consists of calcareous shale mixed with argillaceous limestone nodules. These weather to a coarse rubble.

The upper and lower parts of the Blackjack Creek formation are separated by shale in northeastern Bates County (Plate 5, Section 34).

Stratigraphic relationships -- The Blackjack Creek formation is underlain by the Excello formation and overlain by the Little Osage formation. The lower boundary is a relatively sharp contact between limestone of the Blackjack Creek formation and shale of the Excello formation. The upper boundary in some places is gradational between nodular limestone of the Blackjack Creek formation and shale of the Little Osage formation (Plate 5, Sections 5, 33, 34).

Little Osage formation

Name -- The name Little Osage was introduced by Jewett, (1941, p. 308) for exposures on the south valley wall of the Little Osage River in Bourbon County, Kansas, and includes the beds between the top of the Blackjack Creek formation and the base of the Higginsville

formation, (Plate 5). It was originally designated by Jewett as a member of the Fort Scott formation but the unit was raised to formational rank when the Fort Scott formation was elevated to a subgroup, (Searight, 1961, p. 90).

The Little Osage formation includes among other beds the Houx member and the Summit coal. The name Houx was proposed by Cline (1941, p. 36) for exposures on the Houx Ranch in sec. 15, T. 46 N., R. 27 W., Johnson County, Missouri. The name was suggested to Cline by F. C. Greene.

Since Cline did not describe or specifically designate a type section, Jefferies (1958, p. 52) designated as the type section exposures in the hillside and road ditch north of a private road leading to a farm house in the NE¼ NE¼ sec. 15, T. 46 N., R. 27 W., Johnson County, Missouri.

The name Summit was applied by McGee (1892, p. 331) to a coal bed in Macon County, Missouri. It is regarded as the informal name of a coal bed.

Description -- The Little Osage formation varies irregularly in thickness from 2½ to 11 feet along the outcrop belt from northwestern Vernon County to western Henry County (Plate 5).

The lower part of the Little Osage formation consists of gray shale overlain by a poorly developed thin underclay. The Summit coal is represented by a thin coal smut or is absent throughout most of the area. The greatest observed thickness of the Summit coal bed is in west-central Bates County in the vicinity of the Marais Des Cygnes

River where it is 4 inches thick (Plate 5, Section 31). The Summit coal is overlain by a few inches of dark-gray to black shale which is commonly interbedded with dark-gray, shaly, argillaceous limestone. The shales and limestones contain Kozlowskia splendens (Norwood and Pratten), Derbyia crassa (Meek and Hayden), Composita and Mesolobus mesolobus (Norwood and Pratten).

The most persistent unit in the Little Osage formation is a black, fissile shale which averages about 1½ feet in thickness. It contains flattened to round phosphatic concretions. The black, fissile shale is overlain by a few inches to a few feet of shale which is black at the bottom and grades upward into light-gray shale at the top. At places where the shale is thickest it commonly contains several thin lenses of limestone which are darkest in color near the bottom. The limestones are shaly to blocky, argillaceous and contain Kozlowskia, Crurithyrus, Mesolobus mesolobus (Norwood and Pratten), and Antiquatonia (Plate 5, Section 31). These limestone lenses occupy the same stratigraphic position and are lithologically and faunally similar to the Houx limestone of Johnson County and counties to the northeast of it.

Stratigraphic relationships -- The Little Osage formation is overlain by the Higginsville formation and underlain by the Blackjack Creek formation. The Little Osage formation is easily recognizable in outcrop and in the subsurface because, lithologically, it is predominantly shale and occupies the interval between two formations which are predominately limestone.

Figure 11. Upper part of the Little Osage formation at Marble Bridge, Stratigraphic Section No. 31, west-central Bates County. Pick has been placed at the base of the black, fissile shale which is separated from the underlying Summit coal by a few inches of gray shale. Thin slabby limestone bed near top of photo appears to be transitional between the Houx limestone and beds forming the basal part of the Higginsville limestone.

Higginsville formation

Name -- The name Higginsville was proposed by Cline (1941, p. 36) for exposures east of Higginsville, Lafayette County, Missouri. No definite type section was given. The name was suggested by F. C. Greene in a letter to Cline. Greene considered it to be the most appropriate name because Hinds, (1912, pp. 242, 243) had included the unit in a measured section of the overlying Lexington coal east of the town of Higginsville.

Jefferies (1958, p. 56) did not find good exposures of the formation east of Higginsville and designated as the type section exposures about 4 miles southeast of Higginsville in a small drain just north of a gravel road near the center of the NW¼ SW¼ SE¼ sec. 15, T. 49 N., R. 26 W., Lafayette County, Missouri.

The Higginsville formation contains only one unit, the Higginsville limestone.

Description -- The Higginsville formation varies irregularly in thickness from 12 to 21 feet along the outcrop belt from northwestern Vernon to western Henry County (Plate 5). The formation is approximately 20 feet thick in central Bates County, southwest of Butler (Plate 5, Section 32) and 21 feet thick in southwestern Bates County at the town of Pleasant Gap (Plate 5, Section 33). Both areas of increased thickness appear to be local and of limited areal extent.

The Higginsville formation is composed of limestone. The lower part of the formation is even to wavy-bedded and becomes crinkly-bedded to nodular at the top. The limestone is light-gray with

Figure 12. Wavy-bedded limestone in basal part of the Higginsville formation, northeastern Bates County, NW¼ NW¼ sec. 12, T. 41 N., R. 30 W. Reentrant is formed by erosion of the underlying soft shale of the Little Osage formation. Right foot of man rests on top of black, fissile shale bed.

dark-gray mottling. Minor amounts of greenish-gray clay occurs between bedding planes and joints. Small waxy-looking nodules of brown chert are a minor constituent. Fossils include Phricodothyris, Composita, Crurithyris, abundant crinoid columnals and sparse horn corals. Brachiopod fossils are in most places recrystallized and held firmly in the limestone matrix. The upper part of the formation contains abundant fusulinids and Chaetetes colonies. The Chaetetes colonies form mounds on the top surface of the formation.

Stratigraphic relationships -- The Higginsville formation is underlain by the Little Osage formation and overlain by the Labette formation. The Labette formation lies conformably on the Higginsville formation in northwestern Vernon County (Plate 5, Section 28). At this location sandstone-filled shallow channels are present in the top part of the formation.

Several thin, limestone beds occur locally at the base of the Higginsville formation (Plate 5, Section 31). The limestone beds at the bottom of this sequence resemble those of the Little Osage formation in that they are dark-gray, thin-bedded and fossiliferous while those at the top are light to medium-gray, sparsely fossiliferous and resemble the limestone of the Higginsville formation. The limestone beds in the middle are gradational and the contact between the Little Osage and the Higginsville formation has to be placed according to the judgement of the geologist.

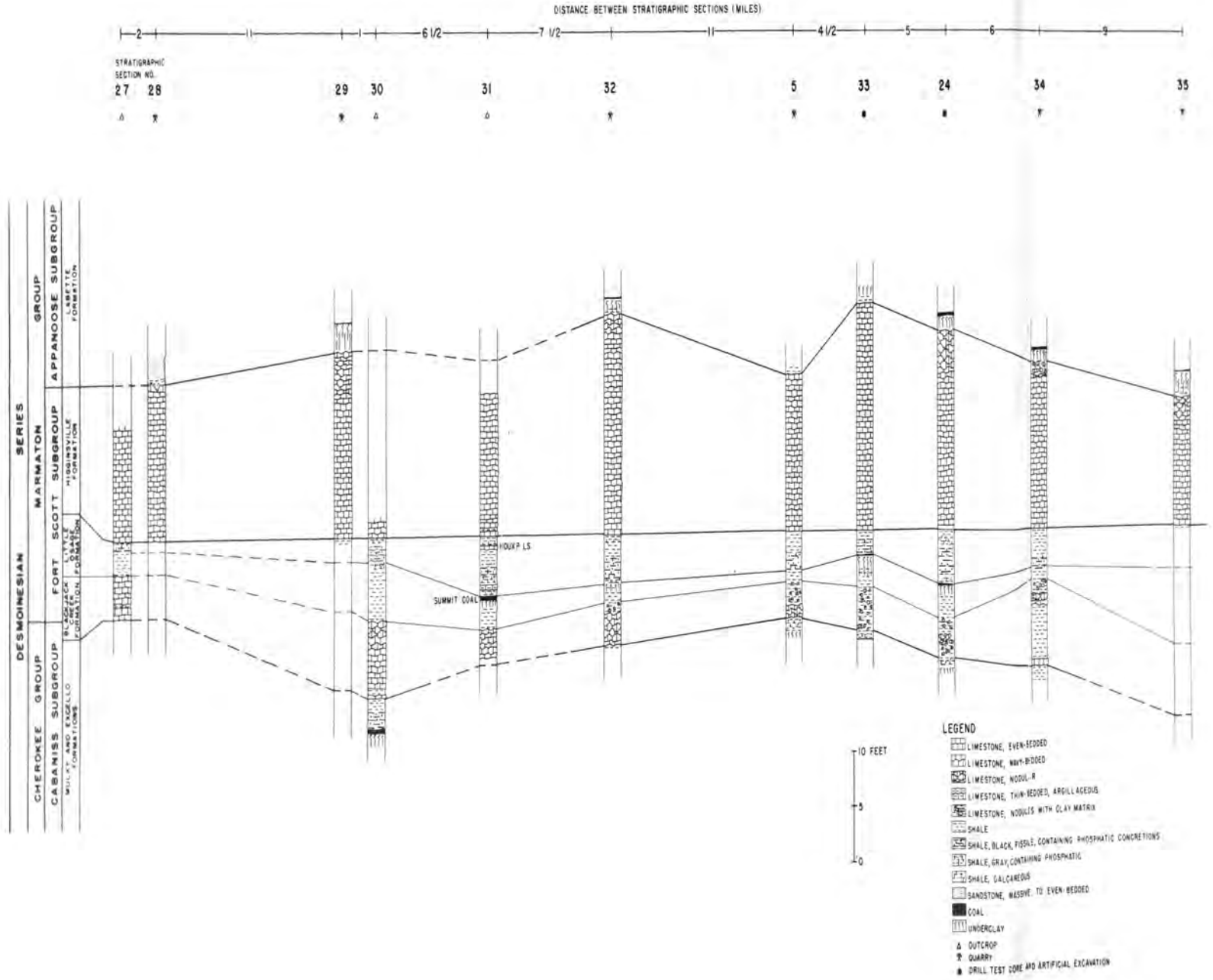


PLATE 5

CORRELATED

STRATIGRAPHIC SECTIONS

OF THE

BLACKJACK CREEK, LITTLE OSAGE, AND HIGGINSVILLE FORMATIONS

WESTERN MISSOURI

BATES COUNTY AREA

BY

RICHARD J. GENTILE

JULY, 1964

Appanoose subgroup

The name Appanoose was applied by Bain (1896, p. 378) to beds containing the Mystic coal (Lexington) and associated strata in Appanoose County, Iowa.

Searight (1961, p. 92) included in the Appanoose subgroup all Marmaton formations above the Fort Scott subgroup. The name as now applied in Missouri includes essentially the same beds as did Bain when he proposed the term.

Only the four lowermost formations which include in ascending order the Labette, Pawnee, Bandera and Altamont will be dealt with in this dissertation.

Labette formation

Name -- The term Labette shale was used by Haworth (1898, p. 36), for the beds lying between the top of the Oswego (Higginsville) limestone and the Pawnee limestone. The name is derived from the town of Labette in Labette County, Kansas.

Jewett (1941, pp. 312-317), working in Kansas named beds in the upper part of the formation the Anna shale and classified the Anna as a member of the Pawnee limestone. Jewett drew the base of the Pawnee below a thin bed of blue, dense limestone occurring under the black, fissile shale of the Anna member. This limestone has not been recognized with certainty in western Missouri and, consequently the top of the Labette formation is placed at the base of the black, fissile shale of the Anna member.

The interval between the top of the Higginsville limestone and the Anna shale was designated a formation at the 1947 Lawrence Conference (in Moore 1948, p. 2025).

The Labette formation includes among other beds the Englevale member which is predominately sandstone and the Alvis and Lexington coal beds.

The name Englevale was designated by Pierce and Courtier (1935, pp. 1061-1062) for exposures of channel-filling type sandstone in the vicinity of the town of Englevale, Crawford County, Kansas.

The Alvis coal was named by Jefferies (1958, p. 95) for exposures at the Alvis limestone quarry, SW¼ SE¼ sec. 19, T. 40 N., R. 31 W., 2½ miles west of Butler, Bates County, Missouri.

The Lexington coal derives its name after the town of Lexington in Lafayette County, Missouri. The name was introduced into the literature by Broadhead (1873, p. 46). It is assumed that the term was first used by miners to denote a particular coal bed.

Description -- The Labette formation varies considerably in thickness from place to place along the outcrop belt from northwestern Vernon to western Henry County. The minimum thickness is about 25 feet and the maximum thickness is over 45 feet (Plate 6). Average thickness is approximately 30 feet.

The Labette formation is composed predominately of sandstone, shale, arenaceous limestone, calcareous sandstone and minor amounts of limestone and conglomerate. The formation includes two coal beds or horizons. A lower coal (Alvis) and an upper coal (Lexington).

The Alvis is from 1 to 6 inches thick and is separated in Bates County and western Henry County from the Higginsville limestone by about 2 feet of gray underclay. In northwestern Vernon County 5 feet or more of sandstone occurs below this coal (Plate 6, Section 36). The sandstone is fine-grained, light-gray, massive and cross-bedded to thin-bedded. Locally it fills channels eroded into the top of the Higginsville limestone. A thin conglomerate composed of particles of limestone lies below the coal in northwestern Vernon County and appears to be of very limited extent (Plate 6, Section 37).

The Alvis coal is overlain by 1 to 5 feet of dark-gray to black calcareous shales which in most exposures contain from 1 to several thin beds of argillaceous limestone that are gradational with the shale. The shales and argillaceous limestones contain abundant brachiopod fossils. In some exposures brachiopod fossils form thin beds of coquina. Brachiopod fossils include Mesolobus mesolobus (Norwood and Pratten), Antiquatonia, Composita, Derbyia crassa (Meek and Hayden), Neospirifer, Kozlowskia, Linoproductus, and Chonetes. Other fossils are crinoid columnals and fenestellate bryozoans. As a rule individual genera and species of brachiopods are restricted to zones (teilzones or local range zones) and as a result some coquina beds are composed almost entirely of Mesolobus mesolobus while other coquina beds contain Derbyia or Composita as the dominant genus.

The shale overlying the Alvis coal grades upward into about 20 feet of sandstone and shale which become very calcareous in southwest-

Figure 13. Conglomerate lens underlying Alvis coal at Stratigraphic Section No. 37, northwestern Vernon County. Head of pick has been placed at base of coal. Conglomerate appears to have filled in a small channel eroded into the underclay of the Alvis coal. Channel-filling sandstone occupies the interval in most of northwestern Vernon County.

ern Bates and northwestern Vernon Counties (Plate 6, Section 37). Localized lenses contain sufficient calcium carbonate to classify them as arenaceous limestones.

Fossils include Crurithyris, Mesolobus, and Taonurus caudagalli (Vanuxem). Specks of carbon and pieces of charcoal are mixed randomly in the calcareous sandstones and shales. Some scour and fill markings are exposed along the bedding planes.

Traced northwestward along the outcrop belt to northeastern Bates County the sandstone is in most places even-bedded but in limited areas it is massive and cross-bedded (Plate 6, Section 24). It is fine-grained, subangular, micaceous and weathers to a reddish-brown color.

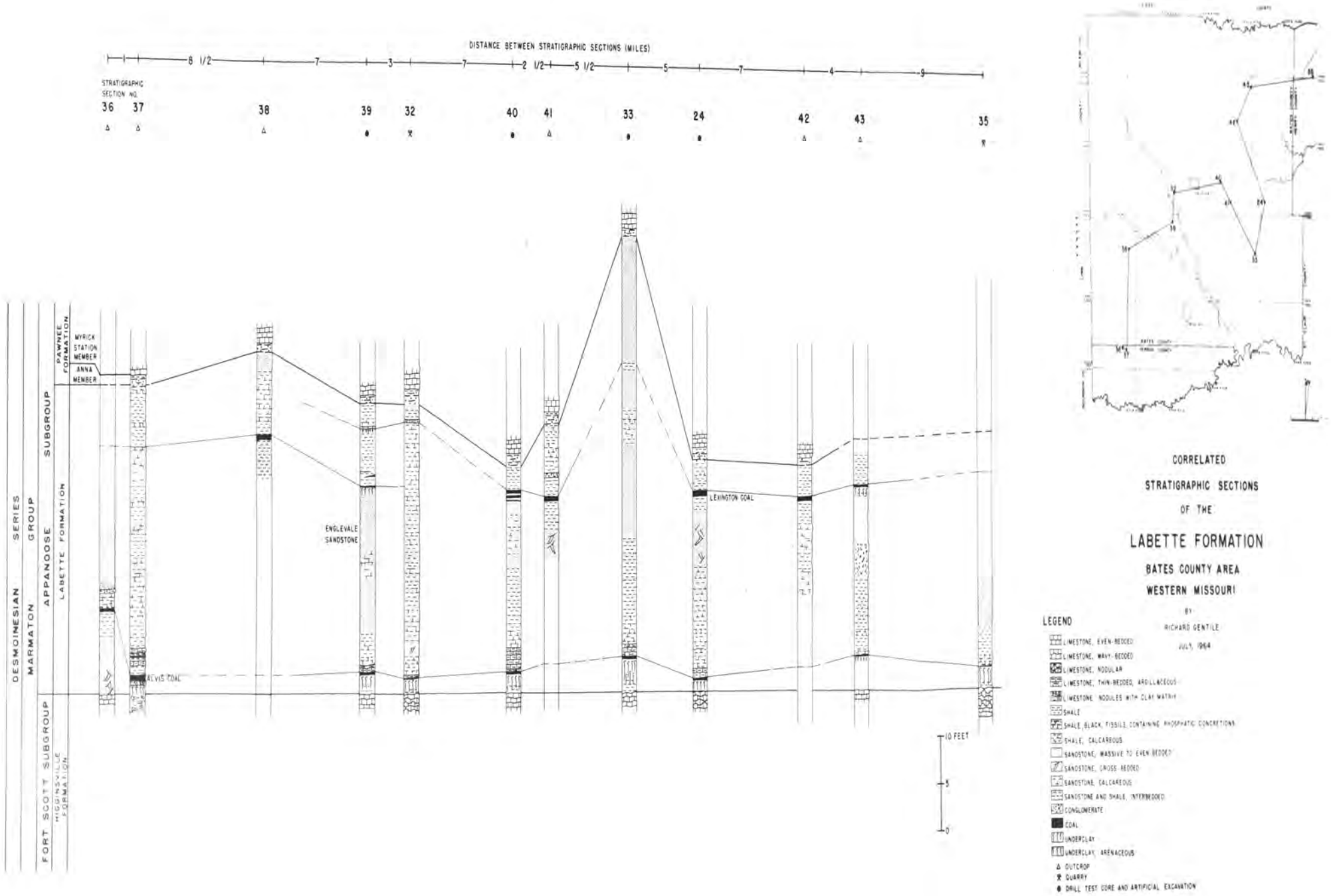
Several feet of conglomerate which consists of pea-sized particles of limestone, chert and brachiopod fragments occurs near the middle of the sandstone-shale interval in the vicinity of Ballard in northeastern Bates County, (Plate 6, Section 43).

In the eastern part of Bates County the Lexington coal occurs near the top of the formation. It is thin-bedded and commonly contains thin beds or lenses of dark shale (Plate 6, Section 40).

The upper part of the Labette formation contains two coal horizons approximately 4½ miles southwest of Butler (Plate 6, Section 39). It has not been established with certainty which one of these horizons develops into the Lexington coal bed of eastern Bates County and areas to the northeast of Bates County. Jewett (1941, p. 310) working in Kansas and Oklahoma also recognized two coal horizons at

Figure 14. Interbedded sandstone and shale of the Labette formation, west-central Bates County, near center of north line of section 2, T. 39 N., R. 33 W. Characteristically the sandstone is even-bedded and weathers to a reddish-brown color.

PLATE 6



CORRELATED

STRATIGRAPHIC SECTIONS

OF THE

LABETTE FORMATION

BATES COUNTY AREA

WESTERN MISSOURI

BY

RICHARD GENTILE

JULY, 1964

LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, WAVY-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, THIN-BEDDED, ARGILLACEOUS
- LIMESTONE, NODULES WITH CLAY MATRIX
- SHALE
- SHALE, BLACK, FISSILE, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, CALCAREOUS
- SANDSTONE, MASSIVE TO EVEN-BEDDED
- SANDSTONE, CROSS-BEDDED
- SANDSTONE, CALCAREOUS
- SANDSTONE AND SHALE, INTERBEDDED
- CONGLOMERATE
- COAL
- UNDERCLAY
- UNDERCLAY, ARENACEOUS
- △ OUTCROP
- ★ QUARRY
- ● DRILL TEST CORE AND ARTIFICIAL EXCAVATION

Pawnee formation

The name Pawnee was first used by Swallow (1866, p. 24) for the limestone beds occurring next above the Fort Scott limestone. No definite boundary limits were designated. The name was derived from exposures on Pawnee Creek near the village of Pawnee southwest of Fort Scott, Bourbon County, Kansas.

Moore (1936, p. 42-62) included in the Pawnee limestone the beds between the Labette and Bandera shales.

Jewett (1941, p. 315) subdivided the Pawnee into four units which are, in ascending order, the Anna shale, Myrick Station limestone, Mine Creek shale and Laberdie limestone. The name Laberdie was later suppressed in favor of Coal City. Inasmuch as the type locality as designated by Swallow was indefinite, Jewett (1941, p. 315) selected as the type an exposure along State Highway 7, slightly north of the center of section 7, T. 27 S., R. 34 E., Bourbon County, Kansas.

The Lawrence Conference (in Moore 1948, p. 2025) designated the Pawnee limestone a formation and the four included units were given member status. Thus, the present classification subdivides the Pawnee formation into four members which are, in ascending order, the Anna, Myrick Station, Mine Creek and Coal City.

Anna member

Name -- The Anna member is the lowermost member of the Pawnee formation and includes beds from the top of the Labette formation to the base of the Myrick Station member of the Pawnee formation.

The name was designated by Jewett (1941, p. 312) for exposures in Bourbon County, Kansas. The type locality is the same as that of the Pawnee formation.

Description -- The Anna member is a very thin but persistent unit. It does not exceed 2 feet in thickness and in some places in western Missouri is less than 1 foot thick (Plate 7).

The Anna member is composed essentially of black, fissile shale which in most exposures contains phosphatic concretions which vary in shape from irregular to spheroidal. Most of the phosphatic concretions are approximately one-half inch in diameter with some spheroidal phosphatic concretions attaining diameters of 1½ inches. A thin bed of soft shale which grades from black at the bottom to greenish-gray at the top overlies the black, fissile shale in most areas, but in a few exposures this unit is absent and limestone of the Myrick Station member lies directly on the black, fissile shale (Plate 7, Section 49). The only fossils found in the Anna member were conodonts of the genus Hindeodella.

Stratigraphic relationships -- The upper boundary of the Anna member is well marked by an abrupt lithologic change from shale to limestone of the Myrick Station member.

In this report the base of the Anna member has been placed at the bottom of the black, fissile shale which is one of the most persistent units of western Missouri. The top of the Lexington coal, which has been used as the base of the Anna member in other parts of Missouri, was not selected because the exact stratigraphic position

Figure 15. Black, fissile shale of the Anna member at Stratigraphic Section No. 32, central Bates County. Total thickness of the Anna member is approximately 12 inches and is represented by the length of the pick handle. The Myrick Station member consists of the overlying thick-bedded limestone. Shale of the Labette formation underlies the Anna member. The Lexington coal is not present.

of the Lexington coal has not been established in southwestern Bates and northwestern Vernon Counties.

Myrick Station member

Name -- The name Myrick Station was proposed by Cline (1941, p. 37) for the lowermost limestone member of the Pawnee limestone. Cline designated as the type section exposures in ravines in the south bluff of the Missouri River near Myrick Station on the Missouri Pacific Railroad, just west of Lexington, Lafayette County, Missouri. In Missouri this unit was formerly called the cap rock of the Lexington coal (McQueen and Greene, 1938, p. 25).

Jewett (1941, p. 316) included in this member the limestone beds lying between the Anna shale member and the Mine Creek shale member.

Description -- The thickness of the Myrick Station member is relatively constant throughout western Missouri. The average thickness is 3½ feet (Plate 7). The thickness rarely exceeds 5 feet and at no outcrop was the Myrick Station member observed to be less than 3 feet thick.

The Myrick Station member consists of finely crystalline, bluish-gray limestone which weathers brown. Bedding is thick and even. The main joint patterns are NW-SE and NE-SW. The fracture is angular or hackly. Fossils include poorly preserved recrystallized brachiopods and platy algae. Large, elongate fusulinids, some of which are seven mm. in length, occur at the top of the member (Plate 7, Section 44, 50). The Myrick Station member is overlain and under-

lain by shale. The gradation from the limestone of the Myrick Station member to the shale is abrupt.

Stratigraphic relationships -- The Myrick Station member is underlain by the Anna member of the Pawnee formation and overlain by the Mine Creek member also of the Pawnee formation. Both contacts are sharp.

Mine Creek member

Name -- The name Mine Creek was used by Jewett (1941, p. 318) for exposures on a tributary of Mine Creek in Linn County, Kansas about 1 mile west of the Missouri-Kansas border, (near the middle of the south side of section 23, T. 21 S., R. 25 E.).

Description -- The Mine Creek member varies considerably in thickness, (Plate 7). It is from 6 to 15 feet thick in Bates County and thins to about 1 foot in northwestern Vernon County.

The lower part of the Mine Creek member is composed of dark-gray, non-calcareous shale, which grades upward into calcareous shale interbedded with limestone. The limestones are seldom more than a few inches thick and are dark-gray, argillaceous, thin-bedded and jointed into blocks. They have the characteristic of weathering a brownish-red and locally may contain considerable fine sand (Plate 7, Sections 48, 49). The limestones and shales in the upper part of the Mine Creek member are very fossiliferous and contain Derbyia crassa (Meek and Hayden), crinoid columnals, Mesolobus mesolobus, Antiquatonia, and Linoproductus. Fossils become more abundant near the top of the Mine Creek member and the shales and shaly limestones directly under-

Figure 16. Mine Creek member of the Pawnee formation at Stratigraphic Section No. 49, central Bates County. Pick has been placed just above one of several limestone beds that are present in the upper part of the member at most places. The limestone and shale beds near the top of the member (above pick handle) are abundantly fossiliferous with chonetid brachiopods.

lying the Coal City member are a coquina of "Chonetes"[1] granulifer Owen, Mesolobus mesolobus, Antiquatonia sp., large crinoid columnals and sparse bryozoans. The abundantly fossiliferous zone at the top of the Mine Creek member persists throughout most of western Missouri and is an aid in identifying the member.

In northeastern Vernon County the Mine Creek member thins considerably and is composed of a few inches of dark shale with a thin-bedded, dark-gray, limestone bed near the middle (Plate 7, Section 44). The top few inches consist of dark-gray to black platy shale with abundant Lingula, Crurithyris and sparse Mesolobus.

Stratigraphic relationships -- The Mine Creek member is underlain by the Myrick Station member and overlain by the Coal City member.

Coal City member

Name -- The name Coal City was applied by Cline (1941, p. 59) for exposures of limestone in northern Missouri which he somewhat hesitatingly correlated with the upper limestone member of the Pawnee of western Missouri. The type area is along the Chariton River near the town of Coal City in southwestern Appanoose County, Iowa.

At this time, Jewett who was working in Kansas used the term

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[1]Recent research work indicates that specimens of brachiopods occurring in Pennsylvanian rocks and assigned to the genus Chonetes are in reality homeomorphs of similar appearing specimens from pre-Pennsylvanian rocks. It has been suggested by C. C. Branson (personal communication) that the generic name Chonetes be restricted to specimens occurring in pre-Pennsylvanian rocks.

Laberdie for the upper member of the Pawnee limestone (1941, p. 320). Because Cline was not certain that the Coal City was the uppermost member of the Pawnee limestone the name Laberdie was adapted for this unit at the Lawrence Conference in 1947 (Moore, 1948, p. 2025). Later field studies by Cline and Greene (1950, p. 9, 10) established the correlation of the Coal City and Laberdie limestones across Iowa, Missouri and Kansas. Inasmuch as the term Coal City has priority over Laberdie the latter name was suppressed in favor of Coal City.

Description -- The Coal City member is 13½ feet thick in northwestern Vernon County and thins to about 6 feet in northeastern Bates County (Plate 7, Sections 44, 50, respectively).

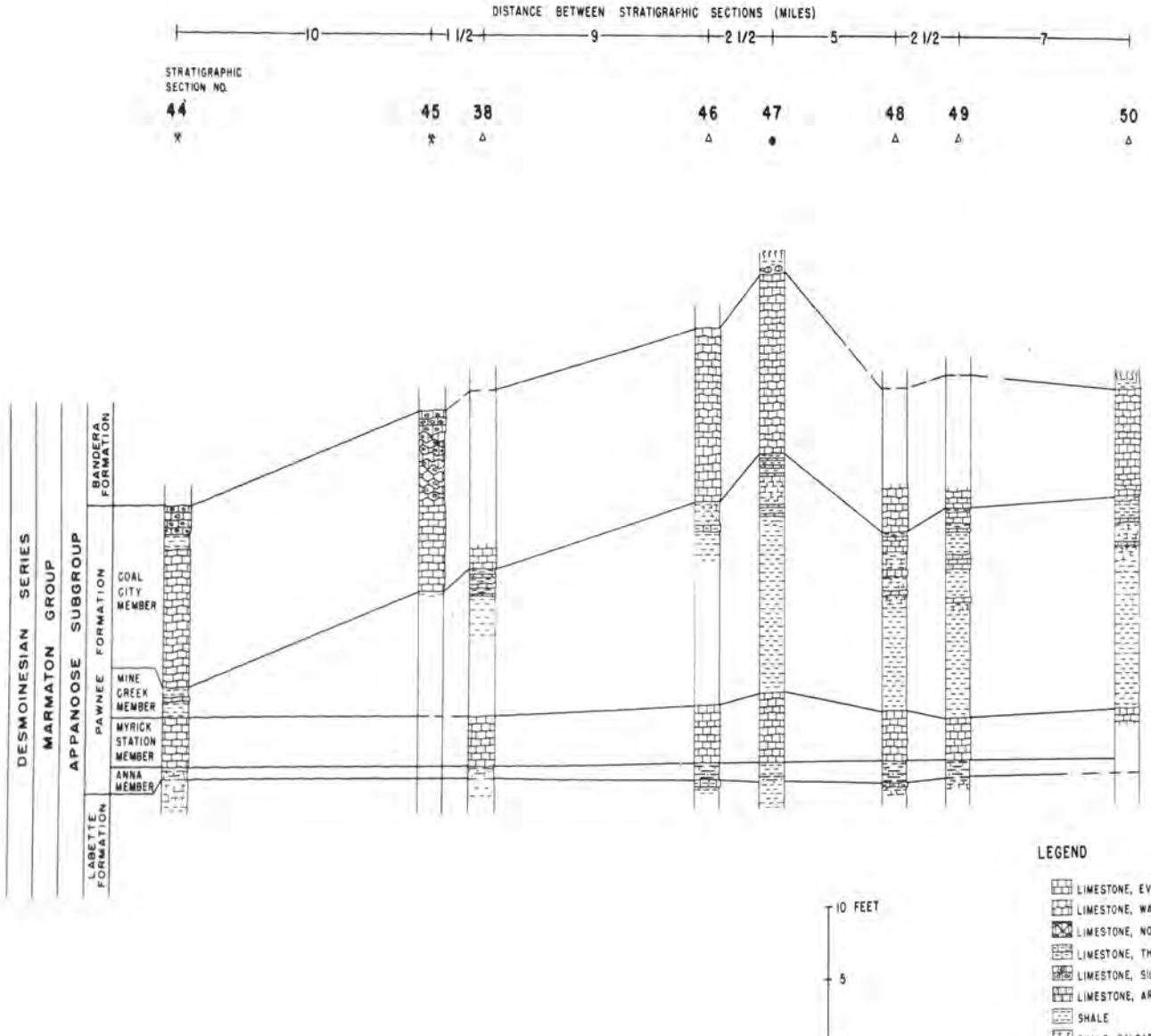
The Coal City member is composed predominantly of gray, wavy-bedded limestone. At most exposures the bedding is from 2 to 6 inches thick at the bottom and 1 inch or less at the top.

In southwestern Bates County the upper 4 or 5 feet consists of thin, nodular-bedded, siliceous limestone which is overlain by about 1 foot of thick-bedded, blocky, siliceous limestone (Plate 7, Section 45). The siliceous limestone weathers to angular pieces of white chert which cover the slopes as a thick mantle of residuum. In northwestern Vernon County the top part of the member consists of interbedded shale and limestone with some cherty limestone beds near the top (Plate 7, Section 44).

The upper surface of the Coal City member commonly has an uneven or humpy appearance as a result of numerous colonies of Chaetetes milleporaceous Edwards and Haime. Other fossils include recrystal-

Figure 17. Coal City limestone member exposed in face of Quarry at Stratigraphic Section No. 45 southwestern Bates County. The thick dark-gray limestone bed at top of Quarry is very siliceous and weathers into blocks of white chert.

PLATE 7



LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, WAVY-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, THIN-BEDDED, ARGILLACEOUS
- LIMESTONE, SILICEOUS
- LIMESTONE, ARENACEOUS
- SHALE
- SHALE, CALCAREOUS
- SHALE, CALCAREOUS, ARENACEOUS
- SHALE, BLACK, FISSILE, CONTAINING PHOSPHATIC CONCRETIONS
- SANDSTONE, WITH SHALE LENSES
- △ OUTCROP
- ✱ STRIP MINE OR QUARRY
- ● DRILL TEST CORE AND ARTIFICIAL EXCAVATION

CORRELATED STRATIGRAPHIC SECTIONS OF THE PAWNEE FORMATION BATES COUNTY AREA, WESTERN MISSOURI

BY
RICHARD J. GENTILE

JULY, 1964

Bandera formation

Name -- The term Bandera shales was used by Adams (1903, p. 32) for exposures of shale and sandstone near the town of Bandera in Bourbon County, Kansas, (section 29, T. 25 S., R. 23 E.). At this place the thin-bedded sandstone in the upper part of the formation was extensively quarried for flagging. The name Bandera Quarry was later proposed for this sandstone by Jewett (1941, p. 292).

The Mulberry coal bed which has been extensively mined in southwestern Bates County lies near the base of the Bandera formation. The Mulberry coal was named by Broadhead (1873-74, p. 168) for exposures along Mulberry Creek in western Bates County.

Description -- The thickness of the Bandera formation decreases irregularly along the outcrop belt from southwestern to northeastern Bates County, (Plate 8). The formation is over 50 feet thick in southwestern Bates County but there is an abrupt decrease in thickness to 20 feet or less along the line of the Marais des Cygnes River between the towns of Amoret and Worland in western Bates County (Plate 8, Sections 54, 55). Northeastward from this area the formation decreases to 8 feet or less. But locally in central Bates County the formation increases in thickness to 35 feet or more (Plate 8, Section 59).

The lithology of the Bandera formation also varies considerably along the outcrop from southwestern to northeastern Bates County. South of a line approximately the position of the Marais des Cygnes River the formation is composed of shale, arenaceous shale, sand-

stone, coal, underclay and minor amounts of limestone and conglomerate. The Mulberry coal lies near the base of the formation and averages about 30 inches in thickness and has been extensively mined. It is underlain by 2 to 4 feet of underclay and in some places an equal amount of light-gray, calcareous shale. Overlying the Mulberry coal is approximately 30 feet of shale which locally contains large, flattened septarian concretions composed of clay with the cracks filled by coarsely crystalline limestone (Plate 8, Section 53). The Bandera Quarry sandstone member lies near the top of the shale but in limited areas may be 30 or 40 feet thick and lie near the top of the Mulberry coal, (Plate 8, Section 52). The sandstone is commonly well-bedded and is fine-grained and micaceous. In the highwall of some strip mines, the sandstone has been observed to grade laterally through arenaceous shale into shale. Locally it is absent. About 1 mile northeast of Hume the Bandera Quarry sandstone thickens abruptly to about 35 feet in a small synclinal structure (Plate 8, Section 52). At this place it is lenticular and saturated with asphalt. Near the bottom it contains a thin conglomerate bed composed of particles of coal, shale and limestone.

The Bandera formation south of the Marais des Cygnes River contains few invertebrate fossils. Fragments of plants are abundant in the shale and arenaceous shale overlying the Mulberry coal.

North and northeast of the Marais des Cygnes River the Bandera formation thins considerably. The Mulberry coal is irregular in thickness and decreases in thickness from 2 feet to a thin smut in a

lateral distance of 25 feet have been observed (Plate 8, Section 47). In some exposures the Mulberry coal contains thin lenses of dark shale (Plate 8, Section 58). The shale overlying the Mulberry coal contains limestone of at least two different lithologies (1) a thin, dark-gray concretionary limestone bed which locally overlies the Mulberry coal (Plate 8, Section 57, 61). and, (2) Small limestone nodules which commonly occur near the top of the shale but locally they may be present down to the Mulberry coal.

In most exposures north of the Marais des Cygnes River, the Bandera Quarry sandstone is absent but locally, in central Bates County the Bandera formation thickens to 35 feet or more (Plate 8, Section 59). At this place the Bandera Quarry sandstone is represented near the top by thin shaly sandstone or isolated masses of sandstone. Several feet of dark-gray to black shale with numerous interbedded, thin coal lenses underlie the Mulberry coal. The shale contains abundant Calamites and in some places is almost completely composed of fragments of fossil plants. A thin, conglomerate of very limited extent occurs near the bottom of the formation. The conglomerate is composed of pebble-sized particles of limestone and Chaetetes colonies. The shale and underclay below the Mulberry coal contain several lenses of siderite concretions. Most of the concretions are about 3 inches in diameter (Plate 8, Sections 59, 60).

Stratigraphic relationships -- The Bandera formation is underlain by the Coal City member of the Pawnee formation and overlain by the Amoret member of the Altamont formation. The lower boundary is

sharp in contrast to the upper boundary which is gradational from shale into nodules of limestone mixed with clay. The upper boundary has been arbitrarily placed within the shale-nodular limestone sequence instead of at the bottom of it mainly because it appears that some of the lowermost limestone nodules may grade laterally into a dark-gray, concretionary limestone bed which is genetically related to the Mulberry coal.

Altamont formation

The Altamont formation is composed of two relatively thin limestone beds separated by shale.

The name was first used by Adams (1896, p. 22) for exposures at the summit of a ridge near Altamont, Labette County, Kansas.

Apparently the Altamont formation was considered to be one limestone unit until Jewett (1940a, p. 23) recognized that the Altamont formation consisted of two limestone units separated by a shale member.

A few years earlier Greene (1933, pp. 14-18) working independently in northern Bates and Cass Counties, Missouri, recognized a similar sequence of two limestone units separated by shale, however, Greene believed that the sequence occurred in the Bandera shales and named the limestone beds the upper and lower Worland for exposures near Worland in western Bates County. As a result, Greene miscorrelated an overlying limestone, probably the Lenapah, with the Altamont.

In an attempt to alleviate the confusion which existed between Missouri and Kansas a field conference was organized (Cline, 1941, p. 29) which included R. C. Moore and J. M. Jewett of Kansas, L. M. Cline of Iowa, and F. C. Greene of Missouri. The participants of this conference traced the lower and upper Worland limestone units of Greene from the Missouri River across southwestern Missouri and into southeastern Kansas and showed them to be equivalent to the upper and lower Altamont limestones respectively.

It is not difficult to see why Greene considered the Altamont limestones to be part of the Bandera formation for just north of Worland the Bandera formation thins to less than 10 feet in contrast to a thickness of 40 or 50 feet southwest of Worland, (Plate 8, Sections 54, 55).

According to present classification the Altamont formation consists of the strata between the Bandera and Nowata formations and has been subdivided into three members which are, in ascending order, the Amoret, Lake Neosho, and Worland.

Amoret member

Name -- The name Amoret was applied by Cline and Greene (1950, p. 18) to the lowermost limestone of the Altamont formation and includes the beds between the top of the Bandera formation and the base of the Lake Neosho member of the Altamont formation. The type section was designated as two miles south of Amoret, Bates County, SW¼ sec. 33, T. 40 N., R. 33 W. (Plate 8, Section 56).

The name Amoret replaced the term "Tina" which had been applied

to the lower limestone of the Altamont formation by Cline (1941, p. 29) for exposures about two miles southeast of Tina, Carroll County, Missouri. The term "Tina" was suppressed because the limestone at the type section is not the lower Altamont but in all likelihood the top part of the Higginsville limestone.

Description -- The Amoret member varies in thickness from a few inches to slightly over 8 feet. The member is thickest at the type section in western Bates County and thins irregularly northeast and southwest along the outcrop belt, (Plate 8).

Lithologically the Amoret member consists of nodules of limestone embedded in a clay matrix which grade locally into bedded limestone that may be only slightly nodular (Plate 8, Sections 54, 55, 56). The nodules of limestone are in most places argillaceous, the percentage of clay increases with increasing nodularity. At the type locality in western Bates County the Amoret member consists predominantly of limestone which is wavy to nodular bedded (Plate 8, Section 56). The bedded limestone of this area frequently has a granular appearance which is the result of abundant specimens of Osagia. Brachiopod fossils include, Derbyia crassa (Meek and Hayden), Composita ovata Mather, Punctospirifer kentuckensis (Shumard), Antiquatonia portlockiana (Norwood and Pratten) and several species of Mesolobus. An organ pipe tabulate coral Syringopora spp. is found occasionally. The fossil content decreases with increasing nodularity.

The lithology of the Amoret member at the type locality is not

representative of the unit in most other areas of Bates County. Southwestward and northeastward along the outcrop belt from the type section in western Missouri the unit consists predominantly of sparsely fossiliferous nodules of limestone embedded in a greenish-gray clay, however, local thickening to very fossiliferous bedded limestone does occur.

Stratigraphic relationships -- The Amoret member is underlain by the Bandera formation and overlain by the Lake Neosho member of the Altamont formation. At most places the contact between the Amoret member and the Bandera formation is gradational from nodular limestone into clay or shale. At places where no lithologic break was visible between the limestone and shale the formational contact was arbitrarily placed within the clay-nodular limestone sequence. The boundary between the Amoret member and the Lake Neosho member is somewhat less gradational and has been placed at the top of the limestone nodules or nodular limestone.

Lake Neosho member

Name -- The Lake Neosho member was named by Jewett (1941, p. 331, 332) for exposures southeast of Lake Neosho in Neosho County State Park, Neosho County, Kansas.

Description -- The Lake Neosho member is a thin, persistent unit which averages about 3 feet in thickness. At no place was the member found to be more than 5 feet thick (Plate 8).

The Lake Neosho member consists of from 1 to 3 feet of dark-gray to black shale which grades vertically into light-gray, calcar-

eous shale. In most exposures the dark-gray to black shale contains large, spheroidal phosphatic concretions some of which are 1¼ inches in diameter. The center or core of most of the phosphatic concretions is hollow; however, some have formed around a crinoid columnal or other fossil fragment. The majority of the spheroidal phosphatic concretions are concentrically banded. The phosphatic concretions are present in most outcrops and aid in the indentification of the unit. Nevertheless, spheroidal phosphatic concretions of equal size are present in the Anna member and other criteria must be included when identifying the Lake Neosho member.

The top part of the Lake Neosho member consists of a few inches of light-gray shale which contains Mesolobus lioderma Dunbar and Conrad and Crurithyris planoconvexa (Shumard). Specimens of very small Mesolobus, approximately one-sixteenth inch in length are fairly abundant at this horizon. Wallace Howe of the Missouri Geological Survey (Personal communication) has used these small brachiopods as an aid in the identification of the Altamont formation.

Stratigraphic relationships -- The Lake Neosho member is overlain by the Worland member and underlain by the Amoret member. The base of the Lake Neosho member has been placed on top of the limestone nodules which are abundant in the Amoret member in most areas.

Worland member

Name -- The name "upper Worland" was applied by Greene (1933,

p. 18) to the upper of two limestone units separated by shale in the vicinity of Worland in western Bates County, Missouri.

The name Worland was later retained by Cline (1941, p. 24) after the "upper Worland" of Greene was recognized as the top limestone unit of the Altamont formation of southeastern Kansas.

Jewett (1941, p. 334) designated the type section as being along the Kansas City-Southern Railroad just north of the grade crossing northeast of Worland, Missouri (SW¼ SW¼ sec. 5, T. 39 N., R. 33 W.).

Description -- The Worland member is from 3 to 6 feet thick, (Plate 8). It attains its greatest thickness in southwestern Bates County (Plate 8, Section 51) and thins to approximately 3 feet in northeastern Bates County, (Plate 8, Section 50).

The Worland member consists predominantly of limestone which is commonly light-gray, wavy-bedded and jointed into large blocks or slabs which are several feet across. Main joint patterns are NW-SE and NE-SW. In the vicinity of Worland the lower surface of the member contains sinuous, elevated structures about one-half inch in diameter. They are believed to be filled-in burrows or to have formed by differential compaction. These structures have the appearance of a piece of coiled rope and have been informally termed "ropy" structures. The upper surface of the Worland member is irregular and pitted, probably as a result of differential solution by the processes of erosion. In places, colonies of Chaetetes give the upper surface a humpy appearance.

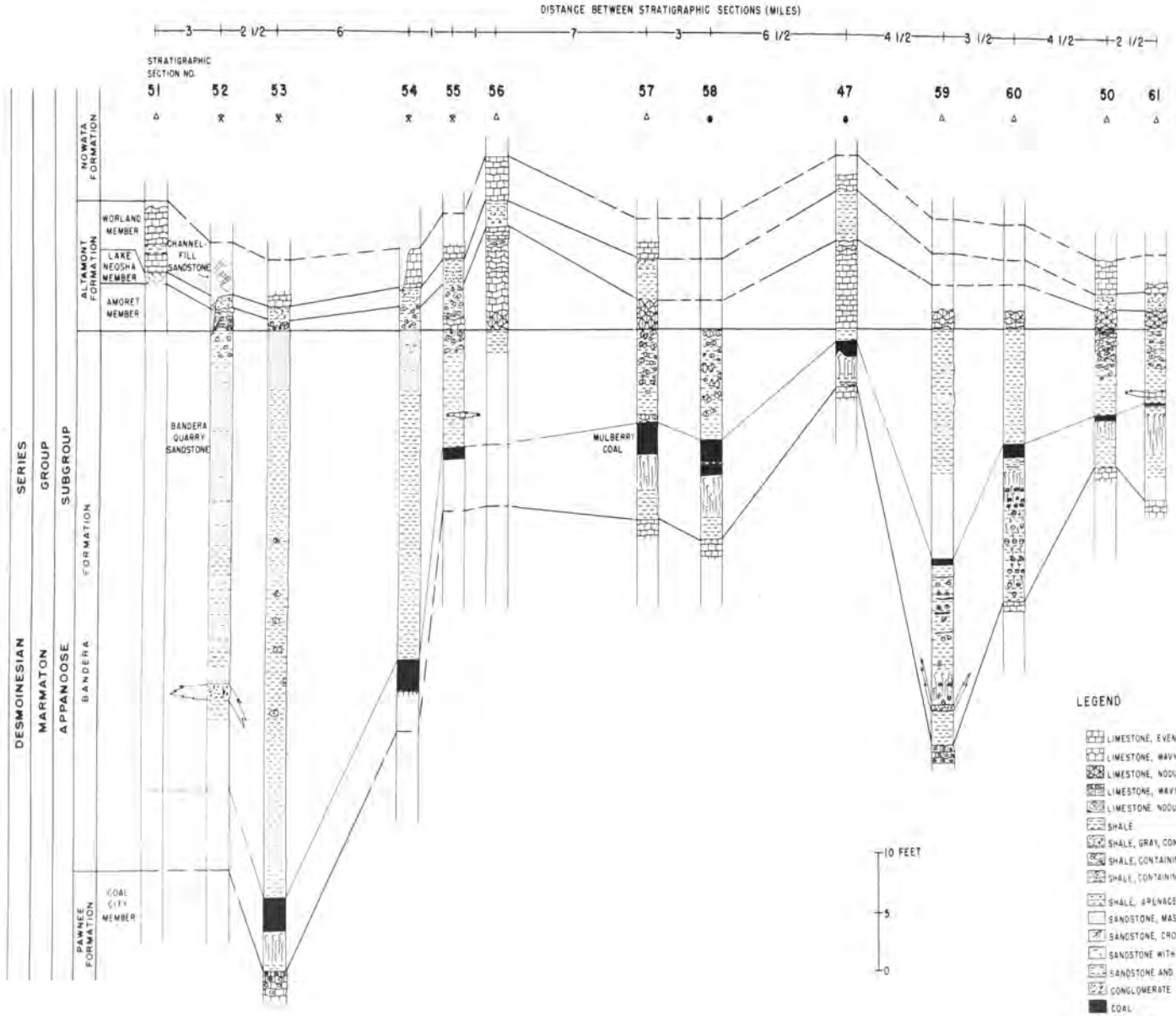
Figure 18. Altamont and Bandera formations exposed in highwall of abandoned Mulberry coal strip mine near Worland, western Bates County, NE¼ NW¼ sec. 7, T. 39 N., R. 33 W. The blocky limestone bed at top of highwall is the Worland member. The Lake Neosho member is represented by a thin dark-gray shale bed below the Worland limestone. The Amoret member which is composed of a few inches of nodular limestone is barely visible below the Lake Neosho member. The Bandera formation is represented by approximately 40 feet of gray shale. Three miles north of this location the Amoret member thickens to include 5 feet or more of bedded fossiliferous limestone and the Bandera formation thins to 10 feet or less.

In southwestern Bates County the lower several inches of the Worland member consists of thick-bedded limestone which is frequently jointed into blocks. A gray shale bed which is 1 foot or less in thickness separates this unit from the upper part which is composed of 4 or 5 feet of thin, wavy-bedded limestone (Plate 8, Section 51).

Common fossils are Fusulina, Composita, Cleiothyridina, Crurithyris, and small horn corals. Abundant platy algae frequently imparts a minute wavy appearance to the outcrop surface.

Stratigraphic relationships -- The Worland member is underlain by the Lake Neosho member of the Altamont formation and is overlain by gray shales of the Nowata formation. In southwest-central Bates County from Worland southeastward to the town of Sprague a channel-filling, reddish-brown sandstone has locally replaced the Altamont formation and the upper part of the Bandera formation (Plate 8, Section 54).

PLATE 8



CORRELATED
STRATIGRAPHIC SECTIONS
OF THE

BANDERA AND ALTAMONT FORMATIONS

BATES COUNTY AREA,
WESTERN MISSOURI

BY
RICHARD J. GENTILE

JULY, 1964

LEGEND

- LIMESTONE, EVEN-BEDDED
- LIMESTONE, WAVY-BEDDED
- LIMESTONE, NODULAR
- LIMESTONE, WAVY-BEDDED
- LIMESTONE NODULES WITH CLAY MATRIX
- SHALE
- SHALE, GRAY, CONTAINING PHOSPHATIC CONCRETIONS
- SHALE, CONTAINING CLAY-IRONSTONE CONCRETIONS
- SHALE, CONTAINING SEPTARIAN CONCRETIONS
- SHALE, ARENACEOUS
- SANDSTONE, MASSIVE TO EVEN-BEDDED
- SANDSTONE, CROSS-BEDDED
- SANDSTONE WITH SHALE LENSES
- SANDSTONE AND SHALE, INTERBEDDED
- CONGLOMERATE
- COAL
- UNDERCLAY
- UNDERCLAY CONTAINING CLAY-IRONSTONE CONCRETIONS

△ OUTCROP
✳ STRIP MINE
● DRILL TEST CORE AND ARTIFICIAL EXCAVATION

CYCLIC SEDIMENTATION

The preceeding discussion of the upper Cherokee and lower Marmaton groups of western Missouri has shown that the rocks of this area consist of beds of shale, limestone, sandstone and minor amounts of coal, underclay and conglomerate. These occur in relatively thin units and are repetitive or cyclic in nature.

Cyclic deposition has long been recognized as one of the most outstanding features of the Pennsylvanian rocks in many parts of North America and Europe. Pennsylvanian strata were first observed to be repetitive or cyclic in nature by Udden (1912) who was working in a portion of western Illinois. He suggested that the regular repetition of a similar sequence of beds reflects a rhythmic recurrence of similar environmental conditions.

Weller (1930), also working in Illinois, was the first to clearly present an interpretation of Pennsylvanian cyclic deposits. He recognized a sequence consisting of eight members which he believed represented the succession of deposits formed during a complete Pennsylvanian sedimentary cycle. To this sequence of rocks Weller proposed the name "cyclothem".

The cyclothem as proposed by Weller begins with the deposition of sand on an erosion surface, proceeds through a stage of lowland and swamp conditions, and culminates in marine inundation. This process is followed by rapid withdrawal of the sea and subsequent erosion, after which a new cycle starts with deposition of more sand.

The "ideal" cyclothem as first proposed by Weller contains the following members (1930, p. 102):

Marine	8)	shale, containing "ironstone" bands in upper part and thin limestone layers in lower part
	7)	limestone
	6)	calcareous shale
	5)	black "fissile" shale
Continental	4)	coal
	3)	underclay, not uncommonly containing concretary or bedded fresh-water limestone
	2)	sandy and micaceous shale
	1)	sandstone
unconformity		

Later studies have prompted Weller to include ten units in the "ideal" cyclothem.

According to Weller's concept, as it was first proposed, a cyclothem is a record of a single cycle of transgression and regression of the Pennsylvanian sea over wide areas of the central and eastern United States. The transgressive phase culminated in the deposition of marine limestone and the regressive phase culminated in subaerial erosion which is recorded in the stratigraphic record by an unconformity.

Later stratigraphers have recognized that minor transgressions and regressions did occur during a single cycle and as a result the "ideal" cyclothem as first proposed by Weller was modified, usually to include more units. The sedimentary record of such a complex cycle in Kansas was designated a megacyclothem by Moore (1936).

The lithologic and faunal characteristics of a cyclothem are not only determined by the number and magnitude of the transgressions and regressions of the Pennsylvanian seas but also by other factors

such as source and supply of sediment, climate, and irregularities of the depositional surface. For this reason cyclothems will vary in character from place to place depending on the environmental conditions under which they were formed. Cyclothems in the Mid-Continent area are predominately marine and contain large amounts of marine limestone and shales in comparison to those of the Eastern Interior basin which are composed predominately of thick beds of sandstone, and shale of non-marine origin. Standard or "ideal" cyclothems which consist of the lithologic types recognized in a particular area have been proposed by several workers (Moore 1936; Wanless 1950; Searight 1955; Wheeler 1957). The well developed or "ideal" cyclothem of the Mid-Continent, of which there are few, is shown below (Branson 1962, p. 450):

9) shale, dark, unfossiliferous, with clay-ironstone concretions
8) limestone, locally rich in fusulinids
7) shale, gray, containing myalinids
6) limestone or clay ironstone, marginiferids abundant
5) shale, black, fissile, phosphatic
4) coal
3) underclay
2) shale, silty, fossil plants
1) sandstone, non-marine, locally conglomeratic

Most units of a cyclothem are discontinuous, although some of them can be traced from outcrop to outcrop for hundreds of miles.

The cyclical repetition of beds is regional rather than local and requires a mechanism which would send the seas of Pennsylvanian times pulsating back and forth across large areas of the central and eastern parts of the United States. Three major theories have been

proposed to account for the widespread occurrence of cyclical deposits. (1) Weller (1930) proposed the theory of diastrophic control which requires oscillatory crustal movements in both source areas and basins of deposition. (2) Wanless and Shepard (1936) visualized an intermittently subsiding basin combined with fluctuations in sea level controlled by the advance and retreat of continental glaciers. (3) Wheeler and Murray (1957) proposed a continuous subsiding basin with sea level fluctuations controlled by glacial cycles.

Other theories which have been proposed have incorporated some combination of the processes mentioned above.

The complete sequence of beds composing the ideal cyclothem as visualized by Weller and other workers is seldom observed in outcrop and never occurs over wide areas. This does not alter the concepts which have been proposed to account for cyclical deposition but implies that conditions were operative which prevented the complete cycle from being deposited.

STRUCTURE

The Bates County area lies on the southern margin of the Forest City basin (Figure 19). The Bourbon arch, an eastward extension of the Nemaha structural belt, lies directly south of the Bates County area and separates the Forest City basin from the Cherokee platform. The Missouri platform which lies on the northwest flank of the Ozark uplift is to the east. Thus, the Bates County area of western Missouri is situated near the junction of three major tectonic features, the Forest City basin, Bourbon arch, and the Missouri platform.

Regionally the Pennsylvanian strata of the Bates County area dip northwestward toward the Forest City basin at 10 to 15 feet per mile. However, the attitude of the beds has been modified to a great extent by several northwest plunging, broad folds and intervening synclines (Plate 9). The largest of these folds is the Schell City-Rich Hill anticline which was first mentioned by Hinds and Greene (1915, p. 206). This structure enters Bates County in the southeastern corner and trends northwestward to near the Kansas-Missouri border in northwestern Bates County where it plunges beneath younger sediments. The Schell City-Rich Hill anticline is asymmetrical in shape. Dips of over 30^{o} may be observed on the southwestern limb using the Higginsville limestone as a datum. The attitude of the northeastern limb is somewhat less steep. The closure is about 150 feet.

The trend and configuration of the Schell City-Rich Hill anticline has been recognized in subsurface studies of the lower

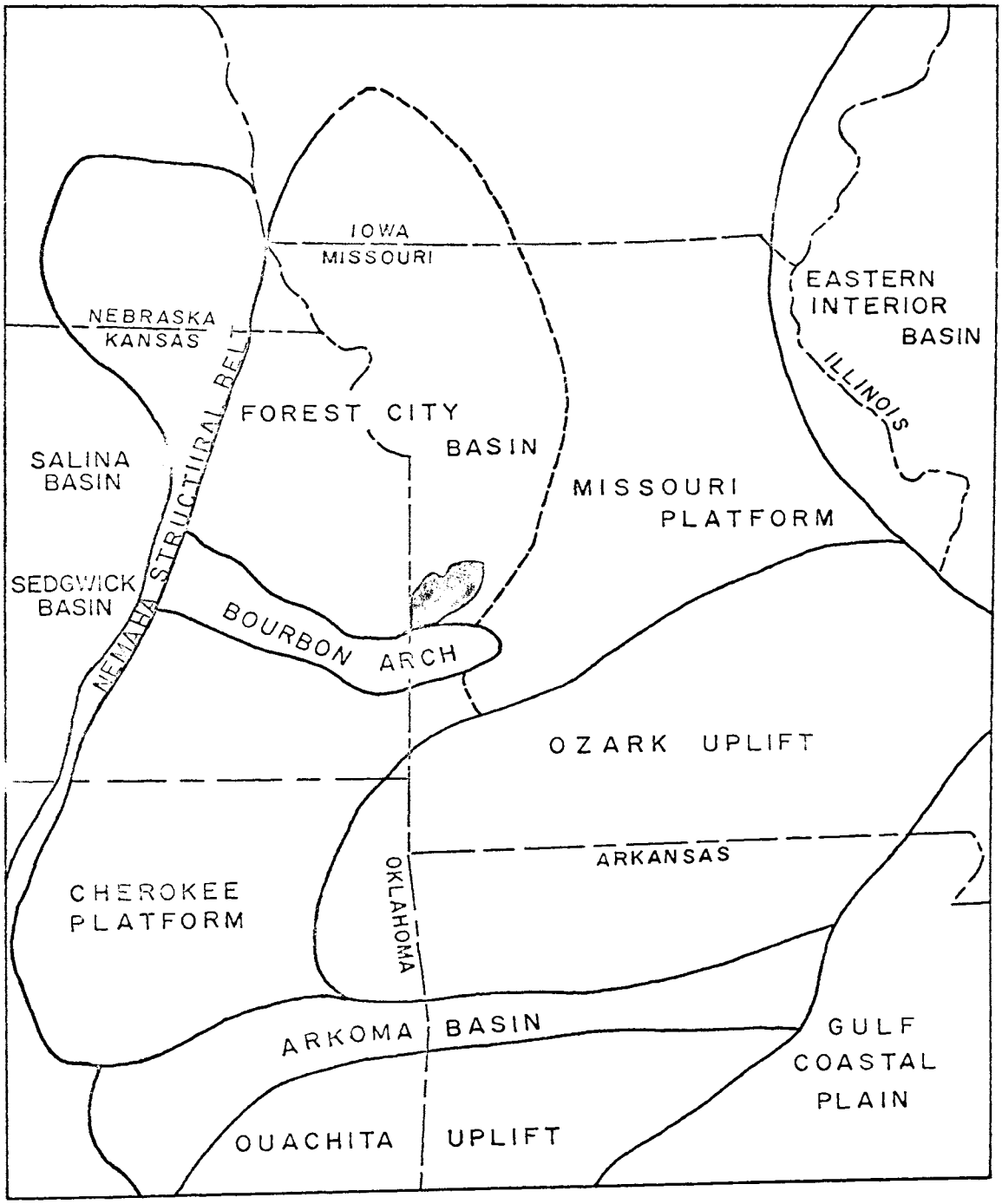


Figure 19. Major Pennsylvanian structural features of the Mid-Continent area and their relationship to the project area (modified after Branson 1962, p. 432). Project area shown by shading.

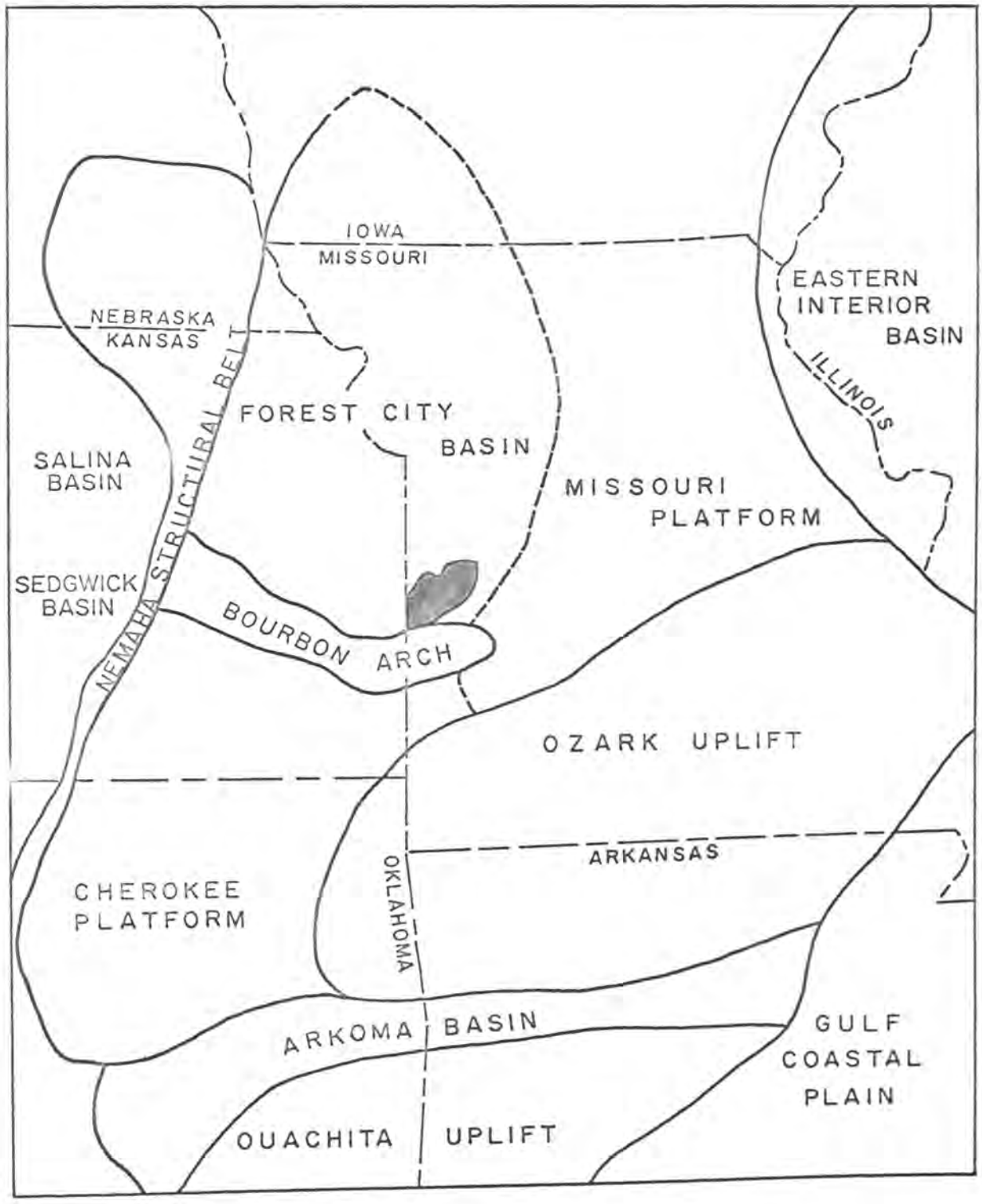


Figure 19. Major Pennsylvanian structural features of the Mid-Continent area and their relationship to the project area (modified after Branson 1962, p. 432). Project area shown by shading.

Paleozoic rocks of western Missouri by Robert Knight and Mary McCracken of the Missouri Geological Survey. Although conclusive subsurface data is lacking, the possibility exists that the Schell City-Rich Hill anticline may be represented in the subsurface of Bates County by a fault or series of faults located near the steeply dipping southwestern limb. When traced southeastward the axis of the Schell City-Rich Hill anticline is aligned approximately with the Eldorado Springs fault zone in Cedar County (see geologic map of Missouri, 1961 edition). Faulting and considerable distortion of the strata has been observed in strip mining operations of the Mineral coal in northern Vernon County. The strip mines in which the faulting and distortion is the greatest are aligned with the southwestern flank of the Schell City-Rich Hill anticline.

On the basis of work in progress by W. C. Hayes of the Missouri Geological Survey (personal communication) two faults or fault zones are present in the Precambrian rocks of Bates County. The location and trend of these faults or fault zones is similar in position to the axes of the Schell City-Rich Hill anticline and the Ladue-Freeman anticline which is also a northwest-southeast trending structure that crosses northeastern Bates County in the vicinity of Ballard (Plate 9). The Ladue-Freeman anticline was named by Hinds and Greene (1915, p. 206). Perhaps the steeply dipping southwestern limb of these structures project downward into a fault zone in the subsurface rocks. The possibility then exists that the area between the steeply dipping southwestern limbs of the Schell City-Rich

Hill anticline and the Ladue-Freeman anticline is in reality a fault block in subsurface rocks.

A northwest-trending asymetrical fold has been recognized in northwestern Vernon County but the configuration and closure of this structure could not be determined because of the lack of subsurface information.

With the exception of the southwest flank of the Schell City-Rich Hill anticline which can be traced for miles, most directly observable dips seem to be connected with entirely local structures which are superimposed on the larger regional structures. These larger structural features are recognizable only through broad base mapping.

Several smaller folds which are not more than a few square miles in area are present on the southwestern limb of the Schell City-Rich Hill anticline. They appear to plunge steeply northwestward but at an angle of several degrees to the major structural axis of the Schell City-Rich Hill anticline. In other parts of the Bates County area dips of 100 feet per mile have been observed and appear to be related to structures of limited areal extent.

These smaller folds of not more than a few square miles in areal extent are themselves wrinkled by still smaller minor structural features. These minor structural features vary in shape from asymmetrical folds to irregular dipping surfaces whose inter-relationships could not be determined.

Hinds (1912, p. 76; Hinds and Greene 1915, p. 461) reported

steep dips in mines of the Rich Hill District. The elevation of the Rich Hill (Mineral) coal often varied as much as 150 feet in less than one-half mile. Dips steep enough to necessitate the use of special equipment for mine haulage were commonly encountered.

The structures of less than a few square miles may have resulted from one or more of the following processes: (1) solution and collapse of underlying carbonate rocks; (2) differential compaction; (3) slump; (4) irregularity of the original surface of deposition or (5) true structural deformation resulting from diastropism.

The larger structural features of the Bates County area, particularly the Schell City-Rich Hill anticline, are considered to be the result of structural deformation resulting from diastrophic movements that acted intermittently over a long period of time.

The Bourbon arch is considered to have developed in late Mississippian time and to have persisted into early Pennsylvanian time (Lee 1943; Jewett 1945). It is not known to what extent the Bourbon arch affected the structure of the Bates County area. The east-west trending nature of this structure is contrary to the major northwest-southeast trending structural features of the Bates County area. However, the Bourbon arch is located south of the Bates County area (Lee, 1943, Figure 2). It is also doubtful if it extended far enough to the east to cross the main structural axis of the Schell City-Rich Hill anticline.

On the basis of limited reconnaissance work done by the

writer south of the project area in Vernon County, the upper Cherokee and lower Marmaton rocks do not seem to thin or otherwise to be appreciably different lithologically in the vicinity of the Bourbon arch than in Bates County. Therefore, it is assumed that the Bourbon arch did not actively affect deposition at the time the upper Cherokee and lower Marmaton rocks were laid down.

Figure 20. Steeply inclined strata forming the southwest limb of the Schell City-Rich Hill anticline, 1½ miles west of Rich Hill, SE¼ SW¼ sec. 1, T. 38 N., R. 32 W. Dip of Higginsville limestone recorded at small quarry is 35° S.45°W. Photo taken looking south. Attitude and trend persists for 3 miles.

Figure 21. Disturbed strata in west highwall of abandoned coal strip mine at Stratigraphic Section No. 15, north-central Vernon County. Light-gray bed near center of photo is 4 ft. thick and is composed of sandstone. It underlies the Croweburg coal in the Rich Hill area. The Mineral coal was mined. Structurally the section is on the southwest flank of the Schell City-Rich Hill anticline. Dip is 30° S.45°W. Photo taken looking west.

Figure 22. Verdigris limestone with steep dip at Stratigraphic Section No. 15, north-central Vernon County. Dip is 35° S.45°W. Photo taken looking north.

Figure 23. Small asymmetrical fold in Atokan(?) strata. North side of drainage ditch, 1½ miles south of Prairie City, SW¼ NW¼ sec. 24, T. 38 N., R. 30 W. Axis of fold strikes N.20°E. Structurally the fold is located near the axis of the Schell City-Rich Hill anticline.

Figure 24. Eroded fold in Atokan(?) strata. Approximately one-fourth mile west of the fold shown in Figure 23.

Figure 25. Inclined beds in abandoned quarry at Stratigraphic Section No. 50, northeastern Bates County. Coal City limestone quarried. Dip of quarry floor is 10^{o} N.45^{o}E. Photo taken looking west.

Figure 26. Inclined sandstone beds forming rapids in the South Grande River, 5 miles northeast of Adrian, SE¼ SE¼ sec. 12, T. 42 N., R. 31 W. Northwest limb of small fold. Dip of beds is 16° N.45°W. Southeast limb of fold is exposed 300 feet downstream.

Figure 27. Folded sandstone and shale beds of the Bandera formation exposed in highwall of abandoned Mulberry coal strip mine, southwestern Bates County, NE¼ SE¼ sec. 21, T. 38 N., R. 33 W.

Figure 28. Slightly disturbed strata at the Alvis quarry, Stratigraphic Section No. 32, central Bates County. Higginsville limestone and overlying Labette and Pawnee formations are dipping 3^{o} N.25^{o}E.

Figure 29a. Croweburg coal lying horizontally on disturbed sandstone and shale beds which pinch out near top of small fold, east-central Bates County, NW¼ NE¼ sec. 22, T. 40 N., R. 29 W.

Figure 29b. Close-up of faulting on west limb of structure shown in Figure 29a. Displacement of the Croweburg coal is 2 feet. It is assumed that the sandstone beds pinch out through non-deposition near the crest of a small fold. At some later time (after the Croweburg coal was deposited horizontally on the underlying strata) the southwest flank of the fold was faulted by renewed movement.

PHYSICAL VARIATIONS IN CYCLOTHEMS IN THE BATES COUNTY AREA

Cyclothems of the Bates County area of western Missouri are characterized by variability. Although a few lithologic units of this area persist for miles without any noteworthy changes in physical characteristics, other units, when traced along the outcrop belt were observed to vary considerably in physical characteristics. Some lithologic units composing the cyclothem are facies changes of short lateral extent. This is particularly true of most of the sandstones, shales and shaly limestones. Other units, particularly the purer limestones, black, fissile shales and coal beds, are very persistent. Nevertheless, many of the purer limestone and black, fissile shale units were observed to be characterized by abrupt changes in thickness, lithology and faunal characteristics in the Bates County area. Some coal beds considered to be persistent in other areas pinch out in this area and their stratigraphic positions could be determined only by a study of the associated strata. Noteworthy examples of stratigraphic units which vary in thickness or lithology are as follows: (1) The Verdigris (Ardmore) limestone,which consists of two beds of well-bedded limestone separated by shale in northwestern Vernon and southwestern Bates County, becomes a single bed of nodular to bedded limestone in the vicinity of the Schell City-Rich Hill anticline in south-central Bates and north-central Vernon County. Although it thins somewhat irregularly, it persists along the outcrop belt as a nodular limestone bed to at least western Henry County. In central Henry County, a limestone facies similar to that in south-

western Bates and northwestern Vernon County is once again encountered. (2) The black fissile shale underlying the Verdigris limestone is over 2 feet thick in the southwestern part of the Bates County area. When traced northeastward to the vicinity of the southwest flank of the Schell City-Rich Hill anticline, the black, fissile shale thins to a few inches of soft, greenish-gray shale which persists to western Henry County. (3) The black, fissile shale of the Excello formation thins and loses its fissility in some areas along the axis of the Schell City-Rich Hill anticline. (4) The Mulky coal, which is from several inches to 3 feet thick in Henry and Vernon Counties, is represented by a thin coal smut throughout most of Bates County. (5) The Wheeler coal bed and associated strata are not present throughout much of southeastern and south-central Bates County. (6) This is also true of the coal bed or beds in the lower part of the Mulky formation which could not be traced southwestward from northeastern Bates County. (7) The Bevier coal was not recognized southwestward from western Henry County. (8) The Amoret limestone changes abruptly from an unfossiliferous, nodular limestone to a very fossiliferous, bedded limestone along the axis of the Schell City-Rich Hill anticline in western Bates County, between the towns of Worland and Amoret. Still other variations can be cited.

PROBABLE CAUSE FOR PHYSICAL VARIATIONS IN CYCLOTHEMS IN AREAS OF LIMITED EXTENT

The persistence and physical characteristics of a particular stratigraphic unit of a cyclothem in limited areas does not appear to be completely controlled by the mechanism or mechanisms responsible for the extent of the transgressions or regressions of Pennsylvanian seas over wide areas. The lithology and thickness of some of the units appear to have been influenced by local irregularities of the depositional surface at the time of deposition because most variations in lithology and thickness are associated with mappable structures of local or regional extent. Irregularities may have originated by one or a combination of the following processes: (1) Solution and collapse of the underlying Mississippian or older carbonate rocks. (2) Differential compaction of the underlying, earlier deposited, Pennsylvanian sediments. (3) Irregularities in the original surface of deposition. (4) Structural deformations synchronous with subsidence of the major basins such as the Forest City. Structural deformation must be considered a likely possibility for the following reason:

Lithologic and paleontologic features of Pennsylvanian cyclical deposits indicate that deposition took place in shallow, marine, brackish or fresh water near zero elevation. In the Bates County area a maximum of 800 feet of Pennsylvanian strata that were deposited under these conditions overlie Mississippian rocks. It must be concluded that several hundred feet of subsidence occurred

to account for the deposition of this thickness of strata. It is reasonable to assume that the regional subsidence in the Bates County area was north or northwestward into the Forest City basin and was accompanied by minor undulations which could have affected sedimentation. Variations in the thickness, lithology, and faunal characteristics of the units composing the cyclic deposits of western Missouri may be the result of these crustal disturbances.

According to Weller (1957, pp. 326-328) the Pennsylvanian, more than any previous Paleozoic period, was a time of crustal instability. During the Pennsylvanian Period, the central and eastern parts of the United States existed as a somewhat irregular depression, bounded by a low upland to the north, higher areas to the east and south, and irregular, lower mountains to the west. This interior region was interrupted by the Cincinnati arch with its northern branches; the Ozark dome; the Michigan basin; the Illinois-Indiana-Western Kentucky basin; and the Forest City basin. Important, but less pronounced structures such as the Nemaha structural belt of eastern Kansas and southeastern Nebraska and the LaSalle anticline and DuQuoin axis in Illinois came into existence. Finally, many minor structures either were accentuated or made their appearance (Weller 1957, p. 328).

In the basins subsidence predominated, interrupted by periodic, brief intervals of minor uplift which resulted in characteristic cycles of deposition. Minor irregularities-local unsynchronized movements of either uplift or depression-may account for uncommon

irregularities in the stratigraphic sequence that do not entirely fit into the general cyclical pattern (Weller 1957, p. 363).

Lithologic units which crop out in the Bates County area several hundred feet above sea level are found at a depth of several hundred feet below sea level in the Forest City basin. Thus, hundreds or even possibly thousands of feet of subsidence occurred in the Forest City basin during the Pennsylvanian period.

PALEOGEOGRAPHY

During the Pennsylvanian period seas repeatedly transgressed over the Bates County area and flooded a somewhat uneven surface close to a shifting shore. The water was salty, brackish or fresh and everywhere shallow but of unequal depth. Numerous depositional environments prevailed in the area. Sometimes diversified environments existed simultaneously in adjacent areas. At other times these diversified environments were separated by short intervals of time.

Sediments included lime and detrital muds that were deposited under conditions of unrestricted marine circulation to black organic muds laid down in a restricted lagoonal or tidal flat environment.

The withdrawal of the shallow seas into the deeper parts of the Forest City and Arkoma basins caused streams to extend their courses over the newly emergent region. Sand, silt and mud was deposited in the form of deltaic, floodplain or channel-fill deposits.

The record of these gradual shifting environments has been preserved in the stratigraphic sequence as facies of diverse lithology.

According to most students of the Pennsylvanian the major direction of sediment transport was from the north or northeast (Wheeler and Murray 1957, p. 1990). Nevertheless, the Nemaha structural belt of Kansas and the Ouachita Mountain Region of Oklahoma and Arkansas could have contributed considerable quantities of

sediment to the area. If direction of sediment transport was from the north or northeast it would have been necessary for some sedimentary units deposited in a non-marine environment to have had the sediment composing them transported across areas where marine or lagoonal sedimentation was in progress (Figure 31a).

The Ozark dome is considered to have been a minor source area which at times was itself inundated by marine transgressions. Gradation from a marine to non-marine environment upon approaching the Ozark dome is indicated by sedimentological studies of some of the units. It is assumed that during most of the Pennsylvanian Period the Ozark dome was a low emergent area and marine waters inundated the region around it.

Numerous northwest-southeast trending structures extended from the Ozark dome into the Forest City basin. The Schell City-Rich Hill anticline was the most prominent of these structures in the Bates County area. Intermittent movement along the structure influenced the depositional environment throughout much of the area.

The paleogeography of the Bates County area during deposition of the Verdigris formation, the lower part of the Bevier formation and parts of the Bandera, and Altamont formation is reconstructed on paleosedimentological maps arranged in chronological sequence (Figures 30 and 31). The environments of deposition corresponding to each map are discussed in detail in the following paragraphs:

Following the deposition of the Croweburg coal, a non-marine to brackish water environment prevailed in the Bates County

area. Detrital mud, sand and silt were being deposited to form deltas or tidal flats (Figure 30a). Thickest accumulations were in the Rich Hill area in the southern part of the Bates County area (Plate 3).

The tidal flat or deltaic environment was followed by marine transgression and a restricted lagoonal environment came into existence. In the western half of the area black organic muds containing a high percentage of phosphate was formed in an environment or restricted marine circulation. The eastern half of the region at this time was aerated sufficiently to cause oxidation of the organic matter with the result that greenish-gray phosphatic muds were deposited. It is postulated that the eastern half of the Bates County area was a shoal area and waves agitated the bottom sediments. The restricted lagoonal environment was gradually replaced by an environment of less restricted circulation (Figure 30b). A eustatic rise in sea level or a lowering of the land surface by epeirogenetic movements allowed marine waters to enter the area which had previously been a lagoon. Lime and detrital muds were deposited in this newly formed marine or lagoonal environment in the western part of the area while sand, mud and lime were being deposited in the northeast. Throughout most of the central part of the area the restricted environment was gradually replaced by marine encroachment that was accompanied by deposition of lime muds. Progressive marine transgression continued and beds of lime and detrital mud were deposited in the western one-third of the area in an environ-

ment of normal marine circulation while in the eastern two-thirds the shoal-type environment, which came into existence during deposition of the underlying phosphatic shales, persisted with deposition of lime muds (Figure 30c). A facies change from a well-bedded limestone in the west to nodular limestone in the northeast, infers that waves agitated the bottom sediments in the eastern part of the area. The northeastern part of the area continued to receive considerable amounts of sand derived from some unknown source area. Following deposition of the Verdigris limestone marine waters withdrew from the area. It is a likely supposition that deltaic sandstones and shales were deposited during the non-marine portion of the cyclothem but were removed subsequent to the development of the underclay of the Wheeler coal.

The gradual encroachment of the seas over the region resulted in the development of a near shore environment (Figure 30d). Marine limes and muds were deposited in the western part of the area. These now compose the fossiliferous shale and argillaceous limestone overlying the Wheeler coal. Coal swamps existed in the brackish or fresh water environment to the east. Most of the central part of the area was elevated slightly so that organic matter was oxidizied with the result that the Wheeler coal is absent in this area.

The thickness pattern of the Verdigris formation is shown in (Figure 30e).

During the time interval corresponding to deposition of the upper part of the Bandera formation thick beds of sand and mud were

accumulating to form deltas and tidal flats in the southwestern part of the area (Figure 31a). Meanwhile the remainder of the region was receiving accumulations of lime mud and detrital mud in a lagoonal environment. Isolated lenses of sand and detrital mud occur in the middle of the lagoonal environment. It is postulated that these isolated areas were small structurally controlled basins which were subsiding more rapidly than the surrounding area. Detrital mud and sand were the major sediments carried into them by currents with lime mud being a minor constituent. (The writer has studied small bodies of sand and silt in an area of black mud deposition in the Mississippi Sound off the southern coast of the United States. Currents appear to have winnowed the coarser fraction from the black muds).

Progressive marine transgression continued and beds of lime and detrital mud were deposited in areas where the bottom sediments were not agitated to an appreciable degree (Figure 31b). Throughout the major part of the Bates County area shoaling conditions prevailed and lime muds were shaped into nodules by wave agitation of bottom sediments. In the southwestern part of the Bates County area detrital mud and sand continued to be deposited in the form of deltas or on tidal flats.

Gradation from a lagoonal environment in the northeast to a predominately non-marine deltaic environment in the southwest implies that sediment was derived from a source area which lay to the southwest, west or northwest. However, until studies of a more regional nature can be completed this conclusion is tentative and premature.

The combined thickness of the Bandera and Altamont formations is shown in (Figure 31c).

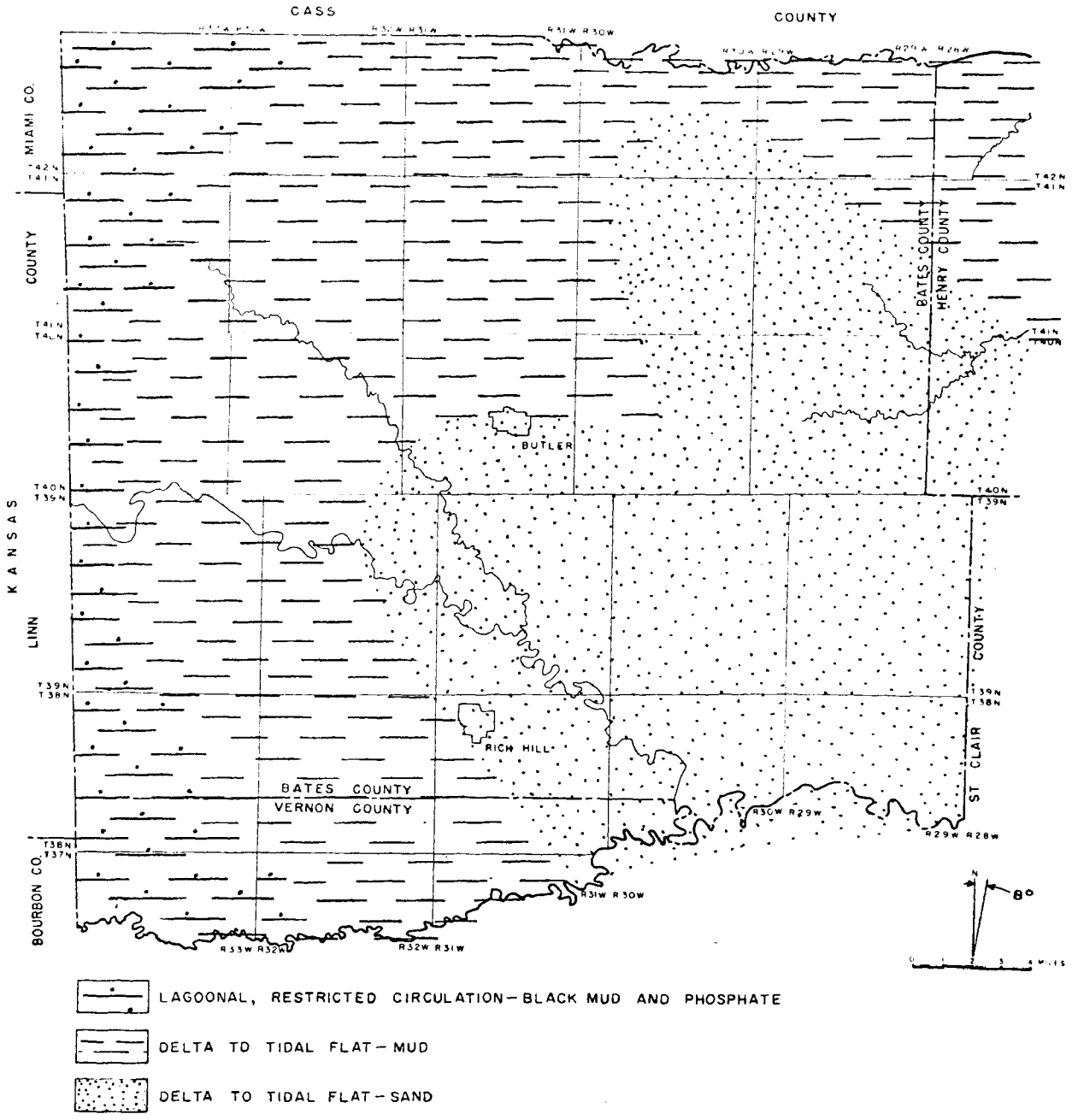


Figure 30. Paleosedimentological maps, Verdigris formation (a) Sandstone, gray shale and phosphatic shale interval beneath Verdigris limestone.

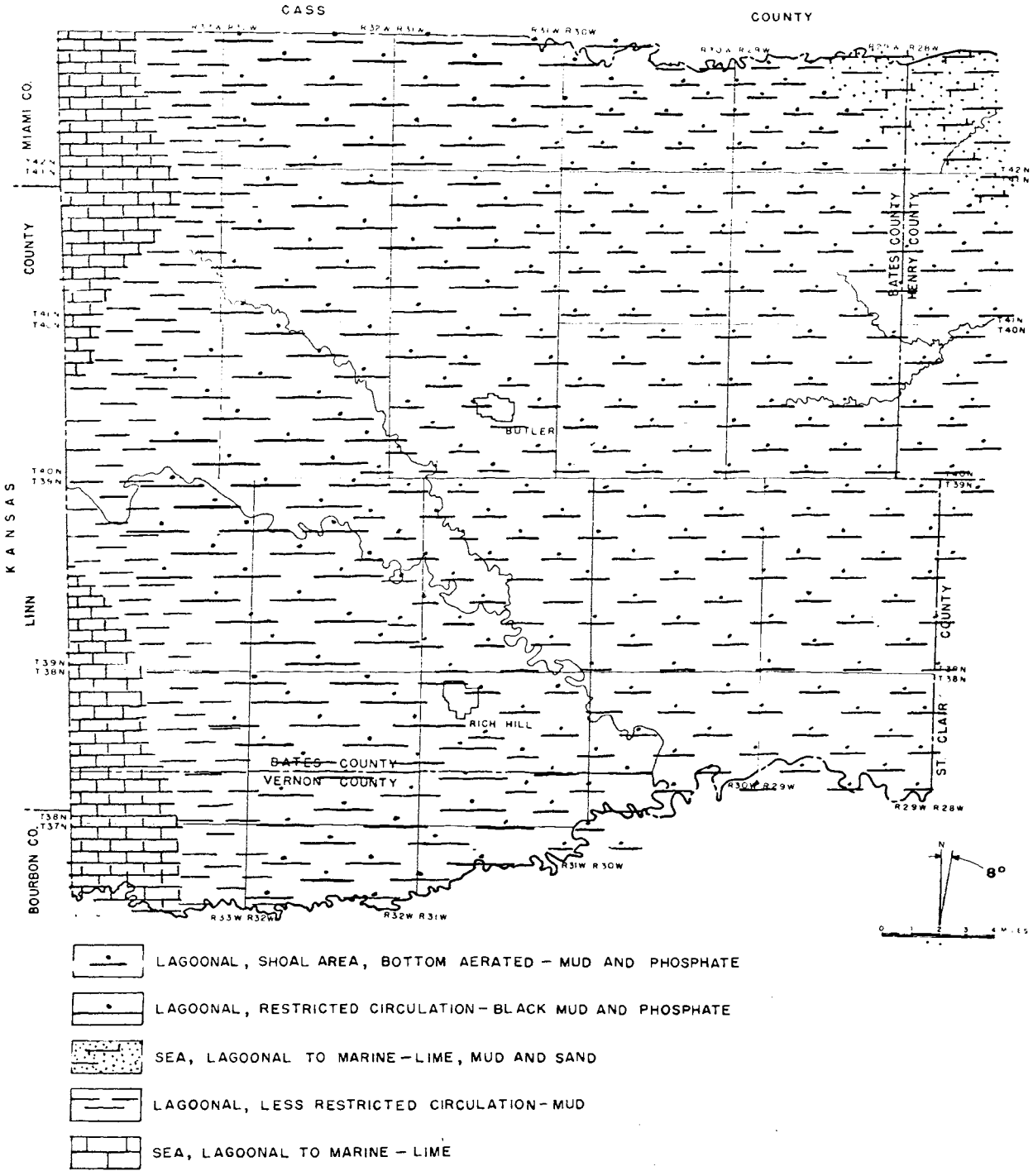


Figure 30. (continued), (b) Phosphatic shale beneath the Verdigris limestone and the lower part of the Verdigris limestone.

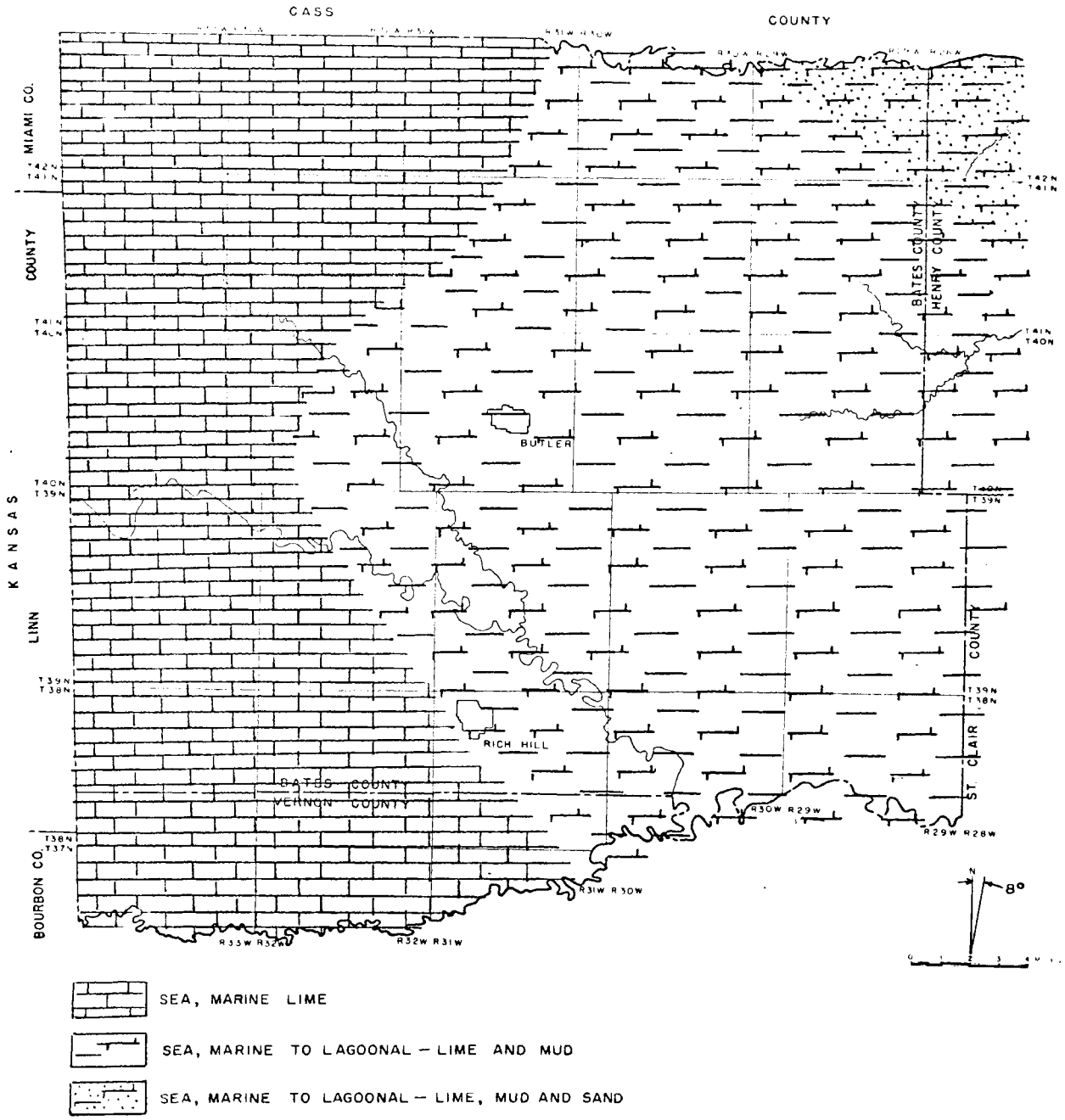


Figure 30. (continued), (c) Verdigris limestone

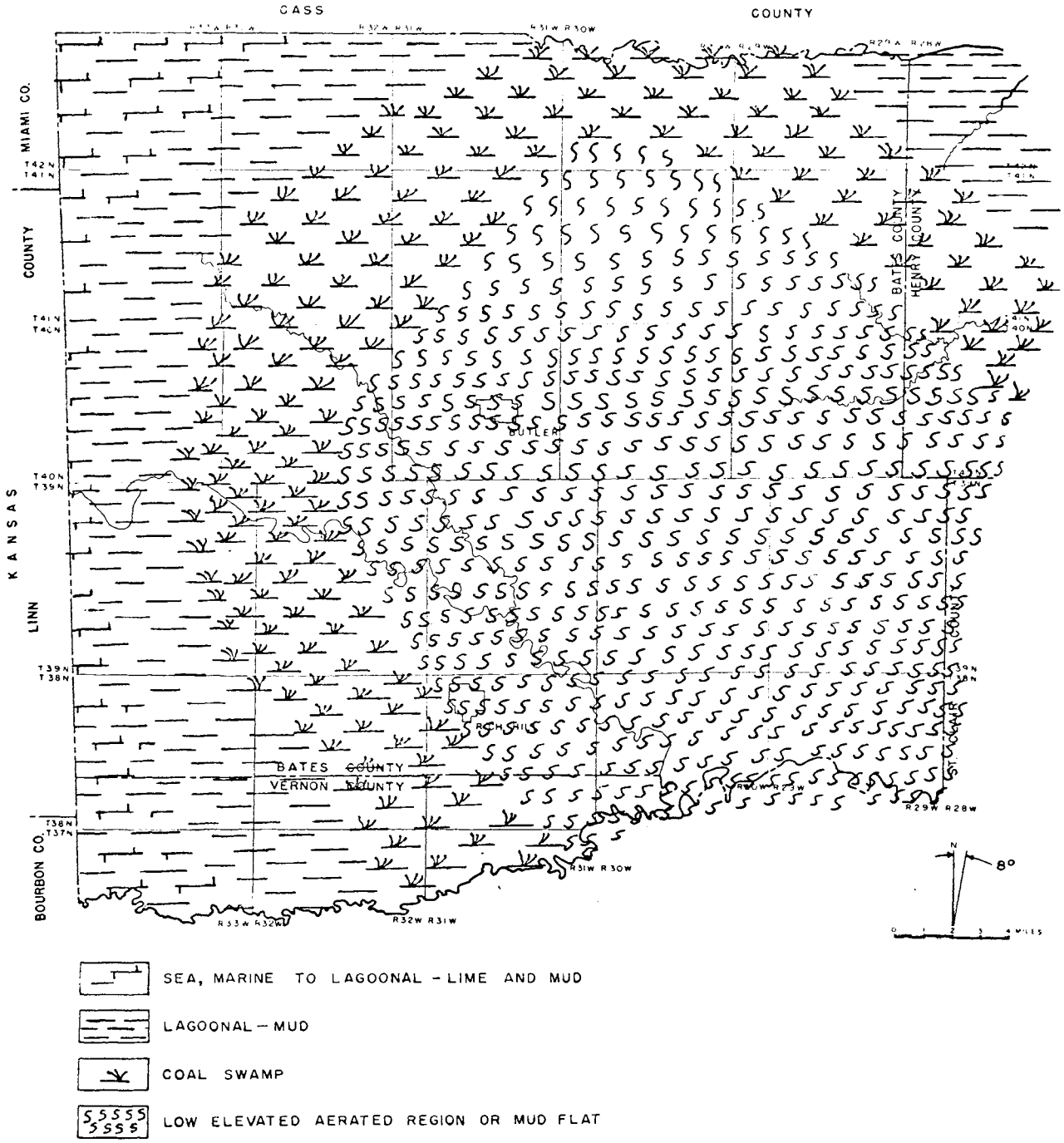


Figure 30. (continued), (d) Wheeler coal, underclay and lower part of Bevier formation.

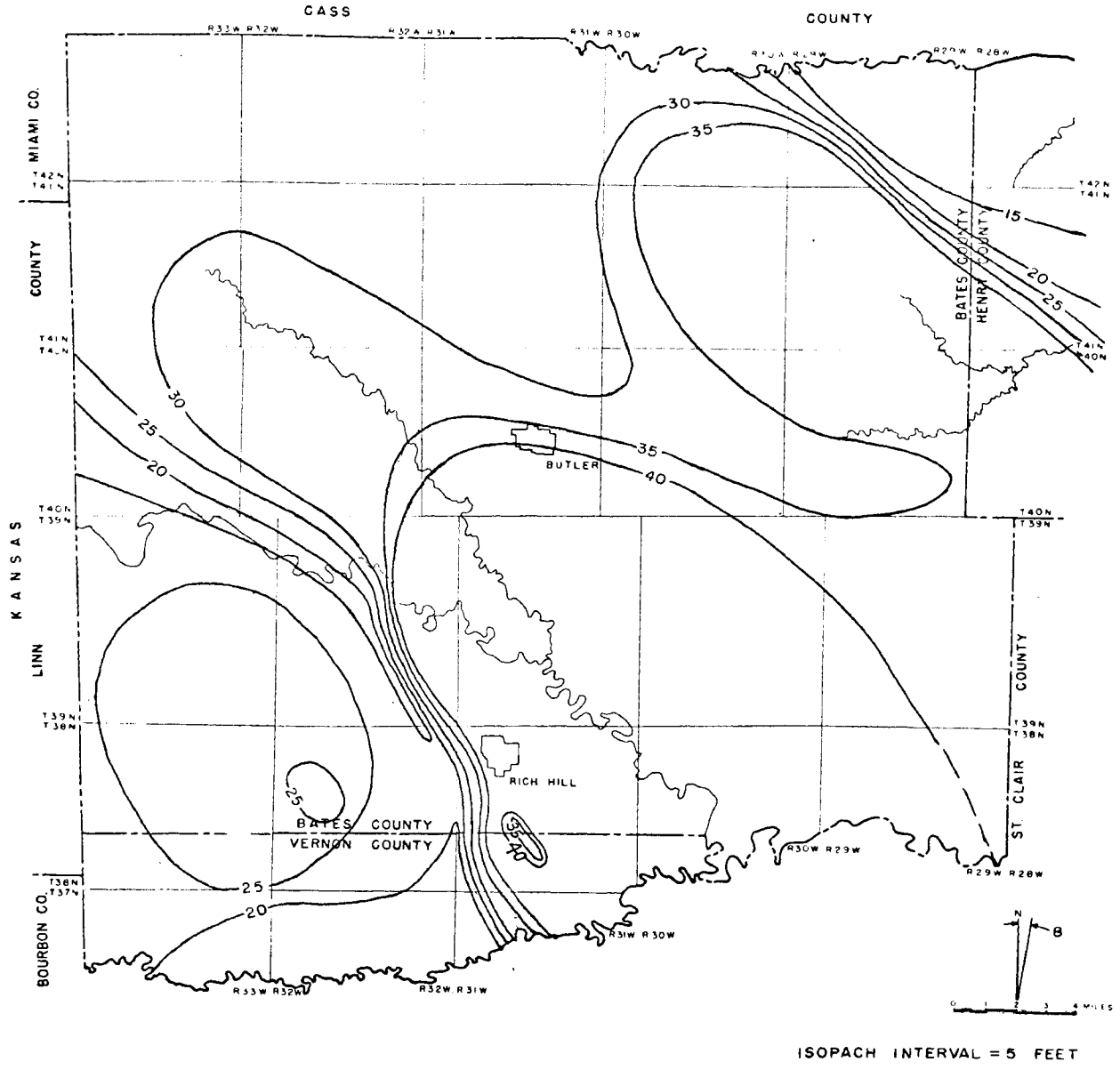


Figure 30. (continued), (e) Isopach map of the Verdigris formation.

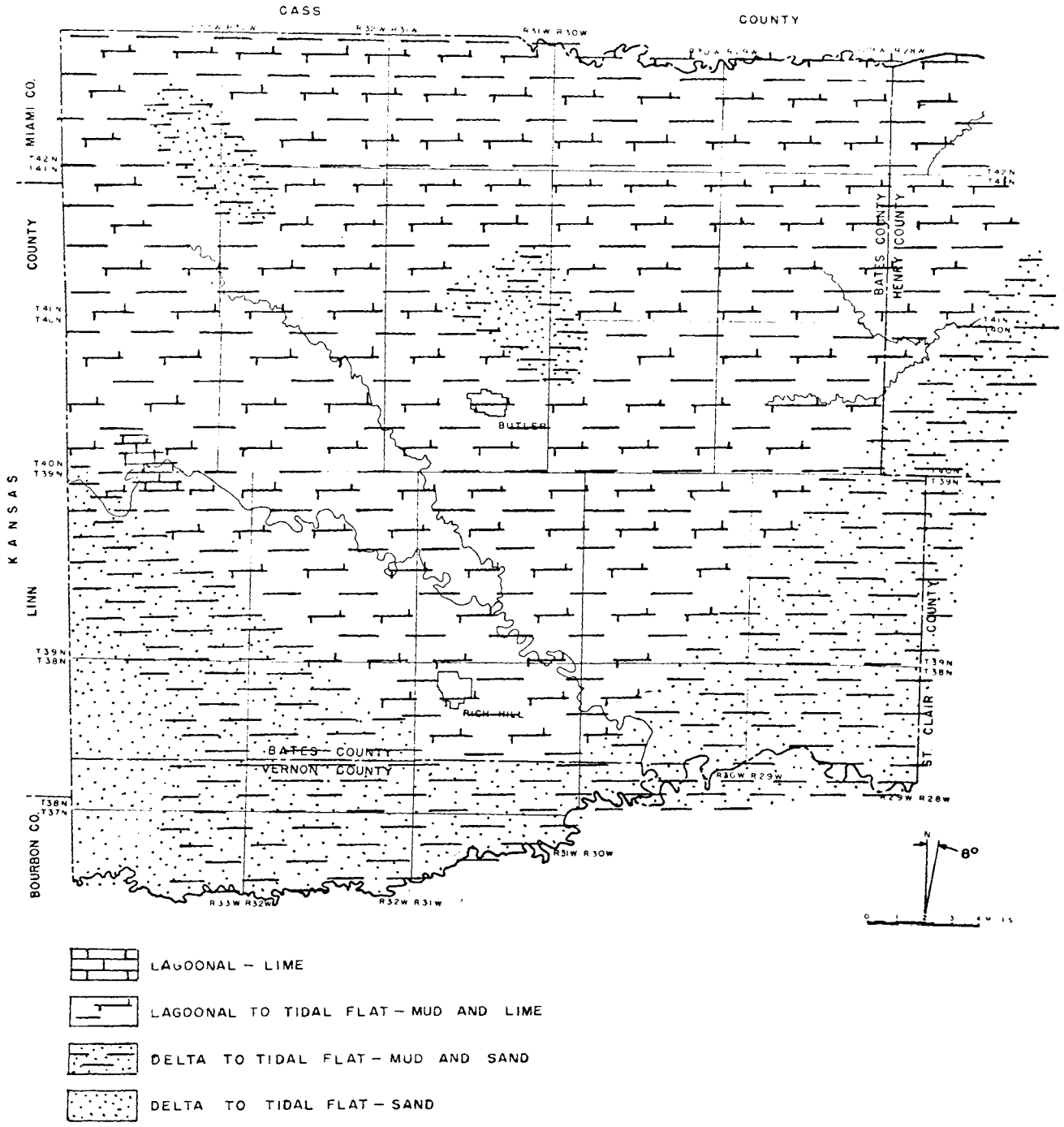


Figure 31. Paleosedimentological maps, upper part of the Bandera formation and lower part of the Altamont formation (a) Interval beneath Amoret limestone member of the Altamont formation

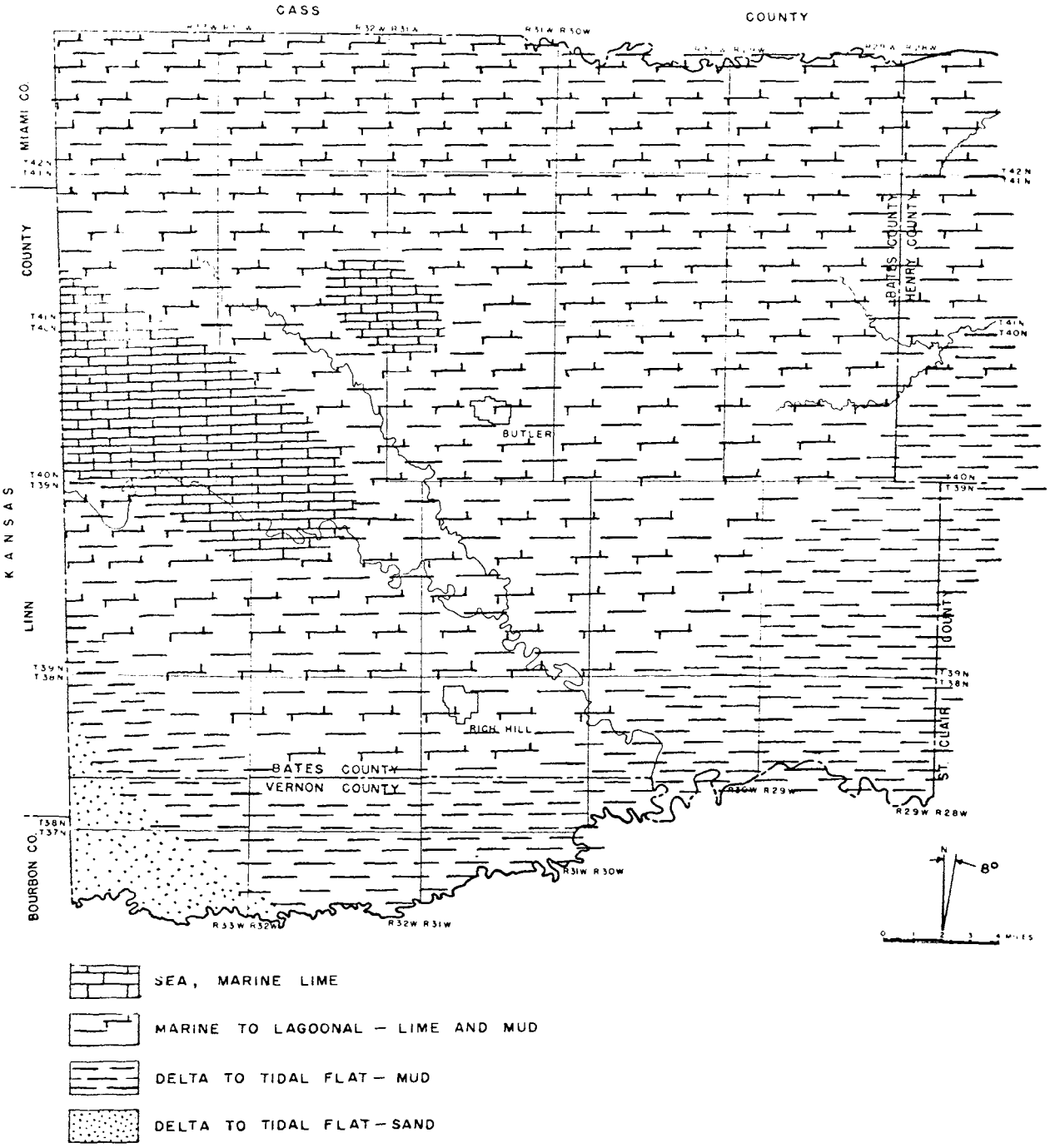


Figure 31. (continued), (b) Upper part of the Bandera formation and lower part of the Amoret limestone member.

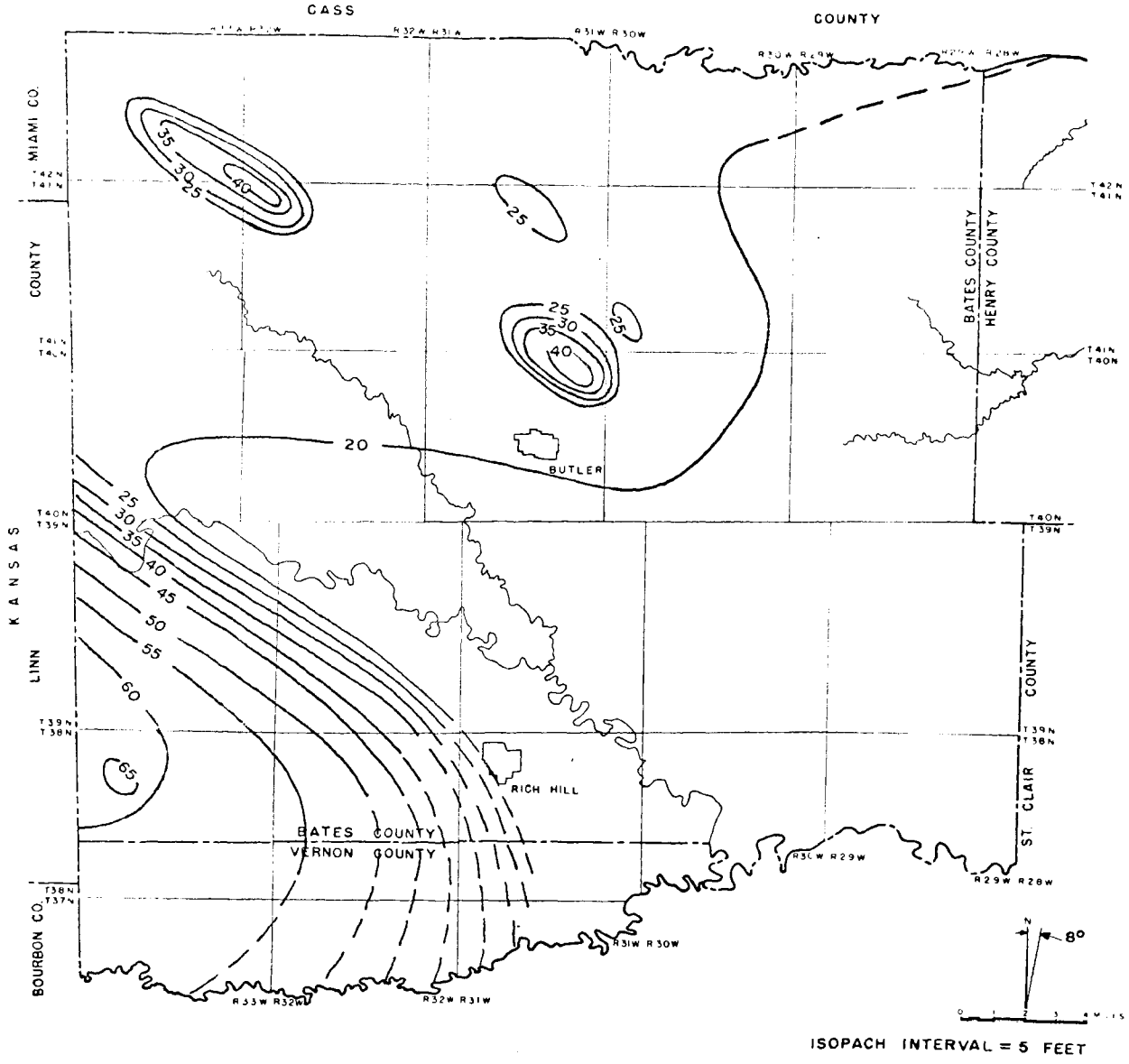


Figure 31. (continued), (c) Isopach map of the Bandera and Altamont formations.

AFFECT OF STRUCTURAL MOVEMENTS ON SEDIMENTATION

The variation in thickness of the Verdigris and Bandera formation is particularly interesting when traced along the outcrop belt from Kansas to the vicinity of the southwestern limb of the Schell City-Rich Hill anticline. The thickness of the Verdigris formation increases from 25 to 45 feet, while the Bandera formation thins from over 50 feet to less than 20 feet, (Plates 3 and 8). The variations in thickness of these formations along the Schell City-Rich Hill anticline are regionally related to this structure. Facies changes previously mentioned on pages 123 - 124 and indicated on the paleosedimentological maps (Figures 30 and 31) also occur in the formations. It seems a likely supposition that movements of the Schell City-Rich Hill anticline affected the deposition of these and other units and is responsible for many of the physical variations observed in some of the stratigraphic units when traced to the vicinity of this structure.

The area between the Schell City-Rich Hill and the Ladue-Freeman anticlines which in reality may be a structural block bounded by deep seated faults appears to have been active intermittently throughout the time interval corresponding to deposition of the upper Cherokee and lower Marmaton groups. Periods of greatest activity appear to coincide with intervals containing predominately non-marine units and include the Fleming, Croweburg, Verdigris, Bevier, Lagonda Mulky, Labette, Bandera and the lower part of the Altamont formation. The structure was probably in a state of quiesence during the time

corresponding to the deposition of the thick marine limestone of the Pawnee formation and Fort Scott subgroup because only slight lithologic variations are observed in these units.

During deposition of the Verdigris formation the structural block first subsided more rapidly than the surrounding area which resulted in an expansion of the lower part of the Verdigris formation from the top of the Croweburg coal to the base of the black, fissile shale underlying the Verdigris limestone. Later the block subsided less rapidly than the surrounding area with the result that the strata composing the upper part of the Verdigris formation are reduced in thickness and contain features characteristic of first a shoal area and then of a slightly emergent region.

The relationship of structure to the physical variations in the Verdigris formation are shown in Figure 32.

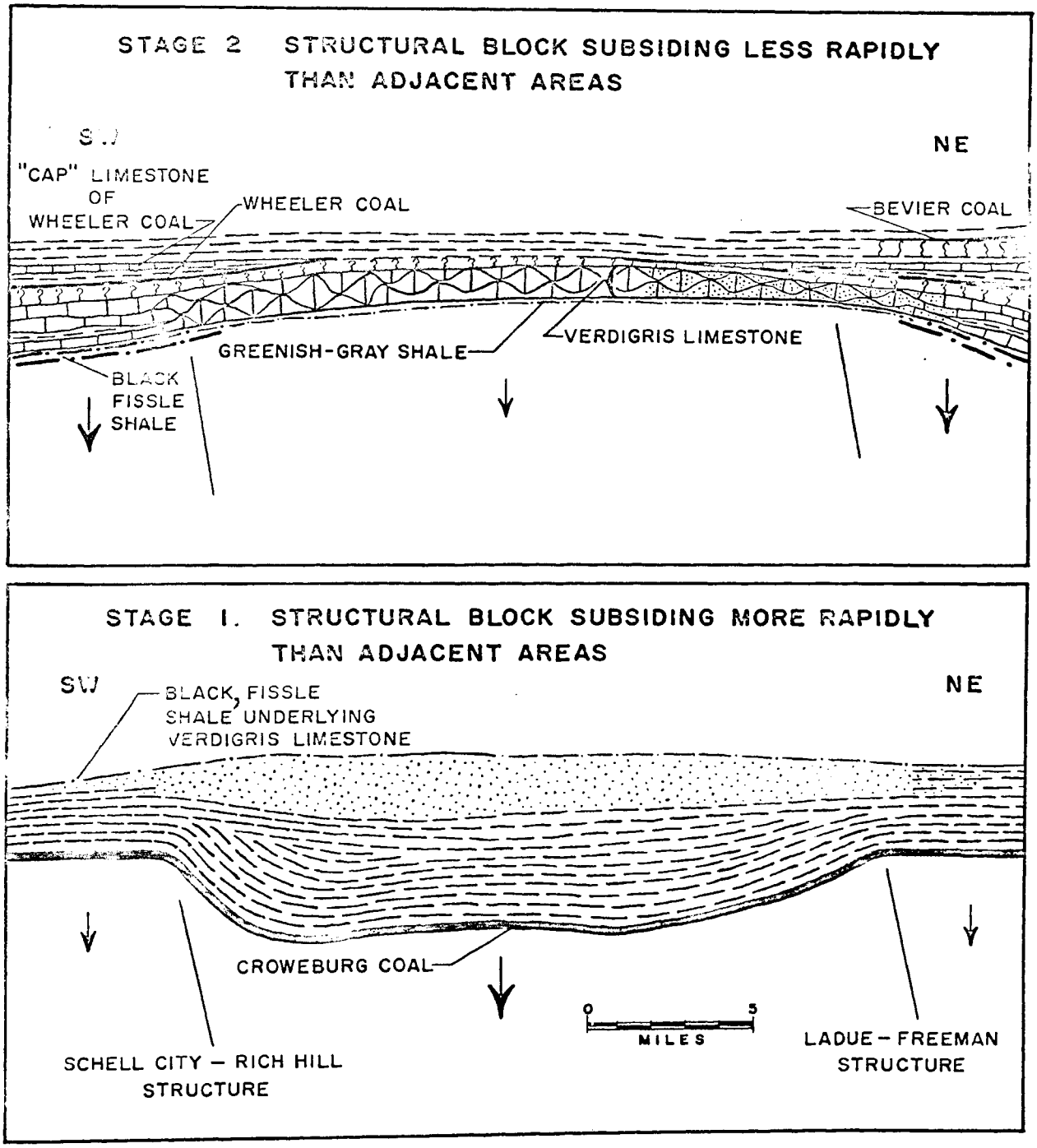


Figure 32. Diagrammatic cross-sections showing in chronological sequence the inter-relationships between structure and sedimentation in the area from southwestern Bates County to west-central Henry County during the time interval corresponding to deposition of the Verdigris formation. Movement of the structural block between the Schell City-Rich Hill and the Ladue-Freeman structures may have been the cause for the physical variations observed in the Verdigris formation.

CONCLUSIONS

It seems evident that the Bates County area was subjected to local and regional structural deformations of undetermined origin and magnitude during the Pennsylvanian Period. These movements affected the sedimentation in the area. The movements do not appear to have been completely synchronized in time or geographic location and as a consequence the resulting cyclical sequences do not show the same degree of lithologic variations. Deviations from the standard or "ideal" cyclothem as postulated by different authors should be an expected occurrence in Pennsylvanian rocks.

It is believed that a detailed study of the influence of local structure on sedimentation in other areas of the Mid-Continent will result in a better understanding of many of the problems concerned with the correlation of Pennsylvanian rocks.

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Appendix

Measured Stratigraphic Sections

The stratigraphic sections appended to this report have been included to serve the following purposes. (1) to supplement discussion of the rocks presented earlier in the text portion of the report. (2) to aid in the interpretation of the stratigraphic profiles presented in plates 2 - 9. It will be noted that most stratigraphic sections shown in the cross profiles contain only a part of the section as listed in the appendix. This method of illustration was necessary in order to present lithologic detail. Most sections appear in more than one cross profile. (3) to record the basic data used in the preparation of the dissertation.

STRATIGRAPHIC SECTION NO. 1

High wall of inactive strip mine; NE¼ NW¼ sec. 14, T. 37 N., R. 33 W.; 4.5 miles west of Metz, Vernon County, Missouri

Cherokee group
Cabaniss subgroup
Verdigris formation
Ardmore member (15,16,17)

		Thickness (Feet)
17	limestone, weathered brown; fossil fragments; only base exposed	1.00
16	shale, gray, soft	2.00
15	limestone; weathered brown; jointed; thin-bedded; Desmoinesia	0.40
14	shale, weathered brown, soft	0.35
13	shale, black, calcareous, soft	2.00
12	shale, black, fissile; large concretions (1 ft. diameter) composed of dark-gray, finely crystalline limestone with some pyrite; small irregular-shaped phosphatic concretions	1.65
11	shale, gray, soft, non-calcareous	3.00
	Croweburg - Fleming formation	
10	coal	1.00
9	underclay; only top exposed	0.25
8	covered	15.00
7	shale, medium-gray; few small phosphatic concretions	0.45
6	limestone, dark-gray, weathers red, thin-bedded, argillaceous; Derbyia crassa	0.25
	Robinson Branch formation	
5	coal, weathered; varies from 0.1 to 0.8 feet in thickness over short lateral distances	0.75
4	shale, light-gray; angular fracture	2.00
3	shale, medium-gray	5.00
2	shale, dark-gray to black, hard, calcareous	1.00
	Mineral formation	
1	coal; only top exposed	1.00
	Total thickness	37.10 Feet

STRATIGRAPHIC SECTION NO. 2

Southwest cut bank on Pryor Creek; NW¼ SW¼ sec. 8, T. 37 N., R. 32 W.; 2 miles northwest of Metz, Vernon County, Missouri.

Cherokee group
Cabaniss subgroup
Verdigris formation

		Thickness (Feet)
24	limestone, dark-gray, finely crystalline; one blocky bed; Crurithyris, fragments of productid brachiopods	0.45
23	shale, black, platy	2.00
22	shale, black, fissile; a few irregular-shaped phosphatic concretions	1.50
21	shale, light to medium-gray	6.50

Croweburg formation

20	coal, jointed, bright	1.00
19	underclay, gray; angular fracture; root impressions; pieces of carbon	2.30
18	shale, medium-gray	1.50
17	shale, greenish-gray; irregular-shaped calcareous, claystone nodules which weather reddish-brown	1.50
16	shale, medium-gray	4.00
15	limestone, light-gray, weathers reddish-brown; composed of irregular-shaped nodules; fragments of Desmoinesia	0.25
14	shale; black at bottom to medium-gray at top	1.45

Fleming formation

13	coal, bright	0.10
12	clay, medium-gray; angular fracture; sparse root impressions	1.50
11	shale; bottom few inches black, becoming medium-gray at top	6.00
10	shale, black, platy to fissile; a few oblong-shaped phosphatic concretions	0.25

Robinson Branch formation

9	coal, bright; thin-bedded at top	0.65
8	underclay, medium-gray; few coal streaks and joints filled with coal; melanterite on exposed surfaces	2.00

		Thickness (Feet)
7	clay, light-gray, non-calcareous	1.50
6	clay, greenish-gray; mixed with calcareous clay nodules which are irregular-shaped and weathered reddish-brown, largest are 0.3 ft. in diameter	3.00
5	clay, dark-gray	0.50
4	clay - ironstone concretion zone; slightly calcareous; concretions are 0.5 ft. in diameter	0.25
3	shale, dark-gray	2.00
2	limestone, dark-gray; weathers reddish-brown; thin-bedded; slabby; abundant Desmoinesia muricatina	0.35
1	shale, dark-gray, very carbonaceous	0.25
	Total thickness	40.80 Feet

STRATIGRAPHIC SECTION NO. 3

High wall of abandoned strip mine; north side of dirt road; SE¼ SE¼ sec. 35, T. 39 N., R. 32 W.; 2 miles northwest of Rich Hill, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Verdigris formation

		Thickness (Feet)
17	limestone, light-gray; exposed as float	0.50
16	shale; weathered brown	6.00
15	shale, dark-gray	3.00

Croweburg formation

14	coal, bright, jointed; thin-bedded at top; apparent dip 3° NW	0.75
13	underclay, grading from dark-gray at top to light-gray at bottom; arenaceous at base; fossil root impressions	3.00
12	sandstone, light-gray to white, fine-grained, cross-bedded, micaceous; calcareous near bottom; forms sharp contact with underlying unit; small (.05 ft. diameter) holes at top, many of which are filled with brown sandstone	2.00

		Thickness (Feet)
11	clay and shale, light-gray to greenish-gray, non-calcareous	1.00
10	limestone, dark-gray, weathers reddish-brown, thin-bedded, argillaceous; abundant Desmoinesia, Crurithyris	0.25
9	shale; black at bottom and lighter gray near top may be the result of weathering	0.85
8	shale, dark-gray to black, hard; forms small ledge; very calcareous	0.50
	Fleming formation	
7	shale, dark-gray to black	5.00
6	shale, black, platy; Desmoinesia muricatina, Lingula, echinoid spines ...	2.00
	Robinson Branch formation	
5	coal, bright; jointed into blocks; some iron and sulphur staining; joints filled with calcite; thickness varies considerably over short distances	2.00
4	underclay, light-gray, silty, iron stained	2.85
3	shale, medium-gray, non-calcareous	6.50
2	shale, dark-gray, non-calcareous	0.50
	Mineral formation	
1	coal, blocky	3.60
	Total thickness	40.30 Feet

STRATIGRAPHIC SECTION NO. 4

Artificial excavation and drill test core, U.S. Air Force Missile site; NE¼ sec. 9, T. 38 N., R. 31 W.; south side of county road BB; 5 miles east of Rich Hill, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Verdigris formation

		Thickness (Feet)
27	shale, gray	8.00
26	shale, dark-gray, non-calcareous	0.30

		Thickness (Feet)
	Croweburg formation	
25	coal, thin-bedded, sulfur-stained	0.40
24	underclay, light-gray, arenaceous	1.00
23	shale, dark-gray, non-calcareous	1.80
22	shale and sandstone, interbedded; gray; non-calcareous	0.50
21	covered	1.00
20	sandstone, fine-grained; lower 1 ft. interbedded with dark-gray to black carbonaceous shale	5.00
19	sandstone, asphaltic	2.20
18	sandstone, gray, argillaceous, non-permeable	2.30
17	shale, gray, non-calcareous	1.10
16	limestone, medium-gray, weathered reddish-brown, fossiliferous, argillaceous	0.40
15	shale, medium-gray, non-calcareous ...	0.30
14	sandstone, medium-gray, lower half interbedded with shale; carbonized wood in basal 1 ft.	4.50
	Fleming formation	
13	coal	0.20
12	underclay, arenaceous	2.30
11	sandstone, argillaceous, fine-grained, micaceous	6.70
10	sandstone, few shale lenses; asphaltic.	3.20
9	shale, gray; 0.3 ft. calcareous zone near middle	4.50
8	sandstone, light-gray, micaceous; middle part interbedded with dark-gray carbonaceous shale; argillaceous near base	30.10
	Robinson Branch formation	
7	coal	0.20
6	underclay; slickensided	1.00
5	sandstone, light-gray, micaceous	2.20
4	shale, dark-gray	0.20
3	limestone, dark-gray to black, weathered reddish-brown, argillaceous	0.80

Mineral formation

2	coal, bright; pyrite nodules	1.30
1	underclay; slickensided	1.70
	Total thickness	83.20 Feet

STRATIGRAPHIC SECTION NO. 5

Composite section - artificial excavation and drill test core, U. S. Air Force Missile site and outcrops in road cut on west side of highway N northward to active quarry on top of hill; W½ sec. 29, T. 39 N., R. 30 W.; 6 miles northeast of Rich Hill, Bates County, Missouri.

Marmaton group
Fort Scott subgroup
Higginsville formation

		Thickness (Feet)
43	limestone, light-gray; wavy bedding; dip 1° N. 45 E.	13.00
42	limestone, medium-gray; one bed	1.50
	Little Osage formation	
41	shale, dark-gray	1.50
40	shale, black, fissile, numerous oblong phosphatic concretions	2.00
39	clay or shale, light-gray	1.00
38	shale, medium-gray; numerous pea-sized limestone nodules	2.00
	Blackjack Creek formation	
37	limestone, medium-gray, nodular; brachiopod fragments	1.35

Cherokee group
Cabaniss subgroup
Excello formation

36	shale, dark-gray; contains oblong phosphatic concretions	1.50
	Mulky-Lagonda formation	
35	clay or underclay, light-gray	1.00

		Thickness (Feet)
34	shale, weathered brown, arenaceous, non-calcareous	2.50
33	sandstone, calcareous; grades into nodular limestone; apparent dip 4° NE	2.50
32	sandstone, weathered brown, fine-grained, non-calcareous	1.00
31	shale, weathered brown, arenaceous	10.00
30	shale, weathered brown, poorly exposed	40.00
29	sandstone, weathered brown, thin-bedded, fine-grained, quartzose	4.00
28	shale	3.00
	Lagonda-Bevier formation	
27	limestone, dark-gray, thin-bedded, very arenaceous; abundant Mesolobus mesolobus	3.00
26	shale; with clay ironstone concretions	5.00
25	limestone, dark-gray, argillaceous; weathers reddish-brown; one blocky bed; discontinuous; Desmoinesia, numerous fossil fragments	0.15
	Verdigris formation	
24	underclay; fossil root impressions ..	0.25
23	limestone, light-gray, nodular	0.25
22	limestone, thick-bedded to nodular; jointed into blocks, main joint system trends NE-SE	3.50
21	shale, dark-gray; small phosphatic concretions	0.25
20	limestone, dark-gray, nodular	0.05
19	shale, light-gray, micaceous; top part arenaceous	15.00
18	shale, dark-gray, non-calcareous	25.00
	Croweburg formation	
17	coal; few nodules of pyrite	0.75
16	underclay, medium-gray; carbonized roots	2.00
15	shale; arenaceous at bottom; asphaltic	6.00
14	sandstone, cross-bedded	2.00

		Thickness (Feet)
13	shale; medium-gray to black at base	8.90
	Fleming formation	
12	shale, black, flaky; streaks of vitrain and carbonized wood	0.20
11	underclay, light-gray, slickensided; carbonized roots	1.10
10	shale, light-gray, non-calcareous; arenaceous at base	2.90
9	sandstone, light-gray, fine-grained, cross-bedded; flakes of muscovite, biotite	10.00
8	shale; dark-gray to black at base; sharp contact with overlying unit; non-calcareous	3.00
	Robinson Branch formation	
7	coal, bright, blocky	1.40
6	shale, dark-gray to black	0.10
5	underclay, dark-gray; carbonized roots	2.50
4	clay-shale, gray; few irregular-shaped reddish-brown calcareous clay nodules.	0.50
	Mineral formation	
3	shale, gray, non-calcareous	4.00
2	shale, gray, reddish-brown; calcareous clay nodules	2.00
1	shale, gray, non-calcareous	1.70
	Total thickness	187.35 Feet

STRATIGRAPHIC SECTION NO. 6

East cut bank of Camp Branch Creek, 600 feet north of east-west dirt road; SE¼ NE¼ sec. 18, T. 39 N., R. 29 W.; 2 miles southeast of Pleasant Gap, Bates County, Missouri.

Quaternary System		Thickness (Feet)
13	gravel with matrix of red clay	4.00

		Thickness (Feet)
Cherokee group - Pennsylvanian System		
Cabaniss subgroup		
Croweburg formation		
12	shale, dark-gray	2.00
11	limestone, dark-gray; weathers reddish-brown; thin-bedded; argillaceous; jointed into slabs; Desmoinesia muricatina	0.50
10	shale, dark-gray, fossiliferous	0.75
Fleming formation		
9	coal	0.05
8	underclay, gray	1.00
7	shale, greenish-gray	2.50
6	limestone, weathered reddish-brown, nodular; may be of secondary origin since some stringers of it fill the joints in the underlying shale	0.50
5	shale, greenish-gray	5.00
4	limestone, dark-gray, weathers reddish-brown, argillaceous; Desmoinesia muricatina	0.15
3	shale, dark-gray	0.15
Robinson Branch formation		
2	coal, smutty	0.05
1	underclay, gray; fossil root impressions	2.00
	Total thickness	18.65 Feet

Dip of strata is 1° NW

STRATIGRAPHIC SECTION NO. 7

Highwall of abandoned coal strip mine, from south bank of Panther Creek, about 1,000 feet north of right angle bend to south in dirt road; SW¼ sec. 3, T. 39 N., R. 29 W.; 1.5 miles southwest of Hudson, Bates County, Missouri.

		Thickness (Feet)
Cherokee group		
Cabaniss subgroup		
Fleming formation		
11	shale, dark-gray; only base exposed .	0.50

		Thickness (Feet)
10	limestone, dark-gray, weathers reddish-brown, thin-bedded, argillaceous, jointed into slabs; abundant Desmoinesia muricatina, sparse Crurithyris planoconvexa	0.25
9	shale, dark-gray, calcareous	1.85
8	limestone, black, weathers reddish-brown, one bed, jointed into rectangular slabs; argillaceous; discontinuous; Desmoinesia	0.75
7	shale; dark-gray to black at base; few fossil fragments, Trepospira	2.40
	Robinson Branch formation	
6	coal, hard, bright	1.35
5	underclay, gray; only top exposed ..	0.25
4	covered interval; few spots of gray shale exposed	6.00
3	limestone, dark-gray to black, thin-bedded, argillaceous; abundant Desmoinesia, sparse Neospirifer	0.60
	Mineral formation	
2	coal	2.35
1	underclay, gray; top exposed in creek	0.50
		16.80 Feet

STRATIGRAPHIC SECTION NO. 8

Artificial excavation and drill test core, U. S. Air Force Missile site; SW¼ NE¼ sec. 1, T. 39 N., R. 29 W.; 2 miles southeast of Hudson, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Verdigris formation

		Thickness (Feet)
21	sandstone, weathered brown, fine-grained, thin-bedded at top and base, thick-bedded at middle	10.00

		Thickness (Feet)
20	shale, dark-gray, argillaceous at top	20.00
	Croweburg formation	
	Croweburg coal (units 1 and 3)	
19	coal	0.25
18	shale	0.01
17	coal	0.35
16	underclay, gray; carbonized roots ..	0.50
15	covered	1.10
14	clay-shale, medium-gray; top calcareous	3.30
13	sandstone light-gray, fine-grained, micaceous; brown rootlike structures	2.00
12	shale, gray, calcareous, arenaceous at top	2.50
	Fleming formation	
11	shale, medium-gray, non-calcareous becoming black and calcareous at base	0.80
10	limestone, dark-gray to black, thin-bedded, argillaceous; Desmoinesia ..	0.30
	Robinson Branch formation	
9	shale, black, calcareous; fragments of brachiopods near top	12.80
8	shale, black, non-calcareous	0.10
	Mineral formation	
7	coal, bright	0.20
6	underclay, gray; carbonized roots ..	0.80
5	shale, gray; bits of carbon	4.00
4	clay-ironstone, black; weathering reddish-brown	0.20
	Cabaniss subgroup	
3	shale, black, calcareous	13.80
2	shale, medium-gray, non-calcareous .	7.50
1	shale, gray; interbedded sandstone lenses in lower half	10.50
	Total thickness	91.01 Feet

STRATIGRAPHIC SECTION NO. 9

Cut banks of small northward flowing tributary to South Deepwater Creek on south side of east-west dirt road; SW¼ NE¼ sec. 23, T. 40 N., R. 29 W.; 4 miles southwest of Johnston, Bates County, Missouri.

Cherokee group
Cabaniss subgroup

		Thickness (Feet)
	Verdigris formation	
19	shale, gray	6.00
18	shale, dark-gray, non-calcareous ...	3.00
	Croweburg formation	
17	coal, blocky, iron stained	1.25
16	underclay, gray; fossil root impressions	0.50
15	covered interval	2.00
14	sandstone, fine-grained, thin-bedded, calcareous	1.00
13	covered interval	2.00
12	shale, gray, non-calcareous	1.00
11	limestone, dark-gray, weathers reddish-brown, thin-bedded, argillaceous	0.25
	Fleming formation	
10	shale, dark-gray, non-calcareous ...	0.85
9	limestone, dark-gray, thin-bedded, argillaceous; jointed into large rectangular slabs; abundant <u>Desmoinesia muricatina</u>	0.50
8	shale, dark-gray, calcareous	0.30
	Robinson Branch formation	
7	shale, dark-gray, non-calcareous ...	0.10
6	shale, gray, non-calcareous	0.15
5	limestone, weathered reddish-brown	0.05
4	shale, weathered brown	0.20
	Mineral formation	
3	coal, smutty	0.05
2	underclay or clay, gray, slickensided, breaks out in angular chips	2.00

		Thickness (Feet)
1	shale, gray	2.00
	Total thickness	23.20 Feet

STRATIGRAPHIC SECTION NO. 10

Cut banks and bed of small stream on west side of dirt road above bridge over creek; SE¼ SW¼ sec. 19, T. 41 N., R. 28 W.; 1.5 miles northeast of Johnston, Henry County, Missouri.

Cherokee group
Cabaniss subgroup
Croweburg formation

		Thickness (Feet)
13	limestone, dark-gray, weathers reddish-brown, nodular; fossil fragments	0.10
	Fleming formation	
12	shale, dark-gray; a few thin beds of siderite concretions	5.00
11	limestone, weathers to red ferruginous clay, nodular; Composita ovata, Mesolobus, Crurithyris	0.35
10	shale, dark-gray	0.15
	Robinson Branch formation	
9	coal, smutty	0.025
8	underclay; fossil root impressions .	1.00
7	shale, gray	2.50
6	sandstone, thin-bedded, micaceous, specks of carbon	1.00
5	shale, black, soft, non-calcareous .	1.50
4	limestone, gray, thin-bedded argillaceous; jointed into the large rectangular slabs; Desmoinesia muricatina, algae	0.60
3	shale, black, fissile; irregular-shaped phosphatic concretions	0.65

		Thickness (Feet)
2	shale, black, soft, discontinuous; in places where this unit is absent the overlying black, fissile shale is gradational with the underlying coal	0.50
	Mineral formation	
1	coal; only top exposed	0.35
	Total thickness	137.25 Feet

STRATIGRAPHIC SECTION NO. 11

Drainage ditch south side of east-west dirt road; section extends from culvert eastward to top of hill; NE¼ sec. 5, T. 41 N., R. 28 W.; 3 miles southeast of Mayesburg, Henry County, Missouri.

Cherokee group
Cabaniss subgroup

	Mulky formation	Thickness (Feet)
23	sandstone, weathered brown, thin-bedded, fine-grained	3.00
22	shale, gray	6.00
21	limestone; weathers to reddish-brown blocks, argillaceous; one bed	0.25
20	shale, gray	5.45
19	limestone, dark-gray, argillaceous; jointed into rectangular slabs; numerous small crinoid columnals which protrude from weathered surface	0.40
18	sandstone, thin-bedded; sharp contact with overlying unit	3.00
17	shale, gray; lower few feet contains fern fronds and Calamites	12.00
	Lagonda - Bevier formation	
16	coal, thin-bedded	0.15
15	shale, gray	3.00
14	sandstone, thin-bedded	10.00
13	shale, gray	11.00
12	sandstone, thin-bedded, fine-grained	5.00
11	shale, gray, non-calcareous	22.00

		Thickness (Feet)
	Verdigris formation	
10	coal, weathered	0.50
9	underclay, fossil root impressions .	1.00
8	limestone, nodular; clay matrix ...	0.50
7	shale, greenish-gray; contains oblong phosphatic concretions	0.50
6	limestone, dark-gray; nodular to massive bedding; Mesolobus mesolobus	0.50
5	shale, light-gray, calcareous	2.00
4	shale, medium-gray, non-calcareous .	5.00
	Croweburg formation	
3	coal, hard, bright, jointed; some iron and sulphur staining	1.35
2	underclay, gray; fossil root impressions; sulphur stained	2.50
1	limestone, dark-gray, nodular, some nodules 0.5 ft. diameter; irregular-shaped with clay matrix	0.55
	Total thickness	95.65 Feet

STRATIGRAPHIC SECTION NO. 12

Cut banks and bed of small northwest flowing stream; section extends from under bridge on east-west dirt road upstream for a distance of 0.25 miles; NW¼ NW¼ sec. 19, T. 42 N., R. 28 W.; 2 miles northeast of Mayesburg, Bates County, Missouri.

Cherokee group
Cabaniss subgroup

	Verdigris formation	Thickness (Feet)
16	limestone and phosphatic concretions; exposed as float	--
15	shale, medium-gray, poorly exposed .	6.00
	Croweburg formation	
14	coal, weathered soft, poorly exposed	0.50
13	underclay, gray; fossil root impressions	2.00
12	sandstone and shale, interbedded ..	1.00
11	shale, dark-gray	7.00

		Thickness (Feet)
	Fleming formation	
10	coal, smutty	0.10
9	underclay	1.00
8	shale, dark-gray	4.00
	Robinson Branch formation	
7	coal, smutty	0.01
6	shale, black, structureless, slickensided	0.10
5	underclay, dark-gray; fossil root impressions	1.00
4	shale, dark-gray	5.00
3	limestone, dark-gray, thin-bedded, argillaceous; grades into calcareous shale; Desmoinesia muricatina	0.85
	Mineral formation	
2	coal	1.10
1	underclay	2.00
	Total thickness	31.66 Feet

STRATIGRAPHIC SECTION NO. 13

Cut banks and bed of Muddy Creek; NW¼ NW¼ sec. 19, T. 38 N., R. 31 W., and SE¼ sec. 13, T. 38 N., R. 32 W.; 1.5 miles southwest of Rich Hill, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Lagonda-Bevier formation

		Thickness (Feet)
17	sandstone, weathered brown, thin-bedded	3.00
16	shale; bottom half medium-gray, top half weathered brown; arenaceous; jointed SW-NE and NW-SE; a few large exfoliated clay concretions	20.00
15	limestone, dark-gray, thin-bedded; jointed into large rectangular slabs; abundant Mesolobus mesolobus.	2.00
14	shale, gray	4.50

		Thickness (Feet)
13	limestone, dark-gray, very argillaceous, blocky to concretionary, exfoliated; *Neospirifera* sp.	0.35
12	shale, dark-gray, non-calcareous; few ironstone concretions	6.00
11	limestone, dark-gray; weathers reddish-brown; thin-bedded; *Desmoinesia*, *Linoproductus*	0.25
10	shale, black, soft, non-calcareous .	2.50
	Verdigris formation	
9	coal, hard, blocky, bright	0.65
8	underclay, light-gray; plant remains, including root impressions	0.85
	Ardmore member (units 2,3,4)	
7	limestone, light-gray, nodular to blocky; *Antiquatonia*	1.75
6	shale, gray, poorly exposed	1.50
5	limestone, dark-gray, finely crystalline; main joint system NE-SW; breaks into long rectangular blocks; crinoid columnals, *Mesolobus*, productid brachiopods; apparent dip 30° SW ...	0.50
4	shale, black, fissile; only top exposed	1.00
3	shale, gray	13.50
	Croweburg formation	
2	coal	90
1	underclay, gray	2.00
	Total thickness	61.25 Feet

STRATIGRAPHIC SECTION NO. 14

West highwall of abandoned strip mine; NE¼ NW¼ sec. 34, T. 38 N., R. 31 W.; 3.5 miles southeast of Rich Hill, Vernon County, Missouri.

Cherokee group
Cabaniss subgroup
Bevier formation

		Thickness (Feet)
7	limestone; weathered reddish-brown; concretionary; Desmoinesia, Mesolobus mesolobus	0.50
	Verdigris formation	
6	shale, weathered brown	1.00
5	limestone, light-gray, thick-bedded; crinoid columnals, other fossil fragments	6.00
4	shale, black, fissile; spheroidal to irregular-shaped phosphatic concretions; sharp contact with overlying and underlying units	1.10
3	sandstone, dark-gray, calcareous; Mesolobus mesolobus and other fossil fragments	0.35
2	sandstone, dark-gray, thin-bedded, calcareous, micaceous	5.00
1	shale, dark-gray, arenaceous at top.	6.00
	Total thickness	19.95 Feet

STRATIGRAPHIC SECTION NO. 15

West highwall of active strip mine; NE¼ sec. 34, T. 38 N., R. 31 W.; 4 miles southeast of Rich Hill, Vernon County, Missouri. Section exposed as a series of faulted blocks, apparent dip 25°SW.

Cherokee group
Cabaniss subgroup
Bevier formation

		Thickness (Feet)
26	shale, gray	2.00
25	limestone, blocky to concretionary, weathers brownish-red; Desmoinesia, Mesolobus mesolobus	0.25
24	shale, gray	1.15
	Verdigris formation	
23	shale, dark-gray	0.05
22	clay, light-gray; breaks with angular fracture	1.00

		Thickness (Feet)
21	limestone, light-gray; thick nodular bedding; brown root-like structures near top; crinoid columnals, numerous thin thanatocoenoses of fragments of chonetid brachiopods (Ardmore member)	6.00
20	shale, greenish-gray, calcareous; numerous small irregular-shaped phosphatic concretions which coalesce into lenses	0.25
19	rock phosphate, dark-gray, non-calcareous; exposed as one bed, composed of microscopic nodules or oolites of phosphate	0.10
18	shale, greenish-gray	0.10
17	sandstone, fine-grained; thin shaly bedding; micaceous	5.00
16	shale, gray; arenaceous at top	30.00
	Croweburg formation	
15	coal, weathered	0.25
14	underclay, gray; breaks with angular fracture	3.00
13	sandstone, fine-grained, thick-bedded, brown, micaceous	4.00
12	shale, dark-gray	0.25
11	shale, medium-gray; contains two or three discontinuous, concretionary limestone beds which weather reddish-brown	1.75
10	limestone, blocky; weathers reddish-brown; Desmoinesia	0.15
9	shale, dark-gray	0.35
8	limestone; one blocky bed; weathers reddish-brown; Desmoinesia, Crurithyris	0.35
	Fleming formation	
7	shale, dark-gray to black at base ..	0.50
6	shale, brown, arenaceous	2.00
5	shale, black, hard, flaky; joints filled with clay ironstone; numerous flat siderite concretions some of which are 0.5 ft. in diameter	10.00

		Thickness (Feet)
4	shale, black, hard; Desmoinesia, large productids, other fossil fragments; gradational with underlying coal	1.65
	Robinson Branch formation	
3	coal; varies considerably in thickness over short lateral distances; represented by a smut 25 feet to north; sulphur stained; some joints filled with calcite and calcium sulphate; pyrite	1.60
2	clay, medium-gray; breaks with angular fracture	4.00
	Mineral formation	
1	coal, thin-bedded, hard, bright ...	3.50
		70.25 Feet

STRATIGRAPHIC SECTION NO. 16

South side of escarpment, 0.25 miles west of county road W, section exposed from pond by barn to top of hill; NE¼ SE¼ sec. 29, T. 39 N., R. 29 W.; 4 miles southeast of Pleasant Gap, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Lagonda-Bevier formation

		Thickness (Feet)
10	shale; weathers out as brown chips; few thin sandstone beds	24.00
9	covered; patches of brown shale exposed by trenching	11.00
8	limestone; weathered to red ferruginous clay; Desmoinesia ...	0.15
	Verdigris formation	
7	clay	0.50

		Thickness (Feet)
6	limestone; thick nodular bedding; top part contains reddish-brown cylindrical structures which resemble roots; crinoid columnals	2.65
5	shale, gray	1.50
4	sandstone, weathered brown; one massive bed	1.50
3	shale, dark-gray	4.50
2	sandstone, thin-bedded at base to thick (1 foot) bedded at top; fine-grained; argillaceous; light-gray but with some black grains which produce a salt and pepper effect under 10X magnification	3.50
1	shale, dark-gray, arenaceous	2.00
	Total thickness	51.30 Feet

STRATIGRAPHIC SECTION NO. 17

South cut bank of eastward flowing tributary to Newberry Branch Creek, about 200 feet west of bridge on county road BB; NE¼ SW¼ sec. 22, T. 40 N., R. 29 W.; 3.5 miles northwest of Hudson, Bates County, Missouri.

Cherokee group
Cabaniss subgroup

	Bevier formation	Thickness (Feet)
9	shale, gray	1.00
8	limestone, jointed; weathered to ferruginous, earthy, argillaceous blocks; Desmoinesia	0.15
	Verdigris formation	
7	clay, gray	1.00
6	limestone, light-gray, nodular; apparent dip 1° NE	1.50
5	shale, gray	2.00
4	shale, gray; becoming arenaceous at base	3.00
3	sandstone-concretion bed; concretions are 0.5 ft. in diameter and are slightly calcareous	0.50

		Thickness (Feet)
2	sandstone, gray; bedding thickness varies from .01 foot to 1 foot or more; some interbedded shales	4.50
1	shale; consisting of alternating dark and light-gray laminae; arenaceous; micaceous; some plant fossils; measured to water line in creek	3.00
	Total thickness	16.65 Feet

STRATIGRAPHIC SECTION NO. 18

Section exposed in ditch on west side of hill a few hundred feet north of east-west dirt road; SE¼ SW¼ sec. 18, T. 42 N., R. 28 W.; 2.5 miles northeast of Mayesburg, Henry County, Missouri.

Marmaton group
Fort Scott subgroup
Blackjack Creek formation

		Thickness (Feet)
28	limestone, weathered brown, thick-bedded	1.00

Cherokee group
Cabaniss subgroup
Excello formation

27	shale, black, fissile; contains oblong to flat phosphatic concretions	4.00

Mulky formation

26	coal	1.50
25	underclay, gray; only top exposed ..	0.50
24	covered interval, patches of shale and sandstone exposed	13.00
23	limestone, medium-gray, thin-bedded, argillaceous, jointed, breaks into large rectangular slabs; numerous small crinoid columnals which protrude from weathered surface; Mesolobus, Antiquatonia	0.35

		Thickness (Feet)
22	shale, gray	0.15
21	limestone, medium-gray, thin-bedded, arenaceous; Antiquatonia, Trepospira(?), fusulinids	1.25
20	shale, gray, arenaceous	4.00
19	limestone, medium-gray, arenaceous, thin-bedded, crinoid columnals, jointed, breaks out into large rectangular slabs; discontinuous	0.50
18	shale, gray	1.00
17	limestone, medium-gray, arenaceous, thin-bedded, argillaceous, discontinuous	0.35
	Lagonda-Bevier formation	
16	shale, gray, arenaceous	5.50
15	sandstone, gray; thin-bedded (.01 ft.) at base to medium bedded (0.5) at top; Calamites; specks of carbon	12.00
14	shale, gray, arenaceous	3.00
13	shale, black, fissile	0.15
12	shale, gray	16.50
	Verdigris formation	
11	coal, bright, thin-bedded	0.35
10	underclay, gray; hackly fracture ...	1.75
9	limestone, light-gray; predominantly limestone nodules 0.1 ft. in diameter; clay matrix; forms ledge but weathers to rubble; Linoproductus	3.50
8	limestone, gray, weathers greenish-gray, argillaceous, arenaceous, jointed, blocky	0.50
7	shale, greenish-gray; small spheroidal to flat phosphatic nodules, some of which are calcareous	0.25
6	limestone, dark-gray, weathers reddish-brown; occurs as one bed; brachiopod fragments common	0.25
5	shale, gray	5.00

		Thickness (Feet)
	Croweburg formation	
4	coal, weathered soft	0.75
3	underclay; fossil root impressions; structureless	2.50
2	shale, weathered brown, arenaceous at top	10.00
	Fleming formation	
1	shale, greenish-gray, weathers reddish-brown to purple	1.00
	Total thickness	98.85 Feet

STRATIGRAPHIC SECTION NO. 19

East road cut, south cut bank of Wolf Creek; NW¼ NE¼ sec. 11, T. 37 N., R. 33 W.; 6 miles southeast of Hume, Vernon County, Missouri.

		Thickness (Feet)
	Marmaton group	
	Fort Scott subgroup	
	Blackjack Creek formation	
10	limestone, light-gray; only base exposed	1.00
9	shale, gray	1.50
8	limestone, light-gray, jointed into blocks	0.25
	Cherokee group	
	Cabaniss subgroup	
	Excello formation	
7	shale, gray	1.00
6	shale, black, fissile; flattened phosphatic concretions	1.50
	Mulky formation	
5	coal, smutty	0.30
4	underclay and shale, gray	2.00

		Thickness (Feet)
	Breezy Hill member	
3	shale with nodules of limestone	0.75
	Mulky-Lagonda formation	
2	shale and sandstone, interbedded ...	6.00
1	sandstone, medium-gray, fine-grained, micaceous, thin-bedded	15.00
	Total thickness	28.30 Feet

STRATIGRAPHIC SECTION NO. 20

Road cut on west side of dirt road, south side of hill, above bridge over Pryor Creek; NW¼ NE¼ sec. 36, T. 38 N., R. 33 W.; 5 miles southeast of Hume, Bates County, Missouri.

Marmaton group
Fort Scott subgroup
Blackjack Creek formation

		Thickness (Feet)
8	limestone, medium-gray, jointed; one bed	2.35
7	shale, gray; small pea-sized limestone nodules; abundant Mesolobus mesolobus	1.50
6	limestone, medium-gray; jointed; one bed	0.50

Cherokee group
Cabaniss subgroup
Excello formation

5	shale, black, fissile; contains large concretions of finely crystalline, dark-gray limestone	1.50
	Mulky formation	
4	coal, thin-bedded	1.10
3	underclay, dark-gray; breaks into angular fragments	1.50

		Thickness (Feet)
	Mulky-Lagonda formation	
2	sandstone, weathered brown; medium-bedded at base to thin-bedded at top	5.00
1	shale, gray, non-calcareous	15.00
	Total thickness	28.45 Feet

STRATIGRAPHIC SECTION NO. 21

Section measured from water line of Osage River under bridge southward along east drainage ditch of north-south dirt road to top of hill; SE¼ sec. 6, T. 39 N., R. 32 W.; 3 miles northeast of Foster, Bates County, Missouri.

		Thickness (Feet)
	Marmaton group	
	Fort Scott subgroup	
	Blackjack Creek formation	
23	limestone, light-gray	2.00
22	covered interval	5.00
	Cherokee group	
	Cabaniss subgroup	
	Mulky-Lagonda formation	
21	sandstone, fine-grained, concretionary, calcareous	1.00
20	sandstone, thin-bedded, non-calcareous	4.00
19	shale, gray	5.00
18	covered interval	25.00
17	shale, medium-gray	2.00
16	limestone, dark-gray, thin-bedded, argillaceous; weathers to soft reddish-brown blocks; crinoid columnals, productids	0.45
	Lagonda-Bevier formation	
15	sandstone; fossil root impressions; non-calcareous	0.50

		Thickness (Feet)
14	sandstone, fine-grained, thin-bedded, non-calcareous; carbonized roots at top	10.00
13	shale, medium-gray, arenaceous	6.00
12	shale, medium-gray, non-calcareous.	7.00
11	limestone, dark-gray, weathers reddish-brown, thin-bedded, blocky; jointed NW-SE and NE-SW; Neospirifer, bryozoans, fossil fragments	0.85
10	shale, dark-gray	0.50
9	shale, medium-gray, arenaceous at top	10.00
8	shale, dark-gray, non-calcareous; many dike-like structures of clay-ironstone	10.50
7	shale, dark-gray, non-calcareous; lenses of clay-ironstone concretions	5.00
6	limestone, dark-gray, weathers reddish-brown, thin-bedded, argillaceous; Mesolobus mesolobus, crinoid columnals, fossil fragments; fucoidal structures resembling scour and fill	0.25
5	shale, dark-gray to black, soft, calcareous	1.75
4	limestone, dark-gray to black, discontinuous; grades into top of coal; very fossiliferous with Desmoinesia muricatina and Mesolobus mesolobus .	0.10
	Verdigris formation	
3	coal, bright; small amount of sulfur	0.75
2	underclay; fossil root impressions; hackly fracture	1.50
	Ardmore member	
1	limestone, light-gray, nodular bedding; only top exposed	1.00
	Total thickness	100.15 Feet

STRATIGRAPHIC SECTION NO. 22

Road cut on east side of U. S. Highway 71; SE¼ SE¼ sec. 5, T. 39 N., R. 31 W.; 4 miles south of Butler, Bates County, Missouri.

Marmaton group
Fort Scott subgroup
Higginsville formation

		Thickness (Feet)
24	limestone, light-gray, crinkly bedded; only bottom exposed	6.00

Little Osage formation

23	shale, dark-gray, very fossiliferous with Mesolobus, Crurithyris and Kozlowskia splendens	0.50
22	shale, black, fissile	1.50
21	coal, smutty (Summit)	0.01
20	underclay	0.50

Blackjack Creek formation

19	clay, light-gray; pea-sized limestone nodules	1.50
18	limestone, blocky, jointed; one bed; Linoproductus	2.00

Cherokee group
Cabaniss subgroup
Excello formation

17	shale, black; small irregular-shaped phosphatic concretions	0.85
16	limestone, dark-gray, argillaceous .	0.02

Mulky formation

15	coal, smutty	0.01
14	clay, gray, structureless	1.50
13	limestone, very light-gray, arenaceous, nodular	0.25

Mulky-Lagonda formation

12	shale, light-gray, hard	1.00

		Thickness (Feet)
11	sandstone, thick-bedded	2.00
10	shale, gray	3.00
9	sandstone, gray, weathers brown, thin-bedded, fine-grained	11.00
8	shale, dark-gray; joints filled with clay	15.00

Lagonda-Bevier formation

7	sandstone, weathers reddish-brown, calcareous; pieces of carbon and fossil fragments; hard; one bed	0.50
6	sandstone, weathered brown, fine-grained, thin-bedded, non-calcareous; pieces of carbonized wood	4.00
5	shale, dark-gray, non-calcareous ...	16.00
4	clay-ironstone concretions, weathers reddish-brown; occurs as one bed; calcareous	0.35
3	shale, weathered brown, calcareous .	3.00
2	limestone, dark-gray, thin-bedded, argillaceous; Mesolobus mesolobus ..	1.50
1	shale, dark-gray	6.00
	Total thickness	78.01 Feet

STRATIGRAPHIC SECTION NO. 23

Artificial excavation and drill test core, U. S. Air Force Missile site; west side of north-south gravel road, SE¼ SE¼ sec. 1, T. 39 N., R. 31 W.; 5 miles southeast of Butler, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Mulky-Lagonda-Bevier formation

		Thickness (Feet)
15	shale, gray	2.00
14	limestone, dark-gray, argillaceous, weathers reddish-brown	0.25
13	shale, dark-gray, very calcareous; grades into thin-bedded argillaceous limestone; Mesolobus, productid brachiopods	2.00

		Thickness (Feet)
12	shale, dark-gray, calcareous	15.00
11	shale, dark-gray, interbedded with sandstone	5.00
10	shale, dark-gray, non-calcareous ...	19.50
	Verdigris formation	
9	limestone, dark-gray, argillaceous; weathers reddish-brown; fossil fragments	0.55
8	underclay, gray; carbonized roots; slickensided	1.50
7	limestone, light-gray, hard; nodular bedding	3.35
6	clay, greenish-gray; phosphatic concretions and lenses of rock phosphate; non-calcareous	0.40
5	shale, greenish-gray; fossil fragments	0.10
4	shale, greenish-gray to medium-gray; top part interbedded with sandstone.	37.80
3	shale, dark-gray; lenses of vitrain.	0.20
	Croweburg formation	
2	coal, bright; thin lens of dark shale or fusain 0.1 ft. from top	0.90
1	underclay, medium-gray; slickensided; carbonized roots	1.00
	Total thickness	89.55 Feet

STRATIGRAPHIC SECTION NO. 24

Artificial excavation and drill core test, U. S. Air Force Missile site; SE¼ SE¼ sec. 29, T. 40 N., R. 29 W.; 4.5 miles northeast of Pleasant Gap, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Myrick Station member

		Thickness (Feet)
37	limestone, dark-gray, thin- bedded	2.50

		Thickness (Feet)
	Anna member	
36	shale, dark-gray to black	0.50
35	shale, black, fissile; large spheroidal phosphatic concretions.	1.00
	Labette formation	
34	shale, gray; sulfur or iron stained	0.50
33	sandstone and shale alternating in thin beds; non-calcareous	1.00
32	sandstone, calcareous, fine-grained, massive; Mesolobus	0.50
31	shale, gray	0.45
30	shale, black	0.25
29	coal, thin-bedded (Lexington)	0.60
28	clay and shale	1.00
27	clay, arenaceous	0.50
26	sandstone, fine-grained, thin-bedded	1.00
25	sandstone, thick-bedded (1 to 2 ft.), planar cross bedding, hard, calcareous, fine-grained	5.00
24	sandstone and shale in alternating laminae, calcareous; shales are dark-gray and contain abundant carbonaceous matter	6.00
23	shale, dark-gray, calcareous	4.50
22	limestone, dark-gray, thin-bedded, argillaceous; Composita	1.00
	Alvis coal	
21	coal, bright	0.25
20	underclay, light-gray; carbonized roots	1.20
	Fort Scott subgroup	
	Higginsville formation	
19	limestone, light-gray, wavy bedded; upper 5 feet nodular; finely crystalline; shale lenses along bedding planes; recrystallized brachiopods	18.50

		Thickness (Feet)
Little Osage formation		
18	shale, black; fossiliferous near middle with Mesolobus	1.50
17	shale, black, fissile; phosphatic concretions and lenses in lower half	2.40
16	shale; black to dark-gray at base; bottom 0.4 ft. fossiliferous ...	0.90
15	shale, black, thin lenses of coal; coalified Calamites	0.20
14	underclay	1.00
Blackjack Creek formation		
13	clay-shale, greenish-gray; pea-sized limestone nodules near base	3.00
12	limestone, nodular; nodules to 0.2 ft. diameter; greenish-gray clay matrix	1.10
11	shale, greenish-gray; few irregular-shaped limestone nodules	1.30
Cherokee group		
Cabaniss subgroup		
Excello formation		
10	shale, greenish-gray, mottled black; a few phosphatic concretions and lenses of phosphate	0.40
Mulky formation		
9	underclay, slickensided	0.80
8	clay, greenish-gray, calcareous.	2.10
7	clay greenish-gray, non-calcar-eous	2.50
Mulky-Lagonda formation		
6	shale and sandstone, interbedded, greenish-gray; non-calcareous ..	2.20
5	sandstone, greenish-gray, non-calcareous, cross-bedded	4.50

		Thickness (Feet)
4	shale, greenish-gray, micaceous, non-calcareous; interbedded with lenses of sandstone in top half ...	11.80
3	shale, medium-gray	10.00
2	shale, medium-gray; crinoid columnals; thin-shelled brachiopods	3.80
1	shale, medium-gray; carbonized wood, fern fronds	0.20
	Total thickness	96.25 Feet

STRATIGRAPHIC SECTION NO. 25

Drainage ditch, east side of north-south dirt road on west side of hill; NE¼ NE¼ sec. 28, T. 41 N., R. 29 W.; 2 miles southeast of Ballard, Bates County, Missouri.

Cherokee group
Cabaniss subgroup
Mulky formation

		Thickness (Feet)
16	sandstone, fine-grained, thin to medium-bedded, becoming calcareous and nodular near top	5.00
15	shale, gray	10.00
14	limestone, dark-gray to black, thin-bedded, argillaceous, Desmoinesia	1.00
13	clay or underclay	0.50
12	shale, dark-gray, non-calcareous ..	2.00
11	limestone, dark-gray, thin-bedded, argillaceous; jointed into blocks; Mesolobus mesolobus	0.50

Lagonda-Bevier formation

10	coal	0.25
9	underclay, arenaceous; fossil root impressions	1.00
8	shale, gray	5.00
7	shale and sandstone interbedded in thin lenses	25.00

		Thickness (Feet)
6	shale, dark-gray	5.00
5	shale, dark-gray to black	1.50
4	shale, black, platy to fissile	0.15
3	limestone, weathered reddish-brown; one bed; jointed into blocks; fossil fragments	0.15
	Verdigris formation	
2	shale, greenish-gray; numerous limestone nodules which have weathered red	1.00
1	shale, gray; weathers greenish-gray	8.00
	Total thickness	66.05 Feet

STRATIGRAPHIC SECTION NO. 26

Drainage ditch east side of north-south dirt road eastward through barnyard to top of hill; SE¼ SW¼ sec. 25, T. 42 N., R. 29 W.; 0.25 miles northeast of Mayesburg, Bates County, Missouri.

Marmaton group
Fort Scott subgroup

	Blackjack Creek formation	Thickness (Feet)
13	limestone, light-gray, poorly exposed	1.00

Cherokee group
Cabaniss subgroup

	Excello formation	
12	shale; phosphatic concretions; poorly exposed	1.00
	Excello-Mulky formation	
11	covered interval	3.00
	Mulky formation	
10	sandstone, thin-bedded, fine-grained, micaceous, calcareous	3.00

		Thickness (Feet)
9	shale, gray	16.00
8	limestone, dark-gray, argillaceous, weathers reddish-brown, jointed; bryozoans, Mesolobus mesolobus	0.25
7	shale, weathered brown	6.00
6	limestone, dark-gray, thin-bedded, argillaceous; jointed into large rectangular blocks; Antiquatonia, Linoproductus	1.00
5	shale, gray	2.00
	Lagonda-Bevier formation	
4	shale, black	3.00
3	covered interval	11.00
2	shale, black, fissile	0.15
1	shale	0.50
	Total thickness	47.90 Feet

STRATIGRAPHIC SECTION NO. 27

Road cut on south side of east-west dirt road, east side of hill; SE¼ SW¼ sec. 31, T. 38 N., R. 33 W.; 4 miles southwest of Hume, Vernon County, Missouri.

Marmaton group
Fort Scott subgroup

		Thickness (Feet)
	Higginsville formation	
7	limestone, light-gray, wavy bedded; crinoid columnals; only base exposed	10.00
	Little Osage formation	
6	shale, black, fissile at base becoming light-gray near top	0.85
5	shale, dark-gray	0.01
4	shale, gray	2.00
	Blackjack Creek formation	
3	limestone, gray, jointed into blocks; top surface humpy as a result of abundant elevated Chaetetes colonies	2.50

		Thickness (Feet)
2	shale, light-gray	0.25
1	limestone, medium-gray, finely crystalline, jointed, occurs as 2 beds	1.00
	Total thickness	16.61 Feet

STRATIGRAPHIC SECTION NO. 28

Abandoned quarry west side of Highway V; NW¼ NW¼ sec. 9, T. 37 N., R. 33 W.; 5 miles south of Hume, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Labette formation

		Thickness (Feet)
3	sandstone, reddish-brown, medium-bedded, (0.5 ft.) to thin shaly bedding at top	2.00
2	shale, dark-gray; numerous pieces of carbon; lies unconformably on underlying unit	0.50

Fort Scott subgroup
Higginsville formation

1	limestone, light-gray, wavy bedded	14.00
	Total thickness	16.50 Feet

STRATIGRAPHIC SECTION NO. 29

Abandoned limestone quarry on north side of east-west dirt road, west side of hill; SE¼ SE¼ sec. 28, T. 39 N., R. 32 W.; 2 miles north of Sprague, Bates County, Missouri, (modified after Jefferies, 1958, p. 160).

Marmaton group
Appanoose subgroup
Labette formation

		Thickness (Feet)
5	coal (Alvis)	0.05
4	underclay, gray, structureless	0.75

		Thickness (Feet)
Fort Scott subgroup		
Higginsville formation		
3	limestone, gray, finely crystalline; thin nodular bedding; abundant shale lenses	4.75
2	limestone; gray with dark-gray mottling; finely crystalline; smooth subconchoidal fracture; medium-bedded (.5 ft.) fossiliferous	12.00
Little Osage formation		
1	shale, black, platy; only top exposed in quarry floor	0.35
	Total thickness	19.90 Feet

STRATIGRAPHIC SECTION NO. 30

Drainage ditch south side of road; NW¼ NW¼ sec. 28, T. 39 N., R. 32 W.; 3 miles north of Sprague, Bates County, Missouri.

		Thickness (Feet)
Marmaton group		
Fort Scott subgroup		
Higginsville formation		
13	limestone, light-gray, finely crystalline, breaks with smooth fracture; only base exposed	1.50
Little Osage formation		
12	shale, medium-gray, calcareous	0.45
11	shale, black, fissile; flat phosphatic concretions	1.65
10	clay or underclay, medium-gray, platy to massive, top silty; iron-stained; bottom poorly exposed	5.25
Blackjack Creek formation		
9	limestone, gray; nodular bedded, finely crystalline; lower part argillaceous; <u>Antiquatonia</u>	2.50

		Thickness (Feet)
8	limestone, weathered brown; finely crystalline, smooth fracture; occurs in one bed; sparsely fossiliferous with crinoid columnals, Neospirifer and Kozlowskia splendens	3.50
7	shale, weathered brown, calcareous	0.50
6	limestone, weathers to brown earthy blocks; occurs in one bed ...	0.35

Cherokee group
Cabaniss subgroup
Excello formation

5	shale, gray, calcareous	1.00
4	shale, dark-gray to black, fissile to platy; small flattened phosphate concretions	1.65

Mulky formation

3	coal; interbedded with several thin lenses of shale	0.35
2	underclay; fossil root impressions .	1.50
1	shale	1.00
	Total thickness	21.20 Feet

STRATIGRAPHIC SECTION NO. 31

Northeast cut bank of Osage River at Marble Bridge; NW¼ NW¼ sec. 2, T. 39 N., R. 33 W.; 3.5 miles southeast of Amoret, Bates County, Missouri.

Marmaton group
Fort Scott subgroup
Higginsville formation

		Thickness (Feet)
16	limestone, light-gray, crinkly bedded; Crurithyris, crinoid columnals, abundant fusulinids near top	12.00
15	limestone, gray	0.15

		Thickness (Feet)
14	shale, weathered brown	0.20
13	limestone, medium-gray; few fossil fragments	0.50
	Little Osage formation	
12	shale, light-gray	0.15
11	shale, dark-gray, calcareous	0.60
10	limestone, dark-gray; one bed; Kozlowskia splendens, (Houx? limestone)	0.25
9	shale, dark-gray, calcareous at top	1.00
8	shale, black, fissile; phosphatic concretions	1.15
7	shale, black, calcareous	0.75
6	limestone, dark-gray, thin-bedded, argillaceous; abundant Kozlowskia splendens, sparse Derbyia crassa	0.45
5	shale, gray, calcareous; Composita .	0.45
4	coal, thin-bedded	0.35
3	underclay, dark-gray; fossil root impressions; iron and sulphur-stained	0.50
2	shale, dark-gray	2.00
	Blackjack Creek formation	
1	limestone, nodular; Antiquatonia, Kozlowskia splendens; basal few inches bedded.	2.50
	Total thickness	23.00 Feet

STRATIGRAPHIC SECTION NO. 32

East face of active quarry; SW¼ SE¼ sec. 19, T. 40 N., R. 31 W.; 2.5 miles west of Butler, Bates County, Missouri, (modified after Jefferies, 1958, p. 165). This exposure is the type section of the Alvis coal.

Marmaton group
Appanoose subgroup
Pawnee formation
Mine Creek member

		Thickness (Feet)
23	shale, dark-gray	3.00

		Thickness (Feet)
	Myrick Station member	
22	limestone, dark-gray; thick blocky bedding; algae, large fusulinids	4.65
	Anna member	
21	shale, gray, soft	0.15
20	shale, black, fissile; irregular-shaped phosphatic concretions ...	1.00
	Labette formation	
19	sandstone, fine-grained, argillaceous, non-calcareous	0.25
18	shale, dark-gray to black; grades into sandstone at top; non-calcareous	1.10
17	limestone, dark-gray, argillaceous; chonetids, other fossil fragments; forms small ledge	0.25
16	shale, dark-gray, calcareous, silty; pieces of carbon	7.00
15	sandstone and shale in alternating laminae, calcareous; pieces of charcoal; abundant pelecypods at top	16.00
14	sandstone, gray, very hard, cross-bedded, fine-grained	1.00
13	shale, dark-gray, calcareous; Composita, Kozlowskia splendens, Mesolobus, Neospirifer, and horn corals	1.85
12	limestone, dark-gray, very argillaceous; brachiopod fragments	0.25
11	coal, thin-bedded, bright (Alvis)	0.15
10	clay, gray; fossil root impressions near top	1.50
	Fort Scott subgroup	
	Higginsville formation	
9	limestone, light-gray, finely crystalline, wavy bedded, upper part nodular; abundant fusulinids near top	20.00

		Thickness (Feet)
Little Osage formation		
8	shale, light-gray, calcareous; Crurithyris planoconvexa	0.25
7	shale, dark-gray, calcareous ...	0.15
6	shale, weathered brown, calcareous; fossil fragments	0.15
5	shale, dark-gray, calcareous ...	1.00
4	shale, black, fissile; abundant oblong to irregular-shaped phosphatic concretions	2.00
3	limestone, gray, finely crystalline, thin-bedded, argillaceous; fossil fragments	0.10
2	clay, gray, calcareous at base; top few inches appears to be an underclay; few small limestone nodules near bottom	2.50
Blackjack Creek formation		
1	limestone, medium-gray, finely crystalline, nodular; few fossils	3.00
	Total thickness	67.30 Feet

STRATIGRAPHIC SECTION NO. 33

Artificial excavation and drill core test, U. S. Air Force Missile site; SE¼ SE¼ sec. 11, T. 39 N., R. 30 W.; 0.25 miles south of Pleasant Gap, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
29	limestone, medium-gray, thick-bedded at base, crinkly bedded and siliceous near top	6.00
Mine Creek member		
28	shale, black, calcareous; abundant chonetid brachiopods, some Kozlowskia splendens	0.50

		Thickness (Feet)
27	limestone, dark-gray, jointed; breaks with hackly fracture; finely crystalline	1.50
26	shale, dark-gray	1.00
25	limestone, dark-gray; breaks with hackly fracture; finely crystalline; hard	2.00
24	shale, dark-gray	0.50
	Myrick Station member	
23	limestone, dark-gray; breaks with hackly fracture; finely crystalline; hard	3.00
	Anna member	
22	shale, black, fissile; some irregular-shaped phosphatic concretions	0.75
	Labette formation	
21	sandstone, brownish-black, thin-bedded, non-calcareous; contains asphalt; some green sand grains.	12.50
20	shale, dark-gray	1.00
19	sandstone, thin-bedded, asphaltic	4.00
18	shale, arenaceous, greenish-gray, calcareous	3.50
17	sandstone; alternating greenish-gray and light-gray laminae; fine-grained	10.00
16	shale, arenaceous; few sandstone lenses	8.00
15	shale, dark-gray, calcareous ...	3.00
14	limestone, dark-gray, argillaceous	1.25
13	coal (Alvis)	0.25
12	underclay	3.50
	Fort Scott subgroup	
	Higginsville formation	
11	limestone, light-gray, finely crystalline; thin shale lenses along bedding planes	21.00

		Thickness (Feet)
Little Osage formation		
10	shale, gray; Orbiculoidea	0.50
9	shale, black, fissile; phosphatic concretions	1.50
8	coal, thin-bedded	0.10
7	underclay; carbonized roots	2.50
Blackjack Creek formation		
6	shale, greenish-gray, calcareous; abundant pea-sized nodules of limestone	4.70
Excello formation		
5	clay-shale, greenish-gray; few oblong-shaped phosphatic concretions, and lenses of phosphate	0.30
Mulky formation		
4	shale, dark-gray, carbonaceous (Mulky coal horizon)	0.01
3	shale, greenish-gray, non-calcareous	0.20
Breezy Hill member (unit 2)		
2	shale, greenish-gray; pea-sized limestone nodules	1.50
1	shale, greenish-gray, non-calcareous	1.00
	Total thickness	95.56 Feet

STRATIGRAPHIC SECTION NO. 34

Operating quarry, southeast bank of Soap Creek on north side of county road D; SE¼ SW¼ sec. 29, T. 41 N., R. 29 W.; 3 miles southwest of Ballard, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Labette formation

		Thickness (Feet)
19	sandstone, weathered reddish-	

		Thickness (Feet)
	brown, thin-bedded (knife edge to 0.2 ft.) at base becoming thick-bedded (1 foot or more) at top ..	7.00
18	shale, weathered tan; dark-gray laminae near base; grades upward into thin-bedded sandstone	3.50
17	shale, dark-gray to black, calcareous; few laminae of dark-gray to black limestone near bottom; Composita ovata, Derbyia crassa and productid brachiopods near bottom.	3.50
16	coal (Alvis)	0.25
15	underclay; fossil root impressions	1.00
14	clay, light-gray; mixed with nodules of limestone	1.50
	Fort Scott subgroup	
	Higginsville formation	
13	limestone, light-gray; mottled dark-gray; wavy irregular bedding; breaks with angular fracture; jointed; a few thin lenses and pockets of clay in top 6 feet; abundant large fusulinids at top	14.00
	Little Osage formation	
12	shale, gray	0.50
11	covered; patches of shale	2.00
10	shale, black, fissile; few phosphatic concretions	1.15
9	shale, weathered brown	1.00
	Blackjack Creek formation	
8	shale, and nodules of limestone, poorly exposed	1.00
7	limestone, gray; thick nodular bedding; forms one bed	0.65
6	limestone, gray, nodular	0.35
5	shale, gray	5.00
4	limestone, weathered brown; one bed; jointed; crinoid columnals, horn corals	0.60
	Cherokee group	
	Cabaniss subgroup	
	Excello formation	
3	shale, light-gray, calcareous	0.50
2	shale, dark-gray to black; spheroidal to irregular-shaped phosphatic concretions	0.75

		Thickness (Feet)
1	shale, greenish-gray, non-calcareous; only top exposed	0.50
	Total thickness	44.65 Feet

STRATIGRAPHIC SECTION NO. 35

South face of operating limestone quarry, 0.3 mile west of county road K; SW¼ SE¼ sec. 33, T. 42 N., R. 28 W.; 4 miles southeast of Mayesburg, Henry County, Missouri.

Marmaton group
Appanoose subgroup
Labette formation

		Thickness (Feet)
8	sandstone, weathered reddish-brown, thin-bedded, fine-grained	5.00
7	shale, weathered reddish-brown	3.00
6	shale, gray; abundant Composita ovata, productids and other fossil fragments.	1.15
5	coal, thin-bedded; some fusain (Alvis)	0.20
4	underclay; pieces of carbon; breaks out in angular chips; few carbonized root impressions	2.35

Fort Scott subgroup
Higginsville formation

3	limestone, light-gray; thin nodular bedding	2.00
2	limestone, light-gray; mottled dark-gray; crinkly to wavy bedding; very thin clay lenses between bedding planes ...	9.65

Little Osage formation

1	shale, gray; only top exposed	0.15
	Total thickness	23.50 Feet

STRATIGRAPHIC SECTION NO. 36

East cut bank of eastward flowing tributary to Pryor Creek; NW¼ NW¼ sec. 26, T. 38 N., R. 33 W.; 3 miles southeast of Hume, Vernon County, Missouri.

Marmaton group
Appanoose subgroup
Labette formation

		Thickness (Feet)
8	sandstone, reddish-brown; specks of carbon	6.00

		Thickness (Feet)
7	limestone, dark-gray, weathers reddish-brown, thin-bedded, argillaceous, jointed into slabs; abundant Crurithyris planoconvexa	0.35
6	shale, dark-gray; abundant Composita ovata and productids	1.50
5	coal; thin shaly bedding (Alvis)	0.35
4	shale, dark-gray; specks of carbon ...	2.50
3	sandstone, light-gray, thin-bedded, fine-grained	3.00
2	sandstone, light-gray, fine-grained, massive, cross-bedded; lies unconformably on underlying unit	3.00
	Fort Scott subgroup Higginsville formation	
1	limestone, light-gray; only top exposed	0.35
	Total thickness	17.05 Feet

STRATIGRAPHIC SECTION NO. 37

Banks of Pryor Creek below abandoned coal strip mine; NW¼ NE¼ sec. 26, T. 38 N., R. 33 W.; 3.5 miles southeast of Hume, Vernon County, Missouri.

		Thickness (Feet)
	Marmaton group Appanoose subgroup Pawnee formation Myrick Station member	
22	limestone, dark-gray, finely crystalline; breaks with smooth angular fracture; thick-bedded; dip 3° N.35°E; only base exposed .	2.00
	Anna member	
21	shale, black, soft	0.15
20	shale, black, fissile; numerous irregular-shaped, phosphatic concretions	1.00
	Labette formation	
19	limestone, dark-gray, thin-bedded, argillaceous; fossil fragments ...	0.50
18	shale, dark-gray to black, soft, calcareous	3.00
17	limestone, dark-gray; thin-bedded, argillaceous; Crurithyris plano-	

		Thickness (Feet)
	convexa, Mesolobus mesolobus, Neospirifer	0.15
16	shale, black, calcareous; fragments of carbonaceous material ...	2.00
15	limestone, dark-gray, very arenaceous, micaceous; Mesolobus mesolobus	0.35
14	sandstone, thin-bedded, very calcareous, very hard; ropy structures resembling scour and fill markings	3.50
13	shale, dark-gray, calcareous, large concretions; interbedded with several feet of thin-bedded, calcareous sandstone	15.00
12	sandstone, weathered reddish-brown, thin-bedded, very hard; Taonurus caudagalli	0.50
11	sandstone and shale, interbedded .	1.15
10	limestone, weathered reddish-brown, thin-bedded, argillaceous	0.50
9	shale, dark-gray, soft	0.15
8	limestone, dark-gray, argillaceous; Crurithyris, Composita ovata	0.10
7	shale, dark-gray, soft	0.15
6	limestone, dark-gray to black, concretionary, very hard	0.40
5	shale, dark-gray to black; very fossiliferous with Derbyia crassa, Composita, Linoproductus	1.50
4	coal, thin-bedded; exposed in small east-west trending syncline (Alvis)	0.50
3	conglomerate of limestone particles, discontinuous	0.50
2	underclay, light-gray; fossil root impressions	1.00
	Fort Scott subgroup Higginsville formation	
1	shale; with limestone nodules	1.50
	Total thickness	35.60 Feet

STRATIGRAPHIC SECTION NO. 38

Road cut on west side of north-south dirt road a few hundred feet south of bridge over Walnut Creek; NE¼ SE¼ sec. 11, T. 39 N., R. 33 W.; 0.5 miles northwest of Foster, Bates County, Missouri, (modified after Jefferies 1958, p. 163).

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
11	limestone, light-gray, finely crystalline; weathers brown; Hustedia, Kozlowskia splendens, Composita ovata, horn corals and crinoid columnals; only base exposed	1.50

Mine Creek member

10	shale, gray, calcareous; interbedded with 2 or 3 thin beds of limestone; abundant Mesolobus, Chonetes, sparse Antiquatonia, abundant crinoid columnals; poorly exposed	2.00
9	shale, gray	2.50
8	covered interval	5.50

Myrick Station member

7	limestone, dark-gray; breaks with angular fracture; thick-bedded; Composita; large fusulinids near top	3.50

Anna member

6	shale, black, fissile; small spheroidal to irregular-shaped phosphatic concretions	0.85

Labette formation

5	sandstone, gray, thin-bedded; specks of carbon and black shale	1.75
4	shale, gray, flaky to platy, very calcareous, carbonaceous; lower part contains abundant Mesolobus, sparse Crurithyris and crushed gastropods	5.15
3	shale, black; specks of carbon .	1.40
2	coal, shaly bedded	0.50

		Thickness (Feet)
1	shale and sandstone, interbedded; shale contains carbon specks, sandstone is iron-stained	3.65
	Total thickness	28.30 Feet

STRATIGRAPHIC SECTION NO. 39

Artificial excavation and drill core test, U. S. Air Force Missile site; NE¼ SW¼ sec. 1, T. 39 N., R. 32 W.; 4 miles southwest of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Myrick Station member

		Thickness (Feet)
31	limestone, weathered brown	2.50

Anna member

30	shale, black, fissile; phosphatic concretions	0.75

Labette formation

29	shale, black, soft; basal part calcareous	2.00
28	limestone, dark-gray, coarsely crystalline; Kozlowskia splendens, and other fossil fragments; jointed; blocky	0.15
27	underclay, arenaceous; root impressions	0.50
26	shale, gray, arenaceous, micaceous	3.00
25	shale, black; abundant Calamites; few coal lenses	2.00
24	coal, smutty	0.15
23	underclay, arenaceous; fossil root impressions	1.00
22	sandstone, fine-grained, thin-bedded; calcareous near middle .	14.00

		Thickness (Feet)
21	shale, black, calcareous; bits of carbon	3.25
20	limestone, dark-gray, argillaceous; brachiopod fragments	0.75
19	coal (Alvis)	0.25
18	underclay, greenish-gray	2.00

Fort Scott subgroup

Higginsville formation

17	limestone, light-gray, finely crystalline; few shale lenses along bedding planes	19.50

Little Osage formation

16	shale, dark-gray; black at bottom; Mesolobus	0.80
15	shale, black, fissile; light-gray at top	2.75
14	coal (Summit)	0.10
13	clay-shale, gray, non-calcareous .	2.50

Blackjack Creek formation

12	limestone, light-gray, finely crystalline, thick-bedded	3.75

Excello formation

11	shale, greenish-gray; mottled black; calcareous	0.40
10	shale, greenish-gray; mottled black; oblong-shaped phosphatic concretions and lenses of phosphate	0.20
9	shale, greenish-gray; mottled black; slightly calcareous	0.20

Mulky formation

8	coal, thin-bedded	0.05
7	clay-shale, greenish-gray, non-calcareous; few carbonized roots.	0.35

		Thickness (Feet)
	Breezy Hill member	
6	shale, greenish-gray; irregular-shaped nodules of limestone at base	2.20
	Mulky-Lagonda formation	
5	shale, greenish-gray, non-calcareous; arenaceous	6.30
4	sandstone and shale, interbedded.	8.50
3	shale, gray	9.50
2	sandstone, fine-grained, cross-bedded	5.50
1	sandstone and shale, interbedded.	2.70
	Total thickness	97.10 Feet

STRATIGRAPHIC SECTION NO. 40

Artificial excavation and drill core test, U. S. Air Force Missile site; NE¼ NW¼ sec. 20, T. 40 N., R. 30 W.; 3.5 miles east of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
39	limestone, gray, crinkly bedded, (bedding 0.1 to 0.2 ft. thick)	3.50
	Mine Creek member	
38	shale, brown; chonetids	0.15
37	limestone; one thick bed	0.65
36	shale, dark-gray, hard, calcareous; pinches out	0.15
35	limestone, gray; one blocky bed; sparse crinoid columnals and brachiopods	1.50
34	shale, dark-gray, calcareous	2.00
33	limestone, dark-gray, thin-bedded, jointed	1.25

		Thickness (Feet)
32	shale, dark-gray	0.05
31	limestone, dark-gray, thin-bedded; grades into calcareous shale	1.00
30	shale, dark-gray	0.70
29	limestone, dark-gray, argillaceous	0.25
28	shale, dark-gray	8.00
27	shale, dark-gray, hard; hackly fracture	0.25
	Myrick Station member	
26	limestone, dark-gray, hard; large fusulinids; gradational with underlying unit	4.25
	Anna member	
25	shale, black, fissile	1.35
	Labette formation	
24	shale, dark-gray, arenaceous; brachiopod fossils	0.10
23	shale, gray, silty; particles of carbonized wood	1.25
22	shale, gray, soft	1.00
21	coal; shale lenses (Lexington) ..	1.10
20	sandstone, light-gray, calcareous; numerous dark-gray, arenaceous shale lenses	7.00
19	shale, arenaceous; alternating light and dark-gray laminae; some fine-grained sandstone lenses ...	4.50
18	shale, black, calcareous; particles of carbonized wood	3.50
17	limestone, thin-bedded, argillaceous hard; Composita, Chonetes at base	2.50
16	coal (Alvis)	0.25
15	underclay, greenish-gray, carbonized roots	2.00
	Fort Scott subgroup	
	Higginsville formation	

		Thickness (Feet)
14	limestone, light-gray, finely crystalline; some thin shale lenses; asphalt-stained	16.00
	Little Osage formation	
13	shale, greenish-gray, fossiliferous	1.15
12	shale, black, soft	1.50
11	shale, black, fissile; phosphatic concretions	1.00
10	shale, gray; chonetids	0.20
9	underclay	0.75
	Blackjack Creek formation	
8	limestone, light-gray; finely crystalline; some thin shale lenses	4.50
7	limestone, light-gray, nodular; mixed with green clay	2.00
	Cherokee group	
	Cabaniss subgroup	
	Excello formation	
6	shale, medium-gray; few phosphatic concretions	1.00
	Mulky formation	
5	coal, smutty	0.01
4	underclay; slickensided	1.00
	Mulky-Lagonda formation	
3	sandstone, greenish-gray, calcareous; some thin clay lenses	5.75
2	sandstone, greenish-gray, calcareous, hard	6.25
1	shale, silty, greenish-gray	2.00
	Total thickness	91.36 Feet

STRATIGRAPHIC SECTION NO. 41

South cut bank of Root Branch Creek, west side of north-south dirt road; SE¼ SE¼ sec. 28, T. 40 N., R. 30 W.; 4.5 miles southeast of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
20	limestone, light-gray, wavy bedded; top not exposed	3.00
19	limestone, medium-gray, argillaceous, arenaceous; one bed; large crinoid columnals, Neospirifer, chonetid brachiopods; apparent dip 5° NE	2.00

Mine Creek formation

18	shale, gray	2.50
17	limestone, dark-gray; Mesolobus mesolobus decipiens which have the characteristic of weathering red	1.15
16	shale, weathered brown; chonetid brachiopods	0.45
15	limestone, dark-gray, arenaceous; Neospirifer, chonetids, productids	0.25
14	shale, gray; lower half very fossiliferous with Mesolobus, "Chonetes", and productid brachiopods	2.00
13	limestone, dark-gray; Mesolobus which weather red	0.15
12	shale, medium-gray; calcareous at base	4.00

Myrick Creek member

11	limestone, dark-gray, weathers brown; angular fracture; large fusulinids at top	3.50

Anna member

10	shale, black, calcareous, soft ..	0.10

		Thickness (Feet)
9	shale, black, fissile; large spheroidal phosphatic concretions 1¼ inch in diameter	1.00
	Labette formation	
8	shale, gray, calcareous; some thin lenses of calcareous sandstone; several hundred feet downstream unit contains large calcareous sandstone concretions 1 foot in diameter	1.50
7	shale; dark-gray at base, light-gray at top; calcareous	3.50
6	conglomerate; limestone and dark shale particles; largest about 0.1 ft. in diameter; grades into dark-gray arenaceous limestone 50 feet upstream	0.50
5	shale, black, soft; calcareous at top	2.00
4	coal (Lexington)	0.50
3	shale, black; almost completely composed of Calamites	1.00
2	clay, dark-gray; a few thin lenses of black shale with abundant Calamites	2.00
1	sandstone, fine-grained, cross-bedded; measured to water line ..	3.00
	Total thickness	34.10 Feet

STRATIGRAPHIC SECTION NO. 42

South cut bank of northwest flowing stream; NE¼ NE¼ sec. 27, T. 41 N., R. 30 W.; 4.5 miles southwest of Ballard, Bates County, Missouri. Regional dip is to east, local reversals of dip common.

Marmaton group
Appanoose subgroup
Pawnee formation
Mine Creek member

		Thickness (Feet)
16	shale, gray; only base exposed ..	0.25

		Thickness (Feet)
15	limestone, medium-gray, thin-bedded, argillaceous; abundant "Chonetes" granulifer (Owen)	0.50
14	limestone, gray; one bed	1.50
13	shale, weathered brown, arenaceous, calcareous	1.45
12	shale, medium-gray, arenaceous, micaceous; "Chonetes" granulifer (Owen)	1.40
11	limestone, medium-gray, arenaceous; fragments of productid brachiopods	0.25
10	shale, medium-gray, non-calcareous, iron-stained	3.00
9	covered interval	7.50
	Myrick Station member	
8	limestone, dark-gray; breaks with angular fracture	3.50
	Anna member	
7	shale, black, fissile; phosphatic concretions	1.00
	Labette formation	
6	shale, dark-gray; carbonaceous matter; poorly exposed	3.00
5	coal (Lexington)	0.50
4	shale, dark-gray	2.00
3	sandstone, hard, calcareous; Taonurus caudagalli; scour and fill markings; pieces of carbonized wood	3.00
2	sandstone and shale, interbedded.	1.50
1	sandstone, calcareous, thin-bedded, hard	3.00
	Total thickness	33.35 Feet

STRATIGRAPHIC SECTION NO. 43

East road cut just below T in road to east; NE¼ SE¼ sec. 1, T. 41 N., R. 30 W.; 3 miles southeast of Altona, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Myrick Station member

		Thickness (Feet)
16	limestone; exposed as float	0.50
	Anna member	
15	shale, weathered brown	2.00
	Labette formation	
14	shale, black; Calamites	1.00
13	coal, weathered (Lexington) ...	0.25
12	clay, gray; fossil root impressions	1.00
11	covered interval	5.00
10	conglomerate; pea-sized particles of limestone and chert; cross-bedded; sandstone matrix; thin shaly bedding to thick (1 ft.) bedding; Antiquatonia, Composita	3.50
9	shale and sandstone, interbedded, calcareous, hard, micaceous	3.00
8	shale, dark-gray, arenaceous ...	2.50
7	shale, dark-gray; abundant Mesolobus mesolobus	1.00
6	shale, dark-gray, silty; Mesolobus mesolobus	1.25
5	shale, dark-gray, calcareous; grades into thin-bedded, dark-gray limestone; Mesolobus mesolobus	0.45
4	coal, blocky, weathered (Alvis).	0.15
3	underclay, gray; fossil root impressions	0.50
2	covered interval	3.00

		Thickness (Feet)
Fort Scott subgroup		
Higginsville formation		
1	limestone, medium to light-gray; wavy bedded; small crinoid columnals, abundant fusulinids; only top exposed	1.00
		25.10 Feet

STRATIGRAPHIC SECTION NO. 44

Active quarry east side of county road V at bend in road; NW¼ SW¼ sec. 4, T. 37 N., R. 33 W.; 4.5 miles south of Hume, Vernon County, Missouri.

		Thickness (Feet)
Marmaton group		
Appanoose subgroup		
Bandera formation		
12	shale or clay, weathered brown	3.00
Pawnee formation		
Coal City member		
11	limestone, medium-gray, finely crystalline; one bed; siliceous; weathers to chert	2.00
10	shale, light-gray	1.00
9	limestone, light-gray, medium-bedded; recrystallized brachiopods; apparent dip 5° W; reversal of dip common	10.00
Mine Creek member		
8	shale, gray	0.25
7	shale, black, platy; Lingula, Crurithyris planoconvexa, sparse Mesolobus mesolobus decipiens ...	0.15
6	limestone, dark-gray, finely crystalline, jointed	0.35
5	shale, dark-gray	1.00

		Thickness (Feet)
	Myrick Station member	
4	limestone, dark-gray; breaks with angular fracture; large fusulinids at top	3.50
	Anna member	
3	shale, black, fissile; few phosphatic concretions	0.85
	Labette formation	
2	limestone, dark-gray, very arenaceous; pieces of carbonaceous matter	1.50
1	shale	3.00
	Total thickness	26.60 Feet

STRATIGRAPHIC SECTION NO. 45

East highwall of abandoned quarry, east side of county road DD; SW¼ NW¼ sec. 24, T. 39 N., R. 33 W.; 0.5 miles south of Foster, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
4	limestone, light to medium-gray, finely crystalline; one bed; jointed; very siliceous; weathers to white chert	1.50
3	limestone, light-gray; thin nodular bedding; siliceous	5.00
2	limestone, light-gray, thin-bedded	6.00
1	shale, gray	0.25
	Total thickness	12.75 Feet

STRATIGRAPHIC SECTION NO. 46

Section extends from south cut bank of Miami Creek southward to spillway below large lake; NE¼ NW¼ sec. 10, T. 40 N., R. 32 W.; 3 miles northeast of Virginia, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
14	limestone, light-gray; wavy bedding	10.50
13	limestone, medium-gray, thick-bedded, blocky; chonetid brachiopods near bottom	1.50

Mine Creek member

12	shale, gray; almost a coquina of "Chonetes" granulifer with the larger specimens at the top	0.35
11	shale, gray; abundant "Chonetes" granulifer and Mesolobus mesolobus near top	1.00
10	limestone, medium-gray, thin-bedded, argillaceous, silty to arenaceous; chonetid brachiopods, Composita ovata, some fragments of thin-shelled, finely costate brachiopods	0.50
9	shale, gray, calcareous	2.00
8	covered interval	10.00

Myrick Station member

7	limestone, dark-gray; breaks with an angular fracture; apparent dip 3° S.	4.00

Anna member

6	shale, black, fissile	1.00

Labette formation

5	limestone, dark-gray to black, thin-bedded, argillaceous; few brachiopods	0.50

		Thickness (Feet)
4	shale, dark-gray to black, calcareous	1.50
3	limestone, dark-gray to black, thin-bedded, argillaceous; few crinoid columnals	0.85
2	shale, dark-gray to black, calcareous	2.00
1	coal; only top exposed above water line of creek	0.25
	Total thickness	35.95 Feet

STRATIGRAPHIC SECTION NO. 47

Artificial excavation and drill test core, U. S. Air Force Missile site; SW¼ SE¼ sec. 1, T. 40 N., R. 32 W.; 5 miles northeast of Virginia, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
33	limestone, light-gray, nodular to crinkly bedding	1.20

Lake Neosho member

32	shale, light-gray, mottled dark-gray	1.00
31	shale, medium-gray, calcareous, silty; Nuculana	2.90
30	shale, dark-gray, arenaceous, non-calcareous; carbonized roots? ...	0.20

Amoret member

29	limestone, light-gray, finely crystalline; top 1.5 ft. nodular; recrystallized brachiopods	7.70

Bandera formation

28	shale, greenish-gray	1.00

		Thickness (Feet)
27	coal, thin-bedded; during excavation of silo writer noticed that this coal varied in thickness from 1.4 ft. to a smut around silo which was 25 ft. in diameter	1.40
26	underclay, light-gray; limestone nodules in basal 0.5 ft. ..	2.30
	Pawnee formation	
	Coal City member	
25	limestone, light-gray, finely crystalline, asphalt stained; recrystallized brachiopods	12.50
	Mine Creek member	
24	limestone, dark-gray and shale interbedded; abundant chonetids .	2.00
23	shale, dark-gray; thin lenses of fossiliferous limestone near middle	4.00
22	shale, dark-gray, non-calcareous, micaceous	10.60
	Myrick Station member	
21	limestone, dark-gray; large fusulinids near top	4.90
	Anna member	
20	shale, black, non-calcareous; carbonized remains of ferns, Calamites	0.80
19	shale, black, fissile, non-calcareous	0.50
	Labette formation	
18	shale, black, calcareous, arenaceous; few fossils	2.00
17	shale, black; pyritized specimens of Mesolobus	1.00

		Thickness (Feet)
16	shale, black; carbonized fragments of Calamites and fern fronds; few stringers of vitrain; non-calcareous	0.50
15	shale, gray, slightly calcareous; carbonized fern fronds	0.40
14	shale, medium-gray, calcareous; interbedded near middle with light-gray sandstone lenses; fragments of brachiopods near bottom .	6.60
13	coal; fragments of Calamites	0.50
12	shale or underclay	0.60
11	shale, dark-gray, interbedded with light-gray sandstone lenses, micaceous, calcareous; pieces of carbonized wood	2.20
10	shale, dark-gray, fossiliferous...	5.90
9	limestone, dark-gray, thin-bedded, argillaceous; abundant chonetids	1.00
8	coal; interbedded vitrain and fusain, (Alvis)	0.20
7	underclay, dark-gray	0.90
6	clay, light-gray, calcareous	2.10
	Fort Scott subgroup	
	Higginsville formation	
5	limestone, light-gray; stylolites; fusulinids	17.60
	Little Osage formation	
4	shale, gray, slightly calcareous; fossil fragments	1.20
3	covered	0.50
2	shale, black, fissile, phosphatic concretions	2.20
1	shale, dark-gray, brachiopods	0.50
	Total thickness	98.90 Feet

STRATIGRAPHIC SECTION NO. 48

Banks and creek bed of small eastward flowing tributary to Mound Branch Creek; NW¼ SE¼ sec. 11, T. 40 N., R. 31 W.; 1.5 miles northeast of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
13	limestone, light-gray; wavy bedding; only base exposed	3.00
	Mine Creek member	
12	shale, weathered brown	0.15
11	limestone, medium-gray, arenaceous; jointed into blocks; one bed; crinoid columnals and chonetid brachiopods	1.15
10	shale, gray, abundant Chonetes at top	1.20
9	limestone, medium-gray, arenaceous, thin-bedded; Derbyia, Antiquatonia, Linoproductus, very abundant Mesolobus mesolobus	0.45
8	shale, dark-gray, calcareous	0.90
7	limestone, dark-gray, arenaceous; abundant fossil fragments .	0.15
6	shale, medium-gray, top calcareous; iron-stained along joints ..	8.00
	Myrick Station member	
5	limestone, dark-gray; angular fracture; apparent dip 2°W.	3.50
	Anna member	
4	shale, black, soft	0.15
3	shale, black, fissile	1.10
	Labette formation	
2	limestone, black, thin-bedded, argillaceous	0.25
1	shale, black, calcareous	0.50
	Total thickness	20.50 Feet

STRATIGRAPHIC SECTION NO. 49

Cut banks and bed of southward flowing tributary to Willow Branch Creek; E½ SW¼ sec. 8, T. 40 N., R. 30 W.; 3.5 miles north-

east of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Pawnee formation
Coal City member

		Thickness (Feet)
25	limestone, light-gray; wavy bedded; only base exposed	1.00

Mine Creek member

24	shale, light-gray; "Chonetes", Mesolobus, crinoid columnals	0.20
23	limestone, gray; one bed; jointed; "Chonetes", Mesolobus, large crinoid columnals	0.85
22	shale, weathered brown	0.15
21	limestone, medium-gray	0.15
20	shale, weathered brown; abundant "Chonetes"	1.35
19	limestone, medium-gray, arenaceous, finely crystalline; one bed; jointed; blocky; Mesolobus, "Chonetes" and large productids..	1.15
18	shale, dark-gray; weathered brown at top	1.75
17	limestone, dark-gray, hard; many small fossil fragments	0.35
16	shale, dark-gray, slightly calcareous	3.00
15	shale, dark-gray	5.00

Myrick Station member

14	limestone, dark-gray; breaks with angular fracture	3.00

Anna member

13	shale, black, fissile	1.15

Labette formation

12	shale, black, calcareous	0.50
11	covered	3.00
10	sandstone, weathered brown, fine-grained, thin-bedded, hard, jointed NE-SW and NW-SE; Toanurus caudagalli	4.00

		Thickness (Feet)
9	sandstone and shale inter-bedded; weathered brown	5.00
8	shale, dark-gray	4.00
7	shale, dark-gray, calcareous	1.50
6	shale, black, grades into thin-bedded limestone, Composita ovata, Antiquatonia portlockiana	0.85
5	limestone, dark-gray, hard, discontinuous; fossil fragments .	0.10
4	shale, black	0.15
3	coal, bright (Alvis)	0.15
2	underclay, gray; fossil root impressions	2.00

Fort Scott subgroup
Higginsville formation

1	limestone, light-gray, wavy bedded; abundant small fusulinids at top; bottom not exposed	5.00
	Total thickness	45.35 Feet

STRATIGRAPHIC SECTION NO. 50

Section extends from bed of small northward flowing tributary of Elk Fork Creek just below barn southward to school house at top of hill at bend in Highway 18; E½ NE¼ sec. 9, T. 41 N., R. 30 W.; 5 miles west of Ballard, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
14	limestone, light-gray; thick wavy bedding; recrystallized brachiopods; only base exposed	3.00

Lake Neosho member

13	shale, weathered brown; large spheroidal phosphatic concretions 0.15 ft. diameter	1.50

		Thickness (Feet)
	Amoret member	
12	limestone, light-gray, nodular; clay matrix	5.00
	Bandera formation	
11	shale, gray	4.00
10	coal, weathered (Mulberry)	0.50
9	underclay and shale, light-gray..	4.00
	Pawnee formation	
	Coal City member	
8	limestone, light-gray; thickness of bedding varies from 0.1 to 0.5 ft.; wavy bedding; well exposed in quarry at SE¼ NW¼ sec. 14, T. 41 N., R. 30 W., dip 10° N.45E.	6.00
	Mine Creek member	
7	limestone, medium-gray, jointed, blocky; abundant Mesolobus mesolobus, Chonetina, and "Chonetes"; forms one resistant, blocky bed	1.15
6	shale, gray; top part interbedded with thin-bedded limestone; very abundant Chonetes, Mesolobus mesolobus, few Antiquatonia, large crinoid columnals, bryozoans	1.50
5	limestone, medium-gray, arenaceous, jointed, blocky; Derbyia, crinoid columnals; grades into calcareous sandstone in places ..	0.45
4	shale, medium-gray, calcareous ..	1.25
3	limestone, dark-gray; fossil fragments; arenaceous, hard, discontinuous	0.15
2	shale, dark-gray; top part calcareous	11.50
	Myrick Station member	

		Thickness (Feet)
1	limestone, dark-gray; breaks with angular fracture; large fusulinids, some 7 mm. long; only top exposed	0.50
	Total thickness	40.50 Feet

STRATIGRAPHIC SECTION NO. 51

Railroad cut on Kansas City and Southern Railroad, 100 feet north of abandoned bridge over tracks; NW¼ NW¼ sec. 20, T. 38 N., R. 33 W.; 1 mile south of Hume, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
5	limestone, light-gray, wavy bedded	2.50
4	limestone, light-gray; algae and recrystallized brachiopods	1.25
3	shale, black, soft	0.65
2	limestone, dark-gray, jointed; large crinoid columnals, Composita	1.45

Lake Neosho member

1	shale, black; sparse phosphatic concretions	1.00
	Total thickness	6.85 Feet

STRATIGRAPHIC SECTION NO. 52

South highwall of abandoned coal strip mine, 500 feet north of east-west dirt road; SW¼ SW¼ sec. 16, T. 38 N., R. 33 W.; 1 mile southeast of Hume, Bates County, Missouri.

Marmaton and Pleasanton groups		Thickness (Feet)
14	sandstone, weathered reddish-brown, structureless to cross-bedded, fine-grained; unconformable with underlying unit	3.00

		Thickness (Feet)
Marmaton group		
Appanoose subgroup		
Altamont formation		
Lake Neosho member		
13	shale, dark-gray, weathered greenish-gray; few phosphatic concretions	1.00
Amoret member		
12	limestone, gray, jointed, blocky; forms one bed; some recrystallized brachiopods	0.15
11	shale, dark-gray, weathered greenish-gray; calcareous	0.25
10	limestone, gray, nodular; one bed	1.35
Bandera formation		
9	shale, gray; some small limestone nodules	3.00
8	sandstone, dark-brown, asphaltic; some thin shale beds	15.00
7	shale, gray; some thin asphaltic sandstone beds	6.00
6	sandstone, black, asphaltic, hard, micaceous; interbedded with thin shale beds but sandstone predominates	3.00
5	shale, gray; some thin sandstone beds	1.50
4	sandstone, fine-to medium-grained, micaceous, asphaltic	1.10
3	shale, gray	0.25
2	conglomerate; composed of rounded particles of shale, limestone, sandstone and coal; poorly sorted; particles vary from sand-sized to pebbles 0.1 ft. in diameter; discontinuous	1.35
1	shale, gray; interbedded with sandstone	2.00
	Total thickness	38.95 Feet

The sandstone and conglomerate are discontinuous and are not present a few hundred feet to the north and south. These units seem to have accumulated in a small syncline of limited areal extent.

STRATIGRAPHIC SECTION NO. 53

East highwall of abandoned coal strip mine; SW¼ NW¼ sec. 4, T. 38 N., R. 33 W.; 1 mile northeast of Hume, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
9	limestone, light-gray	1.00
	Lake Neosho member	
8	shale, dark-gray to black	1.15
	Amoret member	
7	limestone, light-gray, nodular; clay matrix	0.75
	Bandera formation	
6	sandstone; thin shaly bedding to bedding 0.5 ft. thick; fine-grained	5.00
5	sandstone and shales, interbedded .	5.00
4	shale, gray, calcareous; many flattened septarian concretions 0.5 ft. in diameter which are composed of claystone with coarsely crystalline limestone filling in the septaria	38.00
3	coal (Mulberry)	2.75
2	underclay; carbonized roots	3.25
	Pawnee formation	
	Coal City member	
1	limestone, light-gray; thin crinkly bedding; very siliceous; weathers to white chert; apparent dip 7° NW	4.00
	Total thickness	60.90 Feet

STRATIGRAPHIC SECTION NO. 54

South wall of abandoned coal strip mine, 0.25 miles east of north-south dirt road; SW¼ S½ sec. 4, T. 39 N., R. 33 W.; 1.5 miles northeast of Worland, Bates County, Missouri.

Marmaton - Pleasanton groups	Thickness (Feet)
7 sandstone; weathered reddish-brown; fine-to medium-grained; cross-bedded, fills channel eroded through unit 6	2.50
Marmaton group Appanoose subgroup Altamont formation Worland member	
6 limestone, light-gray; thick wavy bedding	3.50
Lake Neosho member	
5 shale, dark-gray to black at base, light-gray at top; large spheroidal phosphatic concretions 0.1 ft. in diameter	1.50
Amoret member	
4 shale, medium-gray; few limestone nodules; calcareous throughout	2.00
Bandera formation	
3 sandstone, thin-bedded, gray, micaceous, non-calcareous	5.00
2 shale, dark-gray, non-calcareous ..	23.00
1 coal, bright, blocky	2.60
Total thickness	40.10 Feet

STRATIGRAPHIC SECTION NO. 55

East highwall of abandoned coal strip mine, 200 feet northwest of right angle bend to south in dirt road; NE¼ NE¼ sec. 5, T. 39 N., R. 33 W.; 2 miles northeast of Worland, Bates County, Missouri.

Marmaton group Appanoose subgroup Altamont formation Worland member	Thickness (Feet)
7 limestone, light-gray; wavy bedded; only base exposed	1.00

		Thickness (Feet)
	Lake Neosho member	
6	shale, dark-gray to black; spheroidal phosphatic concretions to 0.1 ft. diameter	2.00
	Amoret member	
5	shale, gray; numerous limestone nodules .05 ft. in diameter	3.00
4	limestone, medium-gray, hard; appears silty; one blocky nodular bed with nodules elevated on top of bed to form humpy surface; few fossil fragments; varies from 0.8 to 1 foot in thickness	1.00
	Bandera formation	
3	clay, gray; some nodules of limestone 0.25 ft. in diameter	2.00
2	shale, gray, calcareous; thickness almost doubles 300 feet to north; contains lenticular limestone bed near bottom	8.00
1	coal; only top exposed	1.00
	Total thickness	18.00 Feet

STRATIGRAPHIC SECTION NO. 56

Road cut on east-west dirt road at junction with dirt road to south; SW¼ sec. 33, T. 40 N., R. 33 W.; 2 miles south of Amoret, Bates County, Missouri, (modified after Cline and Greene, 1950, p. 67). This exposure is the type section of the Amoret member.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
7	limestone, gray, crinkly bedded; weathers brown; lower part contains crinoid columnals, brachiopod fragments and fusulinids	3.65

		Thickness (Feet)
	Lake Neosho member	
6	shale, gray; large spheroidal phosphatic concretions 0.1 ft. in diameter	2.00
	Amoret member	
5	limestone, gray, mottled; brachiopod and crinoid fragments, ostracods, Osagia	0.75
4	shale, greenish-gray; small limestone nodules	0.35
3	limestone, gray, crinkly-bedded to nodular	2.20
2	limestone, gray, argillaceous, nodular bedded, Derbyia crassa, Mesolobus, crinoid columnals, few Composita ovata, Punctospirifer kentuckensis and Antiquatonia portlockiana	5.00
	Bandera formation	
1	shale; weathered brown	4.00
	Total thickness	17.90 Feet

STRATIGRAPHIC SECTION NO. 57

East cut bank of Mulberry Creek, 500 feet south of east-west dirt road; NE¼ NW¼ sec. 33, T. 41 N., R. 33 W.; 1.5 miles southeast of Amsterdam, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland member

		Thickness (Feet)
10	limestone, medium-gray; one bed; recrystallized brachiopod fragments	1.50
	Lake Neosho member	
9	shale, black; large spheroidal to irregular-shaped phosphatic concretions	1.50

		Thickness (Feet)
8	shale, gray	2.00
	Amoret member	
7	limestone, light-gray, nodular ...	2.50
	Bandera formation	
6	shale, medium-gray; small irregular-shaped limestone nodules becoming more abundant near top	6.00
5	shale, medium-gray; limestone concretions 0.5 ft. in diameter	2.00
4	coal, iron-stained (Mulberry)	2.65
3	underclay, dark to light-gray, iron-and sulphur-stained; fossil root impressions	3.00
2	shale; mostly covered	2.50
	Pawnee formation Coal City member	
1	limestone, light-gray, thick-bedded; only top exposed in creek bed	0.50
	Total thickness	24.15

STRATIGRAPHIC SECTION NO. 58

Artificial excavation and drill core test, U. S. Air Force Missile site; NW¼ SW¼ sec. 1, T. 40 N., R. 33 W.; 4.5 miles southeast of Amsterdam, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Bandera formation

		Thickness (Feet)
26	shale, gray; contains numerous limestone nodules up to 0.2 ft. in diameter	7.50
25	shale, dark-gray to black; selenite crystals	2.00
	Mulberry coal (units 22 and 24)	
24	coal	1.80

		Thickness (Feet)
23	shale lens, black	0.10
22	coal	0.80
21	underclay, gray	3.50
20	clay, light-gray	2.00
	Pawnee formation	
	Coal City member	
19	limestone, light-gray; wavy bedded; few shale lenses; brachiopods; asphalt-stained	11.20
	Mine Creek member	
18	shale, gray; thin coquina of chonetids near top; 2 zones of thin fossiliferous limestone near middle; productids at base	3.00
17	shale, greenish-gray; pea-sized limestone nodules	0.30
16	shale, medium-gray, non-calcareous.	11.20
15	shale, medium-gray, crinoid columnals; brachiopods	0.20
	Myrick Station member	
14	limestone, dark-gray, finely crystalline; fusulinids; asphalt-stained .	5.10
	Anna member	
13	shale, black, fissile, non-calcareous	1.50
	Labette formation	
12	shale, black; thin-shelled brachiopods	0.10
11	shale, black, micaceous	1.10
10	covered	0.60
9	shale, black; middle part calcareous and contains a few fossils.	1.30
8	coal, bright; sulfur; pyrite (Lexington)	0.70
7	shale, medium-gray; fern fronds; grades into underlying unit	0.30
6	sandstone, medium-gray, slightly calcareous; micaceous; few shale lenses; pieces of carbonized wood; plant fossils	7.50

		Thickness (Feet)
5	shale, dark-gray, calcareous; 0.1 ft. zone of thin-shelled brachiopods near top; basal few inches contains productids	6.00
4	shale, gray, fossiliferous; thin lenses of coal near base (horizon of Alvis coal)	0.30
3	underclay, greenish-gray, slickensided; carbonized roots	0.60
2	clay, greenish-gray; small nodules of limestone	9.10

Fort Scott subgroup
Higginsville formation

1	limestone, light-gray; irregular bedding; shale lenses along bedding planes; brachiopods; asphalt-stained	17.00
	Total thickness	94.80 Feet

STRATIGRAPHIC SECTION NO. 59

Cut banks of small tributary to Mound Branch Creek; NW¼ NW¼ sec. 11, T. 40 N., R. 31 W.; 2 miles north of Butler, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Amoret member

		Thickness (Feet)
9	limestone, nodular; Composita, Syringopora; only base exposed ...	1.50

Bandera formation

8	shale, arenaceous; some isolated masses of sandstone	12.50
7	covered interval	7.50
6	coal, weathered (Mulberry)	0.50
5	shale, dark-gray; numerous thin lenses of coal, Calamites and other fossilized plant debris; many calcareous ironstone concretions, 0.1 ft. in diameter; in places the	

		Thickness (Feet)
	unit is almost completely composed of Calamites	9.00
4	clay, gray; breaks out in angular chips; fossil root impressions; concretions of siderite approximately 0.1 ft. in diameter	3.00
3	conglomerate; pebble-sized particles of limestone and Chaetetes; brachiopod fragments ..	0.50
2	shale, gray, structureless	3.00
	Pawnee formation	
	Coal City member	
1	limestone, light-gray, siliceous; weathers to chert; humpy surface as a result of elevated colonies of Chaetetes	3.00
	Total thickness	40.50 Feet

STRATIGRAPHIC SECTION NO. 60

Section exposed in cut bank along East Mound Branch Creek from county road D, southwestward for a distance of 0.5 mile, NE¼ sec. 31, T. 41 N., R. 30 W.; 4 miles east of Passaic, Bates County, Missouri.

		Thickness (Feet)
	Marmaton group	
	Appanoose subgroup	
	Altamont formation	
	Amoret member	
8	limestone, light-gray, nodular; a few brachiopod fragments	1.50
	Bandera formation	
7	shale; poorly exposed	7.00
6	shale, gray	3.00
5	coal, bright, blocky (Mulberry) ..	1.20
4	shale, black; thin lenses of coal, and plant debris composed almost completely of Calamites	1.00

		Thickness (Feet)
3	underclay, dark-gray; carbonaceous matter; several thin beds of siderite concretions near bottom; concretions are about 0.25 ft. in diameter	3.00
2	shale, medium-gray, arenaceous, micaceous; Calamites and specks of carbon; several beds of siderite concretions; the concretions are about 0.25 ft. in diameter	8.00

Pawnee formation
Coal City member

1	limestone, light-gray; surface humpy as a result of protruded colonies of Chaetetes	0.50
	Total thickness	25.20 Feet

STRATIGRAPHIC SECTION NO. 61

South cut bank of southwest flowing tributary to Fishing Branch Creek; SE¼ NW¼ sec. 13, T. 41 N., R. 30 W.; 2.75 miles southwest of Ballard, Bates County, Missouri.

Marmaton group
Appanoose subgroup
Altamont formation
Worland and Lake Neosho member

		Thickness (Feet)
12	limestone and phosphatic concretions; exposed as float	--

Amoret member

11	limestone, gray, nodular	1.50

Bandera formation

10	shale, gray; abundant small limestone nodules	3.50
9	shale, gray; Composita ovata, productid brachiopods	1.00
8	limestone, medium-gray; blocky to nodular bedding	0.45

		Thickness (Feet)
7	shale, medium-gray	0.45
6	coal, soft (Mulberry)	0.10
5	shale, black; abundant fossil plant debris	0.35
4	underclay, dark-gray	3.00
3	shale, gray	2.00
2	covered interval	1.00

Pawnee formation
Coal City member

1	limestone, light-gray; only top exposed; apparent dip 5°SW; reversal of dip a few hundred feet downstream	1.00
	Total thickness	14.35 Feet

VITA

Richard Joseph Gentile was born in south St. Louis, Missouri June 25, 1929. At the age of seven the family moved to St. Louis County where he attended the Barretts Public Grade School and the Valley Park High School. He graduated from the latter institution in May, 1947.

From 1947 to 1951 Mr. Gentile worked as a laboratory technician for a St. Louis paint manufacturing company. He attended the Washington University Night College from 1947 to 1949.

In February 1951 he was drafted into the U. S. Army and served in the Korean War as a heavy weapons infantryman. Shortly after being honorably discharged in November, 1952, he enrolled at the University of Missouri at Columbia and majored in geology, receiving the B. A. degree in June, 1956 and the M. A. degree in June, 1958. During the summer of 1957 he worked as an assistant instructor at the University of Missouri Summer Field Camp at Lander, Wyoming.

In 1958 Mr. Gentile began employment as a field geologist for the Missouri Geological Survey and Water Resources at Rolla, Missouri.

He began work for the doctorate degree in geology at the University of Missouri at Rolla in September, 1960.