The Stratigraphic Succession in Missouri

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Rolla, Missouri
May 4, 1961

Honorable John M. Dalton
Governor of Missouri
Jefferson City, Missouri

Dear Governor Dalton:

I have the honor and pleasure to transmit herewith THE STRATIGRAPHIC SUCCESSION IN MISSOURI which was compiled by Wallace B. Howe and edited by John W. Koenig.

Because of the numerous reports published in the Missouri Geological Survey since its establishment in 1853 and the changes in rock unit names with time, it is difficult for one unfamiliar with Missouri geology to acquire a concept of the characteristics, distribution, and relative positions of the nearly 400 formally named rock units in the state.

This report is intended to serve as both an expositional and graphic guide to the stratigraphic succession in the state as recognized by the Missouri Geological Survey but does not attempt to debate some of the long-standing stratigraphic controversies. For simplicity, direct bibliographic references are minimized, and a selected bibliography is included at the end of the text.

I wish to express special thanks and recognition to Wallace B. Howe and John W. Koenig of the Survey staff who respectively had the trying and sometimes thankless tasks of coordinating the preparation of and editing the report.

Respectfully submitted,

THOMAS R. BEVERIDGE
State Geologist

The Stratigraphic Succession in Missouri

Preparation coordinated by
WALLACE B. HOWE

Edited by
JOHN W. KOENIG

ABSTRACT

This report summarizes information pertaining to the stratigraphic succession in Missouri. It shows that surficially, the most regionally prominent Systems in the state are the Cambrian, Ordovician, Mississippian, and Pennsylvanian, that the Precambrian rocks and the Silurian, Devonian, Cretaceous, and Tertiary Systems are less extensively exposed, that rocks and deposits of the Quaternary System surface much of northern Missouri, and that several formations of undetermined Devonian or Mississippian age are present in various parts of the state. Classification and nomenclature of these Systems in the past has been based on informally adopted stratigraphic principles which are no longer adequate for the solution of several of Missouri's stratigraphic problems. Because of this the principles have been re-examined and redefined in terms of contemporary requirements. These redefined principles as well as statements regarding stratigraphic nomenclature are, herein, set forth as an expression of the Missouri Geological Survey's stratigraphic policy.

INTRODUCTION

This report is designed to meet the need of a stratigraphic reference. It describes the important physical characteristics and stratigraphic relations of the rock units present within the State of Missouri. The classification, nomenclature, distribution, lithology, and thickness of the rock units are discussed briefly. This information has been synthesized from scattered sources in the literature and from unpublished graduate theses which are not readily available. Additional data have been derived from field notes and unpublished maps and reports on file at the Missouri Geological Survey.

The classification, nomenclature, and stratigraphic concepts of this report reflect views currently held by the staff of the Missouri Geological Survey and Water Resources. In a few instances, new names are introduced, and the classification of some units has been changed. In some parts of the column, classification is regarded as tentative because of insufficient data.

Acknowledgments.—Most of this report has been prepared by Survey staff members, but some of the sections have been written by geologists who are not now but have been associated with the Survey.

These include the following: Garrett A Muilenburg, Alfred C. Spreng, Maurice G. Mehl, John G. Grohskopf, Kenneth G. Larsen, and Earl McCracken.

Garrett A Muilenburg, who was Assistant State Geologist before his retirement in 1958, assisted Wallace B. Howe in the early planning of this report and helped prepare the section on the Silurian System. Alfred C. Spreng, Associate Professor of Geology, University of Missouri School of Mines and Metallurgy, prepared the section on the Mississippian System. Maurice G. Mehl, Professor Emeritus, University of Missouri, discussed many of the problems relating to the Devonian-Mississippian boundary with members of the Survey staff and greatly facilitated the preparation of this report by making preliminary drafts of certain of his own writings available in advance of their publication. John G. Groshkopf, a former member of the Survey staff who is now with the Topographic Division of the U. S. Geological Survey, prepared much of the section on the Cretaceous System. Kenneth G. Larsen, also a former staff member who is now employed by the Bear Creek Mining Company, prepared most of the section on the Silurian System. Earl McCracken, for many years a member of the Survey staff, made several important contributions to the study of lower Paleozoic stratigraphy of Missouri prior to his untimely death in 1959. Much of his work is incorporated in the body of this report.

Specific acknowledgment is due the following persons who have critically reviewed various sections of the report: Kenneth G. Brill, Jr., St. Louis University; O. R. Grawe, University of Missouri School of Mines and Metallurgy; Frank C. Greene, Kansas City, Missouri; Norman S. Hinchey, Washington University; C. D. Holmes, University of Missouri; J. M. Jewett, State Geological Survey of Kansas; Wayne A. Pryor, Gulf Research and Development Company, Pittsburgh, Pennsylvania; Frank G. Snyder, St. Joseph Lead Company, Bonne Terre, Missouri; David H. Swann, Illinois State Geological Survey; A. G. Unklesbay, University of Missouri; Charles F. Upshaw, Pan-American Petroleum Corporation, Tulsa, Oklahoma; and H. B. Willman, Illinois State Geological Survey.

Precambrian Rocks

by

William C. Hayes

The igneous rocks that are exposed in the St. Francois Mountains of southeastern Missouri have been regarded since 1855 as Precambrian in age. Recent isotope dating of some of the younger granitic rocks which occur as intrusives indicates that their age is in the range of 1.40 to 1.45 billion years.

Most of the wells that have penetrated to the Precambrian rocks outside of the St. Francois Mountain area have encountered leucogranitic types. Subsurface data indicate that a belt of metasediments and gneissic granites extends from Vernon, Bates, and Cass Counties in western Missouri to Pike and Ralls Counties in eastern Missouri. Intermediate rock types such as diorite and quartz monzonite are present in Dent County. Basaltic and gabbroic rocks are present in scattered localities throughout the state. The metasediments, gneissic granites, leucogranites, and intermediate and basic rock types are judged from present data to represent the floor complex upon which the acidic flows of the St. Francois Mountain area were extruded.

The areal distribution of Precambrian rocks both in the subsurface and on the surface is shown in Figure 1. Control in the outcrop area is well established by detailed field mapping, and the subsurface information is based on all available well data.

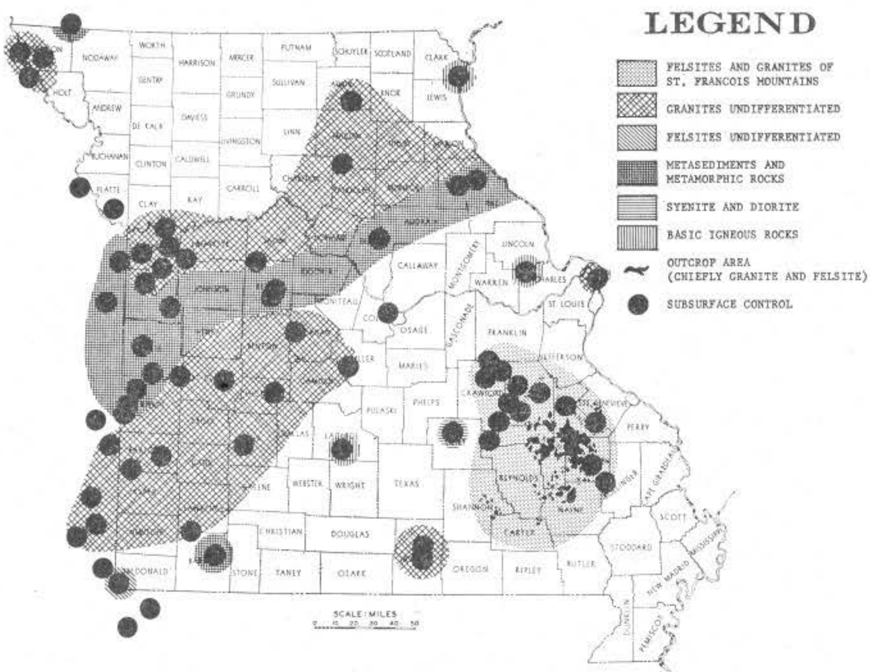

Fig. 1. Map of the Precambrian rock types in Missouri.

Three main rock types are present in the St. Francois Mountain area: extrusive felsites, intrusive granites, and intrusive basic masses. The felsites are the oldest of the exposed Precambrian rocks. The majority of them are extrusive flows of rhyolite and trachyte. Andesites are present in some places. The extrusives generally show well-developed flow structures and are commonly darkly colored and porphyritic. The felsitic flows have been divided stratigraphically into two units which are separated in many places by a water-laid tuff. The older unit, below the tuff, is characterized by a high potash-soda ratio. Several felsite units are intrusive and are probably genetically related to the later granitic intrusions.

The main mass of exposed granite is believed to have intruded, in sill-like form, the felsitic flows. Two phases of intrusion have been distinguished, and differentiates of each phase have been recognized. Granites of the Precambrian are leucogranites and are typically red to pink, medium- to coarse-grained, and characteristically low in iron and dark mineral content. They are massive and show no indication of either gneissic or relict sedimentary structures.

The basic intrusions consist predominantly of basalts, diabase porphyries, and gabbros that occur as dikes or small irregularly shaped stocks in the felsites and granites. Basic dikes are present in both the felsites and granites which are overlain unconformably by the oldest Paleozoic rocks in the state.

A small exposure of Precambrian pegmatite is exposed in extreme south-central Camden County near Decaturville. The mass has been faulted into its present position, and the enclosing rocks are slightly mineralized.

Mineralization during Precambrian time formed high-temperature replacement and fissure-filling deposits of hematite and magnetite in the felsites. Commercial amounts of these deposits occur near the surface in Iron and St. Francois Counties, and at depths of from 1,400 to 3,000 feet in Washington County at the Pea Ridge mine locality southeast of Sullivan. In places, the tuff has been replaced by copper-, iron-, and manganese-bearing minerals. None of these deposits is of commercial grade. High-temperature manganese-bearing veins occur in the felsites of the Eminence area, and in Madison County there are high-temperature tungsten-bearing deposits. Neither of these is of commercial grade.

Before the deposition of the state's earliest upper Cambrian sediments, Precambrian topography within the state was very rugged, consisting of many knobs, hills, and ridges. Local relief of as much as 1,500 feet had been developed in numerous places. This rugged topography is still evident in the area of the St. Francois Mountains. Precambrian rocks are exposed at the highest point in the state which is at Taum Sauk Mountain in Iron County. The summit of the mountain is 1,772 feet above sea level. There is more than 6,000 feet of relief between the top of Taum Sauk Mountain and the surface of the Precambrian rocks in the extreme southeastern corner of Missouri where they are buried by a thick sedimentary cover. Present-day drainage reflects the drainage pattern which had been formerly established on the ancient Precambrian erosion surface. Many small Precambrian knobs and hills surround the main outcrop area. The Precambrian rocks which are exposed in extreme south-central Camden County near Decaturville have been faulted into their present position, and the Precambrian basement is at a relatively high altitude in this area.

PALEOZOIC ERA

Bedrock through most of Missouri is Paleozoic in age. Of all the Systems represented, the Cambrian, Ordovician, Mississippian, and Pennsylvanian are the most prominent from the standpoint of total thickness and areal distribution (Fig. 2). Rocks of the Cambrian and Ordovician Systems are present over most of the southern half of the state. Mississippian rocks are extensively exposed in the northeastern and southwestern parts of the state, and Pennsylvanian rocks make up the balance of the state's bedrock. Relatively limited exposures of Silurian and Devonian rocks are present in eastern Missouri.

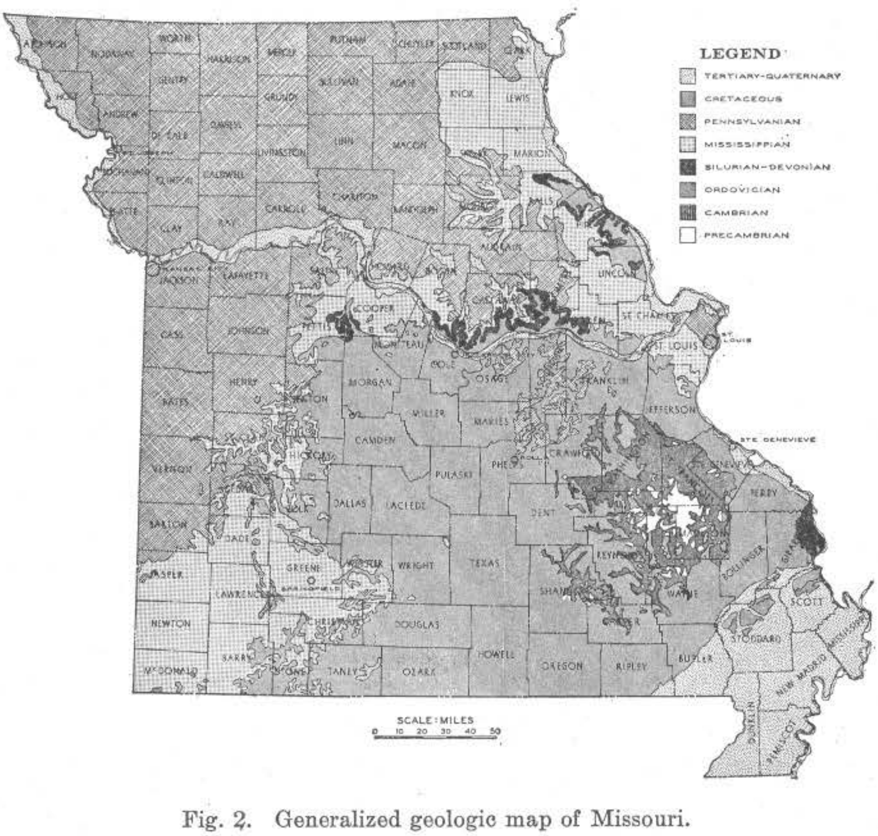

Fig. 2. Generalized geologic map of Missouri.

The aggregate thickness of the Paleozoic rocks within the state is approximately 10,000 feet with less than half of this thickness being present in any one locality. The thickest and most systemically complete section of rocks in the state is present within the confines of the Forest City basin in northwestern Missouri. Here the section is approximately 3,700 feet thick and is composed of rocks representing all the Paleozoic Systems up to and including the Pennsylvanian. In the southeastern part of the state, in the lowland area, the rock succession is thicker but most of the Paleozoic Systems are missing. As much as 4,700 feet of post-Precambrian rock has been penetrated by one of the deepest wells in the area, but only the deepest part of this well is in Paleozoic rock of Cambrian age. The balance of the succession is composed of Cretaceous and Teritary rocks.

The structural attitude of the Paleozoic rocks throughout the state is controlled principally by the shape of the Ozark uplift, the apex of which forms the core of the St. Francois Mountains. Paleozoic strata dip away in all directions from the periphery of the St. Francois Mountains into surrounding structural basins: the Forest City basin to the northwest, the Illinois basin to the northeast, the Anadarko basin to the southwest, the Arkoma basin to the south, and the depression of the Mississippi Embayment to the southeast. Some of the more prominent secondary structural features which locally affect the attitude of Paleozoic strata within the state are the Lincoln fold in northeastern Missouri, the Mineola arch in central Missouri, the Cap au Gres fault north of St. Louis, the Little Saline fault complex in Ste. Genevieve County, and the Chesapeake fault zone southwest of Springfield.

Cambrian System

by

William C. Hayes and Robert D. Knight

Upper Cambrian Series

All the Cambrian strata in Missouri are regarded as Late Cambrian in age. The unconformity at the base of the Series is particularly striking in the St. Francois Mountain area where prominent ridges and knobs of Precambrian granite and felsite are in contact with Cambrian strata. The lower part of the Series consists of a quartzose sandstone, the upper part of dolomite and shale. Exposures of the sandstone are generally limited to the St. Francois Mountain area where they onlap the flanks of Precambrian knobs. Outcrops of successively higher units occur in peripheral, annular patterns around the area. Away from the uplift, Upper Cambrian formations dip beneath younger Paleozoic strata and are present in the subsurface throughout the state except in those areas where they have overlapped Precambrian topographic highs and have been subsequently removed by erosion.

The combined thicknesses of the strata which form the Upper Cambrian Series in Missouri total approximately 2,000 feet. The Series contains six formations, two of which form a group. In order of decreasing age, they are as follows: the Lamotte, Bonneterre, Davis, Derby-Doerun, Potosi, and Eminence formations; the Davis and Derby-Doerun together form the Elvins group.

Lamotte formation.—The Lamotte is predominantly a quartzose sandstone that in many places grades laterally into arkose and conglomerate. Pebbles and boulders of felsite are the chief constituents of the conglomerates which immediately overlie Precambrian rocks in many places. The color of the sandstone ranges from light gray or white to yellow, brown, or red. Red to purple silty shale is locally present, and lenses of arenaceous dolomite are scattered through the upper part of the formation.

The Lamotte attains its maximum thickness of about 500 feet in the depressions between Precambrian ridges and knobs. Where the formation onlaps these knobs and hills, it pinches out and is overlapped by younger formations.

Exposures of Lamotte are in general restricted to the St. Francois Mountain area in Madison, Ste. Genevieve, Iron, and southeastern Washington Counties. The Lamotte appears to be absent in west-central Madison County. The formation is persistent in the subsurface throughout Missouri except on Precambrian highs where younger formations overlap it. Regional variations in thickness of the Lamotte within the state are indicated by the following data: In Howell County the formation is approximately 200 feet thick, in Laclede County it is 300 feet thick, in Barry County, 125 feet, and in Ralls County, 340 feet. In Nemaha County, Nebraska, across the Missouri River from Atchison County in northwestern Missouri, it is 65 feet thick.

The Lamotte is quarried for dimension stone in the St. Francois Mountain area.

Bonneterre formation.—The Bonneterre is typically a light gray, medium- to fine-grained, medium-bedded dolomite but consists of relatively pure limestone in some areas. In places, it is very coarse grained, and it contains small cavities which are lined with dolomite rhombs. Locally, parts of the Bonneterre are glauconitic and shaly with the shale occurring in beds less than 2 inches thick. In some areas, the formation contains beds of relatively pure, thin-bedded, pink limestone which is referred to as "Taum Sauk marble".

In the Fredericktown area, the formation has been divided into six units on the basis of insoluble residues. In the Lead Belt, eight principal units are recognized, although all are not identifiable at any one locality. Because of the importance of the formation as a host rock to the ore deposits of the Lead Belt, the Bonneterre has been studied in more detail there than elsewhere. Structures that are important as ore controls are: clastic carbonate bars or ridges, algal structures, and masses of submarine breccia. Major lead production to date has been from the lower half of the formation. Wherever the Bonneterre has been deposited near or directly on the Precambrian surface, it contains pebbles and cobbles of igneous rock much of which is felsite. The host rock at the St. Joseph Lead Company's Hayden Creek mine is a granite conglomerate cemented by dolomite. The ore is present in the dolomite and fills fractures in the granite boulders.

The relationship of the Bonneterre and the underlying Lamotte is one of conformity. The lower part of the Bonneterre consists of alternating beds of dolomite and arenaceous dolomite with the amount

LEGEND

- LIMESTONE
- SHALEY LIMESTONE
- SANDY LIMESTONE
- LIMESTONE CONTAINING NODULES AND BEDS OF CHERT
- CROSSBEDDED LIMESTONE
- DOLOMITIC LIMESTONE
- OOLITIC LIMESTONE
- NODULAR LIMESTONE
- LIMESTONE CONTAINING CAVITIES LINED WITH QUARTZ DRUSE
- DOLOMITE
- SHALE
- SILTSTONE
- SANDY SHALE
- CALCAREOUS SHALE
- SHALE CONTAINING PHOSPHATIC CONCRETIONS
- CLAY
- SANDSTONE
- CALCAREOUS SANDSTONE
- CROSS BEDDED SANDSTONE
- BEDDED SANDSTONE
- SAND AND GRAVEL
- CONGLOMERATE
- EDGEWISE CONGLOMERATE
- LIMESTONE BRECCIA
- LIMESTONE CONCRETIONS
- CLAY IRONSTONE CONCRETIONS
- SEPTARIAN CONCRETIONS
- CRYPTOZOANS
- GLAUCONITE
- COAL
- FELSITE EXTRUSIVES
- GRANITE INTRUSIVES
- BASIC INTRUSIVES

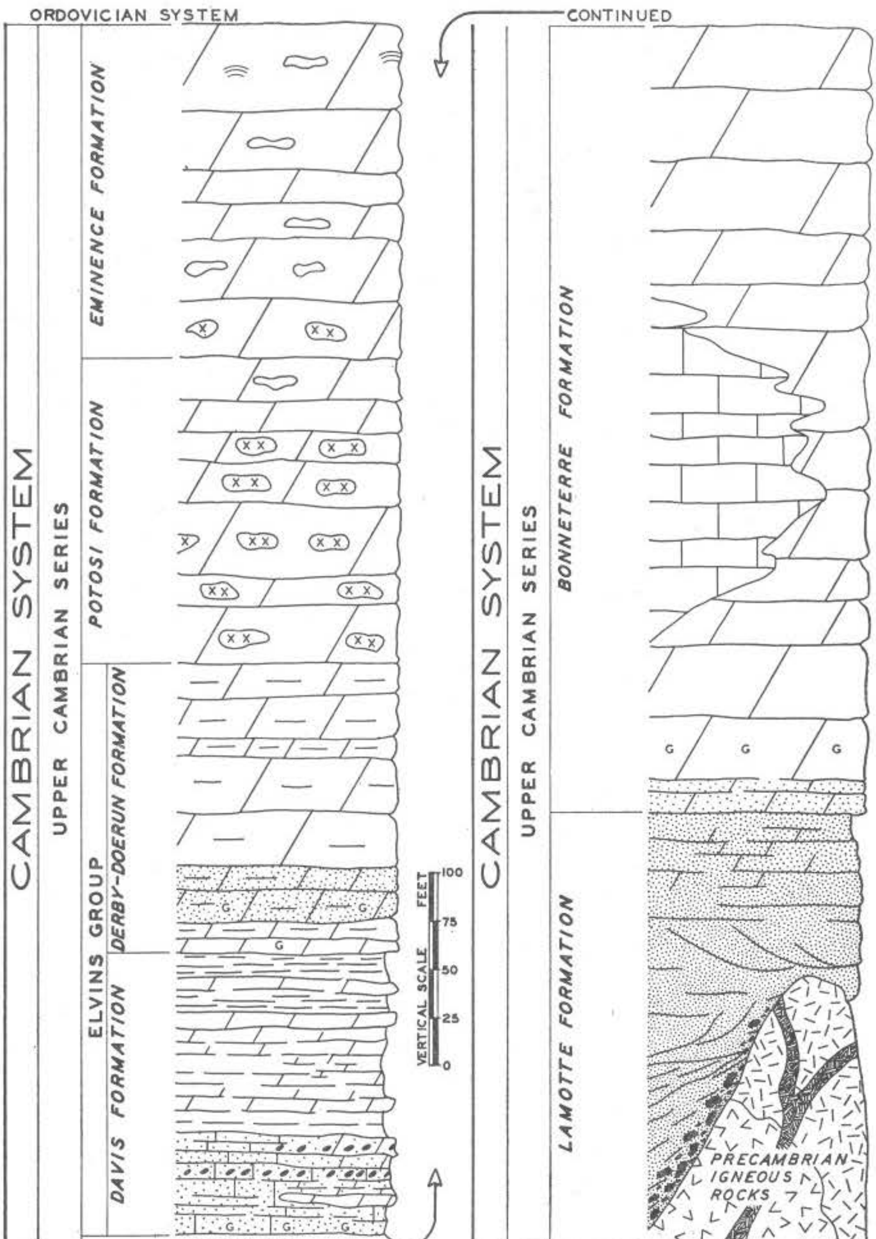

Fig. 3. Cambrian System; Upper Cambrian Series.

of sand increasing toward the base. This sandy zone is usually 10 to 20 feet thick but may approach a thickness of 200 feet. The Bonneterre overlaps the underlying Lamotte on the flanks of Precambrian highs.

Most of the Bonneterre exposures lie to the north and east of the main area of Precambrian exposures, and the formation is concealed by younger beds to the west and south. It occurs in the subsurface throughout most of the state and attains a maximum known thickness of 1,580 feet in the subsurface in Pemiscot County. In the Lead Belt, the formation has an approximate thickness of from 375 to 400 feet.

ELVINS GROUP.—The Elvins group, which consists of the Davis and Derby-Doerun formations, is a readily recognizable unit anywhere in the state. The lower part is shaly in the Lead Belt area but becomes predominantly dolomitic to the south. The upper part of the Elvins consists of fine-grained, thin- to medium-bedded, shaly dolomite.

Davis formation.—The Davis is the lower of the two formations which make up the Elvins group. The formation is conformable with the underlying Bonneterre and contains shale, siltstone, fine-grained sandstone, dolomite, and limestone conglomerate; shale is more prevalent in the Lead Belt than elsewhere. Much of the siltstone and fine-grained sandstone is glauconitic and has a "salt and pepper" appearance.

An important marker in the Davis is the *Eoorthis* brachiopod zone which is usually confined to a bed 1 or 2 feet thick that lies 30 or 35 feet below the top of the formation.

"Flat-pebble" and edgewise conglomerates are characteristic of the Davis. The "flat-pebble" conglomerates consist of rounded disclike pebbles of fine-grained limestone that are embedded in a medium-grained limestone matrix. The pebbles lie with their flat surfaces more or less parallel to the bedding planes. In the imbricate or edgewise conglomerates, the discs or lenses of fine-grained limestone are generally arranged with their longer axes perpendicular to or steeply inclined to the bedding planes. In some places, a group of edgewise pebbles will form a radiating or fanlike pattern.

Rounded, boulder size masses of light-colored, fine-grained, mottled limestone are present about 60 feet below the top of the Davis in the Lead Belt area. This horizon is informally referred to as the "Marble boulder bed".

The formation averages 170 feet in thickness. Its maximum recorded thickness is 225 feet. It thins to a featheredge wherever it onlaps Precambrian knobs.

Derby-Doerun formation.—The Derby and the overlying Doe Run formation were originally defined in 1908 from exposures in the vicinity of mines operated by the Derby Lead Company and the Doe Run Lead Company in the Lead Belt area at that time. However, the conformable relationship and similar lithology of the two units has since led most stratigraphers to consider them as a single unit, and the combination of the two names, Derby and Doe Run, is now accepted as the formation name; Derby-Doerun.

In its outcrop area in southeast Missouri, the Derby-Doerun consists of thin- to medium-bedded dolomite which alternates with thin-bedded siltstone and shale. The dolomite beds are medium to fine grained, buff to brown, argillaceous, and silty. The chert content of the formation is very low, amounting to less than 10 percent of the rock by volume. Glauconite is present in the lower 40 to 50 feet of the formation. About 50 feet below the top of the formation, hexactinellid and other types of sponge spicules are common, and echinoderm ossicles are frequently present.

The contact of the Derby-Doerun and the underlying Davis is conformable, and in many places where it is not exposed, its position may be inferred with considerable accuracy by reference to the *Eoorthis* zone in the Davis formation. The thickness of the Derby-Doerun is approximately 150 feet; however, its range in thickness is from 0 to 200 feet.

Potosi formation.—The Potosi is a massive, thickly bedded, medium to fine-grained dolomite which characteristically contains an abundance of quartz druse or so-called "mineral blossom" that is associated with chert. Druse-free chert is uncommon. The rock is typically brownish gray in color and weathers to a light gray. A notable characteristic of the Potosi, as well as of a few other lower Paleozoic formations, is that the freshly broken rock gives off a pronounced bituminous odor. Deep red, sticky, residual clay is a surface indication of the presence of the Potosi in its outcrop area. The relationship of the Potosi and the underlying Derby-Doerun is one of conformity.

The Potosi outcrop area encircles the St. Francois Mountains and includes a considerable part of southern Washington County where barite is present in commercial quantity. The barite occurs in the residual clay and druse mantle of the weathered formation as well as in the formation. The Potosi is present in the subsurface throughout most of the state, but at widely scattered localities, it is thin or absent.

The thickness of the Potosi in its outcrop area ranges from about 75 feet to a maximum of 300 feet. Its average thickness is 200 feet. Deep well records from southwestern and northern Missouri show that the Potosi thins laterally from its outcrop area. Well records at Springfield show that the Potosi in that area is less than 30 feet thick. In northern Missouri, its thickness ranges from 0 to 75 feet.

Eminence formation.—The Eminence formation is composed principally of medium to massively bedded, light gray, medium- to coarse-grained dolomite. It contains a small amount of chert in the form of small nodules and angular fragments that is present mostly in the upper half of the formation. The small amount of quartz druse which is found in the formation is similar to the druse in the underlying Potosi. In some areas, the Eminence formation contains large massive chert boulders and blocks as much as 6 feet in diameter. White oolitic chert is locally present in the upper part of the formation. Molds and casts of gastropods are commonly found in Eminence chert, and in places masses of *Cryptozoon* occur near the top of the formation. The Eminence and underlying Potosi are conformable. The similarity of their lithologies and other characteristics tends to obscure their actual contact.

The main outcrop area of the Eminence around the St. Francois Mountain area is roughly peripheral to that of the Potosi. The formation is also exposed around Precambrian knobs in Shannon County and in the major stream valleys of Miller and Camden Counties in the central part of the state. In older reports, the Eminence of central Missouri is referred to as the "Proctor" formation.

The Eminence throughout most of Missouri has an approximate thickness of from 200 to 250 feet. Like the Potosi, it thins or is absent over local structural features. In the south-central part of the state, it is locally as much as 350 feet thick. Big Spring at Van Buren, Round Spring, and other large springs as well as many major caves are developed in the Eminence.

Ordovician System

by

James A. Martin, Robert D. Knight*, and William C. Hayes*

Rocks of Ordovician age are exposed over approximately one-third of the State of Missouri and attain an aggregate thickness of approximately 3,800 feet. They crop out chiefly in the southern, eastern, and central parts of the state and are widely present in the subsurface downdip from their outcrop area. They lie around the flanks of the Ozark dome and dip quaquaversally from it.

The Canadian, Champlainian, and Cincinnatian Series are all represented in the state, with the Canadian and Champlainian Series being the most extensive. The strata of these Series are composed predominantly of dolomite and limestone, but several important sandstone units are also present. Unconformities are conspicuous at both the base and the top of the System, with many significant unconformities being recognized as Series and Stage boundaries within the System. Ordovician strata unconformably overlie Upper Cambrian and Precambrian rocks and are, in turn, unconformably overlain by rocks of the younger Systems.

Important economic materials obtained from Ordovician strata are water, silica sand, and various limestone and dolomite products. Many Pennsylvanian filled-sink deposits of refractory clay and sedimentary iron ore are preserved in rocks of Ordovician age. A number of the state's largest springs and caves are present in the Canadian formations.

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*Coauthor of section on Canadian Series.

Canadian Series*

The rocks of the Canadian Series in Missouri are principally arenaceous and cherty dolomite and sandstone. They immediately underlie the surface in a large part of the state south of the Missouri River

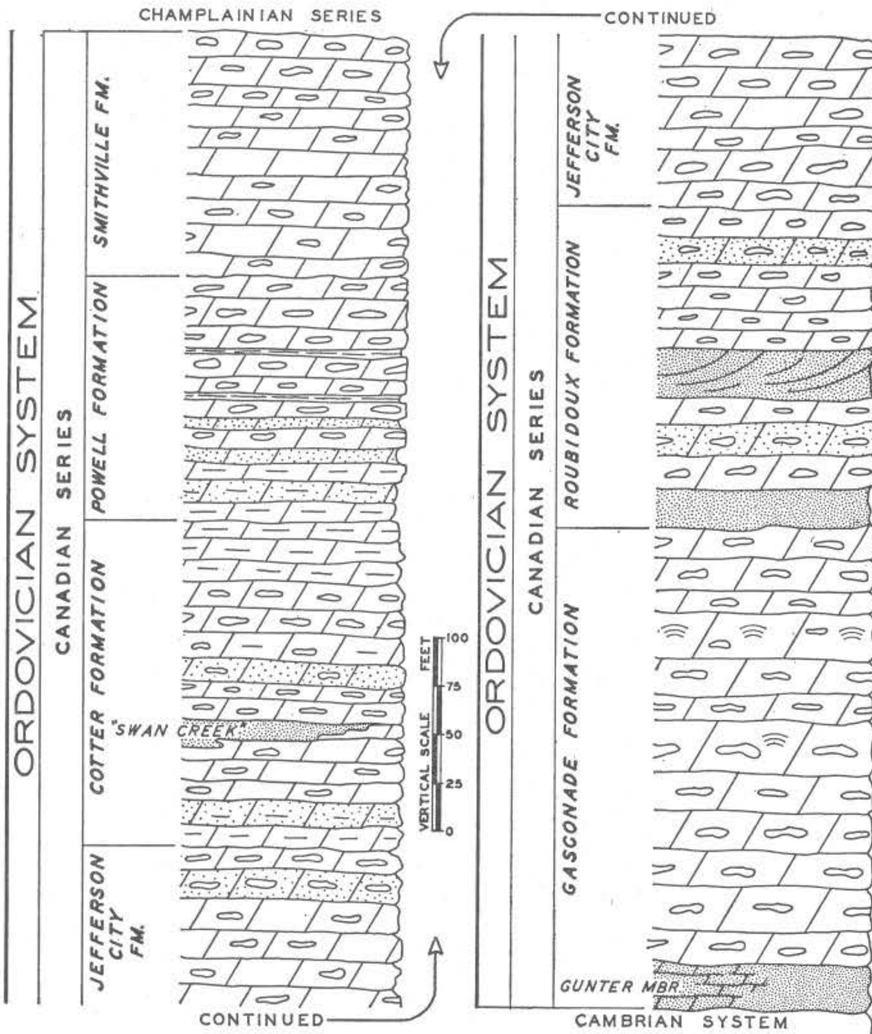

Fig. 4. Ordovician System; Canadian Series.

and extend westward from the Mississippi River to Cedar County. The Series, bounded at the base and top by regional unconformities, contains the following formations: Gasconade, Roubidoux, Jefferson

*The term Canadian, as applied in this report, follows usage set forth in "Correlation of the Orodivician formations of North America," by Twenhofel and others, 1954. It is not to be confused with the Canadian of E. O. Ulrich's classification which was published in 1911.

City, Cotter, Powell, and Smithville. The stratigraphic interval containing the formations from the Jefferson City through to the Smithville is regarded as approximately equivalent to the Beekmantown group of the Appalachian region.

Gasconade formation.—The Gasconade is predominantly a light brownish-gray, cherty dolomite. The formation contains a persistent sandstone unit in its lowermost part that is designated the Gunter member. The lower part of the dolomite which overlies the Gunter member is coarsely crystalline and characterized by large amounts of chert which often exceed 50 percent of the total volume of the rock. In contrast, the upper part of the dolomite is dominantly, finely crystalline and contains relatively smaller amounts of chert.

Several varieties of chert characterize different parts of the Gasconade. The chert in the lower part, above the Gunter, is often oolitic with some of the ooliths being free and bean-shaped. The chert in the middle part includes a smooth, white, porcelaneous type and another type that has a "dead" appearance. The lower half of the upper 25 to 30 feet of the formation contains small amounts of brown- and gray-banded chert.

Fossils are usually scarce except for mollusks which are commonly present in the chert. Widespread masses of *Cryptozoon* are present within the formation. The most persistent masses are 50 to 70 feet below the top of the formation.

Many of the nearly vertical bluffs and cliffs along streams in the central Ozarks are formed by the Gasconade, and caves and springs are common in the formation. The Gasconade is present in the subsurface throughout most of the state.

In the central Ozark region, the average thickness of the Gasconade is 300 feet. Data from wells in southeastern Missouri indicate a maximum thickness of 700 feet for the Gasconade in that area.

Gunter member.—From central Missouri south to Taney County, the Gunter member is a medium-grained, quartzose sandstone. To the east and to the west, it is an arenaceous dolomite. A basal conglomerate containing pebbles from the underlying Eminence has been noted in the Gunter in a few places.

The Gunter is one of the most reliable field-mapping units in the lower Paleozoic of the Ozark region. It is also a reliable subsurface marker throughout most of the state. It is from 25 to 30 feet thick. A number of deep municipal water wells in the state produce from the Gunter.

Roubidoux formation.—The Roubidoux formation consists of sandstone, dolomitic sandstone, and cherty dolomite. In central Missouri, it is predominantly a quartzose sandstone, whereas in other parts of the state as little as 10 percent of the formation contains sandstone and most of the rock is cherty dolomite. The sandstone is composed of fine- to medium-grained quartz sand which characteristically is subrounded and frosted. Gray and brown colors are predominant on weathered surfaces, but the color of the fresh sandstone is commonly light yellow, tan, or red at the surface and white in the subsurface. The dolomite in the Roubidoux is finely crystalline, light gray to brown in color, and thinly to thickly bedded. Individual beds contain brown to gray, banded, oolitic, sandy chert.

The Roubidoux normally is sparingly fossiliferous, but some of the chert locally contains numerous fossils, chiefly mollusks. In many places the sandstone is characterized by exceptionally well-preserved ripple marks, mud cracks, and cross-bedding. In the western part of the state, the formation contains three distinct sandstone units; one near the base, one near the middle, and one near the top. The sandstone units are quarried for building stone at many places in Missouri.

The outcrop area of the Roubidoux occupies a large part of southern Missouri, and the formation is present throughout the subsurface of the state downdip from the outcrop area.

The thickness of the Roubidoux ranges from 100 to 250 feet. The formation's greatest thickness is at the southwestern part of the Ozarks, and its least thickness is along the northeastern part of the area.

Jefferson City formation.—The Jefferson City formation is composed principally of light brown to brown, medium to finely crystalline dolomite and argillaceous dolomite. Lenses of orthoquartzite, conglomerate, and shale are locally present in the formation. A stratigraphic succession of the Jefferson City formation in one locality is rarely duplicated in another locality, although there is a similarity. Finely crystalline, argillaceous dolomite called "cotton rock" is characteristic of the formation. An equally important rock type found in many exposures is thickly bedded, massive, brown, medium crystalline dolomite that weathers with a coarsely pitted surface. This is the informally designated "Quarry Ledge" of the Ozark region that is present 35 to 40 feet above the base of the formation. In the past, rock obtained from this unit was very popular as a dimension stone.

The Jefferson City is exposed around the periphery of the Ozarks and is recognized in the subsurface in all of northern and western Missouri by its characteristic type of oolitic chert. Several insoluble residue zones within the formation contain siliceous spicules which are commonly referred to as "spines". The thickness of the Jefferson City ranges from 125 to 350 feet; its average thickness is 200 feet.

Cotter formation.—The major part of the Cotter formation is composed of light gray to light brown, medium to finely crystalline, cherty dolomite. It is normally medium to thinly bedded and contains thin intercalated beds of green shale and sandstone. A 15- to 20-foot sandstone in the Springfield area is named the "Swan Creek", but this unit is not formally recognized because it is discontinuous and is often confused with other sandstone beds at different stratigraphic positions in the Cotter formation.

The lower part of the Cotter formation is relatively noncherty and contains echinoderm fragments, the middle part is characterized by oolitic chert and large siliceous ooliths, and the upper part is shaly and contains small quartz masses and brown quartzose oolitic chert.

The Cotter is conformable on the underlying Jefferson City, and because it is difficult to differentiate the two formations they are often designated as a combined unit, as Jefferson City-Cotter. The Cotter crops out along the northern and western edges of the Ozark uplift and is present in the subsurface except where it has been removed by pre-St. Peter erosion in west-central and northwestern Missouri. The average thickness of the Cotter is 200 feet, but its maximum thickness is in the subsurface of southeastern Missouri where it is 450 feet thick. The Cotter is absent in St. Clair County where the Mississippian lies unconformably on the Jefferson City formation.

Powell formation.—The Powell formation is composed of medium to finely crystalline dolomite and thin beds of green shale and fine-grained sandstone. In Ste. Genevieve County it is divisible into lower and upper parts. The lower part contains several sandstone beds and is typically dark brown. The upper part is composed of finely crystalline, argillaceous dolomite or "cotton rock" and many thin beds of green shale. Soft, ferruginous and "rotten" chert is characteristic of the residues in its outcrop areas.

The Powell crops out in eastern Missouri from Cape Girardeau County northward to St. Charles County and is also present in extreme southwestern Missouri. It is present in the subsurface except in the west-central and northwestern parts of the state. Its thickness in Ste. Genevieve County ranges from 150 to 175 feet.

Smithville formation.—The Smithville formation is composed of dolomite which contains a small amount of chert. One of the distinguishing characteristics of the formation is the presence of Bryozoa. Smithville fossils have been collected from residual chert over a large area in Bollinger County and from a quarry near Delta in Cape Girardeau County.

The formation is present in the subsurface south and east of Cape Girardeau, and in some areas it is at least 150 feet thick. Because the formation is lithologically similar to the underlying Powell formation, it is most often distinguished from the Powell by the characteristics of its insoluble residue.

In northeastern Arkansas, a deep drill hole which is located close to the Missouri state line has penetrated a thick succession of cherty dolomite and limestone that is considered to be younger than the Smithville rocks that are present in Missouri and older than the Everton rocks within the state. The succession is fossiliferous and contains about 80 percent of insoluble material. This material consists of brown and tan translucent chert, gray and brown silt, and silicified fossil fragments. This succession has been tentatively referred to the Black Rock formation of Arkansas but has no known correlative within Missouri.

Champlainian Series

The two presently recognized Stages (Chazyan and Mohawkian) of this Series are represented in Missouri by eight formations. The boundary between the stages has not been definitely established within the state. Because of this, the formations have been tentatively assigned as follows: Chazyan - Everton, St. Peter, Dutchtown and Joachim; Mohawkian - Rock Levee, Plattin, Decorah, and Kimmswick.

In southeastern Missouri, rocks of the Champlainian Series crop out in a continuous belt 2 to 20 miles wide that extends from northeastern Scott County northwestward through Cape Girardeau, Perry, Ste. Genevieve, and Jefferson Counties to Franklin and St. Louis Counties. North of the Missouri River, an outcrop belt of middle Ordovician rocks roughly parallels the river in St. Charles, Warren, Montgomery, and eastern Callaway Counties. In Lincoln, Ralls, and Pike Counties, in northeastern Missouri, rocks belonging to the Series are present at the surface along the Lincoln fold. The outcrop belt of Champlainian rocks in this area extends northwestward from Winfield in Lincoln County to the vicinity of Spalding in Ralls County, along the north flank of the fold. Outliers of middle Ordovician rocks crop out in Callaway, Cooper, Boone, and Saline Counties. In the subsurface, formations of the Series are recognized from nearly all counties north of the Missouri River. South of the Missouri River, they are present in the subsurface east of the outcrop belt where they dip beneath younger strata into the Illinois basin. In western Missouri, middle and upper Ordovician strata have been removed by pre-Mississippian post-Canadian erosion.

Everton formation.—The Everton is the basal formation of the Champlainian Series and rests unconformably on Canadian strata. It consists mostly of sandy dolomite, but it also contains interbedded sandstone, limestone, and chert. The dolomite is both light and dark gray and commonly contains scattered grains of quartz sand. The sandstone is fine to very fine grained and frequently contains silt. The grains of sand are rounded and are commonly pitted or frosted. The sandstone of the Everton resembles the overlying St. Peter sandstone, but its average grain size is generally smaller. Where the sandstones of the two formations are in contact, they cannot be readily distinguished one from the other. Medium gray to white chert in thin beds, lenses, and nodules is sporadically distributed throughout most of the formation. Poorly preserved fossils are sparsely present in some of the upper limy dolomite beds.

The Everton crops out in Missouri from Scott County northward to Jefferson County. It has not been definitely recognized elsewhere in the state. It is approximately 400 feet thick in Scott County but thins rapidly northward and is probably absent north of Jefferson County.

St. Peter formation.—The St. Peter is typically a well-sorted, quartzose sandstone but locally is an orthoquartzite. The sand grains are fine to medium in size, rounded, spherical, and characteristically frosted. The formation's silica content is as high as 99 percent. A freshly exposed surface of the formation is commonly white with shades of pink and green. Weathered surfaces are a dirty gray or brown and are case-hardened at many localities. Bedding is indistinct, and the formation appears massive throughout. The rock is cross bedded and ripple marked locally. The formation is generally porous and permeable except where it is an orthoquartzite. The St. Peter appears to be unfossiliferous in Missouri, but locally there are elongate, cylindrical structures in the formation that have been interpreted as reed molds.

In southeastern Missouri, the St. Peter is conformable with the Everton. North of Jefferson County, the formation is disconformable on the eroded surface of the Canadian Series.

The St. Peter formation is continuous throughout the Champlainian outcrop belt in Missouri and is present in the subsurface of the northern and west-central part of the state. It has the greatest distribution of any Champlainian or Cincinnatian formation in the state. The St. Peter is mined in eastern Missouri for glass sand and abrasives and is an aquifer in parts of central and eastern Missouri.

The thickness of the formation is variable, ranging from less than 10 to more than 100 feet. Its approximate thickness in the outcrop area is between 60 and 80 feet.

Dutchtown formation.—The Dutchtown formation is composed dominantly of medium to thinly bedded limestone and dolomite and contains varying amounts of dolomitic sandstone, siltstone, shale, and clay. The color of the rock is dark blue, gray, or black. The carbonate rocks contain finely disseminated particles of organic matter and hydrocarbons in the form of asphaltic-filled vugs. Both the limestone and dolomite give off a petroliferous odor when struck with a hammer. The limestone, dolomite, and sandstone are all fossiliferous, though well-preserved fossils are scarce. Pelecypods and gastropods are the most abundant fossils. Masses of *Cryptozoon* are present in the lower part of the formation at a few localities.

The Dutchtown formation is best developed in Scott, Cape Girardeau, and Perry Counties, Missouri, and in southwestern Illinois. Outcrops are few, and information on the distribution and lithology of the formation is based largely on subsurface data. The Dutchtown has been divided into three units on the basis of distinctive insoluble residues.

The formation attains a maximum thickness of approximately 170 feet in southern Cape Girardeau County. It thins rapidly northward and is only 20 feet thick in southern Perry County. It is apparently absent from Perryville northward. South of Cape Girardeau County, the Dutchtown is present only in northeastern Scott County.

The relationship of the Dutchtown to underlying formations has been determined from subsurface information. These data indicate that pre-Dutchtown erosion has removed part or all of the St. Peter formation in some places, and that the Dutchtown thus overlaps the older St. Peter and Everton formations.

Joachim formation.—The Joachim is predominantly a yellowish-brown, argillaceous dolomite which contains interbedded limestone and shale in its lower part. Scattered quartz sand grains are prominent in the lower beds of dolomite, shale, and limestone. Mud cracks are common. Chert is absent throughout the unit except for a thin but persistent, nodular chert bed at the top. Fossils are scarce in the Joachim in Missouri.

The Joachim extends throughout the Champlainian outcrop belt of Missouri but pinches out in the subsurface westward and northwestward of Lincoln and Montgomery Counties. It thins from south to north, ranging from an average thickness of about 175 feet in Cape Girardeau and Scott Counties to less than 50 feet in Ralls and Montgomery Counties.

In Scott, Cape Girardeau, and Perry Counties, the Joachim unconformably overlies the Dutchtown formation. North of this area, the Dutchtown is absent, and the Joachim unconformably lies on the St. Peter formation.

Rock Levee formation.—The Rock Levee includes beds that were formerly assigned to the upper part of the Joachim and to the lower part of the Plattin. Thus, the formation contains a succession of rock units which lie below an oolitic pebble conglomerate at the base of the redefined Plattin and above a very thin but persistent zone of chert at the top of the Joachim as it is now defined. The chert zone is a recognizable subsurface marker, but it is not at all conspicuous in surface exposures; therefore, in field mapping the Rock Levee is usually grouped with the Joachim formation.

In southeastern Missouri, the Rock Levee is predominantly a limestone which contains interbedded dolomite. In east-central and northeastern Missouri, the formation is composed mostly of dolomite and has thin limestone beds near the top. Thin green and tan shale beds are frequently intercalated with the limestone and dolomite. Megafossils are sparse in the Rock Levee formation, but casts of ostracodes are common. A marker zone of silicified echinoderm ossicles is used as an aid in subsurface correlation work.

The thickness of the Rock Levee formation ranges from a few feet in southern Ralls and eastern Callaway Counties to approximately 270 feet in Cape Girardeau County. The Rock Levee appears to be conformable with the underlying Joachim.

Plattin formation.—The Plattin consists of evenly bedded, dark gray, finely crystalline to sublithographic limestone which contains minor amounts of intercalated shale. The basal unit is easily recognized because it is composed of a pebble conglomerate and oolite and contains shale and ostracodes. Tubular or fucoidal structures, which are commonly filled with light brown, saccharoidal dolomite or white calcite, are minor but distinctive features of the formation. Thin metabentonite beds are present in the upper part of the Plattin. Brown, dark gray, and white chert nodules and layers are present throughout most of the formation. Locally, some beds within the formation are dolomitic, but in northeastern Missouri and in parts of east-central Missouri, all of the formation is composed of dolomite. The formation is fossiliferous and contains an abundance of dallmanellid, strophomenid, and orthid brachiopods. Recently, it has been proposed that the Plattin in Missouri and Illinois be subdivided into a number of formational units. These proposals have not as yet been formally adopted by the Missouri Geological Survey.

The Plattin thins to less than 100 feet in Ralls and Montgomery Counties. Northward and westward from Cape Girardeau County, it is approximately 450 feet thick. It lies on the Rock Levee formation in northeastern Missouri where there appears to be a slight disconformity at its base.

Decorah formation.—The Decorah consists of green or brown shales and has numerous, thin, interbedded limestone layers in its lower part that grade upward into a medium to thinly bedded, fossiliferous limestone which contains thin, fossiliferous shale partings. Beds of metabentonite lie in the basal part of the formation. The brachiopods *Pionodema subaequata* and *Rafinesquina* are the most common fossils. In the subsurface of northern Missouri, the Decorah is almost entirely a cherty dolomite or limestone with minor amounts of shale.

The Decorah varies in thickness from a few feet to more than 40 feet. It overlaps the Plattin formation, and in northwestern Missouri, it unconformably overlies formations as old as the St. Peter. The relationship of the Decorah to the Plattin in eastern Missouri appears to be unconformable.

Kimmswick formation.—The Kimmswick is typically a coarsely crystalline, white to light gray, medium bedded to massive limestone. The weathered surface of the rock is distinctive in that it is notably pitted or "honeycombed". Chert is nodular and irregularly scattered locally in the upper part of the formation. Invertebrate fossils, predominantly brachiopods and bryozoans, are common throughout the formation. The "sunflower coral", *Receptaculites oweni*, characterizes the Kimmswick in Missouri. Regionally, the Kimmswick is unconformable on underlying units.

In much of the subsurface of north-central and northwestern Missouri, the Kimmswick is a dolomite which contains interbedded limestone. This is especially true in the Forest City basin in northwestern Missouri. The Kimmswick is also a dolomite in the faulted areas of Perry and Ste. Genevieve Counties, where it is commonly gray to grayish brown, coarsely to medium crystalline and contains chert.

Where the Kimmswick is a limestone, it has a content of 95 to 99 percent calcium carbonate. It is quarried throughout its outcrop belt from northern Scott County to Pike County.

The Kimmswick is 50 to 150 feet thick in eastern Missouri and attains a thickness of more than 250 feet in northwestern Missouri. In the north-central part of the state, it thins over a regional anticlinal high.

Cincinnatian Series

The Cincinnatian strata in Missouri that have been assigned by most observers to the Richmondian Stage of the Ordovician System compose three formations which in ascending order are the Cape ("Fernvale"), the Maquoketa, and the Thebes. A shale unit which overlies

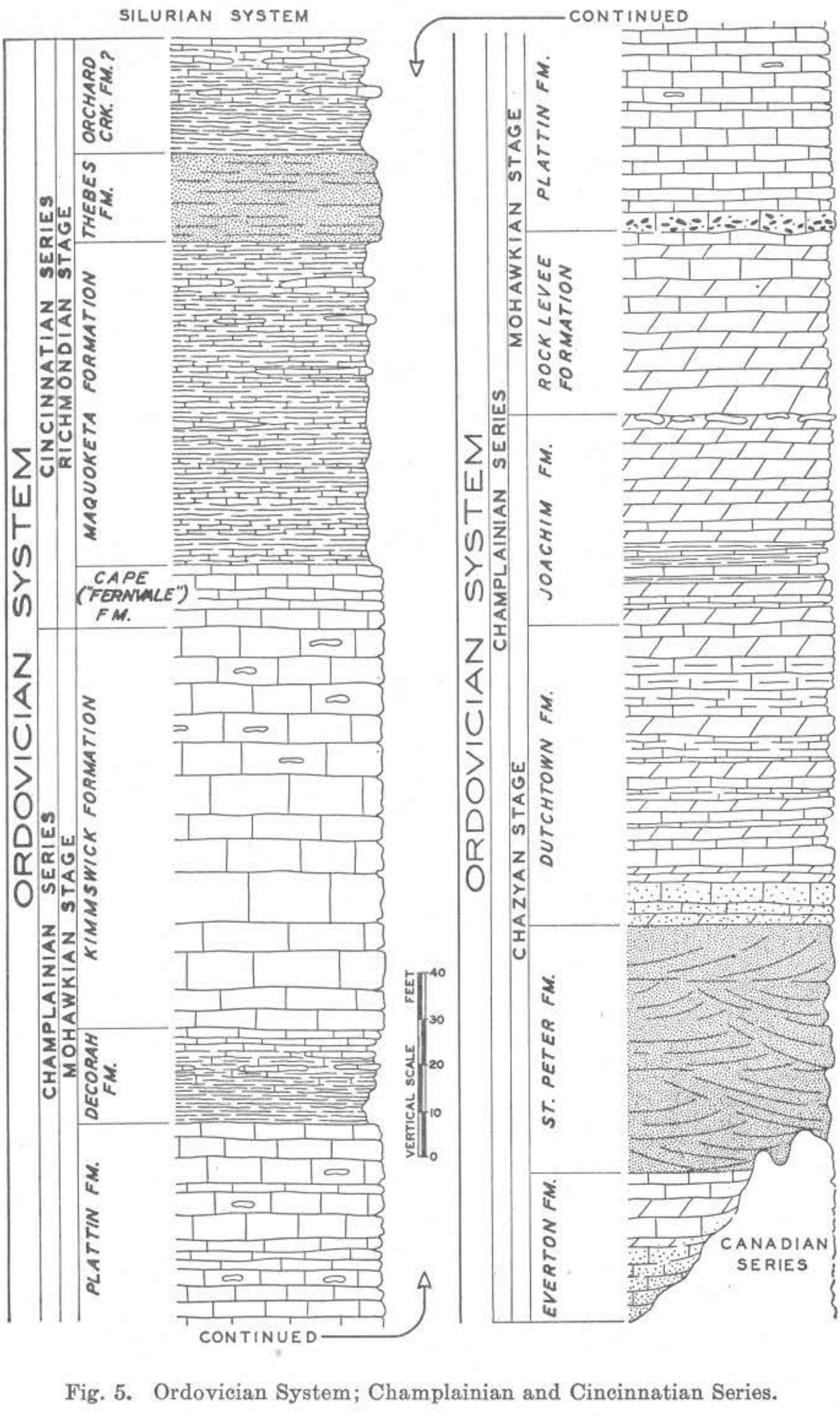

Fig. 5. Ordovician System; Champlainian and Cincinnatian Series.

the Thebes formation in many places in southeastern Missouri and which is considered by some to be equivalent to the Orchard Creek formation of Illinois is also regarded herein as being Ordovician in age. This unit in turn is overlain by the Girardeau formation which on the basis of the faunal studies of Savage (1917) is regarded as Silurian in age although its contact with the underlying shale is gradational and there is reason to believe that it may be Ordovician in age because of a marked unconformity between it and the Edgewood formation (Silurian).

Cape formation.—The name Cape which is to be formally proposed by J. S. Templeton and H. B. Willman of the Illinois Geological Survey in a forthcoming publication (unpublished manuscript) is herein adopted to replace the name "Fernvale" in Missouri. The formation is composed of a coarsely crystalline, argillaceous limestone. The color of the limestone is gray, and fresh exposures have a distinctive purplish or brown tinge. The beds are thin to medium in thickness, wavy, and irregular. Thin beds of shale are present in the lower part of the formation which becomes massive toward the top. Weathered exposures of the limestone crumble readily. Fossils, particularly brachiopods and barrel-shaped crinoid columnals, are abundant but poorly preserved. The brachiopod *Lepidocyclus* is commonly present in the formation in Missouri.

Outcrops of the formation are intermittently distributed, with exposures being present in Cape Girardeau, Perry, Ste. Genevieve, and Jefferson Counties. In the subsurface of northwestern Missouri, beneath Holt and DeKalb Counties, a white crystalline dolomite has been questionably identified as the Cape formation. The Cape lies unconformably upon the Kimmswick formation.

In its outcrop area in southeastern Missouri, the formation ranges from a maximum thickness of about 15 feet in Cape Girardeau County to less than a foot in Ste. Genevieve and Jefferson Counties. In the subsurface of northwestern Missouri, the dolomite questionably identified as the Cape formation is 10 to 40 feet thick.

Maquoketa formation.—The Maquoketa formation is typically a thinly laminated, silty, calcareous or dolomitic shale which locally contains nodular and shaly lenses of limestone. The color of the shale ranges through various shades of dull green, dark gray, and brown. The limestone is commonly light brown or gray. The formation is locally fossiliferous, especially where the shale is calcareous and thin beds of limestone are present. Mollusks, corals, and brachiopods are the most common fossils. Graptolites are commonly regarded as an index of the Maquoketa in subsurface work. Quartz sand grains and quartzose sandstone lentils are present locally in the upper part of the formation.

The Maquoketa formation disconformably overlies the Kimmswick formation throughout most of its extent in Missouri. In southeastern Missouri, however, it locally overlies the Cape formation. An extensive erosional disconformity exists at the base of the Maquoketa.

The Maquoketa crops out in Missouri in most of the counties which border the Mississippi River from Scott County northward to southern Marion County. It is present in the subsurface in northeastern and northwestern parts of the state. The thickness of the Maquoketa in southeastern Missouri ranges from 10 to 60 feet. The thickness of the formation in the Forest City basin of northwestern Missouri ranges from 20 to 70 feet. The average thickness in northeastern Missouri is 100 feet, but it ranges from 30 to 140 feet.

Thebes formation.—The Thebes formation is typically a fine-grained quartzose sandstone which contains variable amounts of silt and mica. The sandstone is gray to bluish-gray and weathers to a yellowish-brown. The beds of the formation are very thin or thin to medium in thickness. At fresh exposures, the formation appears massive, but it soon weathers into shaly layers. Two prominent sets of nearly vertical joints are present in the sandstone and weathering along these joints causes the rock to break into large rectangular slabs.

The Thebes has been traced from Alexander County, Illinois, into southeastern Missouri and is recognized in northern Scott, eastern Cape Girardeau, Perry, and Ste. Genevieve Counties. The thickness of the formation ranges from less than 5 feet to as much as 20 or 25 feet in Missouri. The sandstone thins in the Ste. Genevieve County area and apparently feathers out in that county.

The Thebes formation is generally considered to be Richmond in age, and it has been correlated by some geologists with the lower part of the Maquoketa formation that is present in northern Illinois and Iowa. In the subsurface of southeastern Missouri, several sandstone units are present in a shale unit which lies between the Cape and Girardeau formations, and it is questionable as to which of these units is the Thebes. Thus, there is some reason to believe that the exposed sandstone which in Missouri is regarded as the Thebes may be only a southern facies of the Maquoketa formation of Illinois and Iowa.

Orchard Creek (?) formation.—The shale unit which lies above the Thebes formation and below the Girardeau formation in Missouri and which is herein questionably regarded as equivalent to the Orchard Creek formation of Illinois is composed of olive green to bluish-gray shale and intercalated beds of limestone. The shale is platy, calcareous, and generally weathers brown. The limestone beds are argillaceous and thin in the lower part of the unit but become less so upward where they resemble the limestone of the overlying Girardeau formation. Fossils are present in both the limestone and shale but are not abundant. The contact of the Orchard Creek with the underlying Thebes formation is generally gradational, but locally it is sharp and distinct. The average thickness of the formation is 50 feet. The formation's contact with the overlying Girardeau appears transitional. The unit is present in Cape Girardeau, Perry and Ste. Genevieve Counties.

In Illinois, because of the similarity of Orchard Creek fauna with the Girardeau fauna, Savage (1917) placed the Orchard Creek formation in the Silurian System. Because of its dominant shaly lithology, its gradational relations with the underlying Thebes, and the persistence of some elements of the Richmond fauna, the Orchard Creek has been regarded by Weller and McQueen (1939), Weller (1940), DuBois (1945), Gealy (1955), and others as Ordovician.

Silurian System

by

James A. Martin, Kenneth G. Larsen*, and Garrett A Muilenburg†

In Missouri, the Silurian System is represented by the Alexandrian and Niagaran Series. The Cayugan Series is considered to be absent in the state, but it is possible that the uppermost part of the Bainbridge formation (Niagaran) may represent part of it.

Outcrops of Silurian strata are restricted to two widely separated areas in the state; the east flank of the Ozark highlands in southeastern Missouri, and the flanks of the Lincoln fold in the northeastern part of the state. Silurian rocks have also been reported in the subsurface from wells in St. Louis and St. Charles Counties in eastern Missouri and from wells in the Forest City basin in northwestern Missouri.

In southeastern Missouri, Silurian strata crop out in eastern Ste. Genevieve, Perry, Cape Girardeau, and Scott Counties. East of the outcrop area, the Silurian dips beneath younger Systems into the southern part of the Illinois basin. Both the Alexandrian and Niagaran Series are represented in the area, and they consist predominantly of limestone and shale. The limestones of the lower Series contain minor amounts of chert.

Outcrops of Silurian rocks in northeastern Missouri occur chiefly along the northeastern flank of the Lincoln fold in Ralls, Pike, and Lincoln Counties. A few outcrops in Lincoln County are situated near the crest of the fold and along its southern flank. In this area of the state, only the Alexandrian Series is present, and it is composed largely of limestone and dolomite and contains a characteristic oolite in its lower part.

In northwestern Missouri, Silurian strata have been penetrated by drill holes in the area of the Forest City basin which underlies most of the surface area covered by Atchison, Holt, Andrew, Nodaway, Buchanan, DeKalb, and Worth Counties. The dominant lithology of the Silurian rocks in the basin is dolomite, but some limestone is present. The dolomite is bluish gray to brown, medium to finely crystalline and contains some chert and shale. Arenaceous Foraminifera found in well cuttings from the area suggest that the Silurian in the basin might be correlative with the Alexandrian and lower part of the Niagaran of eastern Missouri and western Illinois.

The total thickness of the Silurian is approximately 200 feet in southeastern Missouri, 100 feet or less in the northeastern part of the

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state, and 300 or 400 feet in northwestern Missouri. Significant unconformities mark the top and base of the System and also separate some units of Series and formation rank.

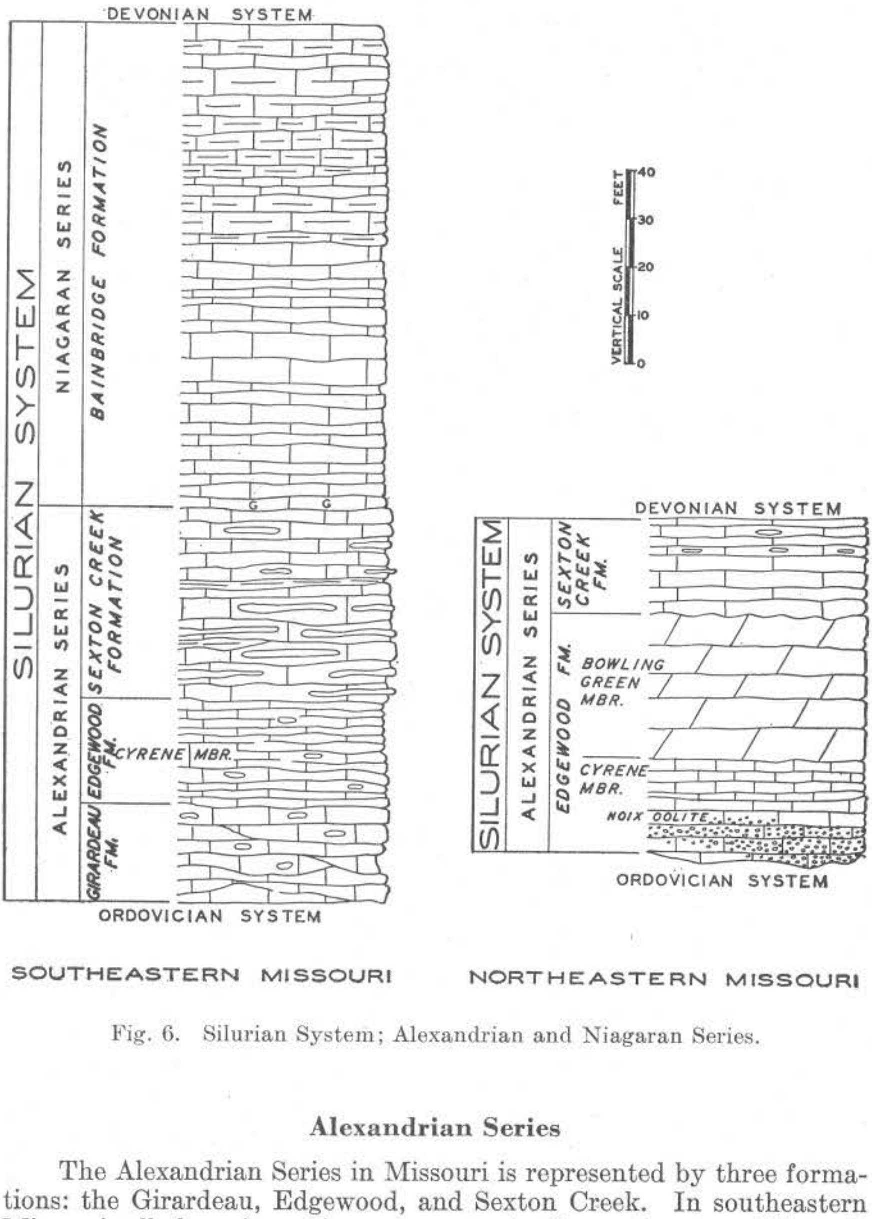

Fig. 6. Silurian System; Alexandrian and Niagaran Series.

Alexandrian Series

The Alexandrian Series in Missouri is represented by three formations: the Girardeau, Edgewood, and Sexton Creek. In southeastern Missouri, all three formations are present. In northeastern Missouri, only the Edgewood formation and a small remnant of the Sexton Creek are present. The Edgewood formation is subdivided into two members, the Cyrene member (lower) and the Bowling Green member (upper).

A prominent oolite in the Cyrene member is herein informally designated as the Noix oolite.

The thickness of the Alexandrian Series in the southeastern part of the state ranges from 30 to 100 feet. The thickness of the Series in the northeastern part of the state is approximately 75 to 100 feet.

Girardeau formation.—The Girardeau is a dark to medium gray limestone which weathers to a light bluish gray. The texture of the limestone is dense to sublithographic, and the rock breaks with a conchoidal fracture. Bedding is thin and irregular with individual beds pinching out in short distances. Black and dark brown chert nodules are irregularly scattered throughout the upper part of the formation. Intercalated with the limestone beds, especially in the lower part, are yellowish-brown and olive, calcareous shale partings. Fossils are generally sparse in the limestone beds but are fairly abundant in many of the shale partings. The thickness of the formation ranges from a few feet to a maximum of 40 feet. The upper boundary of the Girardeau is marked by an erosional unconformity. The Girardeau formation in Missouri is restricted mainly to Cape Girardeau County.

Edgewood formation.—In the type area of the Edgewood in northeastern Missouri, the formation is subdivided into two members, the Cyrene (lower) and the Bowling Green (upper). The Cyrene member in this area and in adjacent parts of Illinois contains a prominent oolite which is informally referred to as the Noix oolite. In southeastern Missouri where only the Cyrene member of the Edgewood is recognizable, the Noix oolite is not known to be present.

The thickness of the Edgewood formation in northeastern Missouri ranges from approximately 10 to perhaps as much as 60 feet. In the southeastern part of the state, its maximum thickness is 20 feet.

Cyrene member.—The Cyrene, in its type area in Pike County, varies, from a light gray, medium to coarsely crystalline limestone to a bluish-gray to brown dolomitic limestone. In this area and in adjacent parts of Illinois, the Cyrene member contains a light gray to brown, fossiliferous, oolitic limestone which is referred to as the Noix oolite. At most localities, the oolite lies on upper Ordovician strata, but in a few places in Pike County, several feet of nonoolitic limestone lie between the oolite and the Ordovician rocks. The Noix oolite is from 3 to 5 feet thick at most exposures, but a maximum of 10 feet has been reported. In southeastern Missouri, the Cyrene member is typically a gray, thin-bedded, argillaceous limestone in which yellowish-brown chert locally forms thin beds, lenses, and nodules.

The thickness of the Cyrene member does not exceed 20 feet, and throughout its extent it lies unconformably on older strata.

Bowling Green member.—The Bowling Green member, which is exposed on the flanks of the Lincoln fold in Pike County, is characteristically a medium to thickly bedded, medium to finely crystalline dolomite. A freshly exposed surface of the dolomite is bluish gray, but a weathered surface is yellowish brown or tan. Individual beds range from 1 to 3 feet in thickness and are frequently separated by thin shale partings. The dolomite contains vugs and veinlets that are filled either with calcite or petroliferous residue. Locally, irregular chert nodules are scattered throughout the member. The Bowling Green is sparsely fossiliferous. Casts and molds of crinoid ossicles are the most abundant fossil material. The thickness of the member ranges from 2 feet to as much as 60 feet. In places it is unconformable on upper Ordovician beds; elsewhere it lies unconformably on the Cyrene member.

Sexton Creek formation.—In southeastern Missouri, the Sexton Creek formation is an olive gray, medium to finely crystalline, cherty limestone. The bedding is thin, irregular, and commonly lenticular but may appear massive on weathered surfaces. Chert in the form of layers and lenses is especially abundant in the lower part of the formation where the chert is intercalated with the limestone. Upon weathering, the limestone forms re-entrants between protruding knobs and layers of the more resistant chert, thus giving the formation a very characteristic appearance. Green shale is also interbedded with the limestone. The thickness of the formation ranges from 20 to 60 feet in this area. An erosional unconformity is present at its base.

In northeastern Missouri, the distribution of the formation is limited to one or possibly two outliers situated along the Mississippi River bluffs near the Lincoln-Pike county line. Here the formation is a white to light gray, finely crystalline, siliceous limestone which contains a small amount of thin, slabby, milk white chert. Its thickness is estimated to be between 10 and 15 feet. Its upper stratigraphic relations cannot be determined in the area, but it is believed, on the basis of outcrops in Illinois, that the formation is unconformably overlain by Devonian strata. In the area, the Sexton Creek is unconformable on the underlying Edgewood.

Niagaran Series

The youngest Silurian rocks presently recognized in Missouri are assigned to the Niagaran Series. The Series is recognized only in the southeastern part of the state where it is represented by one formation, the Bainbridge. Boucot (1958), in a recent report, has indicated that the upper part of the Bainbridge formation may belong to the lowermost part of the Cayugan Series. Lowenstam (1949) raised the Bainbridge to group status and divided the group into two formations, Moccasin Springs (upper) and St. Clair (lower). This proposal has not been adopted by the Missouri Geological Survey.

Bainbridge formation.—The Bainbridge is typically a dark red, argillaceous limestone and is probably one of the most easily recognized formations in southeastern Missouri. Light to medium gray limestone beds which are mottled with purple and green colors are common in the dominantly reddish limestone. The basal part of the formation contains beds of argillaceous and slightly silty limestone that becomes increasingly more shaly upward. Glauconite is common in the basal part of the formation. The bedding is thin and irregular, and the formation's thickness ranges from 30 to about 160 feet. The formation is unconformably overlain by the Baily formation (Devonian) and lies disconformably upon the Sexton Creek formation.

Devonian System

by

John W. Koenig

The Devonian rocks of Missouri consist almost entirely of limestone and dolomite. Shale, sandstone, and chert are secondary in quantity and prominence. The rocks of the System are assigned to nine formations which are present in nearly all parts of the state. The formations range in age from Early to Late Devonian. The older Devonian formations are present in southeastern Missouri, and the younger formations in central and northeastern Missouri. Isolated outliers of undifferentiated Devonian rock occur at a few localities within the area of the Ozark uplift. Formations of questionable Devonian or Mississippian age (Chattanooga, Grassy Creek, Saverton, Louisiana, Glen Park, Sylamore, and Bushberg) are described elsewhere in the report.

In southeastern Missouri, Devonian rocks are exposed in the area of Ste. Genevieve, Perry, Cape Girardeau, and Scott Counties. They are Early and early Middle Devonian in age and comprise six formations which are in ascending order of succession: the Bailey and Little Saline formations (Lower Devonian); and the Clear Creek, Grand Tower, Beauvais, and St. Laurent formations (Middle Devonian). Exposures of these formations are geographically scattered and the sections are incomplete. In Ste. Genevieve County, Devonian rocks are intimately involved in the Little Saline fault complex. In southeastern Perry County, they are exposed along a narrow belt of complex structural deformation. Only the oldest of Missouri Devonian formations, the Bailey, crops out in eastern Cape Girardeau County in an essentially unfaulted belt approximately 8 miles wide. Farther south, in Scott County, small exposures of the formation are present in a fault complex just north of Commerce. Because of the discontinuity and incompleteness of the outcrops in southeastern Missouri the thickness of the System can only be roughly estimated as being between 700 and 1,100 feet.

The Devonian rocks of central and east-central Missouri are late Middle Devonian and Late Devonian in age. The late Middle Devonian is represented by the Callaway formation which is exposed in a narrow belt of outcrops north of the Missouri River and in peripheral exposures around the northwest plunging nose of the Lincoln fold in Ralls County. The Late Devonian formation, the Snyder Creek, crops out in a limited area in Callaway and Montgomery Counties. The total thickness of the Devonian in these outcrop areas rarely exceeds 50 feet, but in the subsurface where these Devonian beds extend into Iowa and Illinois, the System attains a thickness of about 200 feet.

In southwestern Missouri, the Devonian System is represented in a small area of central Barry County by the Fortune formation which is Middle Devonian in age and which does not exceed a thickness of 6 feet.

Missouri's undoubted Devonian rocks are unconformable with older and younger rocks. In northern Missouri, Middle and Upper Devonian rocks rest on various formations of Ordovician and Silurian age and are unconformably overlain by beds of Mississippian age. In southeastern Missouri, Lower and Middle Devonian rocks lie unconformably on Silurian beds and are overlain unconformably by Mississippian formations. In southwestern Missouri, Devonian strata rest on Ordovician rocks and are unconformably overlain by Mississippian strata.

A few Devonian formations are economically valuable as sources for cut stone, agricultural limestone, road metal, and concrete aggregate. The limestone of the Little Saline and Grand Tower formations was quarried near the village of Ozora in Ste. Genevieve County for a number of years for ornamental building stone. The limestone of the Callaway formation in Boone, Cooper, and Callaway Counties is currently quarried for aglime, road metal, and concrete aggregate.

Lower Devonian Series

Bailey formation.—Three characteristic but gradational lithologies can be recognized in exposures of the Bailey formation. The lower part of the formation consists of grayish-tan and light brown, dense, thinly bedded limestone which is intercalated with blue, green, and pink shale. The middle part is characterized by thick beds of argillaceous limestone which is pale blue and mottled with tan colored streaks and blotches. The upper part is a tan colored, thinly and evenly bedded limestone with interbedded chert and shale. Light gray chert is present throughout the formation in the form of nodules and layers. In some places, the chert may amount to as much as one-half of the formation. The thickness of the Bailey, which covers much of the eastern third of Cape Girardeau County and is exposed in the fault areas of Ste. Genevieve and Perry Counties, is about 300 feet. Because of the lithologic similarities of the adjacent parts of the Bailey and the underlying Bainbridge formation (Silurian), there is some question as to the position and character of the contact. Although an unconformity is assumed to be present, it is not readily apparent.

Little Saline formation.—The Little Saline formation is a white, coarsely crystalline, thickly bedded limestone. The lower part is abundantly fossiliferous, and crinoidal beds are present near the top. The formation is approximately 100 feet thick at its type locality near the Little Saline fault area in Ste. Genevieve County, and it thins to 25 feet within a short distance. It rests unconformably on the Bailey formation and is unconformably overlain by the Grand Tower formation.

Middle Devonian Series

Clear Creek formation.—The Clear Creek formation is a white to tan to chrome yellow, thinly bedded chert with brown to reddish ferruginous bands and some concretionary limonitic masses. The estimated thickness of the formation is about 300 feet in its restricted outcrop area in eastern Perry County. Here, it lies unconformably on the underlying Bailey formation, indicating the local absence of

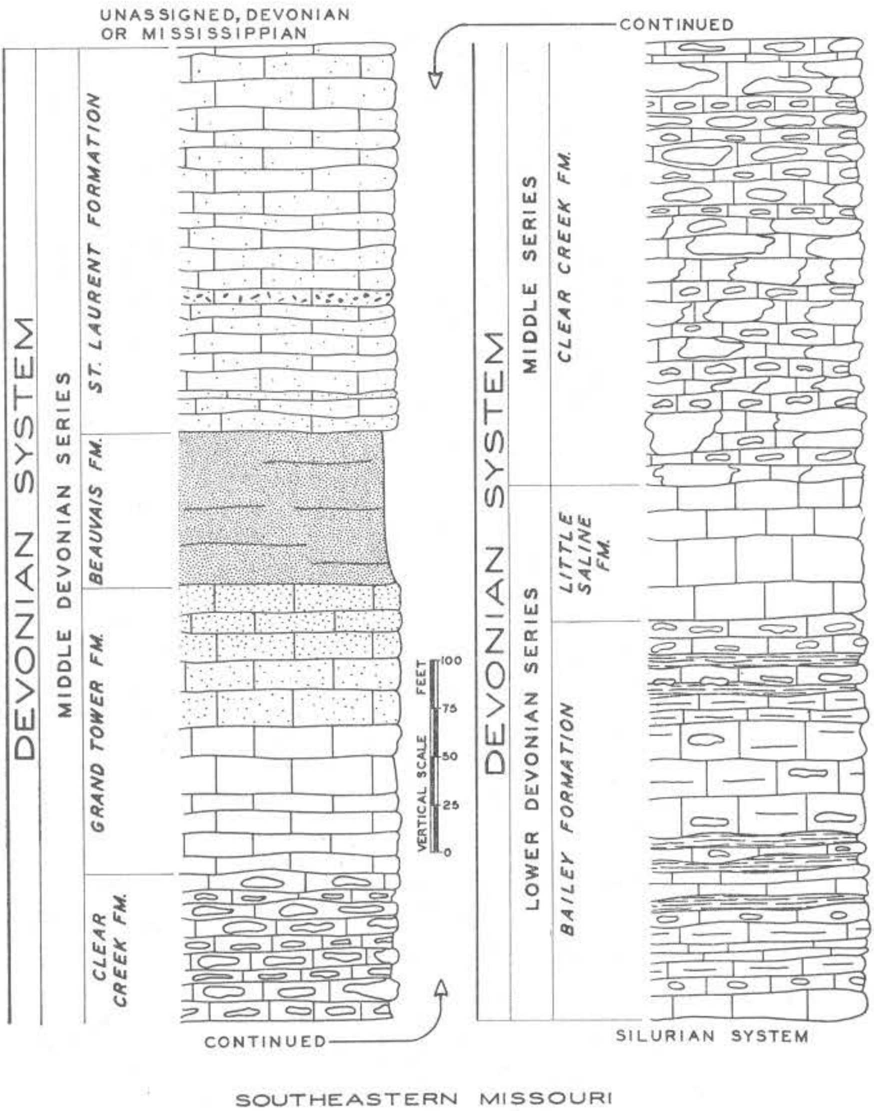

Fig. 7. Devonian System; Lower and Middle Devonian Series.

the Little Saline formation the equivalent of which is present a few miles to the east in Illinois. Where the Little Saline is absent, the Clear Creek is not differentiated from the Bailey in the subsurface of Missouri because of its close similarity to the Bailey.

Grand Tower formation.—The Grand Tower in Missouri is a limestone, the upper part of which is arenaceous. In the area of the Little Saline fault zone in Ste. Genevieve County, the limestone is light gray to almost white, dense to coarsely crystalline, and regularly bedded. In the few limited exposures of the formation in Perry County, it is purplish gray or grayish tan in color and is finely crystalline in texture but varies locally from dense to coarsely crystalline. The upper part of the formation is marked by an abundance of the brachiopod *Schizophoria*, and the lower part is predominantly coralline. In some places, coral remains are so numerous that they form biostromes, with the coral *Favosites* being the most abundantly represented. In Ste. Genevieve County, the formation is approximately 250 feet thick, but in Perry County, it thins to about 100 feet. It lies unconformably on the Clear Creek formation in eastern Perry County and apparently is unconformable on the Little Saline in Ste. Genevieve County. It merges with no observable sedimentary break with the overlying Beauvais formation.

Beauvais formation.—The Beauvais is nearly white to yellowish brown quartzose sandstone which is remarkably similar to the sandstone of the St. Peter formation (Ordovician). It is about 80 feet thick and restricted to an area of less than one square mile within the Little Saline fault complex in Ste. Genevieve County. It is conformable with the underlying Grand Tower and the overlying St. Laurent. The Beauvais occurs sporadically in the subsurface of southwestern Illinois several miles east of St. Louis where it is considered to be the basal member of the Lingle formation.

St. Laurent formation.—Limestone is the dominant constituent of the St. Laurent. It is gray or bluish gray, dense, brittle, and thinly bedded. Most of it is arenaceous with local concentrations of sandstone. At one locality, an intraformational limestone conglomerate has been noted. Although all of the known exposures of the formation in the faulted outcrop areas of Ste. Genevieve and Perry Counties are incomplete, its thickness is estimated as being 275 feet. Its relationship with the underlying Beauvais formation is believed to be conformable. It is unconformably overlain by the Fern Glen formation (Mississippian) and by sandstone blocks suggestive of the Bushberg formation.

Callaway formation.—Until recently (1950), the Callaway formation has been considered as distinct from the Ashland, Cooper, and Mineola formations, all of which were thought to be closely related stratigraphically and chronologically. The Ashland, Cooper, and Mineola are now recognized as facies of the Callaway formation. The lithic characteristics of the Callaway are variable within short distances, both vertically and horizontally. Various limestone types interfinger with one another and with heterogeneously intercalated sandstones and conglomerates. Because of this condition, the formation is regarded as an undifferentiated unit in the subsurface. The formation is typically represented in Callaway County outcrops where the Cooper and Mineola facies interfinger. In this area, the Cooper facies is a light to medium brownish-gray, dense to finely crystalline limestone which in some places is very fossiliferous. Toward the west, in the general vicinity of Pettis, Cooper, and Moniteau Counties, the Cooper facies predominates and is a bluish-gray to dark tan, dense to lithographic, massive limestone which is almost devoid of fossils and impurities. The Mineola facies is commonly a light to medium brown, coarsely crystalline limestone which is locally very fossiliferous and is cross-laminated in some exposures. Sandstone and arenaceous limestone are not uncommon in the basal part of the Callaway formation, and in the eastern part of Ralls County, parts of the formation are conglomeratic. The Ashland facies, which is restricted to a few scattered exposures in Boone and Moniteau Counties, is a white to light brown, coarsely crystalline, clastic limestone. Fragmented internal molds of the brachiopod *Rensellandia missouriensis* are very abundant, and in some places the rock is essentially a mass of these molds.

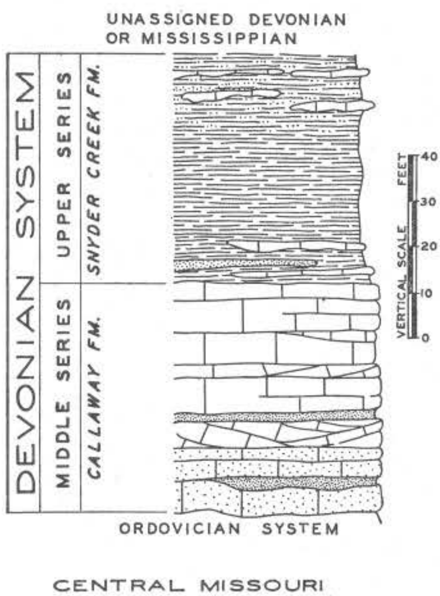

Fig. 8. Devonian System; Middle and Upper Devonian Series.

A white, friable, quartzose sand cemented with calcium carbonate generally lies at or near the base of the Callaway. Where the Mineola facies is present, the sand separates it from the remainder of the overlying formation. Where the sand is absent, the basal limestone of the Callaway is sandy. The sand varies between 16 inches and 5 feet in thickness, averaging 2 feet, and is persistent in the Devonian outcrop area in Callaway County. It has been tentatively traced northeastward in the subsurface to outcrops in Ralls County.

In central and northeastern Missouri, the Callaway formation lies on an erosion surface and is in contact with Ordovician formations from the Jefferson City to the Maquoketa. It is unconformably overlain by Upper Devonian formations, but where these are absent, it is in contact with beds of Mississippian age. Its thickness is variable. In the outcrop area, it ranges from less than an inch to as much as 60 to 70 feet thick. In the subsurface, the Devonian (Callaway in part) thickens to the northwest. In the Forest City basin, undifferentiated Devonian limestones attain a maximum thickness of about 700 feet.

Fortune formation.—The Fortune formation is composed of a lower sandstone, a middle chert, and an upper limestone. The poorly sorted quartzose sandstone is stained brown by iron oxide and cemented with calcium carbonate. The chert varies in color from light cream to olive brown or grayish tan and has alternating light and dark bands of color. It is dense with a waxy luster, and it contains embedded white spicules. The limestone is black and dense. The formation has a maximum thickness of 6 feet. The known surface and subsurface extent of the unit is restricted to the southeastern part of Barry County where it lies unconformably on the Cotter formation (Ordovician). It is unconformably overlain in different places by both the Chattanooga and the Compton formation (Mississippian). Conodonts and a few fragmentary brachiopods and fish teeth in the formation indicate possible equivalence to the Clifty formation of Arkansas.

Upper Devonian Series

Snyder Creek formation.—The Snyder Creek is composed of calcareous and arenaceous shale which contains thin beds of limestone and sandstone. Lithic interrelations vary from place to place. The lower part of the formation is predominantly a grayish-green shale containing an increasing number of thin sandstone and limestone beds near the base. The upper part of the formation is an earthy, yellow drab, concretionary, slightly sandy shale with thin, profusely fossiliferous, light grayish-tan to dark brown limestone beds near the top. Within its limited outcrop area in Callaway and Montgomery Counties, the Snyder Creek varies in thickness from a maximum of 60 feet to a minimum of less than 10 feet. Its surface distribution is patchy, and its subsurface extent is limited to eastern Callaway, western Montgomery, and southeastern Audrain Counties. It lies unconformably beneath Mississippian beds and unconformably upon the underlying Callaway formation. It is characterized by a variety of stropheodontid brachiopods and by the bryozoan *Lioclema occidens* which is very abundant in the lower part of the formation.

Unassigned Devonian or Mississippian Formations

by

John W. Koenig

Because there is no unanimity of opinion concerning the age assignment of the formations described in this part of the report, it is

Table 1

Missouri	*East-Central*	*Northeastern*	*Central*	*Southwestern*	*Northwestern*
Mississippian	Burlington/Fern Glen	Hannibal	Chouteau gp. undif.	St. Joe/Compton	Chouteau/Gilmore City
Unassigned Dev.-Miss.	Bushburg Glen Park	Louisiana Saverton Grassy Creek	Sylamore or Bushberg	Chattanooga Sylamore	"Kinderhook shale"
Older Paleozoic	Ordovician	M. Dev./Sil./Ord.	M. Dev./Ord.	Ordovician	Dev. undif.

considered inadvisable at this time to assign them to either the Devonian or Mississippian Period until agreement is reached on the type of criteria most suitable for the placement of the systemic boundary in this part of the geologic record. The formations are present in various parts of the state and do not occur together in any one area except in short sequences; therefore, they cannot all be described as a succession in the order of superposition. Their relative stratigraphic (not correlative) positions and general geographic locations are shown in Table 1, and they are described in the general order of their appearance from east to west.

The Devonian or Mississippian units of the east-central part of the state originally were assigned to the Sulphur Springs formation by Ulrich in 1904. As originally defined, this formation consisted of three members: an upper sandstone which he referred to as the "Bushberg sandstone", a middle, oolitic limestone which he called the "Glen Park (oolitic) limestone", and a lower shale for which no subordinate name was given but was designated as being either earliest Kinderhook or late Devonian in age. In 1928, Weller and St. Clair proposed that another shale member lying above the "Bushberg sandstone" in Ste. Genevieve County be included in the formation and indicated that they had not certainly recognized the basal shale in that area. Branson, in 1934, raised the Sulphur Springs to group rank. Present usage tends to disregard the black shale units of the original definition and to regard the Glen Park and the Bushberg as the only proper formations of the group.

Unconformably overlying Middle Devonian, Silurian, and Ordovician formations in Marion, Ralls, and Pike Counties, there is a shale sequence which is believed by many geologists to be composed of two formations, the Grassy Creek and the Saverton. The age of these two formations has not been determined to the satisfaction of all concerned with the problem. Some consider the formations to be early Mississippian, and others view them as Late Devonian. Recent conodont studies by M. G. Mehl suggest to him that they are Late Devonian in age. In a few places, the upper shale, the Saverton, is unconformably overlain by the Hannibal formation (Mississippian), but throughout most of the area, the Louisiana formation intervenes, and it appears to lie conformably on the Saverton and in some places disconformably beneath the Hannibal. The age of the Louisiana is also uncertain, being considered as Devonian by some and as Mississippian by others.

The Chattanooga shale of southwestern Missouri and northern Arkansas had originally been referred to as the "Eureka shale", but in 1904 the name "Noel shale" was proposed to replace it because the term Eureka was pre-empted. At this time, E. O. Ulrich regarded the shale as early Mississippian in age and correlative with Kinderhookian strata elsewhere. The following year, after studying the exposures at Noel, Missouri, he stated that he had procured evidence demonstrating the Devonian age of the black shale, as well as proving it distinct from the greenish shale at Eureka Springs, Arkansas, the type area of the "Eureka shale". In 1905, Ulrich correlated the shale with the Chattanooga of Tennessee. Although the Devonian or Mississippian age assignment of the unit has since been debated, the name Chattanooga has remained in common use in preference to the name Noel.

Devonian or Mississippian rocks in northwestern Missouri are present in the subsurface and are essentially confined to the limits of the Forest City basin. The rocks are predominantly black and gray shale with small amounts of dolomite, sandstone, and hematitic oolite. They lie unconformably on undifferentiated carbonate rocks which many petroleum geologists and drillers informally refer to as the "Hunton"—the Hunton, as originally defined, includes rocks of both Devonian and Silurian age—and they are disconformably overlain by lower Mississippian formations (Gilmore City and/or Chouteau). In southwestern Iowa where the central part of the basin is located, the shale unit is 200 to 250 feet thick and thins to less than 30 feet near the basin's periphery.

Nomenclature of the shale sequence as well as its age determination within the Forest City basin is varied and uncertain. In the Missouri portion of the basin, the name "Kinderhook shale" has been applied to the total shale sequence with the understanding that its lower part is correlative with the Chattanooga although the name implies a Mississippian age assignment for the entire unit. In Nebraska and Kansas, that part of the shale succession which is above a persistent zone of hematitic oolite is regarded as Mississippian in age and has been named the Boice shale by E. C. Reed. A thin limestone unit under lying the Boice in the Nebraska section has been tentatively considered by G. E. Condra to be suggestive of the Louisiana of northeast Missouri. The remainder of the Nebraska section is referred to the Chattanooga and placed in the Devonian. In Kansas, the section below the Boice is regarded as Chattanooga but of undetermined Devonian or Mississippian age.

East-central and Central Missouri

Glen Park formation.—The Glen Park is a light to medium gray or yellowish-gray, oolitic limestone. At the type locality in Jefferson County, dark phosphatic bands are scattered throughout the unit. It is conglomeratic near the base where it contains small phosphatic nodules and reworked shale. At its southernmost exposure along the Mississippi River a few miles south of the northern boundary of Ste. Genevieve County, it is represented for the most part by an arenaceous limestone which is yellow or gray in color and cross bedded and which contains small lenticular areas of gray, oolitic, fossiliferous limestone. Small, irregularly shaped, phosphatic nodules are locally abundant. The formation is sporadically present from this locality northward along the Mississippi River to near the vicinity of Sulphur Springs in Jefferson County. Thence, isolated exposures are present in a narrow band trending northwest through Franklin, St. Louis, St. Charles, and Warren Counties. Its northernmost exposure is in west-central St. Charles County on Dardenne Creek. At this locality, calcareous siltstone and sandstone make up the greater thickness of the formation, and the cross-bedded oolitic limestone is confined to the lower part of the section. From this locality, an oolitic limestone at the approximate stratigraphic position of the Glen Park can be traced in the subsurface northwestward through St. Charles, Warren, Lincoln, Montgomery, and eastern Audrain Counties to the Ralls-Audrain county line. This subsurface unit appears to be limited northeastward by the southwest flank of the Lincoln fold, and it has not been identified west of Montgomery County. In most areas, the Glen Park is unconformable on rocks of Ordovician age, but in some localities it is believed to be unconformable on rocks of Middle Devonian age. It is unconformably overlain by undoubted Mississippian rocks in many areas, but locally the Bushberg sandstone or sandstones of undetermined age intervene conformably.

In the Ste. Genevieve County area, the cross-bedded oolitic Glen Park limestone is about 14 inches thick. It crops out as a single bed 2½ feet thick at the type locality in Jefferson County. In west-central St. Charles County, it is approximately 30 feet thick with a 6-foot bed of oolitic, cross-bedded limestone near the base.

The Glen Park was originally considered by Stuart Weller to be of approximately the same age or slightly older than the "Hamburg oolite", an oolitic limestone which lies between the Louisiana and Hannibal formations in southwestern Illinois.

Bushberg formation.—Recent unpublished investigations suggest to M. G. Mehl that in Missouri the use of the term Bushberg has been widespread and indiscriminate, and that many of the sandstones to which the name has been applied may actually be of different ages, some Mississippian, others Devonian. Therefore, in this report the name Bushberg is restricted to the sandstone which occurs in the immediate area of the formation's type locality in Jefferson County. Here, the formation is approximately 14 feet thick and is a yellow to yellowish-brown, fine to coarse grained friable, porous, quartzose sandstone similar in texture to the St. Peter sandstone. The unit can be traced only a short distance along the west side of the Mississippi River from Glen Park to Bushberg. At Glen Park, the formation conformably overlies the Glen Park formation but is unconformably overlain by the Fern Glen formation of Osagean (Mississippian) age. Mehl believes that this particular sandstone unit is Devonian in age, but at this time he does not consider the evidence sufficient to definitely correlate it with sandstones of similar lithology and stratigraphic position elsewhere in Missouri. Such sandstones occur sporadically (in some cases as channel fillings in underlying Ordovician or Middle Devonian rock) in a belt of outcrops along the northern edge of the Missouri River floodplain in St. Charles, Warren, Montgomery, and Callaway Counties. A thin, blanket-type sandstone deposit which Mehl regards as Mississippian occurs immediately beneath the Chouteau group throughout most of central and southwest Missouri. This unit has been called Bushberg by some authors, but others have referred to it as the Sylamore.

Northeastern Missouri

Grassy Creek formation.—The Grassy Creek is a dark olive gray to brownish-black, hard, fissile, carbonaceous shale. In the type area, in northeastern Missouri, the formation contains a basal conglomerate 6 to 12 inches thick that is composed of a silty shale matrix containing dark gray phosphatic pebbles, small chips of hard dark gray shale, quartz sand, fish teeth, and black coprolitic masses. Elsewhere, the base of the formation is marked either by a brownish, fine-grained, argillaceous sandstone 1 to 3 feet thick or by a soft, arenaceous, greenish-gray shale approximately 1 foot thick, overlain by a thin hard sandstone containing phosphatic pebbles and fish teeth. Conodonts and spores are common throughout the formation.

Exposures of the Grassy Creek are almost entirely restricted to the flanks of the Lincoln fold in Marion, Ralls, and Pike Counties. Scattered exposures of black shale, presumably correlative with the Grassy Creek, occur in the counties bordering the Mississippi River as far south as Ste. Genevieve County (see discussion of Sulphur Springs group). In northern Pike County, the formation has a maximum thickness of 43 feet. It thins rapidly southward and westward to less than a foot in thickness. North of the southern Marion County exposures, the formation dips beneath the surface, apparently thickens, and merges with the Maple Mill formation of Iowa. Well cuttings of the Grassy Creek are indistinguishable from cuttings from the overlying Saverton formation; therefore, the formation's true thickness in the subsurface cannot be determined.

A pronounced regional unconformity separates the Grassy Creek from the underlying Ordovician, Silurian, and Middle Devonian formations. The contact with the overlying Saverton formation is conformable and in many instances difficult to determine because of the similarity of the two shales. The Grassy Creek extends into west-central Illinois and is generally considered to be equivalent to part of the Chattanooga of Tennessee and to the New Albany of Indiana and Kentucky. It possibly is equivalent to some part of the black shale commonly referred to as the "Kinderhook shale" present in the subsurface of northwestern Missouri in the area of the Forest City basin. It also is considered to be equivalent to the Chattanooga formation of southwestern Missouri, Arkansas, and Oklahoma.

Saverton formation.—The Saverton is a greenish-gray or bluish-gray, fissile, silty, and sandy shale. It weathers to an unctuous silty clay. The upper part of the formation in most areas is a bluish-gray, calcareous, blocky mudstone. In places, the upper half of the formation contains a single bed of light gray to reddish-brown, friable sandstone which is from 6 inches to 2 feet thick. In northern Pike County, in the type area of the Grassy Creek formation, the Saverton is 14 feet thick. Thence, it thins rapidly to the west, south, and east. It has approximately the same areal extent as the Grassy Creek. The shales of the Saverton formation grade into the underlying shales of the Grassy Creek. There is no distinctive difference in the respective conodont faunas or mineral composition of the two formations. They both contain fish teeth, lingulid brachiopods, and spores. Because of these similarities, several observers regard the Saverton and Grassy Creek as parts of a single formation. Locally, the Saverton appears to grade upward into the basal mudstone of the overlying Louisiana formation. However, in those areas where the sandstone of the Saverton lies directly beneath the Louisiana limestone, the contact is sharp. In areas where the Louisiana is absent the Hannibal formation rests upon the Saverton, and in these areas, the contact is obscure.

Louisiana formation.—The Louisiana in its type area is typically a dense to lithographic, bluish-gray, hard, brittle limestone which breaks with subconchoidal fracture. The limestone beds, which have an average thickness of 6 inches, are separated by yellowish-brown, silty, dolomitic partings. In the area of Clarksville and Louisiana in Pike County, except for a thin zone of dolomitization adjacent to the upper contact, the Louisiana is very pure limestone. Northward, the dolomitized upper part gradually thickens at the expense of the lower limestone. In Marion County near Hannibal, the formation is entirely composed of yellowish-brown, massive to slabby beds of silty dolomite. The dolomite is interbedded with silty claylike dolomitic partings. Scattered irregular masses of clear, very coarsely crystalline calcite 2 to 3 inches in diameter are common throughout the formation. The lowest bed of the Louisiana is about 15 inches thick and is underlain by a thin, yellowish-brown, sandy, calcareous, mudstone or soft, silty limestone which is variable in thickness and which may be absent or unrecognizable in many places. In the type area, this unit is 4 inches thick.

In the vicinity of the junction of the Ralls-Marion county line and the Mississippi River, the Louisiana has a maximum thickness of 67 feet. From this locality, the formation thins rapidly in all directions except northward. It is absent west of Bowling Green in central Pike County and south of Clarksville. Northwest of southern Marion County, the formation dips beneath the surface and maintains a fairly uniform thickness of approximately 60 feet in a wide belt subparallel to the Mississippi River at least as far north as the Iowa line. It thins westward and is absent in well records west of central Knox County.

To some observers, the Louisiana presumably is conformable with the underlying Saverton formation because the adjacent mudstones of the two formations appear to merge one into the other and to have similar faunas. On the other hand, some investigators have shown that a distinct lithologic, disconformable break between the two formations can be seen at some exposures. At a few localities in Missouri, it appears that the overlying Hannibal formation is disconformable on the Louisiana, but in many exposures the relationship appears conformable where thin, discontinuous, silty, dolomitic beds of the upper Louisiana merge with beds of siltstone and shale in the lower Hannibal.

Southwestern Missouri

Chattanooga formation.—The Chattanooga is a fissile, black, carbonaceous, slightly arenaceous, spore-bearing shale. It has a fetid but not a bituminous odor and yields small quantities of oil upon distillation. Local concentrations of pyrite nodules and concretions are common. Fresh exposures exhibit a jointed structure, with the joints obliquely inclined to the bedding, thus giving the shale a tendency to break into prismatic blocks. The formation breaks down quickly and is covered in most areas. Major exposures of the Chattanooga in Missouri are limited to McDonald and Barry Counties in the extreme southwest corner of the state. In McDonald County, the shale has a maximum thickness of 20 to 30 feet in the vicinity of the town of Noel and along Mill Creek. It thins eastward to 10 or 12 feet in Barry County and feathers out in the subsurface near the east edge of the county. It does not extend northward in the subsurface much beyond the southern part of Newton County. However, a few thin, isolated occurrences of black shale 3 to 6 feet thick are recorded in the well records of Greene County and western Christian County, and a few exposures 2 to 3 feet thick occur along the James River in Christian County a few miles southwest of Nixa. The black shale rests unconformably on Ordovician dolomite (Jefferson City and/or Cotter formations) in southwestern Missouri. It is unconformably overlain by various Mississippian formations ranging in age from Kinderhookian to Osagean. The Chattanooga extends southward into northern Arkansas and is correlated by most geologists with some part of the black shale sequence present at the type locality of the formation in Tennessee. The formation has been traced in the subsurface of Kansas northward into the Forest City basin where it is considered at present as part of the "Kinderhook shale" sequence of Missouri.

Northwestern Missouri

"Kinderhook shale".—As pointed out by Wallace Lee (1956), the name "Kinderhook shale", however inappropriate, has been widely accepted and commonly used by most petroleum geologists. The subsurface division of the Missouri Geological Survey also recognizes the limitations of the term but applies it consistently in the designation of this particular shale unit on its well records and regards such application as the only practical expedient until such time as the unit can be studied in detail.

In Missouri, the upper part of the "Kinderhook shale", which has been referred by Reed and Lee to the Boice in Nebraska and Kansas, consists of a grayish-green shale which is in part carbonaceous and interbedded with dolomitic shale. The basal part contains beds of oolitic limonite and hematite or of dark red shale. This interval may also include irregularly shaped hematitic oolites in the upper part. The thickness of the unit varies between 25 and 50 feet. Below the lower hematitic oolite zone, there is a black, fissile, carbonaceous shale which is micaceous. Spores are present throughout. In Missouri, the thickness of the shale increases from a feather edge around the periphery of the basin in Clay, Caldwell, Daviess, and Harrison Counties to a thickness of 150 to 200 feet in Holt and Atchison Counties.

Mississippian System

by

Alfred C. Spreng*

Rocks of Mississippian age are widely exposed in the northeastern, central, and southwestern parts of Missouri. They occupy about one-fourth of the state's total surface area and occur in the subsurface in all of northern and northwestern Missouri. All the major Series of the Mississippian System are represented in the state. These are the Kinderhookian, Osagean, Meramecian, and Chesterian. The Series are separated by unconformities that are not particularly noticeable at any one locality or local area; therefore, the units have been defined almost entirely on the basis of paleontologic data. The lower boundary of the Mississippian has not been firmly established (see Devonian-Mississippian discussion), but a definite erosional unconformity does form its upper boundary in Missouri. The break is especially pronounced in the northern half of the state where middle Pennsylvanian strata lie on pre-Chesterian rocks.

One of the difficulties of presenting a statewide description of the Mississippian rocks of Missouri is that the formational succession is not the same in all areas of the state where the System is represented. As in the case of the Chesterian Series, correlative parts of the System may be separated by nearly the width of the state with the respective formational units designated by different names. Also, some units, as the Grand Falls formation, are locally restricted and are not everywhere present within the state. Because of this situation and to facilitate description, six regions of the state where Mississippian rocks are present have been arbitrarily delineated and designated as follows: northeastern, east-central, southeastern, central, southwestern, and northwestern. The areal extent and location of these six regions are shown in Figure 9, and the Mississippian stratigraphic succession for each is given in Table 2.

In northeastern Missouri, the Mississippian System is represented by eight formations which are assigned to the Series as follows: Hannibal and undifferentiated Chouteau (Kinderhookian), Burlington and Keokuk (Osagean), and Warsaw, Salem, St. Louis, and Ste. Genevieve (Meramecian). Except for the Hannibal formation which is composed of shale and siltstone, the System in this part of the state is made up of carbonate rock and minor amounts of chert, shale, and sandstone. The aggregate thickness of the Mississippian System in this area is about 330 feet.

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Table 2

Missouri		*East-Central and Southeastern*	*Northeastern*	*Central*	*Southwestern*	*Northwestern*
MISSISSIPPIAN SYSTEM	Chesterian Series	Vienna Tar Springs Glen Dean Hardinsburg Golconda Cypress Paint Creek Yankeetown Renault Aux Vases			Fayetteville Batesville Hindsville (Carterville)	
	Meramecian Series	Ste. Genevieve St. Louis Salem Warsaw	Ste. Genevieve St. Louis Salem Warsaw	Salem Warsaw	St. Louis Salem Warsaw	Ste. Genevieve St. Louis Salem Warsaw
	Osagean Series	Keokuk Burlington Fern Glen	Keokuk Burlington	Keokuk Burlington Pierson	Keokuk Burlington Grand Falls Reeds Spring Pierson	Keokuk Burlington
	Kinderhookian Series	Chouteau gp. undif.	Chouteau gp. undif. Hannibal	Chouteau gp. Northview Sedalia Compton	Chouteau gp. Northview Compton	Chouteau gp. undif.

All the major time-stratigraphic divisions of the Mississippian System are represented in the east-central and southeastern areas of the state. The Kinderhookian is represented by undifferentiated Chouteau limestone; the Osagean by Fern Glen, Burlington, and Keokuk limestone and chert; the Meramecian by Warsaw, Salem, St. Louis, and Ste. Genevieve limestone, dolomite, and shale; and the Chesterian by the following predominantly clastic formations: Aux Vases, Renault, Yankeetown, Paint Creek, Cypress, Golconda, Hardinsburg, Glen Dean, Tar Springs, and Vienna. The aggregate thickness of the Mississippian in this part of the state is about 1,250 feet.

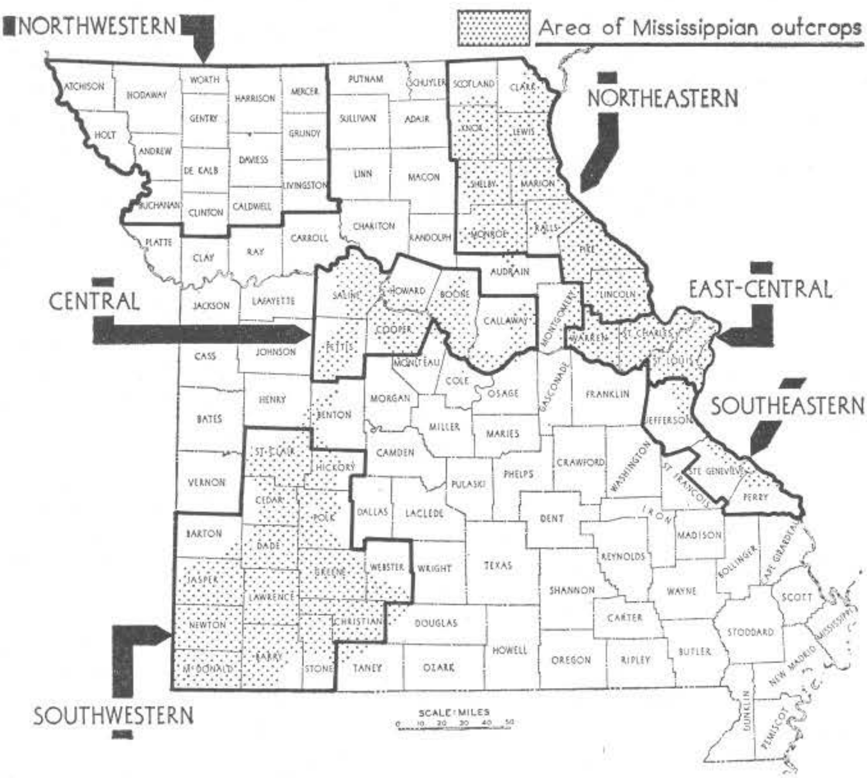


Fig. 9. Map of the regional distribution of the Mississippian System in Missouri.

The Mississippian System in central Missouri is about 400 feet thick and is composed mostly of carbonate rocks and chert. The lower three formations, Compton, Sedalia, and Northview, together form the Chouteau group of the Kinderhookian Series. The Osagean Series is represented by the Pierson, Burlington, and Keokuk formations, and the Meramecian by the Warsaw and Salem formations. In much of the area, the Pierson is thin and difficult to distinguish from the overlying Burlington, and it has been regarded for many years as the lower brown dolomite bed of the Burlington. The Burlington and the Keokuk formations are lithologically very similar within the area, and the position of their contact is difficult to determine. Because of this, the two formations are customarily treated as a combined unit with their names being joined by a hyphen, as Burlington-Keokuk.

Southwestern Missouri contains a sequence of Mississippian rock units which are more variable in lithology than comparable successions elsewhere in the state. The factor most responsible for this variability is lateral facies changes within given units especially in the Kinderhookian and lower Osagean Series. In the northern part of the region, the Kinderhookian is represented by the Compton, Sedalia, and Northview formations of the Chouteau group. Southward, both the Sedalia and Northview interfinger and appear to eventually pinch out so that at the southern limit of the region it is believed by some observers that they are not present and that only a thin extension of the Compton remains. The lower part of the Osagean Series is represented in the northern part of the region by the Pierson formation which is here a thin bed of silty, dolomitic limestone. Southward, the Pierson thickens to a cherty limestone, and as it approaches the southern limits of the region, it becomes a thick varicolored red and green argillaceous limestone unit which in many respects resembles the Fern Glen formation of southeastern Missouri. Here and in adjacent areas of Arkansas and Oklahoma, the unit has been named the St. Joe formation. The balance of the Osagean Series consists of thick cherty units of limestone which make up the Reeds Spring, Grand Falls, Burlington, and Keokuk formations. These four formations are very similar in their lithologies, their formational contacts are difficult to determine, and the limits of their lateral extent are obscure. Throughout most of southwestern Missouri, it is customary to group these formations into two collective units, the Reeds Spring-Grand Falls unit and the Burlington-Keokuk unit. In the southern limit of the area and in adjacent parts of Arkansas and Oklahoma, all four units have been collectively designated as the "Boone formation". The Meramecian Series is represented principally by the Warsaw formation which is lithologically similar to formations in the underlying Osagean, but is somewhat less cherty. The Salem formation is questionably present, and the St. Louis formation is restricted to the relatively small area of eastern Barton and western Dade Counties. The Chesterian Series in this part of the state is represented by outliers of more extensive parts of the Series in Arkansas and Oklahoma. The Carterville formation in the area of Joplin is interpreted as being composed of local filled-sink deposits in older Mississippian rocks. To the south, in the restricted area of southern McDonald and Barry Counties, the Chesterian Series is represented by three formations, the Hindsville (an oolitic limestone), Batesville (a sandstone), and Fayetteville (a shale), which are believed to be the age equivalents of the Carterville. The aggregate thickness of the Mississippian System in the southwestern region is about 1,000 feet.

The character and presence of the Mississippian System in northwestern Missouri is known only from drill cuttings from wells in and around the Forest City basin. Differentiation of the stratigraphic units within the lower part of the System is based on studies of nearly similar lithologies and insoluble residues both of which are not at all diagnostic. Because of the difficulties of differentiation, the formations in this part of the System are grouped into collective units. In the Kinderhookian Series, the formations of the Chouteau group are designated as "undifferentiated Chouteau"; in the Osagean Series, the Pierson, Burlington, and Keokuk are designated as Burlington-Keokuk. The formations of the Meramecian Series, although composed largely of carbonate rock, are more distinctive as individual units, and the Warsaw, Salem, St. Louis, and Ste. Genevieve are readily differentiated. Formations of Chesterian age have not been identified in the area. The aggregate thickness of the System in northwestern Missouri is about 515 feet.

Kinderhookian Series

The type area for the Kinderhookian Series is in northeastern Missouri and in adjacent parts of Illinois and Iowa. Here, the Series is represented by the Hannibal formation which is a thick shale and siltstone unit and by a thin limestone unit designated herein as "undifferentiated Chouteau", that is more commonly referred to in older reports as the "Chouteau limestone". Three formations beneath the Hannibal in this area, the Louisiana, Saverton, and the Grassy Creek, have been assigned to the Kinderhookian in past reports by some authors, while other observers have regarded these same formations as Devonian in age. Because of the uncertainty of the age assignment of these three formations, they have been described elsewhere in this report as assignable to either the Devonian or Mississippian Systems.

South and west of the northeastern area, the Hannibal formation is absent, but the "undifferentiated Chouteau" thickens and becomes a prominent limestone unit in the central Mississippian region of the state where two additional Kinderhookian formations, the Sedalia and Northview, overlie the unit. Together, these three units form the Chouteau group, and the lower unit is herein referred to as the Compton formation. In older reports, this unit was referred to as the "lower Chouteau of Swallow" or "Chouteau (restricted) of Moore". The Sedalia formation is a dolomitic limestone and the overlying Northview a thin silty shale.

Southwestward from the central region, the Northview thickens and laterally interfingers with the Sedalia formation which southward gradually loses its identity as a formation. In the central part of the southwestern region, the Compton becomes much thinner, and it and the Northview together make up the Chouteau group. Farther to the southwest, the Northview thins rapidly and eventually appears to pinch out through overlap of the Osagean Series, and the Compton becomes thinner and apparently discontinuous. Thus, in parts of the extreme southwest area of the state, some observers believe that the Kinderhookian Series is represented by only thin discontinuous remnants of the Compton formation.

Beneath the Chouteau group throughout its extent in the east-central, central, and southwestern parts of the state, a thin, widespread sandstone occurs which has been variously referred to as "Bushberg" or "Sylamore" by different authors. This unit in Missouri has been assigned to the Kinderhookian Series by most authors, but there is no unanimity of opinion concerning its correlative relations to either the Bushberg or Sylamore formations as they are defined at their respective type localities. Because the age assignment of these two formations is in question, the blanket sandstone beneath the Chouteau group has not been specifically assigned to either the Mississippian or Devonian System in this report.

Hannibal formation.—The Hannibal formation is a fissile siltstone or shale, the upper part of which is a very fine-grained argillaceous sandstone. It is typically light gray to bluish-green in color and weathers to pale bluish-green or light brown. When weathered, it forms gentle slopes and has a banded effect wherever it is composed of alternating layers of coarse- and fine-grained siltstone.

The formation crops out throughout the northeastern Mississippian region. Its thickness is variable and reaches a maximum of approximately 100 feet in southeastern Pike County. It thins westward and southward from this area.

Fossils are sparse and are generally pyritized; brachiopods and pelecypods are major constituents of the fauna. "Rooster-tail" markings (*Taonurus caudagalli*) and irregular tubular markings (*Scalarituba missouriensis*), which are thought to be preserved worm borings, are common features in the formation. Because of the latter feature, the Hannibal formation was originally named the "Vermicular shale and sandstone".

The age equivalence of the Hannibal formation to lithologically similar formations in central and southwestern Missouri and southeastern Iowa has not been certainly established. The Hannibal appears to be disconformable on the Louisiana (Devonian-Mississippian) in a few places. Locally it is in contact with the Grassy Creek (Devonian-Mississippian), Callaway (Devonian), or Maquoketa (Ordovician). It is overlain by undifferentiated Chouteau in a few places, but where the Chouteau is absent the Hannibal is overlain by the Burlington formation.

CHOUTEAU GROUP.—The Chouteau group, as it is defined at its type locality in central Missouri, is composed of the following three formations in the order of decreasing age: the Compton, Sedalia, and Northview. The Compton is a limestone, the Sedalia a dolomitic limestone, and the Northview a shale and siltstone unit. Within the type area (Pettis, Saline, Howard, and Cooper Counties), the Chouteau group attains a maximum thickness of more than 100 feet. Exposures 50 to 75 feet thick may be seen in quarries and in the bluffs along the Missouri River in Howard and Saline Counties. The group thins and changes lithologically toward the east. In this direction the lithologies of the Compton and Sedalia formations merge to such a degree that

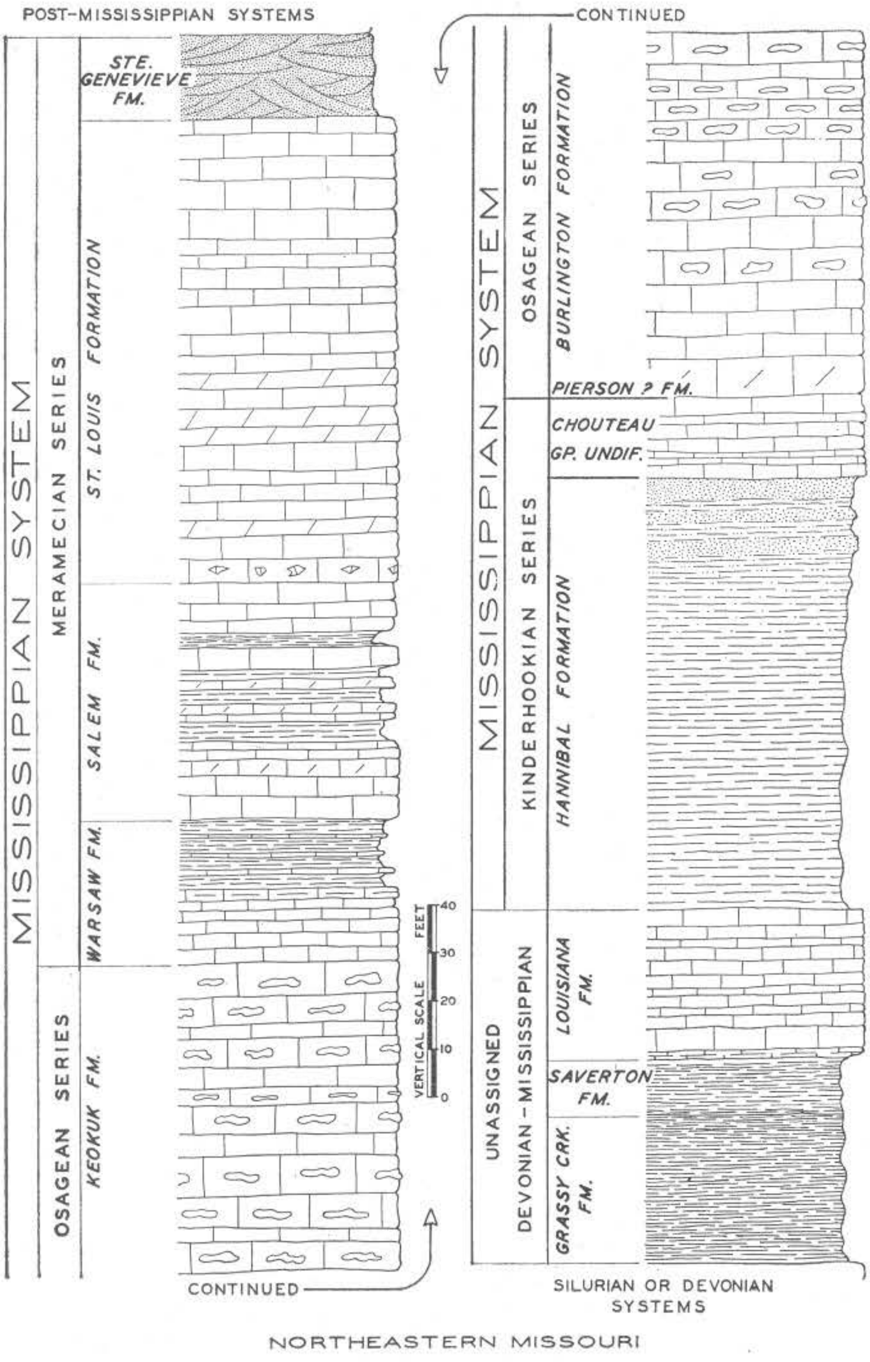


Fig. 10. Mississippian System; Kinderhookian, Osagean, and Meramecian Series, and unassigned Devonian-Mississippian formations in northeastern Missouri.

it is not feasible to subdivide them in east-central and northeastern Missouri. This combined unit is therefore designated as "undifferentiated Chouteau". The Northview thins eastward and is absent east of Howard and Cooper Counties. To the west and southwest of the type area, the Compton thins to a relatively uniform thickness of about 12 feet, and the Northview thickens at the expense of the Sedalia with which it also laterally interfingers. In the southern part of southwestern Missouri, south of Greene County, the Sedalia is absent, and the Compton and Northview together make up the Chouteau group. Farther southwest, the Northview thins rapidly and is apparently absent in the area of southern Barry and Stone Counties. The Compton also thins to less than 10 feet in this same area and is believed to be altogether absent in some places.

Compton formation.—The Compton formation is a finely crystalline to sublithographic, finely crinoidal limestone. It is very thinly bedded, and the beds are separated by green shale partings which break down readily when weathered; thus, weathered exposures of the formation are characteristically slabby or hackly in appearance. Where the formation is locally dolomitic, it is brown and massive. Chert is locally present but not abundant. The chert is bluish-gray to bluish-black with a white rim and is similar to that of the overlying Sedalia. The basal part of the Compton is sandy in places and southward becomes argillaceous.

The Compton formation is not abundantly fossiliferous at any one locality. Its chief faunal constituents are echinoderms and brachiopods. Common brachiopods are: *Schumardella missouriensis*, *S. obsolens*, *Pustula concentrica*, *Chonetes logani*, and *Leptaena analoga*. These also occur in the "undifferentiated Chouteau" of northeastern Missouri. Among the echinoderms, the blastoids *Schizoblastus roemeri* and *S. sampsoni* are the most common, as well as species of the crinoid *Platycrinites*. Weathered exposures exhibit an abundance of small crinoid columnals which stand out in relief on the surface of the rock.

The volumetric percentage of the Compton's insoluble residue is low. It is ordinarily 10 percent or less and consists of silt or clay, latticelike pyrite, and arenaceous Foraminifera, commonly referred to as "siliceous worm casts".

The Compton is differentiated from the Sedalia in the type area and to the southwest by its thinner bedding, by its greater abundance of crinoid columnals, and by its blastoids. Within this area, it has an average thickness which is less than 20 feet. In east-central and southeastern Missouri where the unit is referred to as undifferentiated Chouteau, its thickness varies from 6 to 12 feet and in some places is absent.

In central Missouri, east of Pettis County, and in northeastern Missouri, the Compton and Sedalia lithologies interfinger and form an indivisible unit of limestone and dolomitic limestone; undifferentiated Chouteau. This unit, in most localities of northeastern Missouri, consists of bluish-gray, finely crystalline limestone which becomes more dolomitic and more massively bedded in the upper part and thus resembles the Sedalia lithology of the type area. At some localities, the limestone is very finely crystalline, almost lithographic. The lower part of the unit contains bluish-black, hard, dense chert nodules. Fossils are locally abundant, occurring in shaly partings and also (although sparingly) in the finely crystalline limestone. The maximum thickness of the unit within the area is about 50 feet, but in parts of Pike, Ralls, and Marion Counties it is much thinner or absent.

Throughout most of its extent in central, east-central, and southwestern Missouri, the Compton rests on a thin sandstone unit variously named "Bushberg" or "Sylamore" (Devonian-Mississippian). In northeastern Missouri, the undifferentiated Chouteau unit lies conformably on the Hannibal formation and unconformably beneath the Burlington formation (Osagean). The Northview is absent in this area.

Sedalia formation.—The Sedalia is typically a medium to thickly bedded, finely crystalline, dolomitic and siliceous limestone. It is less crinoidal than the Compton. When fresh, the limestone is gray to bluish gray, but it weathers to shades of brown and buff, and its exposed surfaces become smooth and rounded. Calcite-filled vugs occur in the upper part. Bluish-gray to bluish-black, white-rimmed chert is diagnostic of the Sedalia and is generally confined to it in the area south of central Pettis County. Northward and eastward from this area, this type of chert also appears in the Compton.

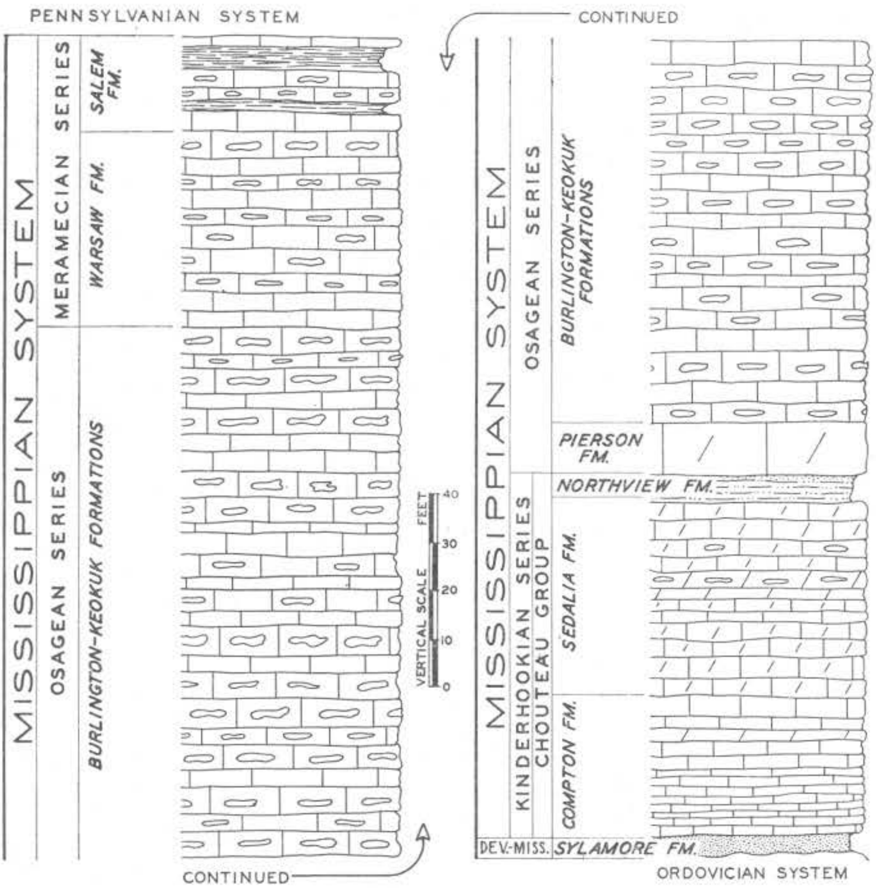
The maximum thickness of the Sedalia formation in west-central Missouri is about 50 feet. Southward from Pettis County, it thins and gradually interfingers with the overlying Northview shales and siltstones. Sedalia type lithology can be identified as far south as Cedar County; beyond, it is absent or unrecognizable. East of Pettis County, the Compton and Sedalia formations are not readily distinguished because of their interfingering relations.

Wherever the Sedalia formation is distinguishable as an independent unit, it is conformably overlain by the Northview and conformably underlain by the Compton.

Northview formation.—The Northview consists of brown, buff, occasionally blue siltstone and blue or bluish-green shale. In its type area in Greene and Webster Counties of southwestern Missouri, it is about 80 feet thick and is divisible into two parts; a lower part which is predominantly shale and an upper part which is predominantly siltstone with subordinate shale. Here, the formation is locally fossiliferous, the fossils consisting chiefly of pyritized and limonitized internal molds of brachiopods. Northward, in the area of Cedar County, the formation laterally interfingers with the Sedalia, and beyond, the Sedalia thickens at the expense of the Northview.

In central Missouri, the thickness of the Northview ranges from 2 to 3 feet, and its lithology varies from place to place. Normally, the formation consists of buff or green siltstones and silty shales, but the entire unit is dolomitic in some places. Fossils in the Northview of central Missouri are restricted to worm markings in the siltstones and to solitary corals. Throughout its extent, the contact of the Northview with the overlying Pierson is distinct and appears to be conformable wherever exposed.

The lithologic character of the Northview, together with the formation's tubular-shaped perforations (worm burrows) and abundant "rooster tail" markings (*Taonurus caudagalli*), are causal factors for the formation being named the "Vermicular siltstone" in earlier reports.



CENTRAL MISSOURI

Fig. 11. Mississippian System; Kinderhookian, Osagean, and Meramecian Series, and an unassigned Devonian-Mississippian formation in central Missouri.

The Northview extends from the Missouri River in central Missouri southward to Barry and Stone Counties. Its maximum thickness of 80 feet occurs along a northwest trend through Greene to Barton County. The formation appears to be absent south of central Stone and Barry Counties in southwestern Missouri and is known to be absent in the northeastern part of the state.

Osagean Series

The Osagean Series is characteristically composed of limestones which are crinoidal, very cherty, generally coarsely crystalline, and fossiliferous. None of the formations within the Series is entirely free of chert.

The Series contains the following formations: Pierson, Fern Glen, Reeds Spring, Grand Falls, Burlington, and Keokuk. All of these formations, however, do not occur together in any one particular section. The most complete sequence in the state that contains them is in southwestern Missouri, where the Pierson, Reeds Spring, Grand Falls, Burlington, and Keokuk occur together in the area south and west of Springfield. In this area, all the formations are composed of cherty limestones, and they cannot be easily distinguished from each other. Southward from this area, differentiation is even more difficult, and the term "Boone formation" has been applied to the entire sequence in southwestern Missouri and northern Arkansas. However, in this area a predominantly chert free and varicolored, red and green, crinoidal, argillaceous limestone in the lower part of the "Boone formation" had been designated in earlier reports as the St. Joe member. This unit is now regarded as a formation in Arkansas and Oklahoma, and the Pierson of Missouri is considered to be equivalent to it in part. In central Missouri and in the subsurface of northwestern Missouri, the Series is represented by only the Pierson, Burlington, and Keokuk; in northeastern Missouri by the Burlington and Keokuk; and in east-central Missouri by the Fern Glen, Burlington, and Keokuk. Throughout this entire area, the contact between the Burlington and Keokuk is obscure, and in most field mapping and subsurface projects the two formations are regarded as a combined unit which is designated as "Burlington-Keokuk". The Fern Glen formation of east-central Missouri is a varicolored, red and green, argillaceous limestone which closely resembles the St. Joe formation of Arkansas and Oklahoma. Its upper part, which is cherty, is regarded as equivalent in part to the Reeds Spring formation.

The rocks of the Osagean Series form a fairly continuous outcrop band around the Ozarks, extending from the northeastern corner of Missouri southeastward to Perry County and southwestward across the state to Arkansas and Oklahoma. In the northeastern part of the state, the Series is about 180 feet thick, in the east-central part about 200 feet thick, and in the southwestern part about 250 feet thick. However, in some areas of the Tri-State district, the thickness of the Series exceeds 400 feet.

Pierson formation.—In the type area of the Pierson, in southern Greene County of southwestern Missouri, the formation contains two units, a lower medium to massively bedded, brown dolomite, 5 to 20 feet thick, and an upper cherty limestone and dolomitic limestone unit about 35 feet thick. The latter is medium bedded and contains a medium amount of cream colored chert in the form of nodules. Northward from Greene County, the lower part of the Pierson thins to less than 10 feet and becomes a silty, buff-weathering limestone or dolomitic limestone. It is definitely recognized as far north as Pettis County, but farther eastward it is questionably regarded by some observers as the lower brown dolomite bed of the Burlington formation. Southward from Greene County, the entire formation gradually thickens. The upper part of the formation becomes more cherty, and the lower part becomes more calcareous and thinly bedded. In the vicinity of southern Stone and Barry Counties, the upper cherts become varicolored and mottled with shades of yellowish-brown and brick red, and the lower and upper limestones both become crinoidal, argillaceous, and mottled with shades of dark brick red and limonitic yellow, and small reef structures up to 20 feet thick occur in the lower part of the section. These features are all characteristic of the St. Joe formation of Arkansas. In this area of southwestern Missouri, the formation is about 50 feet thick.

In 1952, it was proposed by Clark and Beveridge that the St. Joe formation of extreme southwestern Missouri be raised to the rank of a group and that the group should comprise from bottom to top the Compton, Northview, and Pierson formations. As thus defined, the group straddles the boundary between the Kinderhookian and Osagean Series. Their proposal to raise the St. Joe to group status was based on the supposed persistence of the Compton and Northview formations in extreme southwestern Missouri and upon the facts that in many places the limy shale which they regarded as Northview is much too thin to map as a formation and that the limestone which they regarded as Compton is lithologically so similar to the Pierson "that previous workers have overlooked the intervening Northview shaly beds and considered the St. Joe to be a single limestone unit" (Clark and Beveridge, 1952, p. 77). Continued study of the lithology and paleontology of the group by several investigators has indicated that both the Compton and Northview in this part of the state may not be as persistent as had been believed by Clark and Beveridge and that in many places these formations appear to be absent. In such places, it is possible that formations of Osagean age, such as the Pierson of Missouri or the St. Joe of Arkansas, rest directly either on pre-Mississippian strata or on strata of questionable Mississippian or Devonian age. Because of the above situation continued use of the name St. Joe in Missouri as a group term has not been completely resolved.

The Pierson in the western part of central Missouri is not as fossiliferous as it is in the type area south of Springfield where the remains of brachiopods and corals are the most common fossils. These fossils, when compared with those of the Fern Glen, suggest that the two formations are partially equivalent in age.

The Pierson is underlain by the Northview formation (Kinderhookian) throughout most of its extent in west-central and southwestern Missouri. In extreme southwestern Missouri where the Northview and the Compton appear to be absent, the Pierson may rest on the Chattanooga formation (Devonian-Mississippian). In all of the area north of Springfield, the Pierson is overlain by the Burlington

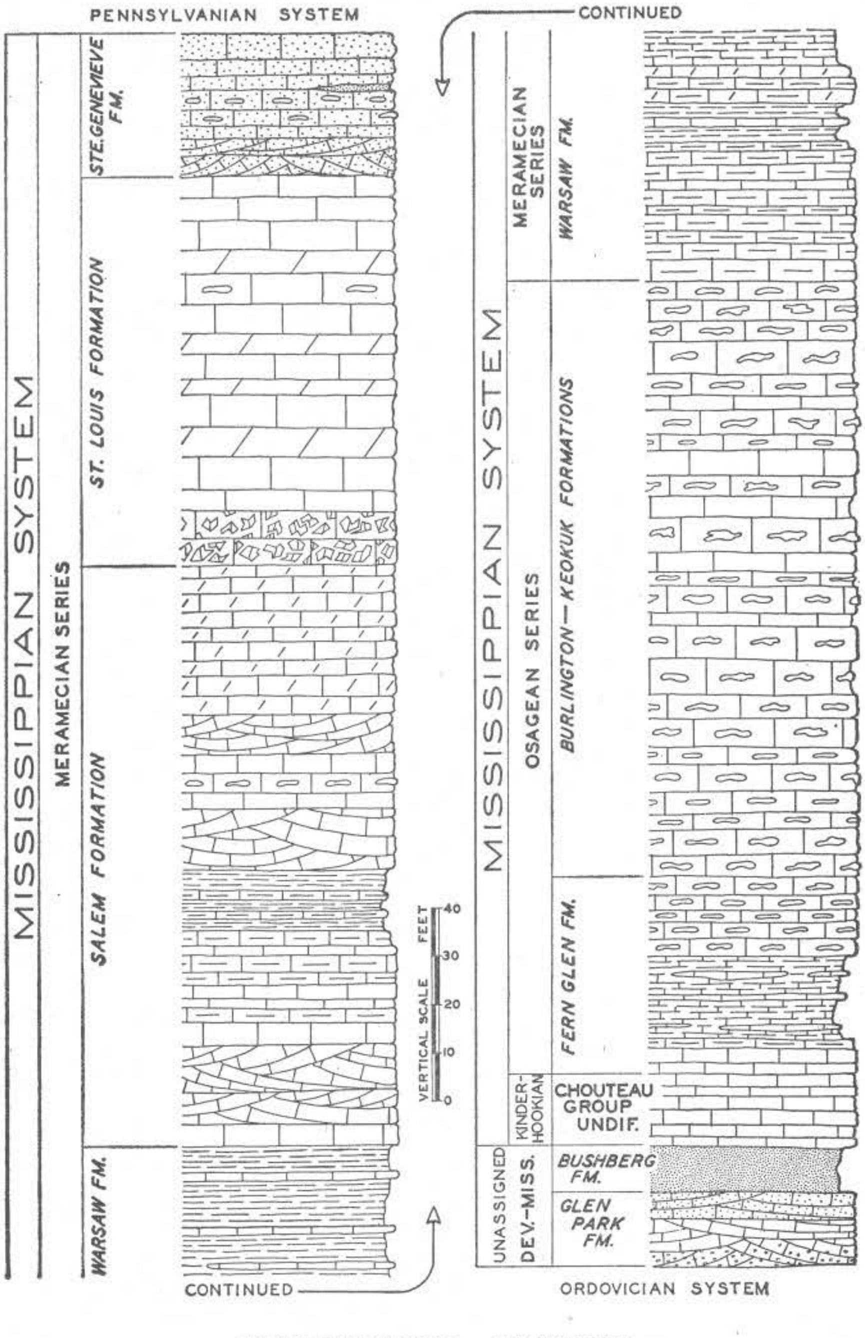


Fig. 12. Mississippian System; Osagean and Meramecian Series, and unassigned Devonian-Mississippian formations in east-central Missouri.

formation, but south of this area the Reeds Spring and Grand Falls formations intervene between it and the Burlington.

Fern Glen formation.—Although the Fern Glen formation and the southwestern extension of the Pierson formation are closely similar in lithology and age, they are separated by almost the entire width of the state. The Fern Glen is recognized only in east-central and southeastern Missouri, from eastern Franklin County east through St. Louis County and south through Jefferson and Ste. Genevieve Counties to northern Perry County.

Throughout this area, the formation consists of gray, grayish-green, and red limestone, and green and red calcareous shale. At most exposures, the lower part is noncherty while the upper part contains small nodules and layers of grayish-green to gray chert. Over much of the area, the formation has three types of lithologies; a lower, noncherty, brown, thickly bedded, crinoidal limestone 4 to 15 feet thick, which contains a few quartz geodes in places; a middle, distinctively red and (or) green, fossiliferous, calcareous shale 10 to 20 feet thick and an upper, nodular, cherty crinoidal limestone 12 to 30 feet thick which contains some quartz geodes. The total thickness of the formation ranges from 20 to 45 feet. Because the limestone in the upper part is crinoidal, there is a suggestion that it is transitional with the overlying Burlington. At the type area in central St. Louis County, the prevailing color of the formation is red, but in southwestern St. Louis County and in Jersey County, Illinois, the formation is predominantly light greenish gray or yellowish gray.

The lower, noncherty limestone unit of the Fern Glen in western St. Louis County is interpreted by some geologists as the eastward extension of the undifferentiated Chouteau unit of central Missouri, but opinions concerning this problem are about equally divided, and no satisfactory solution has yet been reached.

The Fern Glen formation is very fossiliferous and contains many brachiopods, corals, and crinoids. The bryozoan, *Evactinopora sexradiata*, and the brachiopods, *Spirifer vernonensis*, *S. rowleyi*, *Athyris lamellosa*, and *Cleiothyridina*, as well as the coral *Cyathaxonia arcuatas* are common. Many species are restricted to the formation.

The formation usually crops out at the base of bluffs formed by the overlying Burlington-Keokuk formations. Where the upper part of the formation is very cherty, it is ledge forming. From the type area, the upper cherty limestone thickens southward toward Jefferson County. The lithology of this part of the formation resembles that of the Reeds Spring formation of southeastern Missouri, and because of this and faunal similarities, the two are considered correlative at least in part. Toward the northern limits of its occurrence, the formation overlies truncated undifferentiated Chouteau or sandstones which have been regarded as Bushberg (Devonian-Mississippian). In Ste. Genevieve County, the formation overlies Ordovician and Devonian rocks. Residual boulders containing a Fern Glen fauna have been found as far west as Phelps County in central Missouri.

Reeds Spring formation.—The Reeds Spring formation consists of nearly equal parts of alternating bands of hard, finely crystalline, gray or bluish-gray, slightly argillaceous limestone and chert. The chert is nodular and irregularly bedded and is characteristically colored a bluish-black with a distinctive light gray border. However, much of the chert in the formation is colored light tan or mottled tan and gray. Chert makes up from one- to two-thirds of the formation and is most abundant in the upper part. In some places, the base of the formation is marked by a thin, green to brown, sandy shale.

The northeastern limits of the Reeds Spring formation lie within the southwestern part of the state. The formation does not extend north of Greene County or east of Christian, Stone, or Taney Counties. But southwestward, it extends into Arkansas and Oklahoma. The formation in its type area has an average thickness of less than 100 feet, but it thickens to the south and west. It is 100 to 150 feet thick in the Joplin area, and its thickness in the southernmost part of the state is about 225 feet. Throughout the area, the formation lies with apparent conformity on the Pierson formation.

The Reeds Spring contains well preserved fossils. Lateral equivalents of the formation are considered to be the Fern Glen in part, the Grand Falls, and possibly the lower Burlington.

Grand Falls formation.—The Grand Falls formation is present only in southwestern Missouri and in adjacent parts of Arkansas, Oklahoma, and Kansas. It consists of finely crystalline, gray limestone and abundant amounts of chert. The chert is nodular and massively bedded and varies in color from white to gray to brown. Some of the chert which is brecciated and has a gnarly structure is widespread but does not appear to be confined to any particular stratigraphic horizon. Much of the chert when weathered breaks into sharp slivers. In this form, the chert is commonly referred to as "butcher-knife flint". In well cuttings, the chert has a smooth texture and is either tan or cream colored or mottled tan and cream.

The formation is 24 to 40 feet thick in its type area in western Jasper and Newton Counties where exposures are numerous. It is reported to be as much as 100 feet thick in other parts of the Tri-State district. The formation pinches out north of Springfield and thickens to 120 feet along the southern border of Missouri.

Discussion of the Grand Falls is complicated by the fact that there is no definite agreement that the cherty limestone succession beneath the Burlington limestone in the eastern part of southwestern Missouri is the same unit as that at the type section in Newton County where the Burlington limestone is absent. Some geologists regard the entire cherty limestone succession that lies between the Pierson and the Burlington in the eastern part of the area as the Reeds Spring formation, and some regard the upper part of this same succession as the Grand Falls and the lower part as the Reeds Spring. Those who believe that the entire succession is Reeds Spring interpret the Grand Falls as being a lateral facies of the Reeds Spring that is restricted to the Joplin area. Those that regard the unit as being composed of both formations usually designate it as Reeds Spring-Grand Falls. This disputed cherty limestone unit in the eastern part of southwestern Missouri is overlain by the Burlington formation southward to Barry County where the Burlington pinches out, and there the unit is directly overlain by the Keokuk formation.

Burlington formation.—The Burlington in Missouri is a widespread formation of uniform lithology. It is present in nearly all the major Mississippian outcrop areas of the state and also occurs in the subsurface of northwestern Missouri. Throughout this entire area, it consists of white to light buff, very coarsely crystalline, fossiliferous, crinoidal limestone. Layers of chert nodules are common, especially in the upper part. In northeastern Missouri, the formation is arbitrarily divided into a sparsely cherty lower part 20 to 30 feet thick which is informally designated as the "White Ledge" and a cherty upper part 50 to 70 feet thick. In this area, the lower part contains from 95 to 99 percent calcium carbonate ($CaCO_3$), and because of this numerous agricultural limestone quarries have been established in it. In southwestern Missouri, the less cherty parts of the formation are quarried for agricultural limestone, road metal, and lime manufacture.

One of the difficulties in estimating the thickness of either the Burlington or the overlying Keokuk is that the boundary between the two formations is obscure, and in most reports the two are combined as one unit and their total thickness is recorded. However, the thickness of the Burlington formation is believed to be fairly uniform throughout the state, seldom exceeding 100 feet. In northeastern Missouri, the formation's thickness ranges from 70 to 100 feet; in central, east-central, and southeastern Missouri, it ranges from 75 to 100 feet; and in southwestern Missouri, it is about 100 feet thick. The formation is absent in the Joplin area and pinches out in southern Barry County in southwestern Missouri.

The contact of the Burlington with underlying formations varies considerably. In northeastern Missouri, it lies unconformably on the Hannibal formation; in east-central and southeastern Missouri, it is conformable on the Fern Glen; in central Missouri, it is unconformable on both undifferentiated Chouteau and Northview; and in southwestern Missouri, it lies either on Pierson or on the Reeds Spring-Grand Falls unit. Its contact with the overlying Keokuk is obscure and not easily distinguished either on the outcrop or in drill cuttings, but it is considered to be conformable.

Keokuk formation.—The Keokuk formation is widespread throughout the state and like the Burlington formation is of fairly uniform lithology. It is present in all the major Mississippian outcrop areas of the state and is also present in the subsurface of northwestern Missouri. The formation is characteristically a bluish-gray, medium to coarsely crystalline, medium bedded limestone which contains an abundant amount of light gray chert in the form of layers and nodules. Some beds of the formation in the southwestern part of the state are finely crystalline, and some parts of the formation in the same area are extremely crinoidal. In the northeastern part of the state, thin shale beds separate the limestone strata. Stylolites are common and are especially pronounced at the contact of coarsely and finely crystalline beds.

The chert in the Keokuk is irregularly distributed throughout the formation but appears to be more concentrated in the lower and upper parts. It is dense, light gray, and has tripolitic borders. It weathers to buff and reddish brown. In the Barry County area of southwestern Missouri, the chert above and below a persistent oolitic limestone bed (Short Creek member) near the top of the formation contains calcareous areas which when weathered give the chert a matted appearance.

Fossils are common in the formation but are not readily removed from the limestone. The productid brachiopods *Buxtonia*, *Dictyoclostus*, *Linoproductus*, and *Marginirugus* are common, as well as the following species of brachiopods: *Orthotetes keokuk*, *Cleiothyridina obmaxima*, *Echinoconchus alternatus*, *Spirifer logani*, and *Tetracamera* spp. Horn corals and bryozoans, especially the distinctive bryozoan genus *Archimedes*, are relatively abundant in the formation.

As previously stated in the discussion of the Burlington formation, thickness determinations for either the Burlington or Keokuk are difficult to make because of the obscure boundary between them. This is especially true in east-central and southeastern Missouri where the two formations together have a thickness of about 125 feet. Of this amount, about 50 feet belongs to the Keokuk. In northeastern Missouri, the thickness of the formation ranges from 60 to 70 feet. In central and southwestern Missouri, it is about 100 feet thick.

Throughout most of its extent, the Keokuk appears to be conformably overlain by the Warsaw formation, but in southwestern Barry County near the Arkansas border, the Keokuk is overlain by the Hindsville formation (Chesterian). The Keokuk overlies the Burlington in all areas of the state except in the Tri-State district and in parts of Barry County where it lies directly on the Grand Falls or Reeds Spring-Grand Falls unit.

The Keokuk is used for road metal and occasionally for building stone. Agstone quarry operators utilize the less cherty parts of the formation which includes the Short Creek member. Tripoli is mined from weathered Keokuk chert in western Newton County.

Short Creek member.—Throughout southwestern Missouri and adjacent areas of Kansas and Oklahoma, a thin, persistent bed of oolitic limestone, 2 to 8 feet thick is present near the top of the Keokuk. This unit is the Short Creek member of the formation. It is generally a single, massive bed and is commonly used as a datum in field mapping. However, because of the difficulty of determining the Keokuk-Warsaw boundary in drill cuttings, the base of the Short Creek member is arbitrarily designated as the base of the Warsaw in subsurface studies. The ooliths are usually less than one millimeter in diameter, round in cross section, and often have as a nucleus a doubly terminated quartz crystal. The matrix in which the ooliths are embedded is a white limestone which contains scattered glauconite grains. An insoluble residue of the member usually contains doubly terminated quartz crystals, glauconite, and some chert.

Fossils consist mostly of brachiopods such as *Orthotetes keokuk*, *Rhipidomella* spp., and *Chonetes illinoisensis*.

Meramecian Series

The Meramecian Series consists of four formations, the Warsaw, Salem, St. Louis, and Ste. Genevieve. These formations, with the exception of the Warsaw whose upper part in eastern Missouri is a shale, are composed mainly of limestone and some dolomite. Chert is not common but does occur in all of the formations. All four formations are present in east-central Missouri which is regarded as the type area for the St. Louis and Ste. Genevieve formations. The Warsaw and Salem are the only formations of the Series that have been definitely identified in central Missouri. In the southwestern part of the state, the presence of the Warsaw and St. Louis has been established, but not that of the Salem whose presence is only tentatively recognized. In the subsurface of northwestern Missouri, the presence of a complete sequence of Meramecian formations has been determined by studies of drill cuttings and insoluble residues. The maximum thickness of the Series is in east-central Missouri where the unit is between 300 and 450 feet thick. The Series thins northward to 150 feet. In central and southwestern Missouri where the Series is incomplete, thicknesses range from 60 feet in central Missouri to 185 feet in southwestern Missouri.

The position of the boundary between the Meramecian and Osagean Series has long been disputed. The problem involves the assignment of the Warsaw formation. Some geologists regard the Warsaw as the lowest formation of the Meramecian Series because its predominantly clastic lithology differs from the calcareous composition of the Keokuk, and its fauna contains many new species which are not present in the Keokuk. Other geologists have placed the Warsaw at the top of the Osagean Series because the Warsaw fauna resembles the Keokuk fauna in many respects, and the boundary between the two formations is obscure in many areas. In this report, the Warsaw is considered to be the basal formation of the Meramecian Series. As thus defined, the Meramecian Series is considered to be conformable with the underlying Osagean Series. The Meramecian is unconformably overlain by the Chesterian Series wherever the latter is present. In the subsurface of northwestern Missouri and throughout central Missouri, the Chesterian Series is absent, and remnants of the Meramecian are directly overlain by Pennsylvanian strata.

Warsaw formation.—Exposures of the Warsaw formation are widely but discontinuously distributed throughout Missouri. Scattered outcrops of the formation are present in Lewis and Clark Counties in northeastern Missouri where the formation is 40 feet thick and is principally composed of finely to coarsely crystalline, fossiliferous limestone and contains geodes in its lower part. From northeastern Missouri, the Warsaw can be traced southeastward in the subsurface down along the southwestern flank of the Lincoln fold to St. Charles and St. Louis

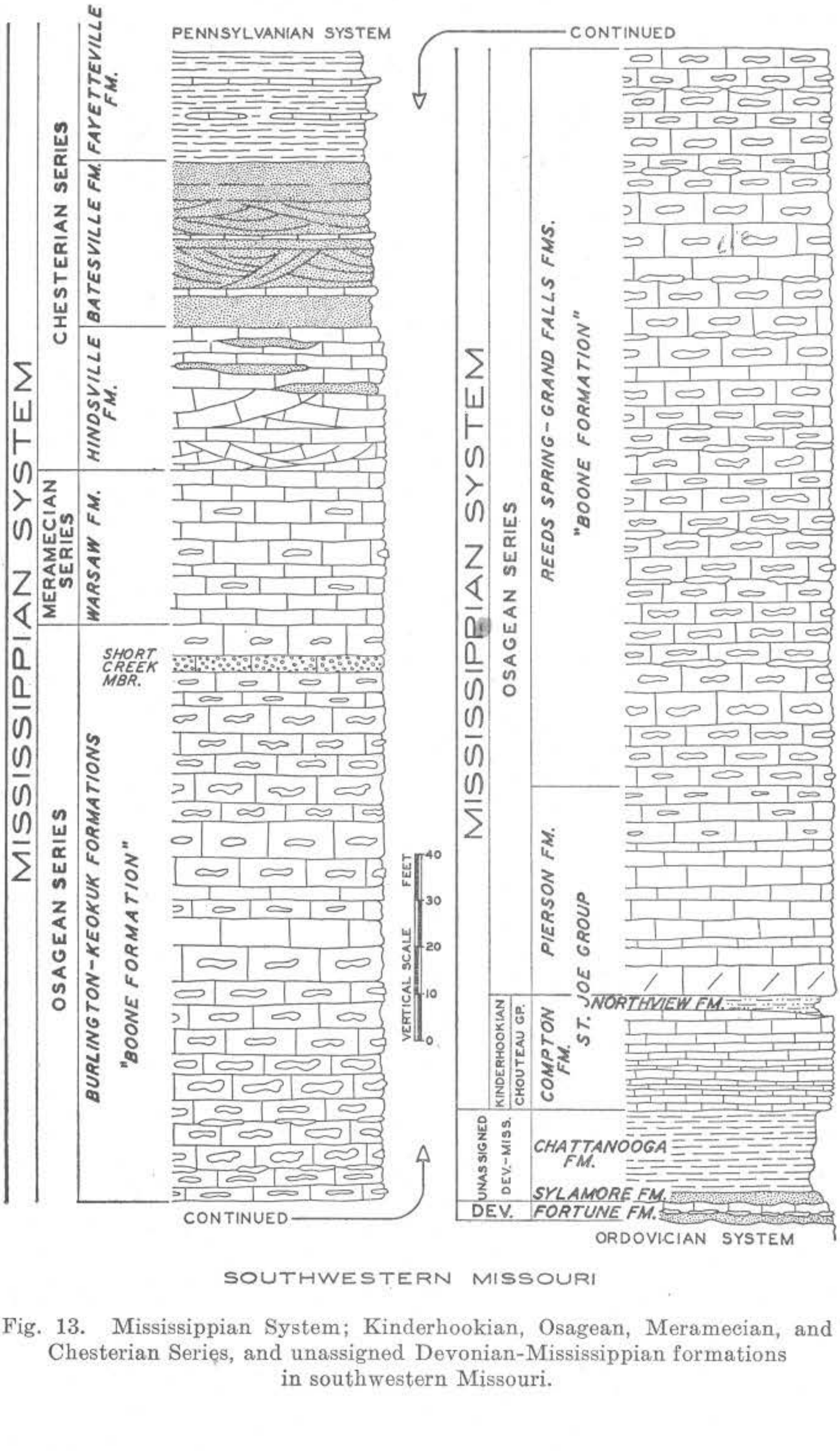
Counties where it again crops out. The formation also is exposed in Ste. Genevieve County and in the extreme eastern part of Perry County. In these areas, the Warsaw is about 80 to 100 feet thick and is very shaly. The lower half is composed of finely crystalline shaly, very fossiliferous, dolomitic limestone, and the upper half is a dark, fissile shale.

Outcrops of the Warsaw are present in central Missouri in Cooper and Howard Counties, where it is about 50 feet thick, and in many areas of southwestern Missouri in Greene, Cedar, Dade, Barton, Jasper, and Barry Counties. Throughout this area, the formation is predominantly a slightly cherty limestone in which the bryozoan *Archimedes* and the brachiopod *Spirifer pellaensis* are common. In the Tri-State area in Newton and Jasper Counties, the formation is over 150 feet thick and has been subdivided into numerous letter designated units. The Warsaw in Jasper County is the source of "Carthage Marble", an ornamental building stone. The formation is also quarried locally for agricultural limestone and road metal.

In northwestern Missouri, the Warsaw is present in the subsurface and is persistent throughout the area. Here, it is about 50 feet thick and composed of coarsely crystalline, cherty, fossiliferous limestone which is interbedded with finely crystalline, dolomitic limestone. Thin partings of shale are common. In subsurface studies, the Warasw is differentiated from the underlying Keokuk by the presence of these thin shale partings and by the presence of abundant bryozoan fragments in the chert.

Salem ("Spergen")* formation.—The most complete and thickest exposures of the Salem formation in Missouri are present in the east-central and southeastern parts of the state in St. Louis, Ste. Genevieve, and eastern Perry Counties. Throughout this area, the formation is 100 to 160 feet thick. In Ste. Genevieve County, the lower part of the Salem is a light gray to white, fragmentally fossiliferous, argillaceous, locally oolitic limestone, and the upper part is a bluish-gray, argillaceous, oolitic, dolomitic limestone in which the oolitic content varies considerably. The formation is commonly cross bedded. In the St. Louis area it becomes more dolomitic. The upper part of the Salem is fossiliferous and contains blastoid, crinoid, echinoid, and bryozoan debris, as well as the coral *Syringopora*. The top of the formation grades upward into the St. Louis formation, and the intermediate beds contain the coral *Lithostrotion*. The insoluble residue from the upper 50 feet of the Salem in the St. Louis area contains a high percentage of speckled gray and tan chert. The residue from the Salem also contains the Foraminifera *Endothyra*, and echinoderm fragments. In Ste. Genevieve County, an exceptionally pure white oolitic limestone in the middle of the formation is used for making lime. Other

*The name "Spergen" has long been synonomous with the term Salem and has been extensively used in publications of the Missouri Geological Survey in place of the term Salem. However, in view of the fact that the latter term has recently been officially adopted by the U. S. Geological Survey and has been customarily used for years by the Illinois and Indiana Geological Surveys, the term Salem is herein used in preference to the term "Spergen."



SOUTHWESTERN MISSOURI

Fig. 13. Mississippian System; Kinderhookian, Osagean, Meramecian, and Chesterian Series, and unassigned Devonian-Mississippian formations in southwestern Missouri.

parts of the formation in the same area have been used for riprap, agricultural limestone, and road metal.

The Salem thins northward from St. Louis County, and in the northeastern part of the state it ranges from 20 to 40 feet in thickness. It is composed of buff weathering limestone, dolomitic limestone, and shale in this part of the state, and its contact with the underlying Warsaw is obscure because the lithologies of the two formations intergrade.

In central Missouri, in Saline and Howard Counties, a medium to coarsely crystalline, medium bedded limestone which is interbedded with green shale and which contains distinctive red jasperoid chert in the form of lenses and nodules has been identified as the Salem. The limestone also contains brachiopod and bryozoan fragments, the Foraminifera *Endothyra* and the coral *Triplophyllites.* It is 10 feet thick at the surface and thickens to 50 feet to the north and west in the subsurface. In Dade and Jasper Counties in southwestern Missouri, a limestone which contains the brachiopods *Tetracamera acutirostris* and *Camarotoechia mutata* has been tentatively identified as the Salem. In the subsurface of northwestern Missouri, fossiliferous limestone and shale, as well as some unfossiliferous, earthy, dolomitic limestone which is usually recorded as uppermost Warsaw is considered to be Salem. These beds contain a few specimens of *Endothyra* and pink to red, chalcedonic, fossiliferous chert. The unit is about 50 feet thick.

St. Louis formation.—The St. Louis formation attains its fullest expression within Missouri in its type area in St. Louis County and in adjacent parts of east-central and southeastern Missouri. Here, the formation is a gray lithographic to finely crystalline, medium to massively bedded limestone which is more than 100 feet thick. Limestone breccia is common in the lower part of the formation but is not necessarily confined to this part. Shale occurs as a matrix between the blocks of breccia. Blue and bluish-gray shale also forms thin beds throughout the formation and increases in abundance toward the northeastern part of the state. Chert is not common. Where it is present, it is usually brown and in the form of small angular fragments. Parts of the formation are locally dolomitic. The compound corals *Lithostrotionella castelnaui* and *Lithostrotion proliferum* are considered to be diagnostic, and the coral *Syringopora* is common. The percentage of insoluble residue that can be extracted from the St. Louis is generally low. The residue from the lower part of the formation normally contains small (less than 1 mm.) euhedral quartz crystals. Gray or tan quartzose chert rosettes are also common residue constitutents. The contact between the St. Louis and Salem formations appears to be conformable. The thickness of the St. Louis formation in northeastern Missouri is generally less than 50 feet. The formation is about 50 feet thick in southwestern Missouri where it is present in Dade, Cedar, and Barton Counties. In the subsurface of northwestern Missouri where the formation is a finely crystalline to lithographic limestone with some interbedded granular and oolitic limestone, its thickness varies from 0 to 75 feet. The formation's local absence in this area is the result of pre-Pennsylvanian erosion.

The limestone from the St. Louis formation is quarried in the St. Louis area for cement manufacture and aggregate. In northeastern and southwestern Missouri, the limestone is used for agstone and road metal.

Ste. Genevieve formation.—The Ste. Genevieve formation is typically developed in the east-central and southeastern parts of Missouri in Ste. Genevieve and St. Louis Counties and in eastern Perry County. It is also present in adjacent parts of Illinois and Kentucky where it has been subdivided into members. Within the Missouri area, the formation is a white, massively bedded, sandy, clastic limestone. It is generally coarsely crystalline and oolitic but does contain a few beds of finely crystalline limestone. The lower part of the formation is sandy, white to light tan or light olive gray in color, and is prominently cross bedded and ripple marked. Lenses and clusters of algal material are present in this part of the formation in regularly-bedded strata. Above the cross-bedded unit and near the middle of the formation, there are some layers of red and gray chert, as well as some lenses and beds of sandstone that occur locally. The lithology of the formation changes laterally, making it difficult to trace individual units. Certain beds contain notable amounts of limonite which lines small cavities in the rock. In the upper part of the formation, various shades of yellow, green, and purple have been noted. The percentage of insoluble residue that can be extracted from the Ste. Genevieve in this area is usually low. The residue contains a proportionately large amount of pink or bluish-gray chert, some quartz sand and crystals, and silicified ooliths.

Fossils are irregularly distributed throughout the Ste. Genevieve in the east-central and southeastern parts of Missouri. The best preserved forms are present above the cross-bedded part of the formation. The brachiopod *Pugnoides ottumwa*, the small crinoid *Platycrinites penicillus*, and the very large gastropod *Bellerophon* are commonly present in the formation in this area.

The average thickness of the Ste. Genevieve in southeastern Missouri is 85 feet with the maximum being less than 100 feet. The formation's thickness in St. Louis County is 30 feet. There is a disconformable contact between the Ste. Genevieve and the underlying St. Louis formation, with a basal conglomerate being present in numerous places. A significant pre-Chester erosional surface marks the top of the formation. In the St. Louis area, the formation is overlain either by beds of the Pennsylvanian System or by Pleistocene deposits.

In the extreme northeastern part of the State, in Lewis and Clark Counties, a white, massive, cross-bedded sandstone which is 1 to 4 feet thick and contains fragments of chert and lithographic limestone has been identified as Ste. Genevieve. In Missouri, this unit is generally overlain by Pleistocene till, and faunal evidence for the age of the unit is lacking within the state. However, in adjacent parts of southeastern Iowa, a similar sandstone is overlain by a finely crystalline limestone, Pella beds, which has been correlated with the type Ste. Genevieve in southeastern Missouri. The contact of this sandstone with the underlying St. Louis formation is gradational in some places and disconformable in others.

In the subsurface of northwestern Missouri, the Ste. Genevieve is a light colored, oolitic, and sandy dolomitic limestone. Scattered wells have encountered as much as 35 feet of subangular, fine- to medium-grained sandstone in the upper part of the formation whose maximum recorded thickness in this area is less than 75 feet.

Chesterian Series

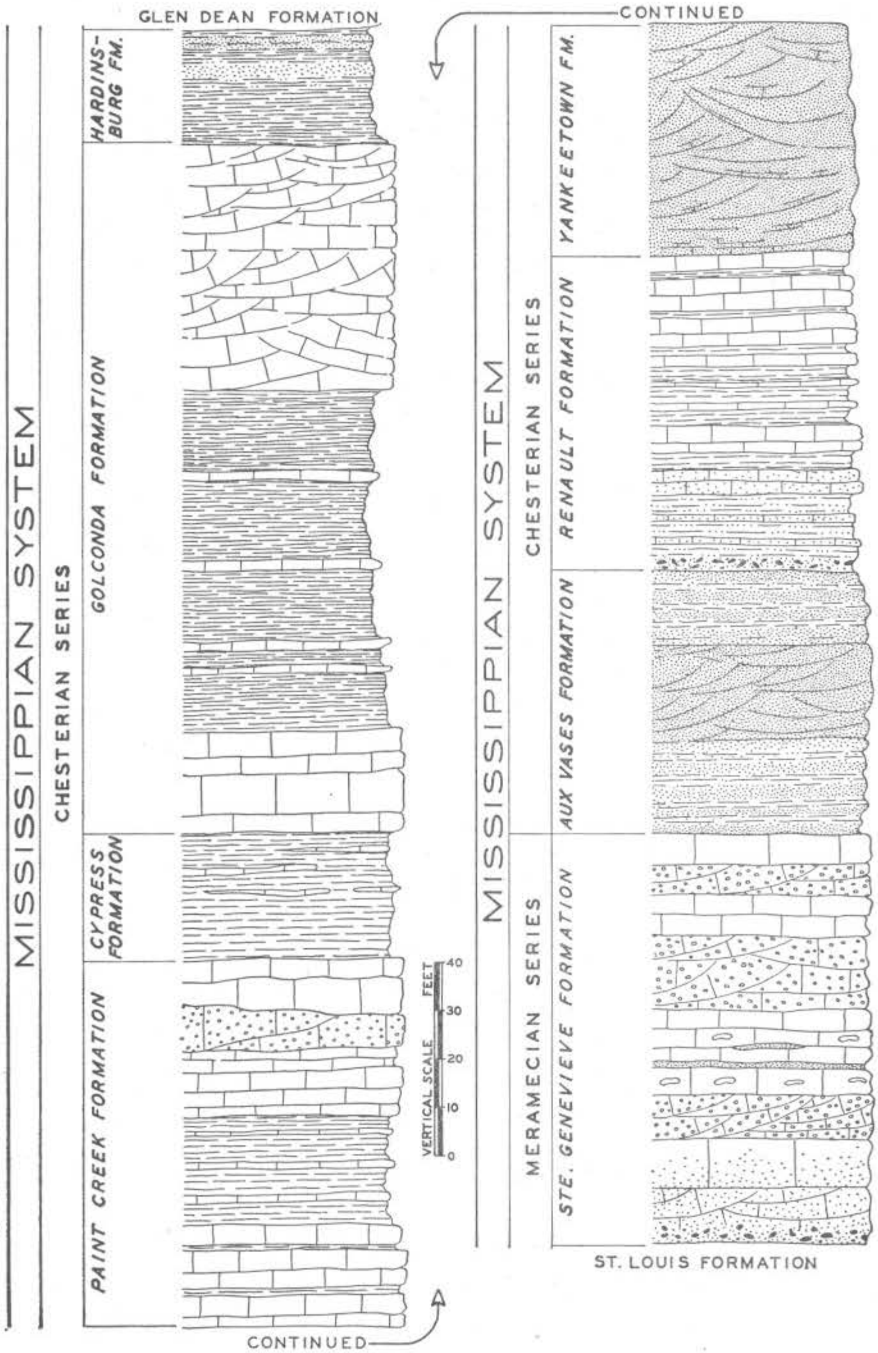
The formations that have been assigned to the Chesterian Series in Missouri form two distinct successions which are widely separated. One succession is located in the southeastern part of the state where it includes approximately the lower half of the type section of the Chesterian Series which is present across the Mississippi River in Illinois. The other succession is located in southwestern Missouri, where it is thinner and forms outliers of more extensive units which are present in Oklahoma and Arkansas. The formations of the two areas and their approximate relationships, as determined by faunal studies are shown in Table 3. Chesterian strata are not present in the subsurface of northwestern Missouri.

Table 3

<table>
<tr><th colspan="2">Southwestern Missouri</th><th>Southeastern Missouri</th></tr>
<tr><th>Jasper & Newton Cos.</th><th>Stone & Barry Cos.</th><th>Ste. Genevieve
& Perry Cos.</th></tr>
<tr><td rowspan="3">Carterville</td><td></td><td>Vienna
Tar Springs</td></tr>
<tr><td>Lower Fayetteville</td><td>Glen Dean
Hardinsburg
Golconda</td></tr>
<tr><td>Batesville

Hindsville</td><td>Cypress
Paint Creek
Yankeetown
Renault
Aux Vases</td></tr>
</table>

The Chesterian formations of southeastern Missouri consist of crudely rhythmic repetitions of sandstone, shale, and limestone which crop out in the bluffs of the Mississippi River only in Ste. Genevieve and Perry Counties in an area of steeply dipping beds and of considerable faulting. Exposures are not continuous, and identity of the formations is established only by their similarity to the better developed



SOUTHEASTERN MISSOURI

Fig. 14. Mississippian System; Meramecian and Chesterian Series in southeastern Missouri.

sections in Illinois. The outcrops in Missouri are situated on the western edge of a thicker and more completely developed succession which is present in Illinois and Kentucky.

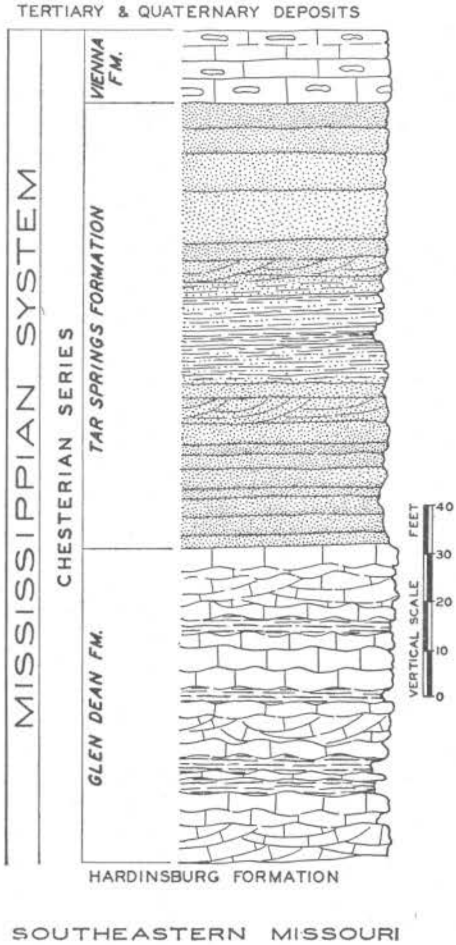


Fig. 15. Mississippian System; Chesterian Series in southeastern Missouri, continued from Figure 14.

The stratigraphic units which make up the Chesterian Series in southeastern Missouri are in ascending order: the Aux Vases, Renault, Yankeetown, Paint Creek, Cypress, Golconda, Hardinsburg, Glen Dean, Tar Springs, and Vienna formations. Little economic use has been made of these units in Missouri. However in the Illinois basin, the succession includes a number of beds from which oil is produced.

The Chesterian Series in southeastern Missouri overlies the Meramecian Series unconformably. Minor unconformities have been noted in many places beneath sandstones within the Series, but because of poor and limited exposures these can not always be verified. The maximum thickness of the Series in this part of the state is 600 feet. This thickness is present in eastern Perry County.

The formations of the Chesterian Series occupy only a small part of the outcrop area of the Mississippian System of southwestern Missouri. In the Joplin area of Jasper, Lawrence, and Newton Counties, the Series is represented by the Carterville formation. A more fossiliferous and better sequence of rocks of probably equivalent age to the Carterville is present farther south in McDonald and Barry Counties. Here the sequence is composed of three formations, the Hindsville, Batesville, and Fayetteville, which are also present in northwestern Arkansas and northeastern Oklahoma where they are thicker and more continuous. These formations are widely separated and lithologically different from the Chesterian formations of southeastern Missouri and southwestern Illinois; hence, correlations are difficult to establish. The Series lies unconformably on the Keokuk formation (Osagean) in the southwestern part of the state and is unconformably overlain by the Hale formation (Pennsylvanian).

(Southeastern Missouri)

Aux Vases formation.—The Aux Vases formation is composed principally of straw- to tan-colored sandstone and interbedded green to variegated shale which contains sandstone stringers in the lower and upper parts. The sandstone is fine grained and even textured. Its coarser portions occur in Perry County where it superficially resembles but differs from the St. Peter sandstone by being finer grained and by containing a considerably greater variety of minerals. The middle part of the formation is bluff forming and contains massive, cross-bedded sandstone which has been used for building stone. The sandstone is locally cemented by silica and is sparingly fossiliferous, containing mostly broken crinoid and brachiopod remains. The formation has about the same areal extent as the underlying Ste. Genevieve formation upon which it lies unconformably. Complete sections are not exposed in any one locality. In Ste. Genevieve County, the thickness of the formation ranges from 40 to 60 feet and in Perry County, from 56 to 105 feet.

Renault formation.—The Renault formation includes a variety of rock types and is not very well exposed. The lower part contains shale and sandy limestone which is conglomeratic near the Aux Vases contact; the conglomerate is composed of limestone, chert, and sandstone fragments. The sandstone is fine grained and commonly contains worm borings. In the upper part, thin, bluish-gray to light gray limestone is interbedded with red, gray, or green, fissile shale. The formation's contact with the underlying Aux Vases is generally covered; thus, the relationship between the two formations is believed to be unconformable. The formation varies in thickness from 46 to 90 feet and is exposed in and near the Mississippi River bluffs from the Aux Vases River in Ste. Genevieve County to a point a few miles south of the Perry County line.

Fragments of the plant *Lepidodendron* are commonly present in the lower sandy beds. In the upper limestone beds, crinoids and bryozoans are common, and the crinoid *Talarocrinus* and the bryozoan *Lyropora* are widespread markers.

Yankeetown formation.—Throughout most of its outcrop area, the Yankeetown formation is a fine-grained, light to reddish-brown, calcareous sandstone. The sandstone is irregularly bedded and cross bedded, shows rib and furrow structure, and in many places is cemented with silica. The irregularity of some of the bedding and cross-bedding may be caused by the leaching of the calcareous cement. At many places, the formation contains gray or red shale. The contact between the Yankeetown and Renault formations is transitional. If most of the sandstone that lies below the Paint Creek formation in Missouri is assigned to the Yankeetown, the thickness of the formation in Perry County will be 60 feet, and in Ste. Genevieve County it will be somewhat less.

Paint Creek formation.—The Paint Creek formation is poorly exposed in Missouri and is present only in northeastern Perry County. The basal part of the formation consists of limestone and interbedded shale. The limestone is light gray, coarsely to finely crystalline, and contains distinctively pink crinoid and blastoid ossicles. This lower limestone unit varies in thickness from 8 to 20 feet. The middle part of the formation consists of shale that has a few limestone beds in the upper part and noncalcareous, red claystone in the lower part. It is from 15 to 30 feet thick. The upper part of the Paint Creek contains light buff oolitic, cross-bedded limestone and very little shale. Crinoid and blastoid debris is common, and the crinoid *Pterotocrinus* is distinctive. This part of the Paint Creek is 40 to 70 feet thick. The total thickness of the formation varies from 80 to 100 feet.

Cypress formation.—The Cypress formation is composed of gray shale and mudstone and contains some red shale layers and a few thin limestone stringers. The limited exposures in east central Perry County are poor, and the contacts of the formation with the overlying Golconda and underlying Paint Greek formations are concealed. The Cypress formation becomes silty and sandy and extends eastward into Illinois where it rapidly thickens so that 10 miles east of the Mississippi River bluffs it consists of 70 to 80 feet of sandstone which may be a channel deposit. Because this facies relationship was not noted in the past, the formation has not been previously recognized in Missouri where the thickness of the unit probably does not exceed 30 feet.

Golconda formation.—The Golconda formation is a limestone and shale succession that can be divided into three parts. The basal part is a dark gray to brown limestone 5 to 20 feet thick which contains an abundance of Foraminifera, small gastropods, and pelecypods. The middle part is 70 to 90 feet thick and is composed of shale which contains beds of darkly colored crinoidal limestone, and the upper part is a very light gray, oolitic, cross-bedded limestone 50 feet thick. Outcrops of the formation are confined to northern Perry County where the limestone beds in the Golconda are massive and form steep bluffs and ledges along the Mississippi River and its tributaries. Because the typical sandstone of the Cypress formation is absent in Missouri, there is a suggestion that an unconformity is present at the base of the Golconda.

Hardinsburg formation.—The Hardinsburg formation consists of dark gray shale or plastic clay which contains quartzose sandstone streaks in the upper part. A thin coal streak has been noted to be present within the unit in one Missouri exposure. This shaly succession between the Glen Dean and the Golconda limestones apparently represents the westward extension of a more typical, thicker, sandy shale and sandstone of western Illinois. This shale has not been differentiated as Hardinsburg in older reports of the Missouri Geological Survey. Limited and poor exposures of the formation are present in east-central Perry County near the Mississippi River bluffs. Its thickness ranges between 13 and 20 feet but may reach 30 feet, a thickness which is comparable to that observed in wells across the river in Illinois.

Glen Dean formation.—The Glen Dean formation consists of limestone and numerous interbedded layers of shale. The limestone is light gray and coarsely to finely crystalline or oolitic. Stratification is very irregular. The bedding planes undulate, and cross-bedding is common. The formation weathers buff to gray. Both the shale and limestone are fossiliferous. The large blastoid *Pentremites spicatus* is characteristic but not common, and the bryozoan *Prismopora serratula* is commonly present in the upper part of the formation. Brachiopods, horn corals, and crinoids also occur. The formation's contact with the underlying Hardinsburg appears to be conformable. Its outcrop belt is confined to a band along the Mississippi River bluff in east-central Perry County. The Glen Dean is 65 to 80 feet thick and contains numerous local disconformities.

Tar Springs formation.—The Tar Springs formation consists chiefly of sandstone and contains shale and shaly sandstone near the middle of the unit. It is buff to rust-brown and red in color, is dominantly fine grained, even textured, and friable except where it is locally an orthoquartzite. The formation is generally thin bedded but is thicker bedded at the top and bottom. Asymmetrical ripple marks and tabular cross-bedding are persistently well developed, especially in the thinner beds. The thicker beds weather to slabs and blocks. Fossils are not abundant and usually consist of plant remains such as ferns, twigs, and pieces of bark from scale trees. The Tar Springs is about 90 feet thick in Missouri.

Vienna formation.—The Vienna formation is present on only a few hilltops along the Mississippi River bluffs in east-central Perry County. Here, the formation is principally represented by loose, residual fragments of dark colored chert and spongy, siliceous, highly weathered limestone. Chert is more conspicuous than in the older Chesterian formations, but fresh exposures of the formation on the Illinois side of the Mississippi River indicate that the chert is not as abundant in the limestone as the residuum would indicate. The formation's thickness of 10 to 15 feet is comparable to its thickness across the river in Illinois where it is more complete. Fossils are not known except for a few crinoid columnals. There is no indication of any younger Chesterian units such as the Waltersburg sandstone or the more persistent Menard limestone above this formation. Its contact with the underlying Tar Springs formation is concealed.

(Southwestern Missouri)

Carterville formation.—Although the characteristics of the Carterville formation are known mostly from prospecting shafts and drill holes, there are a few isolated surface exposures in and around the Joplin area where the formation can be observed directly. Much of the formation is composed of clay and conglomerate and contains oolitic limestone "lumps" or boulders several feet in diameter that are embedded in a shale matrix. The formation also contains sandstone which is in part quartzite or argillaceous, and parts of it contain dark gray to black fissile shale.

The more calcareous parts of the unit are fossiliferous and contain Chesterian fossils such as the brachiopod *Spirifer increbescens*, productids, Bryozoa (chiefly fenestellids including the genus *Archimedes*), and a few corals, trilobites, and fish teeth.

The formation is very variable in thickness and is believed to be made up of local sink-filled deposits in older Mississippian rocks. It is present only in Jasper, Lawrence, and Newton Counties and is reported to be over 200 feet thick in some of the sinks. The three Chesterian formations, the Hindsville, Batesville, and Fayetteville, which are situated farther to the south are regarded as being the more normally and continuously developed parent succession of the Carterville formation.

Hindsville formation.—The Hindsville is a light to dark gray, medium to finely crystalline, oolitic limestone which in some places is interbedded with light gray, calcareous shale and siltstone. The limestone is commonly cross bedded. The upper part contains lenses of sandstone which are indistinguishable from the sandstone of the Batesville formation. In places, glauconite is present and gives the rock a greenish tinge.

The Hindsville is the most fossiliferous of the three Chesterian formations in the southwestern part of the state. The fauna shows some similarities to the fauna of the Ste. Genevieve formation (Meramecian), but it is also very similar to the Chesterian fauna of overlying formations. The formation has generally been regarded as lower Chesterian in age.

Because of the transitional nature of the Hindsville-Batesville contact, the Hindsville has been considered to be the basal member of the Batesville in Arkansas where both of the units are more completely developed. The formation unconformably overlies the Keokuk. The contact is irregular and marked by chert-pebble conglomerates which contain fish teeth. The thickness of the formation ranges from 0 to 50 feet.

Batesville formation.—The Batesville formation is a yellowish-brown, finely crystalline, calcareous sandstone which contains discontinuous, thin beds of gray, medium crystalline, oolitic limestone. The beds in the formation are evenly stratified, but at some localities the sandstone is ripple marked and cross bedded. The fauna is composed chiefly of brachiopods and pelecypods.

The contact between the underlying Hindsville and the Batesville is one of transition. Locally, where the Hindsville is absent, the Batesville lies unconformably on the Keokuk (Osagean). The formation is regarded as equivalent in age to the lower Chesterian Series of the type area, and is 35 to 50 feet thick in Missouri.

Fayetteville formation.—The Fayetteville formation is composed predominantly of black, fissile, carbonaceous shale which is interbedded with dark gray to black, ferruginous limestone. It occurs only in southwestern Missouri near the Arkansas border and forms the slopes of such hills as Oakleigh, Reed, and Lennox Mountains. Brachiopods and ostracodes are the most abundant faunal constituents of the formation.

The Missouri Fayetteville possibly represents only the lower part of the formation which is more completely developed in Oklahoma and Arkansas where it attains a thickness of 350 feet and contains a distinctive sandstone (Wedington) in the upper part. In southwestern Missouri, the Fayetteville is conformable with the underlying Batesville formation. The total thickness of beds identified as Fayetteville in Missouri is about 20 feet, and the formation has been correlated with the Golconda, Hardinsburg, and Glen Dean formations of southeastern Missouri.

Pennsylvanian System

by

Walter V. Searight* and Wallace B. Howe†

Rocks of Pennsylvanian age are present beneath surficial deposits in more than two-thirds of the counties in Missouri and formerly may have covered nearly all of the state, as evidenced by the scattered remnants of the System that occur throughout the Ozark region. Pennsylvanian strata have been assigned to five Series which are from older to younger: the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian. The Morrowan and Atokan Series are patchy in distribution and generally restricted to the area southeast of the Desmoinesian cropline on the Ozark uplift and Springfield plateau. The Atokan

*Prepared sections on the Morrowan, Atokan, and Desmoinesian Series.

†Prepared sections on the Missourian and Virgilian Series.

is more fully represented in the Forest City basin. Desmoinesian and younger Pennsylvanian strata are extensively distributed and crop out in a broad, continuous band across western and northern Missouri. From the cropline, they dip in a northwesterly direction below youngest Pennsylvanian (Virgilian) which crops out in the northwest corner of the state.

Pennsylvanian strata in Missouri are dominantly clastic, but there are also many important limestone and coal beds. Clay (particularly refractory clay), coal, limestone, and petroleum are important economic resources associated with Pennsylvanian rocks in the state. The total aggregate thickness of the System in Missouri is approximately 2,000 feet.

Morrowan Series

South of the Missouri boundary, in the northern part of the Boston Mountains of northwestern Arkansas, the Morrowan Series consists of the Hale formation below and the Bloyd formation above. Northward in Missouri, the Morrowan is represented only by sandstone outliers of the **Hale formation** that cap Oakleigh Mountain, Lennox Mountain, and Reed Mountain in Barry County. The sandstone at these places is quartzose, medium grained, yellowish brown to brown, massive and cross bedded. Sandstone casts and molds of the stems of *Lepidodendron* and other plants are present. The sandstone is as much as 65 feet thick in Missouri.

Atokan Series

Fossil evidence indicates the presence in Missouri of pre-Desmoinesian rocks which are assignable to the Atokan age. The lowermost of these rocks are the Cheltenham clays of eastern Missouri, at least part of which lie below the Burgner formation which contains a post-Morrowan, pre-Desmoinesian fauna, and the McLouth formation of the Forest City basin, which lies below known Desmoinesian and below a limestone which is correlated with the Burgner. The limestone assigned to the Burgner in the Forest City basin lies below black shales and thin coal beds which resemble the Riverton in their lithology and position below the Warner formation of early Desmoinesian age.

Cheltenham formation.—The Cheltenham formation, which is composed of clays and associated clastics, lies above beds whose ages range from Ordovician to Mississippian and below Pennsylvanian strata which range in age from Atokan to latest pre-Marmaton. Although the clays and associated clastics of the Cheltenham are herein assigned to the Atokan Series, it is realized that this assignment is subject to question because there is not complete agreement on the age of this formation. They include clays which are mostly white to light or medium gray to purplish or red in color. Plastic, flint, and burley clays are represented, and all are refractory. Locally, thin coal beds are interbedded, and as many as three are present in some successions. The rootlike organ, *Stigmaria,* and other root impressions are present in the clays below the coal beds.

To the north of the Missouri River, the clays appear to be more or less like bedded deposits laid down on a solution surface, but toward the south the clays tend to be confined to filled-sink structures, each of which is of restricted area.

At the base, and intergrading with the lowest part of the clay in many places, are sandstones, chert conglomerates, and chert rubble or residuum. This is the "rimrock" of the filled-sink type deposits. Sandstone beds appear to lense into the clay in some places.

Patches of Cheltenham clay and associated sandstone and conglomerate extend eastward from Morgan and Randolph Counties in central Missouri to Lincoln and St. Louis Counties in the eastern part of the state, and southward from Monroe County in northeastern Missouri to Phelps and Crawford Counties.

McLouth formation.—Between the Mississippian rocks and beds referred to the Burgner formation in the Forest City basin, there is a succession of dark gray to black shales, clays, and quartzose sandstones that have been described by Wallace Lee (1941) in Kansas and named the McLouth sand. In Missouri, the thickness of this unit ranges from a featheredge along the eastern and southern edge of the basin beneath Putnam, Sullivan, Linn, Chariton, Lafayette, Clay, and Platte Counties to more than 200 feet in the deeper part of the basin beneath Atchison and Andrew Counties in the northwestern corner of the state. Both the McLouth formation and the Cheltenham formation lie below Atokan beds referred to the Burgner formation, but the relationship between the McLouth and the Cheltenham is not known.

Burgner formation.—At its type locality in Jasper County, the Burgner formation consists of two coal beds overlain by black siltstone which is, in turn, overlain by light gray, finely to coarsely crystalline, fossiliferous limestone, all of which is preserved as sink fillings in Mississippian limestone. The Burgner is as much as 16 feet thick. In Miller and Morgan Counties, there is a succession which consists of quartzose sandstone, Cheltenham clay, a coal bed, and chert and cherty limestone as much as 10 feet thick. The fauna in the limestone indicates that the unit is equivalent to the Burgner. Sandy limestone as much as 12 feet thick that lies near the base of the Pennsylvanian and is associated with a black shale regarded as Riverton in St. Clair, Cedar, and Dade Counties is also tentatively referred to the Burgner, although the fauna of this unit is poorly represented and not diagnostic. Limestone in the Forest City basin, below the Warner, and within black shales resembling the Riverton formation is likewise referred to the Burgner. The thickness of the formation varies from a featheredge to 35 feet in Jasper County and from a featheredge to 70 feet in the Forest City basin.

Riverton formation.—The Riverton formation is composed of dark gray to black, fine-grained, relatively brittle shale and contains as many as three coal beds each of which is underlain by underclay. Siderite, in beds ranging from an inch to more than 6 inches thick, is commonly present, particularly in the upper part. In many places, especially where the formation is relatively thin, the beds are very much contorted, slickensided, and faulted. Similar beds of like facies that lie below the Hartshorne (?) or the Warner in the Forest City basin are referred to the Riverton formation.

At the east side of the Forest City basin, the Riverton appears to extend but little farther than the underlying Atokan formations. It appears to be absent below the Krebs subgroup in an area extending from southeast of Kansas City eastward to Saline County. Linear patches of the formation occupy the bottoms of northwestward trending pre-Warner channels in Hickory, St. Clair, and Cedar Counties. The Riverton varies in thickness from a featheredge to 90 feet or more.

Desmoinesian Series

As considered by the Missouri Geological Survey, the Desmoinesian Epoch is the time interval which extends from the beginning of the Venteran to the end of the Cygnian, the major time subdivisions of the Desmoinesian. It includes all post-Atokan, pre-Missourian time. The Cherokee and Marmaton groups are the major rock units which represent this time interval in Missouri. However, the boundary between the Venteran and Cygnian Stages lies within the Cherokee group.

Venteran Stage

The Venteran Age is the time during which the strata of the lower Cherokee group were deposited. The age ended with the completion of deposition of the Seville formation. The rocks laid down during the Venteran Age are classified as the Krebs subgroup of the Cherokee group.

CHEROKEE GROUP.—The Cherokee group comprises all of the strata included in the Krebs and Cabaniss subgroups. Thus, the time of deposition of the Cherokee includes all of the Venteran and the early part of the Cygnian Age.

KREBS SUGBROUP.—The Krebs subgroup is made up of sandstone, siltstone, shale, clay, limestone, and coal beds. Clastics predominate as lithologic constituents. In many places, sandstone makes up the greater part of the succession. In western Missouri, the Krebs is essentially coextensive with the cropline of the Pennsylvanian. The succession is absent in the area between Saline County and the Lincoln fold but is present in and extends across northern Scotland and Clark Counties nearly to the Des Moines River. In northwestern Missouri, it extends across the Forest City basin into Kansas, Nebraska, and Iowa.

Hartshorne (?) **formation.**—Beds of sandstone and shale, some of which is red, that locally lie between the Warner formation and the black shale and coal succession assigned to the Riverton are tentatively assigned to the Hartshorne which in Oklahoma is included in the Desmoinesian. These beds have been identified only in the subsurface of Vernon County and in the Forest City basin. The succession is

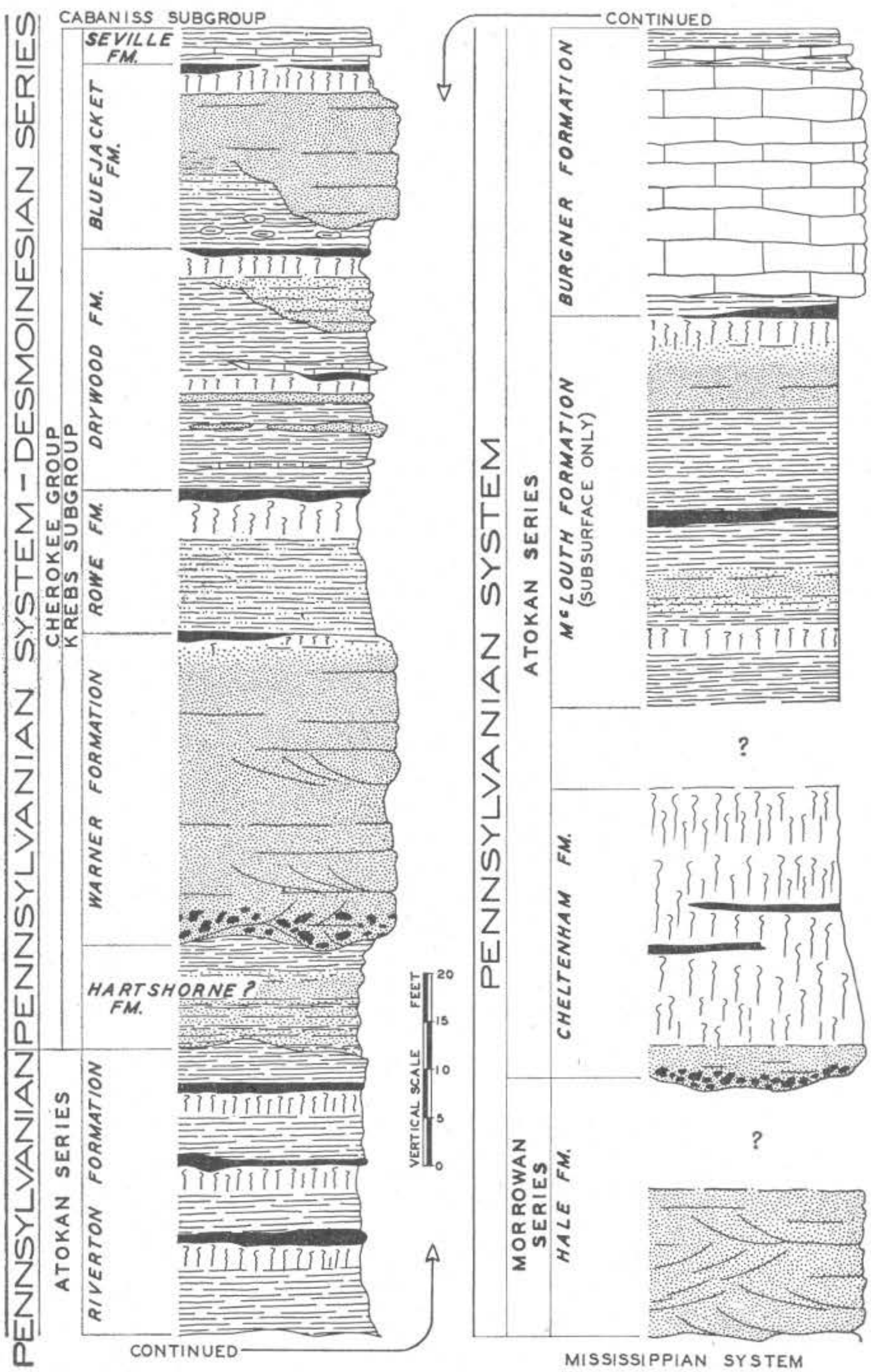


Fig. 16. Pennsylvanian System; Morrowan, Atokan, and Desmoinesian Series (Cherokee group, Krebs subgroup).

absent in many places and ranges in thickness from a featheredge up to approximately 20 feet.

Warner formation.—Conglomerate composed of well worn chert and coarse to fine sandstone commonly lies at the base of the Warner. Where both the conglomerate and sandstone are present, the sandstone overlies the conglomerate. Where the succession is complete, these facies are overlain by a thin underclay followed by a thin coal. The Warner is thickest where it occupies channels that have been cut in older Pennsylvanian and pre-Pennsylvanian rocks. It thins rapidly and grades into siltstone and shale in some localities. The formation thickens from a featheredge to 250 feet. Conglomerates at the base are locally as much as 30 feet thick.

Rowe formation.—From the base upward, the Rowe formation includes sandstone, siltstone, underclay, and the Rowe coal bed. Locally, the formation appears to be mostly sandstone. The Rowe coal bed is persistent but is notably lenticular. It has been mined in many places from Barton County to eastern Henry County and also in Clark County. The formation ranges in thickness between 10 and 25 feet.

Drywood formation.—Where it is completely exposed in Barton and Vernon Counties, the Drywood formation from the base upward consists of: 1) locally developed, fossiliferous, marine limestone, 2) dark gray to black shale which weathers to brittle flakes, 3) fine-grained sandstone, 4) underclay, and 5) the Drywood coal bed. Units 1 and 3 are commonly absent. A similar succession prevails along the strike northeastward, but in many places one or more zones which contain well preserved fern leaves and other plant fossils occurs in an area extending from Cedar County northward into southern and eastern Henry County. Marine fossils are present locally at or near the base of the formation in northeastern Henry County. In the southern part of Henry County, two additional cycles are present within the formation. The formation is thus expanded to include the following units from the base upward: 1) a dark gray to black shale with plant fossils, 2) a thin bed of calcareous shale with brachiopods, 3) a dark gray shale, 4) a sporadic, stigmarian sandstone, 5) a coal smut, 6) a dark gray to black shale, 7) a persistent, ledge forming, calcareous, fossiliferous, fine-grained marine sandstone ("flagstone"), 8) an underclay, 9) a thin, discontinuous coal, 10) a dark gray to black brittle shale, 11) an underclay, and 12) a coal bed referred to the Drywood. Along the southeastern border of the Forest City basin, under deep surface cover, multiple cycles presumably within the Drywood formation are likewise indicated. The formation varies in thickness from a featheredge to 50 feet or more.

Bluejacket formation.—From the base upward, where it is completely represented, the Bluejacket formation consists of: 1) a dark gray to black, brittle shale with abundant siderite or clay-ironstone concretions, 2) a siltstone or fine-grained, thinly laminated sandstone, 3) a medium- to fine-grained sandstone which is conglomeratic in many places with the pebbles of the conglomerate being composed of siderite or clay ironstone "blisters" of shale, 4) an underclay, and 5) the Bluejacket coal. The siltstone, unit 2, makes up most of the formation in some places but is thin or absent in others. The sandstone, unit 3, is very thin locally, but thicknesses of 15 feet or more are common. This sandstone commonly contains *Stigmaria* near the top where it lies below the Bluejacket coal. It contains an "asphaltic" residue in many places in Barton and Vernon Counties. A sandstone in eastern Henry County which is 70 or more feet thick is tentatively referred to the Bluejacket. Locally, the base of the sandstone lies on the Drywood coal. The average thickness of the formation is approximately 25 feet, but because of cutouts and pinchouts, it is locally absent and apparently is as much as 70 feet thick in some localities.

Seville formation.—The Seville formation is a thin, widespread patchy, marine succession at the top of the Krebs subgroup in Missouri. The most widely identified part of the unit is a pinkish-gray or dark gray to black, finely crystalline, brachiopodal limestone which is commonly a foot or less thick but in some places is as much as 2 feet thick. Locally, as much as 3 feet of calcareous shale below the limestone and as much as 2 feet or more of calcareous, fossiliferous shale above the limestone are included in the formation.

The formation has been observed in many places along the Pennsylvanian cropline from Barton County to northeastern Henry County. To the north, the Seville is overlapped by younger Pennsylvanian, but it has also been identified in the logs of many drill holes in the Forest City basin. In northern Missouri, it possibly extends as far east as the western border of Macon County, and it is present north of the Lincoln fold in central Scotland County.

Cygnian Stage

The Cygnian Age spans the time interval between the end of the Venteran Age and the beginning of the Missourian Epoch. The sediments deposited during Cygnian time thus make up the strata of the Cabaniss subgroup of the upper Cherokee group as well as all of the beds of the Marmaton group.

CABANISS SUBGROUP.—The strata assigned to the Cabaniss subgroup of Missouri consist of sandstone, siltstone, shale, underclay, limestone, and coal beds. These are packaged into 12 widely recognized successions, each of which, with certain exceptions noted in formational descriptions elsewhere, is a cyclic unit which includes a coal bed at the top. Where the coal bed is absent, the top of the formation is placed at the inferred position of the coal bed. Each of these successions has been named and is treated as a formation. However, at least seven additional cyclic successions, which are recognized only in restricted or local areas, have been included within the named formations.

The Cabaniss subgroup, wherever it has not been removed by post-Pennsylvanian erosion, is present within the Pennsylvanian outcrop area and forms outliers within the Ozark region where it is essentially absent. In northeastern Missouri, between western Macon County and the Lincoln fold, Cabaniss beds rest directly on the Cheltenham formation. In this same area, much of the lower Cabaniss succession is missing or very greatly reduced in thickness. Thinning

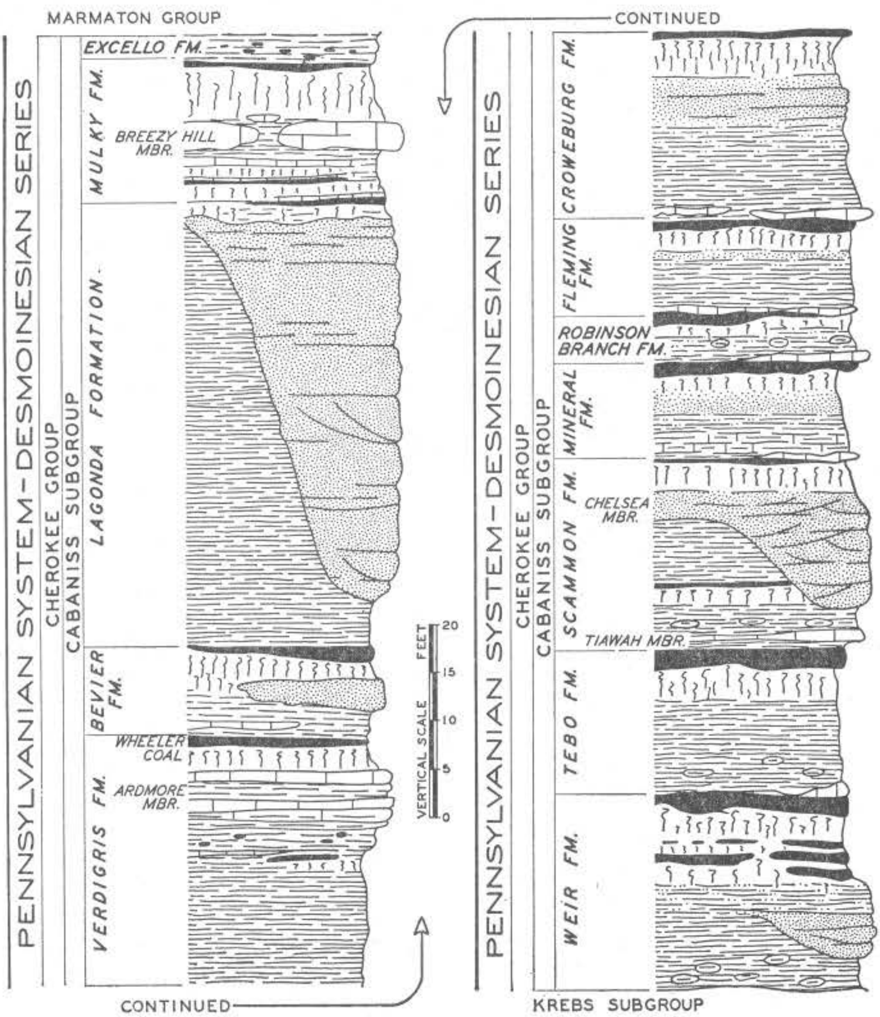


Fig. 17. Pennsylvanian System; Desmoinesian Series (Cherokee group, Cabaniss subgroup).

of the Cabaniss toward the Lincoln fold is so extreme that it is improbable that these beds covered the crest of the Lincoln fold.

The Cabaniss subgroup varies in thickness from essentially a featheredge in the northern Ozark region and in the vicinity of the Lincoln fold up to a thickness of little more than 280 feet in the Forest

City basin. Its average thickness in western Missouri south of the Missouri River is approximately 185 feet.

Weir formation.—The Weir formation is a composite of three cyclic successions. Where it is completely represented, the unit contains the following from the base upward: 1) a unit of shale and clay as much as 6 or more feet thick that contains an abundance of clay-ironstone concretions, 2) a fine-grained sandstone 0 to 30 feet thick, 3) a micaceous siltstone as much as 5 feet thick, 4) an underclay, 5) a coal, 6) a shale as much as 3 feet thick, 7) a sandstone 0 to 2 feet thick, 8) an underclay, 9) a coal, 10) an underclay, and 11) the Weir-Pittsburg coal bed.

The complete succession is developed only locally, being best known in southern Vernon and northern Henry Counties. The formation continues into and across the Forest City basin, but it pinches out to the east of the basin, apparently only a short distance east of the pinchout of the Krebs subgroup. It is not certainly identified east of Range 15 West in Macon County.

The Weir-Pittsburg coal bed and its underclay are the most widely recognized units of the formation. The coal has been mined in many places southwestward along the strike from Henry County. It has been particularly exploited in Barton County.

Tebo formation.—From the base upward, the Tebo formation consists of: 1) a more or less black, carbonaceous shale which contains a few fossiliferous limestone nodules near the base, 2) a gray mudstone with siderite concretions, 3) a micaceous siltstone or sandstone, 4) an underclay, and 5) the Tebo coal bed. In northeastern Missouri, the formation is represented by an underclay and a coal smut or thin coal bed. The formation's thickness averages approximately 15 feet, but it has a maximum thickness of 30 feet or more. In the Tebo district, which extends from northwestern St. Clair County across Henry to southeastern Johnson County, the Tebo coal is from 28 to 36 inches thick. It is too thin to be mined elsewhere. At present, more coal is mined from the Tebo bed than any other bed in the state.

Scammon formation.—From the base upward, the Scammon formation consists of: 1) a black fissile shale which contains flattened and spherical phosphatic concretions and which grades upward into a calcareous gray shale, 2) the Tiawah member which is a dense, persistent, medium to dark gray limestone containing an abundance of tabular algae, *Archeolithophyllum missouriensum*, and which extends from northeastern Henry County southwestward to and beyond the Kansas line—the limestone is nodular in northeastern Missouri, 3) a black, tough, blocky shale which contains siderite concretions and which grades upward into a dark gray mudstone, 4) the Chelsea member which is a fine-grained micaceous sandstone, 5) a thin underclay, and 6) the thin Scammon coal. Locally, in southern Vernon County, another thin underclay, thin coal, and shale, in that order upward, lie above the Tiawah and below the Chelsea sandstone. The Chelsea locally cuts out and replaces lower beds nearly to the Weir-Pittsburg coal bed. The persistent limestone of the Tiawah member appears to be the only recognizable unit of the formation in northeastern Missouri, and this bed pinches out as it approaches the Lincoln fold. The maximum thickness of the formation is probably more than 30 feet.

Mineral formation.—Where the Mineral formation is complete, its lithologic units from the base upward are: 1) a thin, dark gray, finely crystalline, fossiliferous limestone, 2) a calcareous gray shale, 3) a silty, light to medium gray shale, 4) a stigmarian sandstone, 5) an underclay, and 6) the Mineral coal bed. The thin limestone at the base of the formation is rarely present. The Mineral coal bed at the top of the formation ranges from the thickness of a smut streak to as much as 7 feet. This bed was mined in northern Vernon and southern Bates Counties during the early part of the century. It is presently mined in southwestern and northern Vernon County and in northeastern Henry County. The formation is well known in western Missouri and appears to be present in the Forest City basin. It has not been identified in northeastern Missouri. Its average thickness is approximately 20 feet.

Robinson Branch formation.—From the base upward, the Robinson Branch formation includes: 1) a dark gray, earthy, abundantly fossiliferous limestone which grades laterally into dark gray to black, calcareous, fossiliferous shale, 2) a black, fissile shale containing abundant flattened siderite concentrations, 3) a thin-bedded silty shale or siltstone, 4) the underclay of the Robinson Branch coal, and 5) the Robinson Branch coal bed. Units 1 and 2 can commonly be identified above the Mineral coal bed from north-central Henry County southwestward to and across the Kansas line. The underclay and coal are present at widely spaced intervals along the cropline. The formation is 0 to 10 or more feet thick. It has not been identified in the Forest City basin.

Fleming formation.—Where the Fleming formation is complete, the succession includes from the base upward: 1) a thin, dark gray, fossiliferous limestone, 2) a dark gray to black fissile shale, 3) lenses of fine-grained, micaceous sandstone and siltstone, 4) an underclay, and 5) the Fleming coal bed. The formation is continuous along the cropline from the Kansas border to western Henry County where it pinches out toward the east. It continues northward into the Forest City basin. The formation varies in thickness from a featheredge up to 15 feet.

Croweburg formation.—Where it is complete in western Missouri the Croweburg formation contains from the base upward: 1) a thin, patchy, dark gray, fossiliferous limestone, 2) a tough, black, massive shale which grades upward into a medium gray shale or silty shale, 3) a gray, micaceous siltstone or fine-grained, micaceous sandstone, 4) an underclay, and 5) the Croweburg coal bed. The expression of the formation in the Forest City basin is similar to that elsewhere except that red shale lies at the apparent position of the siltstone and sandstone. In northeastern Missouri, the Croweburg formation is represented only by the fairly thick underclay and the coal bed. These are the basal Cabaniss beds which overlap on older Pennsylvanian in many places where the Krebs subgroup is lacking in northeastern Missouri. The formation pinches out toward the Lincoln fold and the northern part of the Ozark uplift. The Croweberg coal bed is probably the most extensively represented coal in the state, and indeed, in North America. The formation's thickness probably averages approximately 20 feet.

Verdigris formation.—The Verdigris formation includes from the base upward: 1) a gray mudstone, 2) a black, fissile shale which contains rounded and flattened phosphatic concretions as well as large, thickly lenticular to subglobular, siliceous, pyritic, more or less calcareous concretions, 3) the **Ardmore member** which is a limestone or succession of limestone and interbedded shale, 4) the underclay of the Wheeler coal, and 5) the Wheeler coal bed. At a single outcrop in western Henry County, a thin coal and an underclay have been observed beneath the black, fissile shale of unit 2. The thickness of the formation is modified greatly by the thickness of the gray mudstone (unit 1) which is locally as much as 40 feet or more thick but which thins to a featheredge within a few miles. The Ardmore member likewise varies in thickness, depending on the number and thicknesses of the limestone beds and interbedded shales. The Wheeler coal bed is relatively thin, but it has been mined in Vernon County, mostly in small stripping operations, and in the Bevier district in northern Missouri where it is separated from the overlying Bevier coal bed by only a thin clay parting and is mined with the Bevier. The Verdigris formation varies from a maximum thickness of 50 or more feet to a featheredge near the Lincoln fold.

Bevier formation.—From western Vernon County northward into western Henry County, the Bevier formation consists from the base upward of: 1) a more or less mottled shale which ranges from a featheredge up to 4 feet thick, 2) a thin, persistent, red or black, abundantly fossiliferous, earthy limestone, and 3) a dark gray shale. Locally, in western Vernon County, as many as three thin limestones which are separated by shale occupy the position of unit 2, between the upper and lower shales. From western Henry County northward into Livingston County, the three units persist but are overlain by underclay which is laterally displaced by a few feet of stigmarian sandstone which in turn thins but extends into western Randolph County as the "bench rock" between the Wheeler and Bevier coal beds. The "bench rock" grades laterally into clay which extends as a parting 2 inches thick, or commonly less, into Boone and Callaway Counties. The Bevier coal bed, which lies above either the underclay, the stigmarian sandstone, or the thin clay parting, is identified from western Henry County northward to the Iowa state line and eastward to Callaway, Boone, and Audrain Counties. The coal is of mineable thickness in the Bevier district in Adair, Macon, Howard, Boone, and Callaway Counties and has been mined extensively in this area. Westward beyond western Henry County, the boundary between the Bevier and Lagonda formations is obscure owing to absence of the Bevier coal bed. The formation ranges from a thickness of 20 feet or more to a featheredge.

Lagonda formation.—The Lagonda formation is composed of shale, siltstone, and sandstone and, locally, consists almost entirely of one lithology, but commonly the shale lies below the sandstone. The sandstone locally cuts down to, and in some places, through the Bevier coal. Thin patches of underclay lie at the top of the formation in some places. The top of the lowermost of three thin coal beds or coal smuts which lie below the Mulky underclay is considered to be the top of the Lagonda formation in Henry County. Locally, in Boone County, brachiopods such as *Desmoinesia* (*Marginifera*), *Mesolobus*, and *Lingula*, and branching bryozoans are present in the lower part of the formation. The position of the base and, consequently, the thickness of the Lagonda is conjectural southwest of southwestern Henry County where the Bevier coal bed has not been identified. The formation's thickness commonly varies between 35 and 95 feet and averages approximately 60 feet except in northeastern Missouri where the unit thins unevenly and pinches out toward the Lincoln fold.

Mulky formation.—The Mulky formation is a persistent unit which extends across the state from Vernon County to the Iowa line of Schuyler County. It is also persistent in northeastern Missouri near the Lincoln fold. It is composed essentially of the underclay of the Mulky coal and the Mulky coal bed. In many places, hackly, nodular limestone known as the Breezy Hill member of western Missouri lies at the base of the underclay either as a bed or as discontinuous masses. Locally, in Henry County, three or more thin limestones, each of which is underlain by a thin coal smut and a thin underclay, lie at the base of the Mulky underclay. The top of the coal resting on the lowermost of these underclays is considered to be the base of the Mulky formation. The other beds are included in the Mulky formation. The Mulky coal varies from the thickness of a smut streak to 2 feet. The formation is 3 to 8 feet thick and averages approximately 4 feet thick.

Excello formation.—The Excello formation consists mainly of black, thinly laminated, fissile shale which contains flattened, drab gray, phosphatic concretions. In the Ozark region and near the Lincoln fold, these beds grade into thin, flaky, greenish-gray shale which has an abundance of phosphatic concretions. Locally, the formation also contains large biscuit-shaped, calcareous, siliceous, and pyritic concretions that are as much as 3 feet or more in diameter. In many places, a bed of gray to buff calcareous shale 2 or 3 feet thick that contains nodules and thin beds of limestone rests on the black fissile shale at the top of the formation. In some localities, a thin bed of fossiliferous limestone lies between the black fissile shale and the Mulky coal below. Locally, pyritized *Lingula*, *Orbiculoidea*, and other brachiopods occur sparingly at the base of the shale. The thickness of the formation varies between 10 inches and 5 feet but probably averages 3 to 4 feet.

MARMATON GROUP.—The Marmaton group consists of a succession of shale, limestone, clay, and coal beds. Compared with the Cabaniss subgroup of the Cherokee below, the Marmaton contains more limestone units which are also thicker and more persistent. The group in Missouri is now divided into two subgroups, the Fort Scott below and the Appanoose above.

FORT SCOTT SUBGROUP.—The Fort Scott subgroup includes three formations which are in ascending order: the Blackjack Creek, the Little Osage, and the Higginsville. These have been raised to the rank of formation in Missouri 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.

Blackjack Creek formation.—The Blackjack Creek formation consists of a lower and an upper unit. The lower unit is persistent and commonly present as a single bed of finely crystalline earthy limestone. It is locally unevenly bedded and becomes wavy bedded or nodular toward the Lincoln fold. The upper unit is absent in many places, but wherever it is present it is composed of nodular limestone or calcareous shale which contains nodules of limestone that are sufficiently abundant in many places to form beds near the top of the unit. A fauna of brachiopods and other fossils, including the coral *Chaetetes*, occurs in the lower unit, whereas the upper unit is fossiliferous only locally where ostracodes and brachiopods rarely occur. The Blackjack Creek is more than 12 feet thick in some localities, but it thins to less than a foot thick in others.

Little Osage formation. The lower part of the Little Osage is a fairly uniform succession which extends across the state from the Kansas to the Iowa state line. It contains an underclay at the base. This is overlain by the Summit coal bed which in turn is overlain by a dark gray, calcareous, fossiliferous shale which is followed by a black fissile shale containing abundant phosphatic concretions. The latter is one of the most conspicuous and persistent units in the Fort Scott subgroup.

In western Missouri, the upper part of the Little Osage is thin and is composed mostly of a dark gray shale which contains one or two thin, fossiliferous limestone beds near the top. North of central Johnson County, the **Houx member,** which is a limestone, appears above the black fissile shale and is persistent to the Iowa line and extends into northeastern Missouri to its outcrop boundary. In northern Missouri, the Houx member is split into thin beds of limestone by a thin shale parting which thickens northward.

North of Johnson County, the Houx is overlain by a medium to dark gray to red or reddish-brown shale which intergrades, possibly both laterally and vertically, into the **Flint Hill member**, a blanket sandstone of wide lateral extent spreading northwestward from central Boone County. Locally, as in central Boone County it appears to be a channel type sandstone. In northern Missouri, as in Putnam County, the upper foot or two of the Little Osage is a light gray shale or clay with

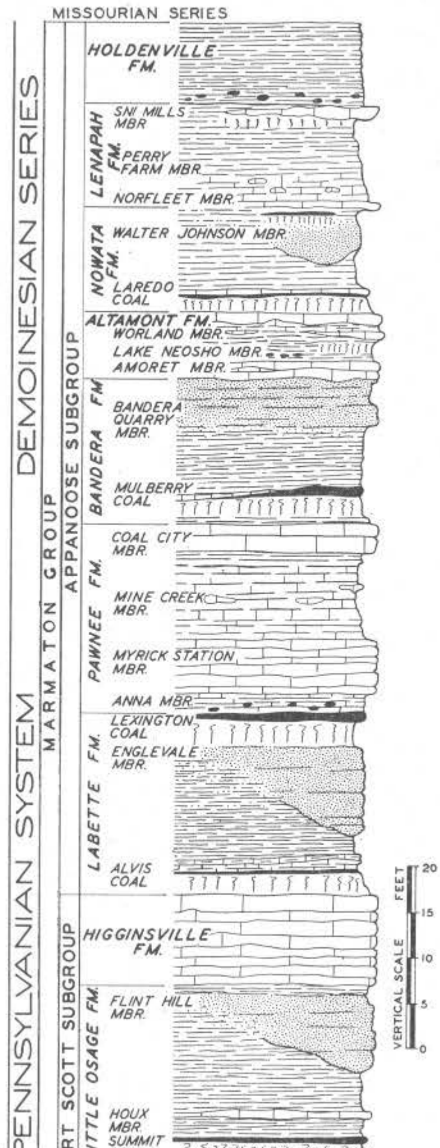


Fig. 18. Pennsylvanian System; Desmoinesian Series (Marmaton group).

a carbonaceous smut streak at the top. Brachiopods are common in the calcareous shales and in the limestone. *Chaetetes* is locally present in the upper part of the Houx. The thickness of the succession averages 8 feet south of central Johnson County, but it attains a local maximum of more than 50 feet in northern Missouri.

Higginsville formation.—In western Missouri, where it is thickest, the Higginsville formation is a dense, finely crystalline, wavy-bedded limestone mottled with medium gray. The rock is thick bedded below and thin bedded above. In northern Missouri where the formation is of intermediate thickness, the unit is a dense, wavy-bedded limestone which is interbedded with nodular limestone. Toward the Lincoln fold in northeastern Missouri, the limestone is yellow to yellowish gray below, light gray above and is mostly rudely bedded and earthy. The fossils include brachiopods, large and small fusuline Foraminifera, algal pellets, and *Chaetetes*. The Higginsville is thickest in western Missouri, particularly in Vernon and Bates Counties where it attains a local thickness of as much as 25 feet. From Johnson County, it thins northward and northeastward.

APPANOOSE SUBGROUP.—The Appanoose subgroup includes all of the Marmaton formations above the Fort Scott subgroup. These formations are composed of shale, sandstone, limestone, and coal beds. The limestone beds are better developed and more persistent in the lower formations. Coal beds likewise are well developed in the formations below the middle of the subgroup, and these thicken locally to mineable thicknesses.

Labette formation.—The basal bed of the Labette formation from the Missouri-Kansas boundary in Bates County to the Missouri-Iowa boundary in Putnam County is a persistent bed of underclay. From Johnson County southwestward along the cropline, the basal underclay is overlain by the thin Alvis coal bed which is in turn overlain by dark gray fossiliferous marine or shaly limestone which is persistent sporadically at least as far north as the Missouri River in Lafayette County where it rests on underclay. The western Missouri succession is completed by a shale, a siltstone, the Englevale member which is a sandstone, and one or more thin coal smuts or bony coal. North of Johnson County, the basal underclay, with patches of thin marine limestone locally intervening, is overlain by the Lexington coal bed which forms the top bed of the Labette formation. This coal is persistent to the Iowa line. The Lexington coal bed has a thin persistent clay parting that is exposed wherever the coal has been extensively mined in Lafayette County and elsewhere, as in Ray, Harrison, and Putnam Counties. The Lexington has been identified as two or more coal smuts as far east as Audrain and St. Louis Counties. The Labette varies in thickness from more than 50 feet in Bates County to less than 2 feet in western Howard County.

Pawnee formation.—The Pawnee formation consists of four members which are from the base upward: the Anna, Myrick Station, Mine Creek, and the Coal City. The Anna and Mine Creek are mostly shale, the Myrick Station and Coal City, mostly limestone. The average thickness of the formation is approximately 20 feet. It is thickest (more than 40 feet) near the Kansas border but is thinner north of the Missouri River, particularly near the Iowa state line and in northeastern Missouri.

Anna member.—The Anna member of the Pawnee formation is mostly black or greenish-gray, fissile, calcareous shale which contains flattened phosphatic concretions. It commonly grades into greenish-gray calcareous shale above. The member is persistent but thin, ranging in thickness from 1 to 3 feet.

Myrick Station member.—The Myrick Station member, in western Missouri, is composed of a dense, bluish-gray limestone which is thinly but irregularly bedded. In northern Missouri, gray shale is intercalated with the limestone. Toward the Iowa state line, the unit is increasingly shaly and becomes a succession of beds of calcareous, fossiliferous shale. Brachiopods such as *Chonetes*, *Mesolobus*, *Marginifera*, *Neospirifer*, *Composita*, and *Crurythyris* are abundant to common. The member is 2 to 10 feet thick.

Mine Creek member.—The Mine Creek member of the Pawnee is mostly a shale of medium to dark gray color with shades of green and brown. It is commonly calcareous and contains limestone nodules in many places. Where the member is thickest, it contains some sandstone. Brachiopods such as *Derbyia*, *Dictyoclostus*, *Mesolobus*, *Chonetes*, *Marginifera*, *Punctospirifer*, *Composita*, and *Linoproductus* are common. The thickness of the member varies between 5 and 30 feet.

Coal City member.—The uppermost member of the Pawnee formation, the Coal City, is a light gray, dense limestone in western Missouri which becomes shaly northeastward. As it approaches the Iowa state line, it is split into two beds by shale. The Coal City commonly is abundantly fossiliferous; the brachiopods *Composita*, *Mesolobus*, *Meekella*, *Punctospirifer*, *Chonetes*, *Noespirifer*, and *Schuchertella* are commonly present. The member is 2 to 6½ feet thick.

Bandera formation.—The succession of beds within the Bandera formation exhibits considerable variation along the line of outcrop from the Kansas state line to the northern boundary of Missouri. A shale which is commonly medium or greenish-gray in color lies at the base of the succession. It is overlain by an underclay which extends from the western boundary of the state northeastward beyond the Missouri River. The Mulberry coal bed rests on this clay. Although it is of mineable thickness in Bates County, the coal diminishes to the thickness of a smut streak north of the Missouri River. A thin marine limestone is present above the underclay in Ray County but is absent in many places in northern Missouri. Elsewhere, it is represented by thin, alternating, fossiliferous limestone and shale beds. The **Bandera Quarry member** which is composed of shale and sandstone occupies the upper part of the formation in many places in western and northern Missouri. In Livingston, Ray, and southern Grundy Counties, the upper limit of the formation is obscure owing to the absence of the Amoret member which is the basal bed of the overlying Altamont formation. The Bandera formation varies from 2 to 21 feet in thickness.

Altamont formation.—The Altamont formation consists of three members, two of which, the lower and upper, are mostly composed of limestone. The lower member is the Amoret, and the upper, the Worland. The two are separated by a shale member, the Lake Neosho.

Amoret member.—This variable unit is composed of fossiliferous beds of limestone and calcareous shale. In many places, it is represented by a thin bed of limestone or by algal limestone nodules which are embedded in fossiliferous green shale. At some localities in the outcrop area in Jackson, Lafayette, Ray, Carroll, and Livingston Counties, the unit appears to be absent, and the boundary between the Altamont and underlying Bandera formations is obscure. The member varies in thickness from a featheredge to 5 feet.

Lake Neosho member.—In Bates County, the Lake Neosho member consists of a calcareous, fossiliferous, greenish-gray shale which contains a zone of dark gray to black shale that has large, subspherical, phosphatic concretions within it. The fossiliferous shale extends across Livingston, Sullivan, and Adair Counties where a coal smut resting on underclay appears below it. The upper fossiliferous shale beds contain a considerable amount of limestone in the form of thin beds in northern localities. Where the Amoret member is absent, the Lake Neosho's contact with the underlying Bandera formation is obscure. The member varies between 2 and 10 feet in thickness.

Worland member.—This persistent limestone member of the Altamont crops out across Bates, Jackson, Lafayette, and Ray Counties, across Grundy County, Sullivan and Putnam Counties to the Iowa state line. It is characteristically a massive bed of limestone which grades laterally into light bluish-gray limestone below and lighter gray, algal limestone above. The limestone is separated into two units by 3 feet or less of calcareous shale northward from eastern Jackson County to the approximate vicinity of Grundy County. From Grundy County to the Iowa state line, the limestone is massive, dove gray, and contains small inclusions of green clay. The member varies in thickness from 1 to 4 feet.

Nowata formation.—The lower part of the Nowata formation consists of an underclay, the thin Laredo coal bed, and a thin, limestone. The beds above the limestone are commonly composed of gray or red shale. The Walter Johnson member, which is a sandstone and siltstone, locally occupies the position of the upper Nowata and possibly cuts well down into the Altamont formation below. A thin coal smut within a shale in Sullivan and Adair Counties is referred to upper Nowata. In Grundy and Sullivan Counties, a thinly laminated black shale as much as 4 feet thick lies on the Laredo coal. The formation's thickness averages between 10 and 15 feet.

Lenapah formation.—The Lenapah formation is typically composed of two limestone members, the Norfleet and Sni Mills, and a shale, the Perry Farm member, which lies between them.

Norfleet member.—The Norfleet member is represented by a single thin bed of greenish-gray, medium to coarsely crystalline, crinoidal limestone. The bed thins to a featheredge in northern Missouri, and it has been identified in many places in the western part of the state. The unit's thickness in western Missouri ranges from 10 inches to a featheredge.

Perry Farm member.—The Perry Farm member is mostly a gray shale which is characteristically calcareous below and green and red above. The lower, calcareous part contains a more or less abundant amount of small limestone concretions. A thin underclay or stigmarian sandstone near the top of the member is locally overlain by either a thin coal or coal smut. The member ranges in thickness from 1 foot in Bates County to 20 feet in Ray County.

Sni Mills member.—The Sni Mills member of the Lenapah formation is typically a light to medium gray, medium to finely crystalline limestone which contains dark gray calcite veinlets. The limestone weathers with a rough, hackly surface. Cone-in-cone structure is commonly associated with it. The unit is absent in many places south of the Missouri River where its position is marked either by a thin bed of fragmental shell limestone, the overlying dark shale of the Holdenville formation, or by a silty maroon clay or mudstone which is included with the uppermost Perry Farm. The Sni Mills varies in thickness from a featheredge to 2½ feet. It probably averages 8 inches or less in thickness.

Holdenville formation.—The Holdenville formation, the youngest recognized unit of the Marmaton group in Missouri, is composed mostly of gray shale. Locally, it is dark gray to black and fissile and has phosphatic concretions near the base. In southern Cass County, it contains dark gray, fossiliferous concretions. The unit contains orbiculoids in some localities, and cephalopods are present within it in southern Cass County. The thickness of the formation ranges from a featheredge to 15 feet or more.

Missourian Series

The Missourian Series is divided into four successively younger groups, the Pleasanton, Kansas City, Lansing, and Pedee. The rocks forming these groups are present in a broad belt which underlies the Kansas City area and extends northeastward across western and northern Missouri. The Series comprises a number of prominent formations which are composed principally of alternating beds of limestone and shale and are separated by comparatively thicker formations of shale and sandstone. The Missourian limestones are especially important because they are the source for most of the crushed rock which is used for road surfacing and concrete aggregate in western and northern Missouri. The Series is separated from the underlying Desmoinesian by a disconformity at the base of the Pleasanton group and is distinguished by the absence of typical Desmoinesian fossils and by the introduction of several new fossils, among which the fusuline *Triticites* is probably the most important. The unconformity beneath the basal Virgilian, Tonganoxie member, marks the upper boundary of the Missourian Series.

PLEASANTON GROUP.—The Pleasanton group comprises all the strata which lie below the base of the Kansas City group and above the regional disconformity which separates the Desmoinesian from the Missourian Series. Pleasanton strata are dominantly clastic and thus contrast lithologically with those of the overlying Kansas City group whose thick limestone beds form a prominent scarp above the less resistant shales and sandstones of the Pleasanton. Exposures of Pleasanton beds lie in a belt of variable width which extends across western and northern Missouri. The group is also represented by channel-fill deposits in the Warrensburg and Moberly channels in western and central Missouri and by outliers in St. Louis County.

The Pleasanton group is herein divided into three unnamed formations. These formations are in turn divided into members, some of which already bear formal names. This subdivision anticipates a more complete classification which is now being prepared in a detailed report on the stratigraphy of the group in Missouri. The group is not completely represented in the St. Louis County area.

The average thickness of the Pleasanton at the surface is approximately 90 feet. The group thins northward and westward from its cropline, and in the subsurface its minimum thickness appears to be as little as 20 feet. Its maximum thickness in areas where it includes channel-fill deposits probably exceeds 150 feet.

Lower formation.—The lower unnamed formation of the Pleasanton group includes the Helper member and all overlying beds up to the base of the Exline member of the next higher formation.

Hepler member.—The Hepler member is a thinly bedded, medium-grained, micaceous sandstone. In many places it is firmly cemented with calcium carbonate. It rests unconformably on upper Marmaton limestones and shales. The member has a maximum thickness of about 15 feet in western Missouri, but it is much thinner and locally absent in the northern part of the state.

Unnamed member.—The unnamed member above the Helper is composed upward of underclay, a thin bed of coal, and shale. The coal is represented by a thin smut over much of western Missouri, and it can be readily traced across the northern part of the state. The combined thickness of the member is rarely more than 3 feet.

Middle formation.—The Exline member and an unnamed shale which lies above it together compose the middle unnamed formation of the Pleasanton group.

Exline member.—Regionally, the Exline is an extremely persistent, thin, crinoidal limestone with an average thickness of less than 1 foot. An abundant molluscan fauna occurs in the Exline in most areas, and in northern Missouri limestone composed principally of the coralline algae *Archaeolithophyllum* lies beneath the more widespread crinoidal bed. The member is continuous from western and northern Missouri into the type area in southern Iowa. It is also present in western Illinois. It has been identified in eastern Kansas, and it may be a correlative of the Checkerboard limestone of northern Oklahoma and southern Kansas.

Unnamed member.—The gray, locally, silty, micaceous shale above the Exline member is bounded at its upper surface either by a channel-fill sandstone or by a more widespread, evenly bedded, calcareous, marine sandstone that is associated with the channel-fill sandstone. The shale member is approximately 50 feet thick where it is overlain by the widespread marine sandstone, but it is absent where the surface of unconformity below the channel-fill deposits extends below the base of the Pleasanton group. The shale of this unnamed member is utilized for the manufacture of brick and tile at a number of places in Missouri and southern Iowa.

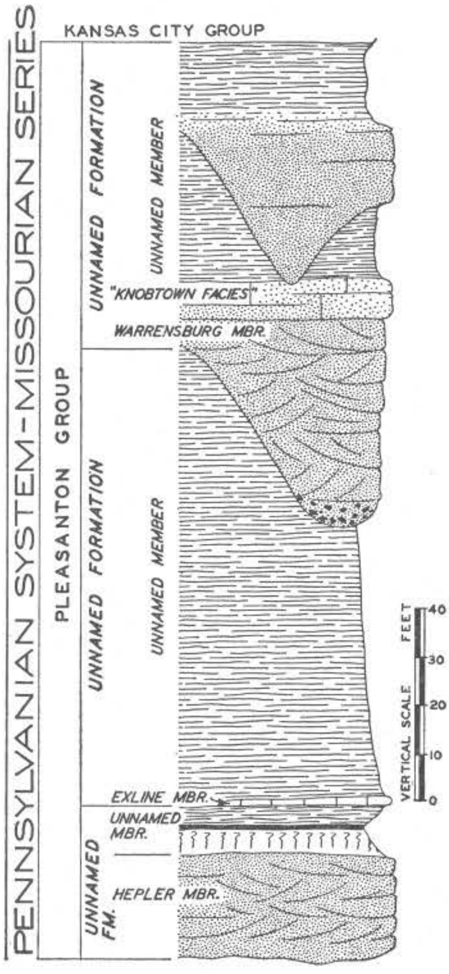


Fig. 19. Pennsylvanian System; Missourian Series (Pleasanton group).

Upper formation.—The Warrensburg member and an unnamed member which lies above it together constitute the uppermost formation of the Pleasanton group.

Warrensburg member.—The strata which are assigned to the Warrensburg member are quite varied in thickness and lithology. The term Warrensburg has heretofore generally been applied only to the channel-fill deposits known as the Warrensburg and Moberly sandstones. In this report it is also applied to other deposits that are considered to be closely related to those in the channel areas. In western Missouri, the thick shale of the middle formation is overlain either by a calcareous marine sandstone which contains an abundance of shell debris, or, as in the Pleasant Hill area of Cass County, by a channel-fill type sandstone which has been referred to as the Warrensburg sand. The calcareous marine sandstone is considered to be a widespread facies of the Warrensburg member that was developed during the final, predominantly marine phase of the filling of the Warrensburg valley system. This facies has been identified as the "marine Knobtown" and "lower Knobtown sandstone" in former reports. The average thickness of this facies is about 5 feet. The channel-fill type sandstone which is assigned to the Warrensburg member is typically fine to medium grained, micaceous, and strongly cross bedded. It is well developed in both western and northern Missouri where it occupies channels cut into middle and lower Pleasanton and, in some localities, into even older strata. Geographic relationships, lithologic characteristics, gross physical aspect, and other factors are all bases for relating these deposits to those of the Warrensburg and Moberly channel areas to the south and east of the Pleasanton outcrop belt. The coarse, locally-developed, limestone conglomerate which is at the base of the channel-fill deposits at some localities is the "Chariton" conglomerate of earlier workers and it is also regarded as a facies of the Warrensburg. The Warrensburg member, including these important facies, constitutes the lower part of the upper unnamed formation of the Pleasanton group. The maximum thickness of the member is possibly as much as 150 feet in the channel areas.

Unnamed member.—The strata above the Warrensburg member and below the base of the overlying Hertha formation of the Kansas City group are assigned to an uppermost unnamed member of the Pleasanton. In much of western Missouri, as in the Jackson County area, this member contains a gray shale and an overlying fine-grained, micaceous sandstone; the latter being the "upper Knobtown sandstone" of many former reports. The sandstone locally occupies channels which have been cut into or through the calcareous, marine facies of the Warrensburg member. In northern Missouri, there is a suggestion that in some areas this sandstone may occupy channels in the upper part of the thick, massive sandstone of the Warrensburg member. The shale and sandstone of the unnamed member are present throughout the outcrop area of the member in western and northern Missouri, but the relationship of the member to older Pleasanton strata in northern Missouri is obscure because of the absence in that area of the Knobtown facies of the Warrensburg. However, in northern Missouri, a coal lies above the sandstone which is referred to as the Warrensburg and below a sequence of shale and sandstone that is considered to be equivalent to the post-Knobtown succession in western Missouri. This coal bed, which locally is of mineable thickness, is regarded as the basal unit of the unnamed member of the upper formation. It is probably equivalent to Chapel or "Trivoli" (No. 8) coal of western Illinois. The average thickness of the unnamed member in western and northern Missouri is approximately 25 feet.

KANSAS CITY GROUP.—The Kansas City group includes a succession of beds that extends from the base of the Hertha formation to the top of the Bonner Springs formation. The succession is divided into three subgroups which in ascending order are the Bronson, Linn, and Zarah. The Kansas City group lies conformably between older and younger strata, and the subgroups are conformable, one upon the other. Rocks of the Kansas City group are well exposed at many localities in western and northern Missouri and are present throughout northwestern Missouri in the subsurface. Thickness data are provided for each of the subgroup divisions.

BRONSON SUBGROUP.—The Bronson subgroup contains in ascending order the Hertha, Ladore, Swope, Galesburg, and Dennis formations. The Bethany Falls and Winterset limestone members of the Swope and Dennis formations respectively are the most prominent lithologic units in the subgroup. The Bronson is about 80 feet thick.

Hertha formation.—The Hertha formation includes two limestones, the Critzer at the base and the Sniabar at the top, and an intervening shale member, the Mound City. The average thickness of the Hertha is approximately 15 feet.

Critzer member.—This member of the Hertha formation is a nodular, locally fossiliferous limestone which is absent in some areas. The limestone is commonly argillaceous or silty and appears to grade laterally into sandstone or siltstone. Where the limestone is absent, its stratigraphic position is occupied by maroon clay. The thickness of the Critzer is generally less than 1 foot.

Mound City member.—The Mound City member contains in its lower part the Ovid coal and its associated underclay. In its upper part it contains beds of dark and light gray shale and thin argillaceous limestone. The thickness of the member ranges from less than 5 feet to more than 10 feet.

Sniabar member.—The Sniabar member is the most conspicuous unit of the Hertha formation. The member is composed of a succession of limestone beds, the lowest of which is particularly massive and brown weathering. Locally, as in parts of Jackson County, bioherms in the upper part of the Sniabar increase its thickness. Dolomitic limestone is commonly present in western Missouri exposures of the member. In north-central Missouri, as in Mercer County, the Sniabar contains two limestone beds, one of which lies above and the other below a shale bed several feet thick. The Sniabar member is about 10 feet thick.

Ladore formation.—The Ladore typically contains clay and shale, the total thickness of which is less than 5 feet in western Missouri. Clay in the Ladore occurs at the top of the unit and is thin and silty at most localities. The formation thins to less than 1 foot in thickness where it overlies bioherms in the upper part of the Sniabar. The formation is as much as 15 feet thick in Carroll and Livingston Counties where sandstone may occupy all or part of the unit. Fossils are generally scarce.

Swope formation.—The Swope formation consists of a lower limestone (Middle Creek), a middle shale (Hushpuckney), and an upper limestone (Bethany Falls). Thickness of the Swope ranges from 20 to 25 feet.

Middle Creek member.—The Middle Creek member contains one to two thin beds of dark gray limestone that have well developed vertical joints. Locally, a great many Bryozoa are present in the thin beds of gray shale which are associated with the limestone. The average thickness of the member is less than 1 foot.

Hushpuckney member.—The Hushpuckney consists of dark gray to black fissile shale in its lower and middle parts and becomes a gray shale in its upper part. The thickness of the member ranges from 1 to 3 feet.

Bethany Falls member.—The Bethany Falls is probably the most extensively quarried Pennsylvanian limestone in western Missouri. Typically, it forms a single massive ledge in most exposures. A pronounced parting separates the wavy-bedded lower part of the member from an upper, generally somewhat thicker, nodular part. The uppermost part of the member is oolitic over wide areas. The member is chert-free in most areas and is about 20 feet thick.

Galesburg formation.—The Galesburg is composed of clay and shale and in some places in western Missouri has a thin coal at the top. At most localities, the basal part of the formation is a gray shale which contains irregularly shaped calcareous concretions that appear to be closely related to the limestone of the underlying Bethany Falls. The thickness of the formation averages less than 10 feet.

Dennis formation.—The Dennis formation contains two limestone members which are separated by a shale member. The thickness of the Dennis ranges from 30 to 40 feet in the outcrop area of Missouri.

Canville member.—The Canville member occurs in only a few counties in western Missouri. It is well represented in Bates County. It is a dark gray, thin, lenticular limestone whose maximum thickness is about 4 inches.

Stark member.—The Stark member is a dark gray to black, fissile shale that grades upward into medium gray shale. It is about 4 feet thick.

Winterset member.—The Winterset member is a thinly to thickly bedded limestone with many shale partings. The Winterset, like most thick Pennsylvanian limestones in this region, is composed principally of fossil debris. Productid brachiopods are among the most common fossils. The rock is light to medium gray on freshly broken surfaces but weathers to light brown or drab shades. It commonly contains an abundance of dark gray chert in its upper part. It has been quarried for riprap, road metal, and agricultural limestone in many localities in northern and western Missouri. The thickness of the Winterset ranges from 25 to 40 feet.

LINN SUBGROUP.—The succession of strata that lies between the top of the Winterset member of the Dennis formation and the base of

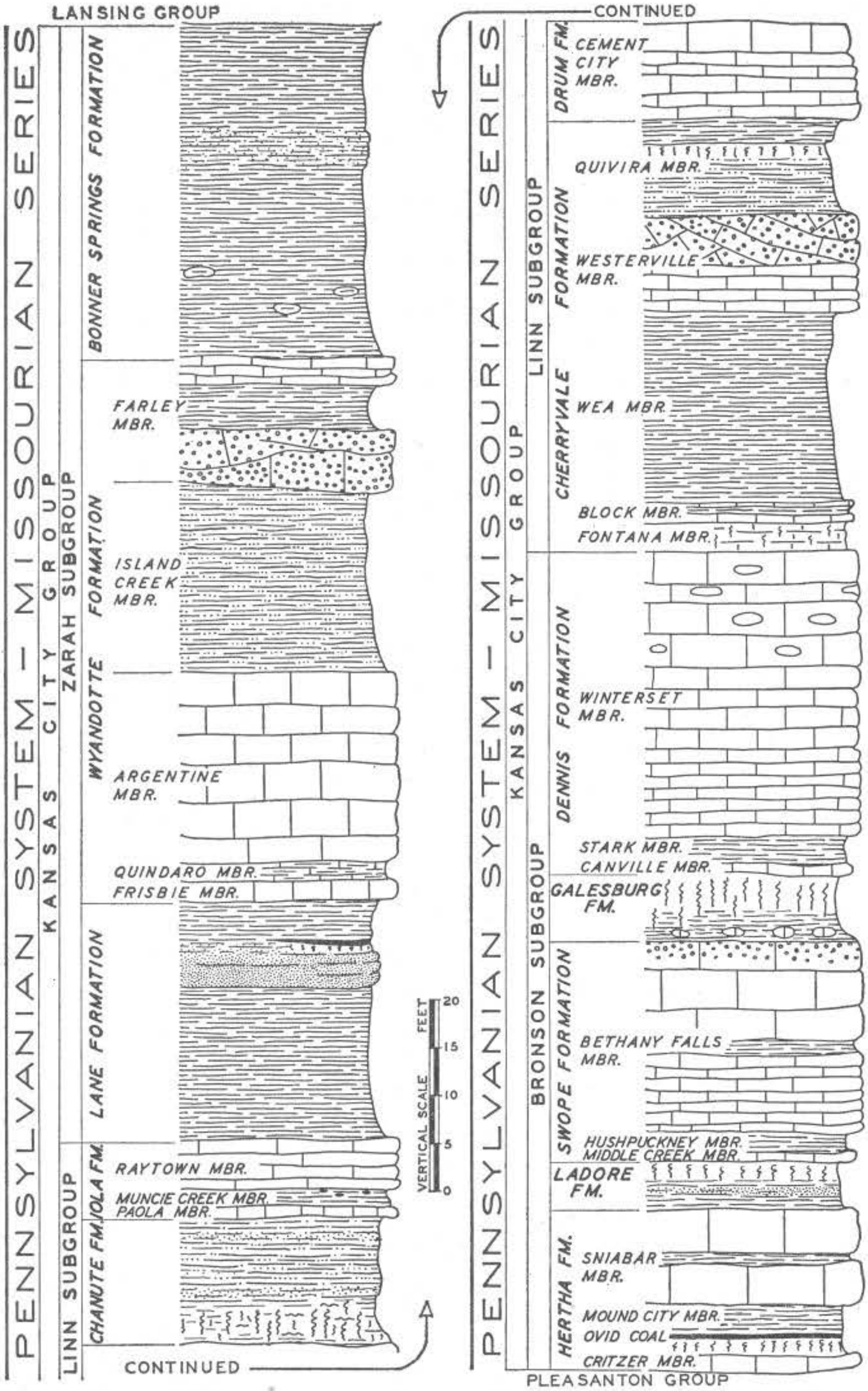


Fig. 20. Pennsylvanian System; Missourian Series (Kansas City group).

the Lane formation is named the Linn subgroup. This succession except for the uppermost formation is one of the most variable in the upper Pennsylvanian section of Missouri. In ascending order, the formations of the subgroup are the Cherryvale, Drum, Chanute, and Iola. The subgroup is about 70 feet thick in the Kansas City area and nearly 100 feet thick in northern Missouri.

Cherryvale formation.—The Cherryvale formation is composed of a succession of limestone and shale that is extremely variable in thickness and in lithology. Its thickness variation is especially pronounced in the Fontana and Westerville members. The average thickness of the Cherryvale formation in western and northern Missouri exposures is about 45 feet.

The formation contains five members which from oldest to youngest are named as follows: Fontana, Block, Wea, Westerville, and Quivira.

Fontana member.—The Fontana member contains silty, gray, micaceous shale and clay. A thin coal bed is present near the base of the member in some places. The Fontana is normally 2 to 5 feet thick and consists mostly of clay, but in the Kingston area of Caldwell County it is between 10 and 15 feet thick and is represented principally by the shale described above.

Block member.—The Block member contains from one to two persistent beds of dark gray fossiliferous limestone. A great many fossils are also present in an associated calcareous shale. The thickness of the member ranges from less than 1 foot to approximately 4 feet.

Wea member.—The Wea member is represented by a bluish-gray, silty, micaceous shale in the Kansas City area where it is from 20 to 25 feet thick. In northern Missouri, the member contains a number of thin, argillaceous, fossiliferous limestone beds and is from 10 to 15 feet thick.

Westerville member.—The Westerville is composed of a lower, relatively uniform, evenly bedded limestone and an upper oolitic limestone which varies greatly in thickness and in lithology. In the Kansas City area, the oolitic limestone locally attains a thickness of 18 or 20 feet, and the total thickness of the member may be as much as 25 feet. In northern Missouri the thickness of the entire member is less than 10 feet.

Quivira member.—The Quivira member comprises a number of distinct beds. At most exposures, it includes gray shale in the lower and middle parts and in the upper part a thin clay and overlying slightly fissile dark gray shale. The shale below the clay is locally maroon in color and is silty or sandy. Its thickness varies greatly in the Kansas City area where it ranges from an average of about 1 foot to a maximum of about 15 feet. This thickness variation is associated with an essentially equivalent variation in the underlying Westerville member. The average thickness of the Quivira in its outcrop area is about 10 feet.

Drum formation.—In most of the northern midcontinent area, the Drum formation contains two limestone members. In Missouri, only the lower member (Cement City) has been recognized to date. However, some evidence exists which suggests that the upper member (the Corbin City limestone of Kansas) is present in Missouri.

Cement City member.—The Cement City member is a gray to buff, thinly bedded limestone which is locally suboolitic in the upper part. It is considered that this suboolitic limestone may possibly prove to be the Corbin City limestone of Kansas. The member is 5 to 10 feet thick.

Chanute formation.—The Chanute formation lies above the Drum formation and below the Paola member of the Iola formation. In essentially all of its outcrop area in Missouri, the Chanute comprises silty gray or maroon claystone in the lower part and silty to sandy shale above. A coal horizon is identified at the base of the upper division of the formation, and a thin coal bed is present at that position at some localities in northern Missouri. The Chanute is from 10 to 15 feet thick in the Kansas City area and thins to a thickness of 5 or 10 feet in northern Missouri.

Iola formation.—The Iola formation contains two limestone members, the Paola below and the Raytown above. A shale member, the Muncie Creek, lies between them. The succession is uniform throughout northeastern Kansas and northwestern Missouri and has an average thickness of about 8 feet.

Paola member.—The Paola is characteristically a single bed of dark gray, fossiliferous limestone which has an average thickness of about 1 foot.

Muncie Creek member.—The Muncie Creek member consists of a fissile shale which contains phosphatic concretions and is uniformly dark gray to black in the lower part and light to medium gray in the upper part. The thickness of the member ranges from a few inches to about 2 feet.

Raytown member.—The Raytown member is generally a massive unit which is composed of several thick beds of fossiliferous, gray and brown limestone, but in some areas the limestone beds alternate with beds of calcareous gray shale. The thickness of the member ranges from 5 to 8 feet.

ZARAH SUBGROUP.—The Zarah subgroup is the uppermost division of the Kansas City group and includes, in the order of decreasing age, the Lane, Wyandotte, and Bonner Springs formations. In the Kansas City area, the subgroup is about 130 feet thick. In northern Missouri this division becomes somewhat thinner because of marked thinning of the Argentine member.

Lane formation.—The Lane formation is a gray, silty, micaceous shale at most of its localities in northern and western Missouri. Thinly bedded sandstone and in some places a thin coal bed are present in the upper part of the formation in Caldwell and probably other counties of north-central Missouri. The thickness of the Lane ranges from 5 to 30 feet.

Wyandotte formation.—The Wyandotte formation is composed of five members. From the base upward, these are the Frisbie, Quindaro, Argentine, Island Creek, and the Farley members. The Frisbie and Argentine members are composed of limestone and are separated by the Quindaro member which is a calcareous shale. The upper members, the Island Creek and Farley, vary considerably in thickness and in lithology. The limestone units of the Farley are more variable than is common for the Missourian Series.

Frisbie member.—The Frisbie member in areas north of the Missouri River is a single, thin, more or less uniform bed of medium to dark gray limestone. Southward it thickens and becomes a more complex unit as in the Kansas City area where it contains several beds of limestone which are interbedded with calcareous shale. The thickness of the member ranges from 1 to 3 feet.

Quindaro member.—The Quindaro is a dark to medium gray, calcareous shale. Locally it contains calcareous, fossiliferous siltstone in the upper part. The thickness of the member varies from less than 1 foot to about 3 feet.

Argentine member.—The Argentine member is a fossiliferous limestone which is extremely variable in thickness. Algal material is thought to be the most important constituent of the rock, although many invertebrate fossils also occur in it. The thickness of the member decreases from a maximum of more than 40 feet at Kansas City to less than 1 foot in northern Missouri. A thick limestone in northwestern Cass County that has long been referred to as the Argentine is now believed to include the Farley member as well.

Island Creek member.—The Island Creek member is a sandy or silty shale which averages about 30 feet in thickness in the area of Jackson, Platte, and Clay Counties, but it is very thin or absent in parts of northwestern Cass County.

Farley member.—The Farley member contains two limestone units and an intervening shale bed in its type area. It is well known only in Platte and western Clay Counties in Missouri. The lower limestone unit is oolitic and extremely variable in thickness. The overlying shale contains a poorly defined coal horizon in its upper part. The member is from 5 to 30 feet thick in Platte and Clay Counties where the complete Farley succession is known. The upper limestone is largley composed of algal debris and ranges in thickness from a few inches to 2 or 3 feet. The member contains many fossil gastropods and pelecypods. The average thickness of the Farley in the area noted above is about 15 feet.

Bonner Springs formation.—The Bonner Springs is composed principally of silty gray micaceous shale but includes lenticular sandstone and locally, silty limestone in the upper part. An extremely thin, irregular coal bed has been reported to occur in the uppermost part of the formation at some localities in northern Missouri. The lower and middle parts of the formation contain scattered clay-ironstone concretions. The thickness of the formation ranges from less than 20 to as much as 40 feet.

LANSING GROUP.—The Lansing group is composed of three formations. The lower and upper formations, Plattsburg and Stanton respectively, are predominantly limestone. The intervening Vilas formation is composed mostly of shale and some sandstone. The Lansing group as a unit is set off sharply by the thick shale formations which lie above and below it; the Weston above and the Bonner Springs below. In northwestern Missouri the group is 60 feet thick.

Plattsburg formation.—The Plattsburg formation contains a lower and an upper limestone member and an intervening shale member. From the base upward, they are the Merriam, Hickory Creek, and Spring Hill members. The lithologic characteristics of each are apparently consistent within the state, and the thickness variation of each is not great. The principal areas of exposure of the formation are in Platte, Clay, Clinton, DeKalb, and Gentry Counties.

Merriam member.—The Merriam member is composed of beds of limestone which are interbedded with calcareous shale. The individual limestone beds have distinctive lithologic and paleontologic characteristics which make it possible to trace the beds for considerable distances. Large myalinid pelecypods are generally present in the lower part of the member. The Merriam is 1 to 3 feet thick.

Hickory Creek member.—The Hickory Creek member is a calcareous, fossiliferous shale which is generally less than 2 feet thick in most outcrops. In unweathered exposures, the upper part of the shale is dark gray to black, while the basal part is light to medium gray.

Spring Hill member.—Where it is typically developed, the Spring Hill member contains a thin, basal, sponge-bearing limestone bed which is overlain by thicker limestone beds that commonly are extremely fossiliferous and are separated by pronounced shale partings. The uppermost part of the Spring Hill is siliceous, hard, and slabby in many areas. The member commonly contains dark gray chert and is 10 to 20 feet thick. It has been quarried at a number of localities in the state for riprap and road surfacing material.

Vilas formation.—The Vilas formation consists of silty to sandy gray shale and locally contains sandstone where the unit is thickest, but in northern Missouri where the formation is thin it is composed of dark gray to black shale. In the westernmost part of Platte County, the Vilas is 20 feet thick; elsewhere, it is no more than 5 feet thick.

Stanton formation.—The Stanton formation contains from the base upward the following members: Captian Creek, Eudora, Stoner, Rock Lake, and South Bend. Parts or all of the formation have been removed by pre-Virgilian erosion in some places, and the basal sandstone unit of the Virgilian Series, the Tonganoxie member, lies upon the eroded surface. The average thickness of the Stanton is about 35 feet.

Captain Creek member.—The Captain Creek member consists of bluish-gray, dense limestone which has pronounced vertical joints. The member occurs either as a thinly and evenly bedded unit or as a single massive bed. It is commonly oolitic. Its thickness ranges from 2 to 4 feet.

Eudora member.—The Eudora is a fissile shale which is black in the basal and middle parts and gray in the upper part. Phosphatic concretions are present at most localities. Its average thickness is about 5 feet.

Stoner member.—Most of the limestone beds of the Stoner member are light gray in color and thinly bedded, but the topmost bed of the member is massive to rubbly, drab or buff limestone and is 1 to 2 feet thick. The middle part of the member contains an abundance of fusuline Foraminifera at most localities, and other fossils are commonly present. A small amount of gray chert is present in the member at some localities. The Stoner is extensively quarried in northwestern Missouri for concrete aggregate and road surfacing material. The average thickness of the member is about 15 feet.

Rock Lake member.—The Rock Lake member consists of greenish shale and is sandy in the upper part. Locally, the upper part consists of thin-bedded calcareous sandstone. The thickness of the Rock Lake ranges from 1 to 16 feet but averages less than 10 feet.

South Bend member.—The South Bend member comprises from one to three thin limestone layers and interbedded shale. The lower part of the basal limestone bed typically is arenaceous. In southern Clay and Platte Counties, the member locally is absent owing to pre-Virgilian erosion, and its position is occupied by sandstone of the Tonganoxie member. Elsewhere in northwestern Missouri the member is persistent and is from 3 to 5 feet thick.

PEDEE GROUP.—The Pedee group contains two formations, the Weston and the overlying Iatan which in turn is overlain locally by a thin unit of shale and clay. In southern Platte and Clay Counties, where pre-Virgilian erosion has removed part or all of the group, the lower Virgilian formations rest unconformably on older beds of the Missourian Series. The thickness of the group varies with that of the Weston formation which thickens from 60 feet in central Platte County to nearly 100 feet in Buchanan County and thence thins rapidly northward and westward to a thickness of only a few feet. The maximum thickness of the group is estimated to be approximately 100 feet. The Pedee group is conformable with the underlying Lansing group.

The uppermost beds of the Pedee group are gray and maroon shale and clay that are locally present above the Iatan and below the horizon of the channel-fill sandstone regarded as the equivalent of the Tonganoxie. These shale beds are restricted in their occurrence to the region outside the channel areas proper and are absent at many localities where their stratigraphic position above the Iatan formation is occupied by a very thin sandstone and sandy shale which is considered to be marginal to the channel-fill sandstone. The shale and clay are interpreted as having been present during the excavation of the channels whose erosion surface is presently recognized as the basal Virgilian unconformity. The maroon coloration is believed to have developed subaerially during the period of channel excavation and deposition of the channel-fill sands, and thus the upper surface of the shale and clay should approximately mark the horizon of the channel-fill sandstone. The thickness of the shale and clay ranges from a featheredge to an observed maximum of approximately 5 feet in Missouri exposures.

Weston formation.—The Weston formation is a gray shale which generally contains a great many clay-ironstone concretions.

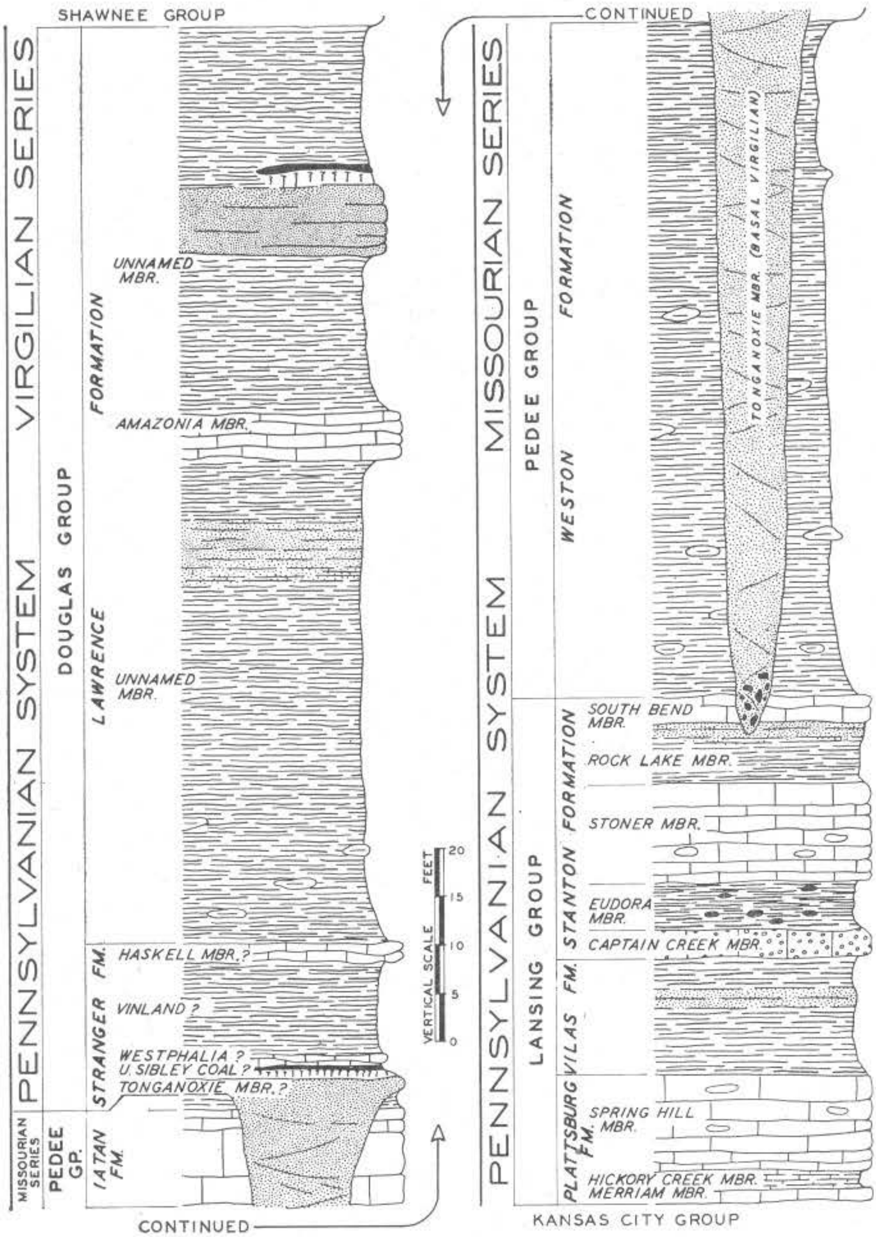


Fig. 21. Pennsylvanian System; Missourian Series (Lansing and Pedee groups), and Virgilian Series (Douglas group).

It is sparsely fossiliferous and usually contains only a few pectenid pelecypods. The shale is presently being used for the manufacture of lightweight aggregate. The thickness of the formation ranges from about 60 feet in Platte County to approximately 100 feet in Buchanan County. North and west of Buchanan County, it thins to a thickness of only a few feet.

Iatan formation.—The Iatan formation consists of a single massive bed of light gray limestone, but locally a few inches of thinly bedded limestone overlies the thick massive bed. The Iatan is an algal limestone which has a brecciated appearance when weathered. The thickness of the formation ranges from less than 5 feet in the St. Joseph area to more than 15 feet in west-central Platte County.

Virgilian Series

The uppermost Pennsylvanian rocks in the northern midcontinent have been classified as the Virgilian Series. In Missouri these rocks are restricted to an area which lies north of the Missouri River and west of Caldwell, Daviess, and Harrison Counties. The boundary separating the Virgilian from the Missourian Series is drawn at a pronounced unconformity which is developed on various upper Lansing and Pedee strata and which is overlain by a thick sandstone which is considered to be the equivalent of the Tonganoxie member of the Stranger formation in Kansas. The boundary is not marked by pronounced faunal changes. The Virgilian comprises in ascending order the Douglas, Shawnee, and Wabaunsee groups. With the exception of those upper Pennsylvanian beds of the Wabaunsee group which lie above the Stotler formation, the entire Virgilian succession is present in Missouri.

DOUGLAS GROUP.—The Douglas group is a dominantly clastic succession which extends upward from the base of the Stranger formation to the base of the Toronto member of the Oread formation which is the basal unit of the Shawnee group. The Stranger formation and the overlying Lawrence formation together make up the Douglas group. The basal Virgilian, channel-fill sandstone of the Stranger formation is well developed only in southern Platte and Clay Counties, and in that area it rests on a surface of erosion which locally extends down through the underlying Pedee group. The contact of the Douglas and overlying Shawnee group is conformable. Outcrops of the Douglas group extend from western Platte County northeastward through Buchanan, DeKalb, and Gentry Counties. The group is commonly represented by a shale slope which lies below a prominent limestone escarpment formed by the Oread formation of the Shawnee group. The thickness of the group ranges from 110 to 150 feet.

Stranger formation.—In Missouri, the Stranger formation comprises lower Douglas beds which lie above the Pedee group and includes at the top a thin crinoidal limestone which generally has been identified as the Haskell member. The Stranger formation also includes a thick, channel-fill sandstone which is considered to be equivalent to the Tonganoxie sandstone of Kansas. A regional study of the Stranger and of the beds below and above it has been undertaken by Kansas geologists, and their work is expected to refine the classification and nomenclature of the succession. For the purposes of this report, the Stranger formation is described as a succession of beds that is not differentiated into members, although some of the beds have already been given stratigraphic names in some Missouri publications. The thickness of the Stranger formation, not including the channel-fill sandstone, ranges from 15 to 20 feet in Missouri. The channel-fill sandstone is believed to have a maximum thickness of about 50 feet.

In Missouri, the channel-fill sandstone is prominently developed only in southern Platte and Clay Counties where it occupies channels which have been cut down into Pedee and upper Lansing strata. The sandstone is massive and strongly cross bedded, and it locally contains limestone conglomerate at the base. In northwestern Platte County exposures, the stratigraphic position of the channel-fill sandstone is occupied by only a few feet of thinly bedded, shaly, fine-grained micaceous sandstone. This bed lies above the Iatan formation and below a coal bed or coal horizon which is tentatively correlated with the upper Sibley coal of Kansas. In other Missouri exposures north of the channel area and in the subsurface, sandstone is apparently absent at this stratigraphic position. The maximum thickness of the channel-fill sandstone in the southern Platte and Clay County area is approximately 50 feet.

The coal bed which is tentatively considered to be equivalent to the upper Sibley of Kansas is present in northwestern Platte County where it is locally nearly 1 foot thick. Commonly, it is represented only by a thin carbonaceous streak, or it is identified simply as a coal horizon on the basis of the presence of other members of the immediate succession. An underclay of varying thickness is associated with the coal or its horizon at most localities.

The beds of the Stranger formation that lie above the coal bed are more or less persistent and include, from the base upward, 1) a few inches of platy limestone which contains carbonized plant material along the bedding planes, 2) fossiliferous calcareous shale and claystone, and 3) rubbly crinoidal limestone. The platy limestone may represent all or part of the Westphalia of eastern Kansas. The calcareous shale and claystone which is tentatively referred to the Vinland of Kansas is extremely fossiliferous and contains an abundance of gastropods and pelecypods. The unit is from 5 to 10 feet thick in Missouri exposures. The crinoidal limestone at the top of the succession is from a few inches to approximately 2 feet thick in Missouri and has been identified as the Haskell by Missouri geologists for a number of years.

Lawrence formation.—In Missouri, the strata of the Douglas group that lie above the Haskell member of the Stranger formation are assigned to the Lawrence formation which within the state consists of two unnamed shale members separated by a limestone unit known as the Amazonia member. In Kansas, a sandstone unit known as the

Ireland member is present at the base of the Lawrence formation. In that state, the sandstone lies disconformably on the Robbins shale member which in Kansas is the highest unit of the Stranger formation. Although there is a sandstone locally present within the lower unnamed shale unit of the Lawrence formation in Missouri that is tentatively regarded as equivalent to the Ireland member of Kansas, it is not extensive enough or sufficiently pronounced to be recognized throughout the area of occurrence of the Lawrence formation. Because of this, all of the shale which lies between the top of the Haskell member and the base of the Amazonia member in Missouri is regarded as the lower unnamed member of the Lawrence formation although it is realized that the lower part of this unit may be equivalent in part to the Robbins shale member of the Stranger formation of Kansas.

Lower member.—The lower unnamed shale unit of the Lawrence formation is in most exposures and drill holes a continuous succession of shale which is medium gray in the lower and middle parts and dark gray in the upper part. Clay-ironstone and unfossiliferous limestone concretions are present in the lower and middle parts. Locally, in southwestern Buchanan County, sandy shale and sandstone are present in the upper part of the unit. This material contains plant fossils and is tentatively regarded as the possible equivalent of the Ireland member of Kansas. Thus, it is possible that the medium gray shale which forms the lower and middle parts of the lower unnamed shale unit may be equivalent to the Robbins shale member of the Stranger formation in Kansas. The thickness of the entire unnamed shale unit varies. It is more than 80 feet thick in southwestern Buchanan and northwestern Platte Counties, approximately 50 feet thick at St. Joseph in Buchanan County, and about 75 feet thick at Savannah in Andrew County.

Amazonia member.—The Amazonia member is a light to medium gray, dense to finely crystalline limestone which commonly crops out as a single ledge. The limestone has a rough brecciated or conglomeratic texture and is characterized by poorly defined bedding. The thickness of the member increases northward from southwestern Buchanan County where it is 2 feet thick to the St. Joseph area and Amazonia area where it is 12 to 15 feet thick. The member is very thin or absent in northwestern Platte County.

Upper member.—The upper unnamed member is composed predominantly of gray shale which is commonly red or maroon in the upper part. Sandy shale or sandstone is generally present near the middle of the unit. Coal of poor quality and of uneven thickness is locally present above the sandy strata. The thickness of the unnamed member decreases from about 50 feet in the southwestern part of Buchanan County to less than 20 feet in Andrew County. Where it is thinnest, the unit is usually composed for the most part of red or maroon shale, and in the same localities it appears that the underlying Amazonia has its thickest development.

SHAWNEE GROUP.—The Shawnee group, from the base upward, includes the following formations: Oread, Kanwaka, Lecompton, Tecumseh, Deer Creek, Calhoun, and Topeka. The group is especially characterized by the relative abundance and greater thicknesses of the limestone beds that are included in it as compared to the underlying Douglas group and overlying Wabaunsee group. The Oread, Lecompton, Deer Creek, and Topeka formations are composed predominantly of limestone, and together they make up about one-half of the total thickness of the group. The intervening units are composed of shale and sandstone and minor quantities of limestone. The repetition of the sequence and lithology of the component units of the successive formations is striking. The dominantly calcareous formations of the Shawnee exhibit an acme of development of the several types of marine limestone that may develop in upper Pennsylvanian cyclothems of the northern midcontinent. Many of these limestones are characterized by the exceptional persistence of their identifying features over very wide areas. The outcrop belt of Shawnee rocks includes parts of Platte, Buchanan, DeKalb, Gentry, Holt, Nodaway, Andrew, and Worth Counties. The thickness of the group in Missouri ranges from 230 to 250 feet.

Oread formation.—The Oread formation is composed of an alternating succession of limestone and shale members, four of which are limestone and three of which are shale. From the base upward, they are as follows: the Toronto, limestone; the Snyderville, shale; the Leavenworth, limestone; the Heebner, shale; the Plattsmouth, limestone; the Heumader, shale; and the Kereford, limestone. Various members of the Oread are exposed in northwestern Platte, Buchanan, Holt, Andrew, DeKalb, Gentry, and Nodaway Counties and possibly in Worth County. The complete succession is well exposed at several places in Buchanan and Andrew Counties. The total thickness of the Oread in Missouri is about 50 feet.

Toronto member.—The Toronto member is a dense, gray limestone which weathers gray and buff. The thickness of the member, which may occur in several distinct beds, is about 5 feet.

Snyderville member.—The Snyderville member is a gray shale. It is reported to include a maroon zone at or near the base in the Buchanan and Andrew County area. The member has an average thickness of about 10 feet.

Leavenworth member.—The Leavenworth member is a dense, dark gray limestone. It consists of two or more beds and is commonly 2 to 3 feet thick.

Heebner member.—The Heebner member is extremely persistent. It is a dark gray to black fissile shale in the lower part, and is a lighter gray nonfissile shale in the upper part. The member is 4 to 5 feet thick.

Plattsmouth member.—The Plattsmouth member is composed of a scarp-forming, wavy-bedded, somewhat cherty limestone. It is extensively quarried, especially in Andrew and Nodaway Counties, for road surfacing material. The member is commonly 20 feet thick.

Heumader member.—The Heumader member is a silty, drab to gray shale which is absent in those areas where the Plattsmouth and Kereford are in contact. Where it is present, its thickness ranges from less than 1 foot to about 3 feet.

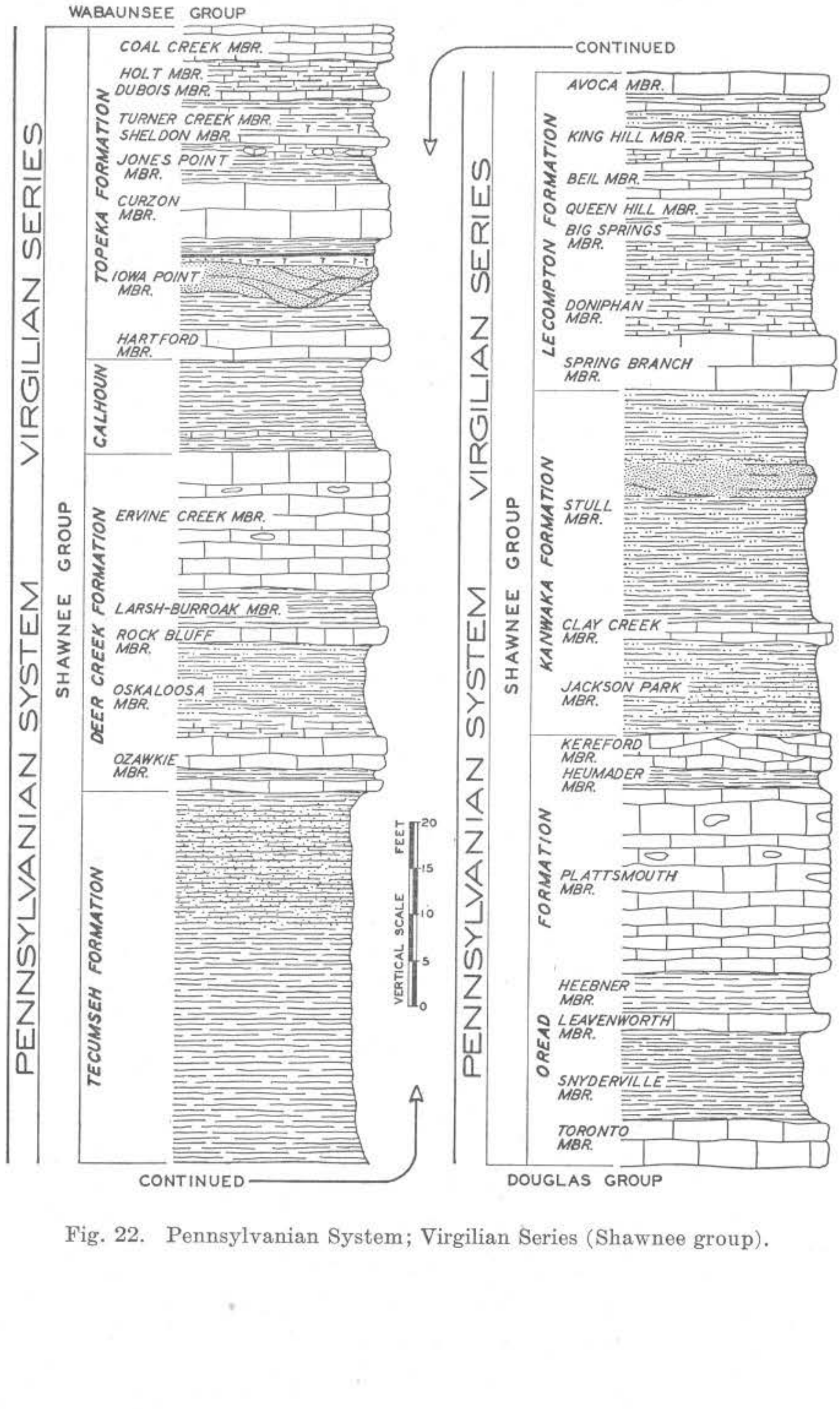


Fig. 22. Pennsylvanian System; Virgilian Series (Shawnee group).

Kereford member.—The Kereford member is a limestone which is composed mostly of "*Osagia*" coated shell material. The member is extremely variable in thickness and may occur either as a thinly bedded unit or as a massive ledge. It is commonly cross bedded. Its thickness ranges from less than 2 feet to more than 10 feet.

Kanwaka formation.—The Kanwaka formation is composed of two relatively thick shale beds and a thin intervening limestone unit. From the base upward these units are the Jackson Park member, the Clay Creek member, and the Stull member. Exposures of the complete formation are present only in southern Holt County. In Andrew County, only the Jackson Park and Clay Creek members are exposed in a number of quarries. The formation is 30 to 40 feet thick.

Jackson Park member.—The Jackson Park member is a gray, silty, micaceous shale. It is 10 to 15 feet thick.

Clay Creek member.—The Clay Creek member is a gray, argillaceous limestone which is a persistent marker bed within the Kanwaka over wide areas of northeastern Kansas and northwestern Missouri. It is about 2 feet thick.

Stull member.—The Stull member is a gray, silty shale which locally contains lenticular sandstone in the upper part. The member also contains plant remains and one or more thin, nonpersistent beds of coal in the upper part. The thickness of the member ranges from 25 to 30 feet.

Lecompton formation.—The Lecompton formation contains four limestone members each of which alternates with one of three shale members. From the base upward, the members are as follows: Spring Branch, limestone; Doniphan, shale; Big Springs, limestone; Queen Hill, shale; Beil, limestone; King Hill, shale; and Avoca, limestone. The principal outcrop areas of the formation are in southern Holt and in western Andrew Counties. The succession is concealed by glacial deposits in eastern Nodaway County. The thickness of the Lecompton is about 35 feet.

Spring Branch member.—The Spring Branch member is a dark gray, massive, argillaceous limestone that weathers to a dark buff color. The member is 5 to 7 feet thick.

Doniphan member.—The Doniphan member is composed of gray, calcareous shale and claystone. In southern Holt County, the member is about 16 feet thick; elsewhere it is less than 10 feet thick.

Big Springs member.—The Big Springs member consists of a single bed of dark gray, dense limestone that has an average thickness of about 1 foot.

Queen Hill member.—The Queen Hill member is composed of a shale which is dark gray to black and fissile in the lower part and light gray, calcareous, and fossiliferous in the upper part. The average thickness of the member is about 3 feet.

Beil member.—The Beil member is composed of several layers of fossiliferous limestone which are interbedded with calcareous shale. The member is 4 to 5 feet thick.

King Hill member.—The King Hill member is a gray shale which is silty in the upper part and calcareous near the base. Its thickness ranges from 6 to 8 feet.

Avoca member.—The Avoca member consists of two or more beds of argillaceous limestone that are separated by shaly partings. The limestone contains an abundance of fusuline Foraminifera. The thickness of the member ranges from 3 to 5 feet in southern Holt County and is of comparable thickness elsewhere in northwestern Missouri.

Tecumseh formation.—The Tecumseh formation is composed of shale which is arenaceous in the upper part. The Ost limestone of Nebraska is possibly represented in Missouri by a lenticular limestone which is less than one foot thick and near the base of the formation in a locality near Savannah in Andrew County. The thickness of the Tecumseh ranges from 40 to 50 feet.

Deer Creek formation.—The Deer Creek formation includes three limestone members and two shale members. From the base upward, they are: the Ozawkie, limestone; Oskaloosa, shale; Rock Bluff, limestone; Larsh-Burroak, shale; and Ervine Creek, limestone. The Haynies limestone, which is known to be present between the Larsh and Burroak members in Nebraska, appears to be absent in Missouri; therefore, the Larsh and Burroak members are considered as a combined unit within the state, and the name Larsh-Burroak is used to designate it. The best exposures of the formation are in southern Holt County. To the northeast, glacial deposits conceal the formation except in those places along the One Hundred and Two River in Nodaway County and along the Nodaway River south of Maitland in east-central Holt County where the Ervine Creek member has been quarried for concrete aggregate and road surfacing material. The Deer Creek formation is about 40 feet thick.

Ozawkie member.—The Ozawkie member is composed of several uneven beds of argillaceous, buff colored limestone that are separated by shaly partings. The thickness of the formation ranges from 5 to 7 feet.

Oskaloosa member.—The Oskaloosa member consists of shale which is nonsilty and calcareous in the lower part and silty in the upper part. The average thickness of the unit is about 10 feet.

Rock Bluff member.—The Rock Bluff member is a single massive bed of dense medium gray limestone which has pronounced vertical joints. It has an average thickness of approximately 2 feet.

Larsh-Burroak member.—The Larsh-Burroak member is composed of dark gray to black fissile shale in the lower part and of gray shale in the upper part. The member is about 4 feet thick.

Ervine Creek member.—The Ervine Creek member is a light gray, wavy-bedded limestone which contains a small amount of chert. It is the uppermost Pennsylvanian limestone unit that is suitable for quarrying in Missouri. The thickness of the member ranges from 15 to 20 feet.

Calhoun formation.—In northwestern Missouri, the Calhoun formation, except for some thin argillaceous limestone near its base, is composed of light to medium gray, silty shale. The formation is absent or not differentiated in many places in the subsurface north and west of its outcrop area in southern Holt and Nodaway Counties. Its thickness ranges from less than 5 feet to a maximum of 10 feet where it is exposed.

Topeka formation.—The Topeka formation consists of alternating limestone and shale members; five of limestone and four of shale. From the base upward, they are: Hartford, limestone; Iowa Point, shale; Curzon, limestone; Jones Point, shale; Sheldon, limestone; Turner Creek, shale; Du Bois, limestone; Holt, shale; and Coal Creek, limestone. Except for a few scattered exposures where the Ervine Creek member of the Deer Creek formation has been quarried along the One Hundred and Two River south of Maryville in Nodaway County, outcrops of the Topeka formation in Missouri are restricted to southern Holt County and to a few places along the Nodaway River as far north as Skidmore. The formation is from 30 to 35 feet thick.

Hartford member.—The Hartford member consists of one or more beds of fossiliferous, brownish-gray limestone and associated calcareous shale. The member is 3 to 4 feet thick.

Iowa Point member.—The Iowa Point member is composed of sandstone and sandy shale. A thin coal is present near the top of the member. The sandstone is locally a channel type deposit. The average thickness of the member is about 10 feet.

Curzon member.—The Curzon member consists of two beds of massive, earthy, brownish-weathering limestone that are separated by a shale parting. The member is 5 to 6 feet thick.

Jones Point member.—The Jones Point member is composed of medium gray shale and calcareous clay which is present in the uppermost part of the unit. The clay contains limestone concretions. The thickness of the member ranges from 3 to 5 feet.

Sheldon member.—The Sheldon member consists of a single bed of light gray limestone which is composed almost entirely of algal material and shell debris. The member is 1 to 2 feet thick.

Turner Creek member.—The Turner Creek member comprises approximately 3 feet of calcareous claystone in its lower and middle parts and interbedded calcareous shale and argillaceous limestone in its upper part. The total thickness of the member is about 4 feet.

DuBois member.—The DuBois member usually consists of a single bed of dark bluish-gray limestone. The member contains a number of brachiopods such as *Derbyia* and *Composita* that are generally unbroken and filled with calcite spar. The average thickness of the DuBois is about 1 foot.

Holt member.—The Holt member is a tan to gray calcareous shale which is gray to black at and near the base of the unit. The thickness of the Holt ranges from 2 to 3 feet.

Coal Creek member.—The Coal Creek member is an argillaceous, brownish-weathering, wavy-bedded limestone whose beds are separated by shaly partings. The member is very fossiliferous and contains many fusuline Foraminifera. Its thickness ranges from 4 to 5 feet.

WABAUNSEE GROUP.—In the northern midcontinent, the Wabaunsee group is the uppermost group of the Pennsylvanian System. Its complete section, which is present in Kansas and Nebraska, includes all the rock units which lie between the top of the Topeka formation of the Shawnee group and the top of the Brownville limestone of the Wood Siding formation. In Missouri, the uppermost part of the group is absent, and within the state the succession of beds forming the Wabaunsee group terminates at what is believed to be the top of the Dry member of the Stotler formation. The formations of the Wabaunsee group in Missouri are composed largely of shale, siltstone, and sandstone. Some of the formations contain a few thin beds of limestone and a few beds of coal that are mineable in some places. The group is divided into three subgroups* which are from the base upward the Sacfox, Nemaha, and Richardson. The Wabaunsee is present in Holt, Nodaway, and Atchison Counties in the northwestern corner of the state, and in this area the group is approximately 340 feet thick.

SACFOX SUBGROUP.—The Sacfox subgroup consists of a succession of beds that lies above the Topeka formation of the Shawnee group and below the base of the Bern formation of the Nemaha subgroup. The subgroup contains the following formations from the base upward: Severy, Howard, and Scranton. The thickness of the Sacfox subgroup ranges from less than 180 feet to more than 200 feet in northwestern Missouri.

Severy formation.—The Severy formation is composed of silty, micaceous, gray shale in the lower part and thinly bedded to massive sandstone in the upper part. The average thickness of the formation is about 25 feet.

Howard formation.—Where the Howard formation is fully developed in the northern midcontinent region, it contains five members which are in ascending order: the Bachelor Creek, Aarde, Church, Winzeler, and Utopia. However, the basal member of the formation is absent in all but one locality in Missouri. Because of this, in all other areas of the state, the formation's lower boundary is placed at the base of the underclay which lies beneath the Nodaway coal which in turn lies near the base of the next higher member, the Aarde. The lithologic characteristics and thicknesses of the formation's members are so unusually persistent that the formation serves as a useful datum throughout the northern midcontinent. Its average thickness is between 10 and 15 feet.

Bachelor Creek member.—The Bachlor Creek member is present in only one locality in Holt County. Here, it is a dense, bluish-gray limestone which is only a few inches thick.

*On July 11, 1961, while this publication was in press, an interstate conference was held at Lawrence, Kansas, and was attended by the representatives of the Geological Surveys of Missouri, Kansas, Oklahoma, Arkansas, Nebraska, Iowa, and South Dakota. It was agreed by those present that the subgroups, Sacfox, Nemaha, and Richardson of the Wabaunsee group, be eliminated from Pennsylvanian classification and that the names Sacfox, Nemaha, and Richardson be suppressed.

Aarde member.—The Aarde member is composed, from the base upward, of an underclay, the Nodaway coal bed which is over one foot thick in some areas, and a fissile dark gray shale which contains thin irregular beds of fossiliferous limestone. Phosphatic concretions are present in the fissile shale at some localities. The member is approximately 4 feet thick.

Church member.—The Church member is a single bed of medium to dark bluish-gray, brittle limestone which weathers to a rusty brown color. It is fossiliferous and contains an abundance of gastropods, brachiopods, crinoids, and bryozoans. The member is about 18 inches thick.

Winzeler member.—The Winzeler member is composed of gray shale which is apparently unfossiliferous. The thickness of the member ranges from 2 to 4 feet.

Utopia member.—The Utopia member is composed of slabby, brownish-gray, clastic limestone which contains crinoidal debris, fusuline Foraminifera, pelecypods, and gastropods, as well as carbonized wood. The average thickness of the member is about 2 feet.

Scranton formation.—The Scranton formation is composed of a succession of beds that lies above the top of the Utopia member of the Howard formation and beneath the base of the Burlingame member of the Bern formation. The formation is divided into five members which from the base upward are named as follows: White Cloud, Happy Hollow, Cedar Vale, Rulo, and Silver Lake. The average thickness of the formation is about 130 feet.

White Cloud member.—The White cloud member is composed predominantly of gray shale. The upper 20 to 25 feet of the member contains numerous, thin, silty and argillaceous beds of limestone and large, irregularly shaped, septarian concretions. Specimens of the brachiopod *Linoproductus* are abundant in the beds of limestone. In the subsurface, a thin fusuline-bearing limestone is present above the middle of the member. Clay-ironstone concretions are common in the lower part of the White Cloud. The boundary between the White Cloud and the overlying Happy Hollow member is arbitrarily placed at the position of a coal horizon which lies above the septarian concretions and beds of silty limestone. A coal horizon is identified at this position in northwestern Nodaway County exposures, where it is overlain by dark gray shale containing lingulid brachiopods and underlain by an underclay. This horizon is also present at other localities in the area. The average thickness of the member is about 100 feet.

Happy Hollow member.—The Happy Hollow member contains three rubbly beds of argillaceous limestone which are interbedded with calcareous gray and green clay. A poorly defined coal horizon is present above the uppermost limestone bed. A clayey shale a few feet thick is present in the lower part of the member. The average thickness of the Happy Hollow is about 15 feet.

Cedar Vale member.—The Cedar Vale member is composed mostly of gray shale which contains clay-ironstone concretions. The Elmo coal bed and its associated underclay occur at the top of the member. The Cedar Vale is between 10 and 15 feet thick.

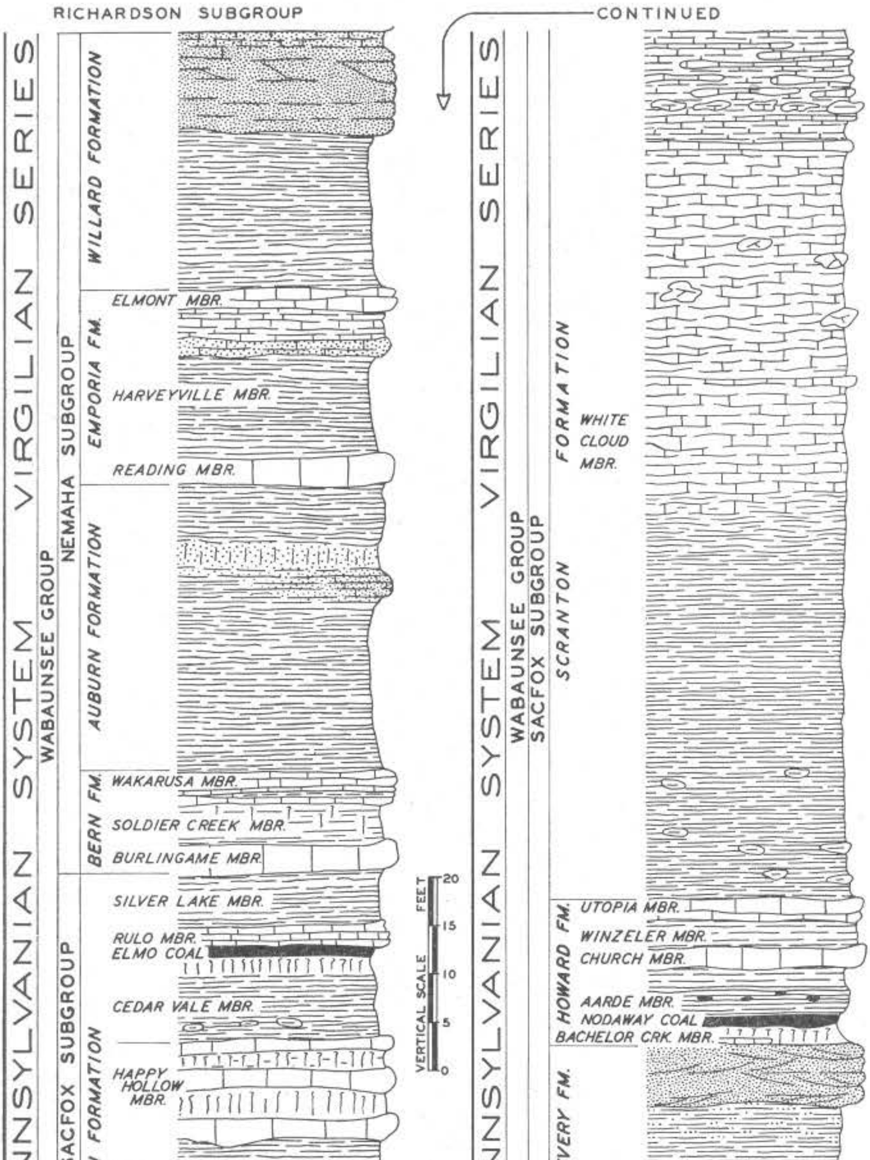


Fig. 23. Pennsylvanian System; Virgilian Series (Wabaunsee group, Sacfox and Nemaha subgroups).

Rulo member.—The Rulo member consists of dark gray, earthy, fossiliferous limestone which grades laterally to calcareous shale. The member commonly contains carbonaceous material and ranges in thickness from less than 1 foot to about 2 feet.

Silver Lake member.—The Silver Lake member consists of gray shale. It is thin in Nodaway County and thickens westward. Where it is exposed, the member is 5 to 10 feet thick.

NEMAHA SUBGROUP.—The Nemaha subgroup is composed of the succession of strata that lies above the top of the Silver Lake member of the Scranton formation and below the base of the Tarkio member of the Zeandale formation. The principal exposures of the Nemaha subgroup are located along the Tarkio River below Fairfax and along the Missouri River bluffs between Rock Port and Craig in Holt and Atchison Counties. The maximum thickness of the subgroup in some of these exposures is about 90 feet. The subgroup is believed to thicken to the north and west in the subsurface. From the base upward, the subgroup contains the following formations: Bern, Auburn, Emporia, and Willard.

Bern formation.—The Bern formation contains three members which from the base upward are named: the Burlingame, Soldier Creek, and Wakarusa. The total thickness of the Bern is about 10 feet.

Burlingame member.—Where it is exposed in Atchison County, the Burlingame member is commonly a single, massive bed of argillaceous limestone that has an average thickness of about 2 feet. The uppermost part of this bed contains a large amount of fossilized material which is coated with "*Osagia*". In Nodaway County, the member is composed from the base upward of about 1 foot of greenish-gray, dense, algal limestone, 3 to 4 feet of calcareous claystone, and of a few inches of slabby limestone.

Soldier Creek member.—The Soldier Creek member contains gray shale in the lower part and calcareous claystone in the upper part. The member is 3 to 4 feet thick.

Wakarusa member.—The Wakarusa member is composed of three units. The lower unit is medium gray, argillaceous limestone about 6 inches thick, the middle unit is a thin dark gray shale bed, and the upper unit is an irregularly bedded, crinoidal limestone about 2 feet thick. The total thickness of the member is about 3 feet.

Auburn formation.—The Auburn formation is composed mostly of micaceous, silty, gray shale, but it contains a persistent layer of silty maroon clay in its upper part. A bed of calcareous siltstone and fine sandstone is present below the maroon clay at some localities. In its outcrop area, the formation is approximately 30 feet thick.

Emporia formation.—The Emporia formation includes from the base upward the Reading, Harveyville, and Elmont members. The total thickness of the formation is about 20 feet.

Reading member.—The Reading member typically occurs as a single bed of dense limestone that contains few fossils. It is commonly dark bluish-gray in color, and locally it is dolomitic. The member is 2 to 3 feet thick.

Harveyville member.—The Harveyville member consists mostly of maroon shale and contains a coal horizon above its middle part. The shale above the coal horizon is calcareous and somewhat darker in color than that below. The member is 15 to 18 feet thick.

Elmont member.—The Elmont member is composed of medium to brownish-gray limestone which occurs either as a massive layer or as a slabby shaly bed. Its diversified fauna contains fusuline Foraminifera. The member is about 2 feet thick.

Willard formation.—The Willard formation consists mostly of gray and drab shale but contains a sandstone bed of variable thickness in its upper part. Where it crops out along the Missouri River bluffs in Atchison County, the thickness of the formation ranges from 20 to 30 feet, but in the subsurface north of Rock Port in Atchison County it is somewhat thicker.

RICHARDSON SUBGROUP.—The remaining beds of the Wabaunsee group that are present in Missouri are assigned to the Richardson subgroup. The subgroup includes all of the stratigraphic units which lie above the top of the Willard formation of the Nemaha subgroup up to and including the Dry member of the Stotler formation. The formations of the subgroup in Missouri are in ascending order: the Zeandale, the Pillsbury, and the Stotler. The succeeding Root and Woodsiding formations are not present within the state.

Zeandale formation.—The Zeandale formation includes from the base upward the Tarkio, Wamego, and Maple Hill members. The formation is well exposed along the Missouri River bluffs south of Rock Port in Atchison County. The Zeandale formation is about 25 feet thick.

Tarkio member.—The Tarkio member is composed of a lower, massive, brown weathering bed of limestone which is separated from an upper, thin bed of algal limestone by a gray or maroon clay which contains roughly textured limestone concretions. Large fusuline Foraminifera, which are commonly encrusted with algae, are present in the lower bed which is 3 to 4 feet thick. The total thickness of the Tarkio member ranges from 4 to 5 feet.

Wamego member.—The Wamego member is predominantly a gray or drab shale which grades upward to sandy shale and sandstone. The lower and middle parts of the member contain clay-ironstone concretions. A thin persistent coal bed, the Nyman, is present near the top of the member. The average thickness of the Wamego is about 20 feet.

Maple Hill member.—The Maple Hill member is composed of two beds of brownish-gray, argillaceous limestone which contain many brachiopods such as *Marginifera lasallensis* and *Dictyoclostus americanus*, as well as the fusuline *Triticites*. The Maple Hill member was formerly regarded as the Dover limestone in Missouri. The thickness of the member ranges from 1 to 2 feet.

Pillsbury formation.—The lower and middle parts of the Pillsbury formation consist of gray silty shale. Clay ironstone concretions are present in the lower part of this division, and the shale becomes increasingly sandy near the top. Beds of massive sandstone several feet thick are present above the sandy shale at most localities, and silty, gray or maroon clay occurs above it and below the overlying Dover member of the Stotler formation. The thickness of the silty clay ranges from a few inches to 3 or 4 feet. The average thickness of the Pillsbury in Missouri is about 28 feet.

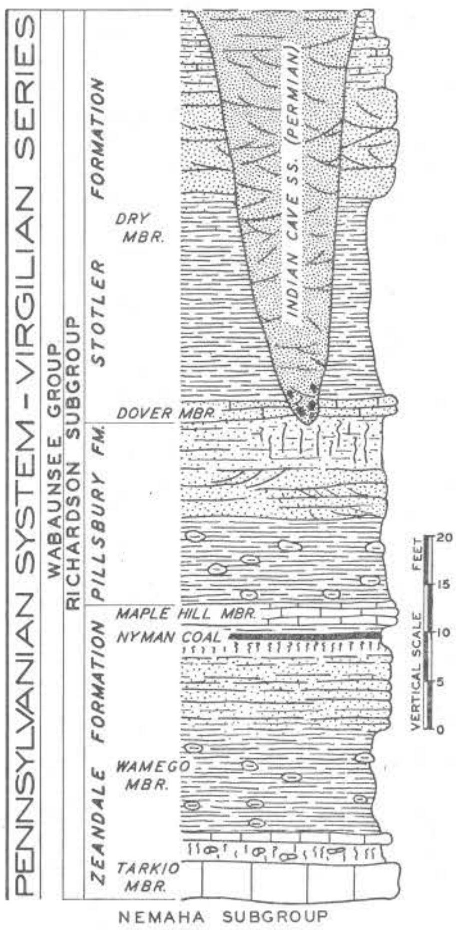


Fig. 24. Pennsylvanian System; Virgilian Series (Wabaunsee group, Richardson subgroup).

Stotler formation.—Where the Stotler formation is complete, it consists of three members which from the base upward are the Dover, Dry, and Grandhaven. The uppermost member is a limestone where it is typically developed outside the state, but in Missouri the presence of the limestone has not been established. Instead, a red clay, which lies at the top of the Dry member in Atchison County, is considered to be at the approximate stratigraphic position of the Grandhaven member.

Dover member.—The Dover member is a sandy limestone that contains algae-coated shell debris and granules and pebbles of limonitic material. It lies on the sandstone, sandy clay, or maroon clay of the underlying Pillsbury formation. It is exposed in Atchison County along the bluffs of the Missouri River from Rock Port northward. The member was formerly regarded as the Grand Haven member in Missouri. The thickness of the member ranges from 2 inches to almost 2 feet.

Dry member.—In Missouri, the complete succession of the Dry member apparently is fully exposed at only a single locality in Atchison County. Here, the lower and middle parts of the member are composed of medium gray shale which is overlain by thinly bedded to massive sandstone. A maroon clay is present at the uppermost part of the succession. It is believed that this clay lies at the approximate stratigraphic position of the Grandhaven. The thickness of the Dry member at the exposure in Atchison County is approximately 40 feet.

Permian System

Permian rocks are known to be represented in Missouri by only a few exposures of massive sandstone in the northwestern corner of the state, in northwestern Atchison County. This sandstone occupies deep channels that have been cut into upper Pennsylvanian beds, and it is identified as the Indian Cave sandstone of early Permian (Wolfcampian) age. The sandstone is fine to medium grained, micaceous, and strongly cross bedded. Fragments of clay-ironstone and limestone occur near the base. Casts and molds of fossil wood also occur in the rock. The sandstone has a maximum thickness of more than 50 feet in the northwestern Missouri exposures.

MESOZOIC ERA

In Missouri, Mesozoic rocks are restricted to that part of the Mississippi Embayment which extends into the extreme southeastern part of the state. Here, the Era is represented only by rocks of the Cretaceous System. Rocks of older Mesozoic Systems (Triassic and Jurassic) are not present in Missouri.

In Ste. Genevieve and St. Francois Counties, a total of 78 known, ultrabasic diatremes are exposed that are tentatively regarded as being Cretaceous in age. At least one of the diatremes is definitely known to be post-Devonian in age because Devonian fossils have been found in limestone inclusions within it. Basic dikes, similar in composition to the matrix rock of some of the diatremes, have been encountered in Cambrian formations by deep drill holes in the Embayment area of southeastern Missouri, and both of these igneous structures are petrographically similar to Cretaceous peridotite intrusives in Arkansas.

Cretaceous System

by

John G. Grohskopf* and Wallace B. Howe

In the Mississippi Embayment of the Gulf Coastal Plain, both the Comanchean (Lower) and Gulfian (Upper) Series of the Cretaceous System are present. In the part of the Embayment that extends into southeastern Missouri, only the uppermost Gulfian formations occur. These include from the base upward, 1) an incompletely known subsurface succession which is provisionally correlated with the Coffee and Selma formations of Tennessee, 2) the McNairy formation, and 3) the Owl Creek formation. The McNairy and Owl Creek formations are exposed in northern Stoddard and in Scott County and dip southeastward beneath overlying Tertiary and Quaternary rocks. The formations include both marine and nonmarine strata and rest unconformably on lower Paleozoic rocks. The thickness of the Cretaceous System in southeastern Missouri exceeds 500 feet.

Pre-McNairy Cretaceous beds.—Wells in the deeper part of the Missouri portion of the Embayment encounter below the McNairy formation Cretaceous beds which do not crop out within the state. These beds are both marine and nonmarine in origin and consist of unconsolidated or partially consolidated sand, chalk or marl, clay, and limestone. The succession is overlapped by the McNairy formation and is provisionally regarded as equivalent in part to the Coffee (sandstone) and overlying Selma (marl and chalk) formations of Tennessee. The combined thickness of the succession in Missouri is more than 100 feet.

*Topographic Division, U. S. Geological Survey, Rolla, Missouri.

McNairy formation.—In its outcrop area in Scott and Stoddard Counties, the McNairy formation is composed of a succession of nonmarine sand, sandy clay, and clay. Southeastward in the deeper parts of the Embayment, the formation becomes more marine in character and contains calcareous material, glauconite, and fossil fragments. At the surface, the formation is roughly divisible into a lower and upper part. The lower part contains in ascending order: 1) a basal gravel, 2) a clay that is thinly bedded, light gray in color and interbedded with thin layers of fine- to medium-grained orange sand, and 3) a sandstone composed of light yellow to orange, medium- to coarse-grained, subangular sand with little or no mica. The upper part of this sandstone is usually silicified and is locally named the "Commerce quartzite". The upper part of the McNairy is made up of a succession of five alternating beds of sandstone and clay which can be traced throughout the outcrop area but which can not be differentiated in the subsurface. They are in ascending order: 1) a yellow to brown clayey sandstone, 2) a white to yellow fine-grained micaceous sandstone, 3) a light gray to brownish-black lignitic clay locally known as the "Zodoc clay" and mined for ceramic clay, 4) an interbedded orange sandstone and gray to brown clay, and 5) a brown, lignitic, sandy clay. The McNairy is an important aquifer in the Embayment area and is also a source of sand. Its thickness ranges from 100 to 250 feet.

Owl Creek formation.—The Owl Creek formation consists of a massive sandy, micaceous, fossiliferous, marine clay which is commonly glauconitic. On fresh exposures, the formation has a dark bluish-gray color but upon weathering alters to a yellowish brown. The Owl Creek is exposed along Crowley's Ridge in Scott and Stoddard Counties and dips southeastward into the subsurface of the Embayment where it consists of brown, calcareous, sandy clay with pyritized fossils and glauconite. The thickness of the formation is variable, ranging from a few inches to 11 feet in the outcrop area to as much as 100 feet in the subsurface. The Owl Creek is unconformably overlain by Teritary rocks.

CENOZOIC ERA

Rocks of the Cenozoic Era mantle much of northern Missouri and are composed principally of glacial, alluvial, and eolian deposits of Pleistocene age. Older rocks of Paleocene, Eocene, and Pliocene? age are also present within the state but with the exception of those of the Pliocene? are restricted to that part of the Mississippi Embayment which extends into the extreme southeastern part of Missouri. Rocks of Oligocene and of undoubted Miocene age are not known to be present within the state.

Cherty residuum, which is locally as much as 300 feet thick, covers much of the bedrock throughout the area of the Ozark uplift. This material is provisionally regarded as being of Cenozoic age, although it is recognized that it may have accumulated during much of Mesozoic time as well.

Tertiary System

by

John W. Koenig

Paleocene Series

The Paleocene Series of southeastern Missouri is represented by the Midway group which, within the state, is composed of the Clayton and Porters Creek formations.

MIDWAY GROUP.—The Midway group in Missouri is composed of two formations, the Clayton formation below and the Porters Creek formation above. In thickness, the Midway group varies from a few inches in some places in its outcrop area along Crowley's Ridge in Scott and Stoddard Counties to more than 650 feet in the subsurface beneath Pemiscot County. The group lies unconformably beneath the Wilcox group (Eocene) and unconformably upon the eroded surface of the Owl Creek formation (Cretaceous). The contact between the Clayton and Porters Creek formations is conformable.

Clayton formation.—The Clayton formation in its outcrop area is a fossiliferous, calcareous, glauconitic sand or clay which contains varying amounts of limonite. The formation has a distinctive green color which makes it noticeable and easy to recognize in the outcrop area. In the subsurface, the formation becomes increasingly calcareous, and in the deeper parts of the Mississippi Embayment within Missouri it becomes a fossiliferous, glauconitic limestone. It also is a very distinctive unit in the subsurface and is frequently used as a datum for mapping purposes. The thickness of the formation varies from a few inches to 10 feet in the outcrop area to as much as 20 feet in the subsurface.

Porters Creek formation.—The Porters Creek formation is a massive, homogeneous, dark gray clay which is almost black when wet. When dry, it spalls with a characteristic conchoidal fracture

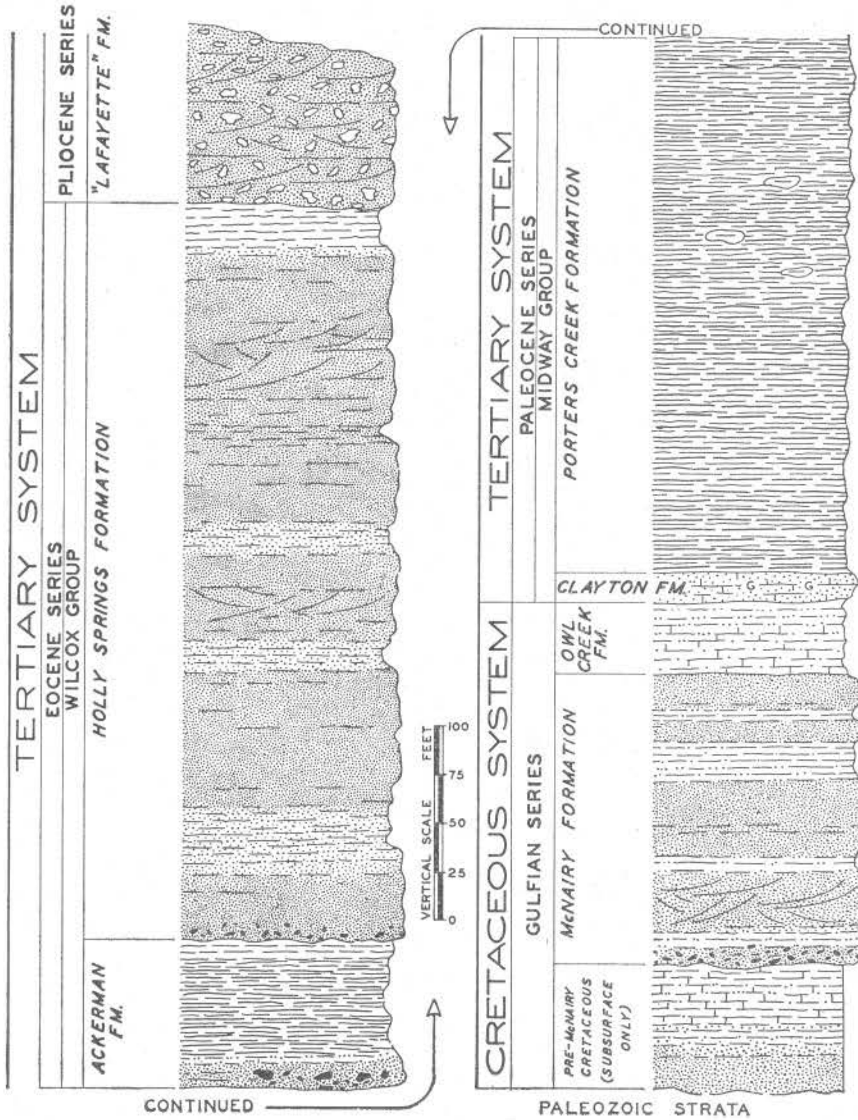


Fig. 25. Cretaceous and Tertiary Systems.

and is white to very light gray. The formation is remarkably uniform in lithologic character and maintains its diagnostic features throughout its extent. In its thicker parts, large boulders of iron carbonate are scattered erratically in the clay. Small quantities of mica and gypsum are disseminated throughout the formation, and in the outcrop area where the clay is bedded, fine-grained, white sand and mica are concentrated along some of the parting planes. In several parts of Stoddard County, bauxitic clay has been noted at the top of the formation. Petrographic studies indicate that the clays of the Porters Creek are bentonite and are commercially valuable as a bleaching clay. The Porters Creek varies in thickness in the outcrop area and is more than 200 feet thick in some places. Southeastward, in the subsurface, it thickens to 650 feet or more. In the subsurface, the formation lacks sand, and its lower 50 feet commonly contains Foraminifera and small pelecypods.

Eocene Series

The Eocene Series in Missouri is represented by two formations of the Wilcox group, the Ackerman formation below and the Holly Springs formation above.

WILCOX GROUP.—In Missouri, the formations of the Wilcox group are widely distributed along Crowley's Ridge in Stoddard County and are present in a limited area in Scott County southwest of Commerce. The group includes beds of sand and clay that lie between the Midway group (Paleocene) and the base of "Lafayette" formation (Pliocene?). On the surface, it is possible to distinguish both the Ackerman and Holly Springs formations as the lower and upper components of the group, respectively, but these two units are difficult to differentiate in the subsurface. The Wilcox group has a thickness in the outcrop area that varies from 0 to more than 300 feet because over much of the area, with the exception of loess and patches of gravel, it forms the uppermost rock succession on Crowley's Ridge. It thickens southeastward, and in the subsurface in the extreme southeastern corner of the state it is more than 1,300 feet thick. The group lies unconformably above the Midway group and unconformably below the gravels of the "Lafayette" formation. The Ackerman and Holly Springs formations of the Wilcox are separated by an unconformity.

Ackerman formation.—The Ackerman formation is predominantly a light gray to brown, silty, nonmarine clay. It is slightly lignitic, and glauconite is locally present at the base. The clay in the upper 6 to 8 feet of the formation is very plastic and is bright red or yellow in color. In a few places, the formation's contact with the underlying Porters Creek is marked by the presence of a lenticular sandstone body. This sandstone is white to yellow in color, medium grained, and has clay particles disseminated throughout the mass. At one locality, boulders of quartzite 3 to 4 feet in diameter are present near the base of the formation. At another locality, rounded boulders of bauxitic clay which were presumably derived from the top of the Porters Creek formation, are erratically incorporated in the basal lenticular sandstone of the Ackerman. The boulders range in size from a few inches to more than 4 feet in diameter.

In its outcrop area in Scott and Stoddard Counties, the distribution of the Ackerman is essentially the same as that of the underlying Porters Creek, but in some places it overlaps the Porters Creek and is in contact with Cretaceous strata. The overlying Holly Springs formation rests on the eroded surface of the Ackerman throughout the outcrop area, and in some places where the Ackerman has been completely removed the Holly Springs lies on the Porters Creek. The Ackerman is, therefore, variable in its thickness which ranges from 0 to 100 feet or more. The presence of the Ackerman has been noted in the subsurface of the Embayment area, south and east of Crowley's Ridge in Stoddard County, but it is not as readily differentiated as it is on the surface. Because of this, most subsurface records do not distinguish the Ackerman from the Holly Springs formation.

Holly Springs formation.—The Holly Springs formation is very variable in composition. It is essentially a loosely consolidated sandstone that varies in texture from fine- to coarse-grained and contains large quantities of sandy clay, clay, and gravel. It is commonly cross bedded and is variably sorted; being well sorted in some places and poorly sorted in others. The color of the sandstone on weathered surfaces varies from an orange to a dark red color, but fresh exposures are colorless or white. The clay of the Holly Springs is erradically distributed as thin beds and lenses which are interstratified with sandstone. The clay is sandy or silty, or in some cases pure and plastic. It is multicolored and ranges from white, gray, yellow, red, lavender, green, brown, and black. The base of the Holly Springs commonly contains a bed of rounded, highly polished, black gravel and intermixed coarse sand. In a limited area of Crowley's Ridge in Stoddard County, the upper part of the Holly Springs contains a thinly bedded, grayish white and chocolate brown clay which has been referred to as the "Idalia clay". In this area wherever the clay is present, a bed of iron cemented sandstone lies between it and the underlying sandy clay and sandstone. The clay contains many well preserved fossil plants.

In the Crowley's Ridge area, the Holly Springs formation thickens southward. It ranges from a few inches thick along the northwestern margin of the ridge to more than 250 feet at the Ridge's southern extremity. Although the Holly Springs and Ackerman formations are not normally differentiated in the subsurface, as much as 1,200 feet of rock has been referred to the Holly Springs in a test well near Caruthersville in Pemiscot County. The formation outcrops in an almost continuous belt along the southeastern edge of Crowley's Ridge where it is separated from the underlying Ackerman by an unconformity. In many places it is unconformably overlain by the sand and gravel of the "Lafayette" formation (Pliocene?).

Pliocene (?) Series

Throughout the Mississippi Embayment area of southeastern Missouri and in that part of the Ozark region adjacent to the Embayment, there is a formation composed predominantly of gravel which caps most of the higher hills and divides. Northward in Ste. Genevieve, St. Francois, Washington, Franklin, and St. Louis Counties, high-level gravels similar in character to those present in the Embayment have been reported to be present. Most authors who have described these gravels have tentatively regarded them as being late Tertiary in age; the Period most generally designated by the authors being that of the Pliocene. However, one author has provisionally stated that the gravels in the St. Louis area and in adjacent parts of Illinois may be Miocene in age.

The names which have been proposed to designate this particular rock unit and similar appearing rock units throughout the Mississippi Valley are almost as numerous as the number of men who have proposed them, but most general references usually refer to the gravel composing the unit or units as the "Lafayette" gravel or as the "Lafayette-type gravel". In Missouri, two formal names have been proposed. For those high-level gravels that are present in and adjacent to St. Louis County, the name **Grover gravel** was proposed by William W. Rubey in 1952. For those gravels that are present in the extreme southeastern part of Missouri, in and adjacent to the Mississippi Embayment, the name **Piketon** was proposed by C. F. Marbut in 1902. In the absence of any conclusive evidence pertaining to the specific age and correlation of these gravels in Missouri, they are herein collectively designated as the "Lafayette" formation and regarded as being possibly Pliocene in age.

"Lafayette" formation.—Descriptions of the various occurrences of the "Lafayette" formation throughout eastern Missouri indicate that in this area there is little variation in its composition. In most exposures, the formation is composed of irregularly bedded gravel with minor amounts of coarse sand and clay. The gravel consists dominantly of pale brown, polished, and rounded pebbles of chert which make up as much as 80 to 90 percent of the formation. Pebbles of quartz and quartzite are present in lesser amounts. Most of the pebbles are between 1½ and 3 inches in diameter; however, large cobbles and a few boulders are not uncommon. The chert pebbles vary considerably in color and texture. Some are oolitic and some are fossiliferous and contain Paleozoic fossils. The quartzite pebbles are commonly pinkish or purplish in color, whereas the quartz pebbles are predominantly white or pale gray. Slight compositional variations exist between the gravels in the St. Louis County area and those in the Embayment area in that in the former locality subangular to rounded fragments of conglomerate occur in which well-rounded quartz pebbles are set in a matrix of dark brown ferruginous sandstone. Pebbles composed of other rock types are rare. Feldspathic igneous rocks and carbonate sedimentary rocks appear to be absent.

The sand which is associated with the gravel is medium to coarse grained, subangular to angular in shape, and heavily stained with iron oxide. This staining gives the formation a distinctive dark red color at most exposures. The clay in the formation is erradically distributed as thin lenses, or else it forms a matrix for the gravel. It is very sandy, plastic, noncalcareous, and varies in color from white, gray, yellow, purple to deep red.

The formation is usually cross bedded, and the gravels and sand are poorly sorted. In the St. Louis area, the formation is approximately 30 feet thick. In southeastern Missouri where the formation caps most of the hills, it is estimated to be as much as 60 feet thick along the southeastern margin of Crowley's Ridge and only a thin veneer on the flanks of the Ozark uplift adjacent to the Mississippi Embayment. The formation lies unconformably upon a very uneven and eroded surface which truncates Paleozoic, Cretaceous, Paleocene, and Eocene rocks. In much of its area of exposure in Missouri, the formation either forms the surface rock or is overlain by Pleistocene loess.

Quaternary System

by

George E. Heim, Jr.*

Pleistocene Series

The Pleistocene Series of Missouri includes all unconsolidated post-Tertiary deposits (Table 4). These deposits consist of clay, silt,

Table 4

			Stage (Age)		*Deposits*
CENOZOIC ERA	QUATERNARY SYSTEM	PLEISTOCENE SERIES	Recent		Alluvium, landslide debris, soil
			Wisconsinan	Upper	Bignell loess, alluvium
				Lower	Brady soil
					Peoria loess (incl. Farmdale), alluvium
			Sangamonian		Soil
			Illinoian		Loveland loess, alluvium, till
			Yarmouthian		Soil
			Kansan		Alluvium Till Sand and gravel
			Aftonian		Soil
			Nebraskan		Till Sand and gravel

*University of Illinois, Urbana, Illinois.

sand, and gravel. The greatest recorded thickness of these deposits is 399 feet.

On the basis of present information, it appears that most of the northern part of the state, north of the Missouri River, was covered by glacial ice during both the Nebraskan and Kansan ages of glaciation with the younger ice sheet extending somewhat farther south than the older as evidenced by the deposits of Kansan age which lie south of the Missouri River west of Jefferson City. During the Illinoian age small areas of the state in the vicinity of the cities of St. Louis and Ste. Genevieve were glaciated (Fig. 26).

Fig. 26. Map showing the limits of glaciation in Missouri.

The soils which were formed during the successively younger interglacial ages (Aftonian, Yarmouthian, and Sangamonian) are known to be present in Missouri, and nonglacial sediments which were deposited during Nebraskan, Kansan, Illinoian, Wisconsinan, and Recent ages have been identified. Loess of probable Wisconsinan age is present throughout most of the state, but loess of the older Illinoian age is apparently confined to areas adjacent to the Missouri River (Fig. 27). Colluvial deposits of various ages of the Pleistocene have also been recognized within the glaciated area of the state.

Several terrace surfaces have been identified within the state, and some of them have been named, although state-wide correlations have not yet been made from them. Samples of wood from one of the terraces at Bonfils in St. Louis County, 2½ miles east of the city of St. Charles, have been dated by radiocarbon methods. The dates obtained are 17,150 ± 600 and 17,800 ± 600 years, Before Present (1960).

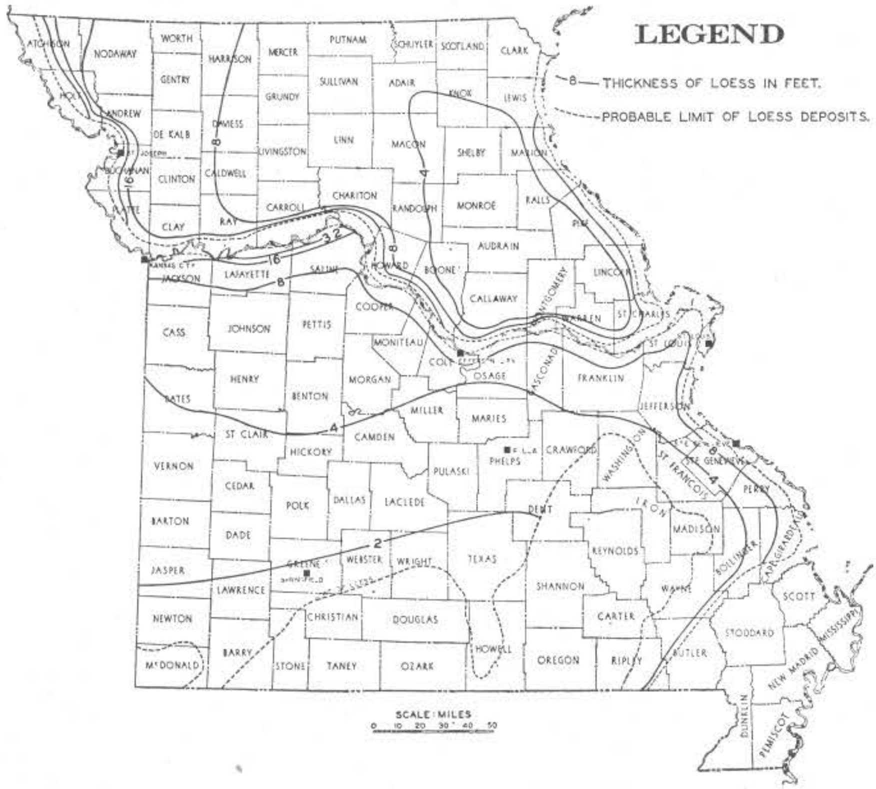


Fig. 27. Isopach map of loess in Missouri. Adapted from Thorpe, J., and Smith, H. T. U., 1952.

Pleistocene deposits are economically important because they are the parent material for much of the soil in the state, they are important sources of water, and they provide much sand and gravel.

Nebraskan Stage

Nebraska sand and gravel.—Deposits of gray sand and gravel underlie unaltered Nebraska till in northern Missouri. The sand is unweathered and unleached, indicating that it is possibly a proglacial deposit. The thickness of the deposit is as much as 100 feet.

Nebraska till.—The depth of weathering of the Nebraska till is variable. The unleached and unoxidized till (blue clay) is commonly a very dark gray, silty clay which contains many locally derived cobbles and boulders. Probably the most distinctive erratic in western Missouri is pink Sioux quartzite. Occasionally sand lenses are present. The upper part of the unoxidized till commonly is jointed. This till grades upward into unleached and oxidized till (yellow clay). The lithology of this unit is essentially the same as that below, but it is calcareous and contains limestone in the form of pebbles and cobbles. The color is yellowish brown, and the lower part is commonly jointed. Sand lenses are common throughout the till. The oxidized till grades upward into leached and oxidized till which like that below is yellowish brown in color but lacks the limestone inclusions which are common in the underlying material. Nodules of secondary carbonate are commonly present in this unit. The leached and oxidized till grades upward into gumbotil. The gumbotil ranges in thickness from less than 5 to as much as 15 feet. It is commonly a light gray, highly tenaceous, noncalcareous clay. It contains sand, granules, pebbles, and cobbles of resistant rock types as well as manganese nodules and limonite concretions. In some places, secondary carbonate nodules are present in it. This unit represents the B-horizon of the Afton soil. Distribution of both Nebraska and Kansas gumbotils is erratic. Some of the material called gumbotil in this region possibly is accretion gley as suggested by Frye and others (1960).

Aftonian Stage

No record of Afton deposits has been reported in Missouri. The Aftonian age is an interglacial period during which soil-forming processes altered all exposed material. The weathering profile on the Nebraska till developed during this interval.

Kansan Stage

Kansas sand and gravel—Deposits of gray calcareous sand and gravel underlie unleached Kansas till in northern Missouri. The sand occurs above weathered Nebraska till, or it lies in buried channels where in a number of cases it appears to rest on bedrock. This sand is possibly a pro-Kansan deposit. Thicknesses of 100 feet are not uncommon in channel-filled areas.

Kansas till.—Kansas till is similar lithologically to Nebraska till and is difficult to differentiate from it. The unleached and unoxidized till (blue clay) is commonly a very dark gray, silty clay which contains erratics and locally derived cobbles and boulders. The pink Sioux quartzite is again the most distinctive erratic in the deposit. Sand lenses are distributed throughout this unit. The upper part of this unit is commonly jointed. The unleached and oxidized till is essentially the same as that below except that it is yellowish brown. The contact is gradational. The lower part of this unit is also jointed. The unleached and oxidized till grades upward into leached and oxidized till. In most localities, the leached and oxidized till is more than 5 feet thick. The limestone inclusions have been removed by leaching.

Secondary carbonate nodules are present in this and the underlying unit. The leached and oxidized till grades upward into the Kansas gumbotil. The gumbotil ranges in thickness from less than 5 feet to as much as 15 feet. It is commonly a light gray, highly tenaceous, noncalcareous clay. It contains siliceous sand, granules, pebbles and cobbles. In many places manganese nodules and limonite concretions also occur. This unit represents the B-horizon of the Yarmouth soil.

Kansas alluvium.—Alluvial terraces which are believed to be Kansan in age are present in the major valleys of eastern Missouri.

Yarmouthian Stage

No Yarmouth deposits have been reported in Missouri. In this interglacial period, soil-forming processes modified all exposed material. A weathering profile developed on the Kansas till during this time.

Illinoian Stage

Illinois loess, which is commonly referred to as Loveland loess, and Illinois alluvium are approximately contemporaneous in age, but they occur in different topographic positions.

Loveland loess.—The Loveland loess is a medium- to coarse-grained, noncalcareous silt which contains very fine grains of sand. The amount of sand is greatest near the base of the loess. The loess is commonly a dark brown color, but its upper part is often a very distinctive reddish brown. The upper reddish-brown part of the loess increases markedly in clay content and represents the B-horizon of the Sangamon soil. Generally, the loess does not exceed a thickness of 20 feet. It is commonly found at high topographic positions near the Missouri River.

Illinois alluvium.—Illinois alluvium grades upward from well sorted sand and gravel at the base to medium and coarse silt. The upper few feet are clayey, and the distinctive reddish-brown Sangamon soil is present. The material is noncalcareous. Stratification is obscure, but jointing is common. Thicknesses of 30 feet or more are common. The alluvium is always found at low topographic positions and is generally confined to stream valleys tributary to the Missouri and Mississippi Rivers.

Illinois till.—Till which is regarded as Illinoian in age has been reported to be present in the vicinity of St. Louis. It is buff to gray, claylike and contains numerous small pebbles. It is leached but possibly contains secondary calcium carbonate nodules.

Erratics on the uplands in the vicinity of Ste. Genevieve suggest Illinoian glaciation. No till has been found in this locality.

Sangamonian Stage

Soil developed during the Sangamonian interglacial age. This soil is one of the most distinctive Pleistocene stratigraphic markers in western Missouri. The soil developed on all materials which were exposed during this time, and the B-horizon usually does not exceed 3 feet in thickness.

Wisconsinan Stage

The deposits of Wisconsinan age in Missouri are separated into upper and lower units. In this report, the top of the Brady soil is recognized as the upper limit of the lower unit which also includes the Peoria loess and the Farmdale loess. The upper unit includes the Bignell loess and alluvium. Other loesses of Wisconsinan age have been differentiated in Illinois, and some of them may possibly be present in Missouri. The loesses are thickest adjacent to the Missouri and Mississippi River valleys. The greatest thickness of loess reported in Missouri is 122 feet.

Peoria loess.—The grain size, calcium carbonate content, and color of the Peoria loess vary with the distance from the river bluffs. Near the bluffs, the loess is a well sorted, medium to coarse silt which contains some very fine- to fine-grained sand. It is light yellowish brown in color and is vertically jointed. Secondary carbonate nodules (loess Kindchen), manganese nodules, and limonite tubes are present. Pulmonate gastropod shells are common near the bluffs where the loess is thick and unleached.

Farmdale loess.—The Farmdale loess is herein treated as basal Peoria, however, in many places it can be differentiated from the remainder of the Peoria deposits only with difficulty. Farmdale loess is present in Cape Girardeau and Stoddard Counties and is presumed to be present at some localities in northwestern Missouri. Farmdale loess is commonly noncalcareous and has a distinctive pinkish cast. It is a medium to coarse silt which contains very fine- to coarse-grained sand. There is a thin accumulation of clay at the top of this unit. The thickest reported Farmdale in Missouri is 22 feet thick.

Brady soil.—The Brady soil is believed to have developed during a brief cessation in the deposition of loess. The Brady is somewhat darker than the underlying Peoria loess. It is generally less than 2 feet thick.

Bignell loess.—The Bignell loess overlies the Peoria loess and is differentiated from it by the presence of the underlying Brady soil or by means of fossil snails. The Bignell loess is approximately one-fourth as thick as the Peoria loess. It is obscured in modern soil profiles where the loess is thin. It is medium- to coarse-grained, light yellowish-brown silt which contains very fine- to fine-grained sand.

Upper Wisconsin alluvium.—Alluvium composed of silt and clay and containing poorly sorted sand, granules, pebbles, and cobbles was deposited along the streams in Missouri at the time of deposition of the Bignell loess. These deposits are more than 50 feet thick in terraces. Another younger terrace is very wide-spread. The exact age of the latter has not been determined, but possibly it is post-Thermal Maximum.

Recent Stage

Recent deposits comprise the alluvium which is associated with the present streams and rivers in the state as well as with minor amounts of landslide debris. The alluvial material which is associated with the Missouri and Mississippi Rivers has sand and gravel at the base and from 10 to 20 feet or more of silt at the top. The total thickness of this material is commonly more than 100 feet. Soils are developing on this and on all exposed material in the state.

STRATIGRAPHIC PRINCIPLES AND POLICY

by

John W. Koenig

An examination of Missouri Geological Survey reports that have been published since 1855 shows that for the most part the stratigraphic principles which have guided much of the Survey's work to the present have been informally adopted from authoritative sources elsewhere and have been fitted, in the best possible manner, to Missouri's own problems. This practice has serious limitations because there is more than one authority that one may follow, and unless some control is exercised as to which and to what is to be accepted, the reports of the Survey, as they have in the past, will reflect the influence of all that is available. Another defect of this practice is that in many instances those policies that have been adopted in the past have not always been adequate for the proper solution of many of the problems peculiar to Missouri's stratigraphy.

Up until the present, there have been five prominent authorities which have had a direct influence on the Missouri Geological Survey's stratigraphic policy. These are James D. Dana, the International Geological Congress, the U. S. Geological Survey, the Ashley Committee, and the American Commission on Stratigraphic Nomenclature. Because the suggestions and judgments of these authorities continue to effect Survey concepts to a large degree, they are briefly reviewed so that the Survey's present position can be viewed perspectively.

1856-1903.—In 1856, James D. Dana published the text of an address "On American Geological History" that he had given before the American Association for the Advancement of Science in August 1855. This paper represents a culmination of a hundred years of discovery and endeavor in the science of geology and marks the beginning of the present stage of work on the classification of stratigraphic units. It is coincidental that the only comprehensive report of the First Missouri Geological Survey (1853-1861) was published in the same year that Dana's address was given. In this publication, it is interesting to note in the light of recent recommendations by the American Commission on Stratigraphic Nomenclature as to the capitalization of rock-stratigraphic terms that the typographic styling of this early publication followed the practice of capitalizing lithologic terms of formation names and of stratigraphic-unit terms "Formation" and "Bed".

Dana's primary thesis, essentially following Agassiz's original idea as set forth in "Principles of Zoology", 1848, is that "From the progress of life, geological time derives its division into Ages" and that these ages are applicable on a global scale and can be distinguished "by the culmination of their grand characteristics" as the Age of Mollusks (Silurian), Age of Fishes (Devonian), Age of Acrogens or coal plants (Carboniferous), Age of Reptiles (Mesozoic), Age of Mammals and Age of Man (Cenozoic), (Dana, 1856, p. 306). His second thesis is that "Division of time *subordinate* to the great ages will necessarily depend on revolution in the earth's surface, marked by abrupt transitions, either in the organic remains of the region, or in the succession of rocks. Such divisions are not universal. Each continent has its own periods and epochs . . ." (Dana, 1856, p. 307).

Using the work that had been done on North American stratigraphy (principally in New York state) as a basis, he summarized his views in the following tabular form (Dana, 1856, p. 318):

I. SILURIAN AGE. [Age of Mollusks]

1. *Lower Silurian*

1. POTSDAM PERIOD.—1st Epoch. Potsdam sandstone; 2nd. Calciferous sandrock.
2. TRENTON PERIOD.—1st Epoch. Chazy limestone; 2nd. Birdseye; 3d. Black River; 4th. Trenton.
3. HUDSON PERIOD.—1st Epoch. Utica Shale; 2nd. Hudson River Shale. (Hudson River Shale and Blue limestone of Ohio in parts of the west.)

2. *Upper Silurian*

1. NIAGARA PERIOD.—1st Epoch. Oneida Conglomerate; 2nd. Medina Sandstone; 3d. Clinton Group; 4th. Niagara Group.
2. ONONDAGA PERIOD.—1st Epoch. Galt limestone; 2nd. Onondaga Salt Group.
3. LOWER HELDERBERG PERIOD.—Limestones. (Statement of epochs here omitted).

II. DEVONIAN AGE [Age of Fishes]

1. ORISKANY PERIOD.—1st Epoch. Oriskany Sandstone; 2nd. Cauda-galli Grit.
2. UPPER HELDERBERG PERIOD.—1st Epoch. Schoharie Grit; 2nd. Upper Helderberg group.
3. HAMILTON PERIOD.—1st Epoch. Marcellus Shales; 2nd. Hamilton group; 3d. Genesee Slate.
4. CHEMUNG PERIOD.—1st Epoch. Portage; 2nd. Chemung group.
5. CATSKILL PERIOD.—Catskill Red Sandstones and Shales.

III. CARBONIFEROUS AGE [Age of Acrogens]

1. SUBCARBONIFEROUS PERIOD.—1st Epoch, Conglomerates, Sandstones, and Shales (with some coal seams); 2nd. Sandstones, Shales and Carboniferous limestone.
2. CARBONIFEROUS PERIOD.—1st Epoch, Millstone Grit; 2nd. Lower Coal Measures; 3d. Upper Coal Measures.
3. PERMIAN PERIOD.—Probably unrepresented in Eastern North America, except by the events of the Appalachian revolution.

Dana's work served as a foundation for further development of a system of stratigraphic classification and nomenclature in this country, and the half century immediately following witnessed the establishment and refinement of his ideas.

The publications of the Second Missouri Geological Survey (1870-1874) reflect the influence of Dana's work even to the point of typographic styling which generally but not completely followed that of British publications. (Note method of capitalization of rock terms in Dana's table above.) This inconsistency in capitalizing stratigraphic terms seems to mirror the uncertainty that existed in the minds of many American geologists who were seeking freedom to explore new ideas as well as new terrains, but who still felt the strength of their bonds to the teachings of the old world. They were also inconsistent in the usage of terms to express the taxonomic rank of stratigraphic and chronologic divisions. G. K. Gilbert, in 1887 (p. 432), summed up the situation current at that time with the statement that "With some writers a group is larger than a series, with others it is smaller. With some an age includes several periods, with others a period includes several ages. There are even writers who ignore the distinction between stratigraphy and chronology; . . ." That such a situation could not be allowed to continue unchecked was evident to many geologists both here and in Europe, and by 1878, with the establishment of the International Geological Congress, a concerted effort was made to establish an acceptable system of classification and nomenclature in the field of stratigraphy.

After three meetings had been held by the Congress (the first at Paris in 1878, the second at Bologona in 1881, and the third at Berlin in 1885), agreement was reached as to the rank and equivalence of the taxonomic terms that were to be employed in chronology and stratigraphy. The terms and order adopted by the Congress were as follows: "Of stratigraphic divisions that with the highest rank is *group*, then *system*, *series*, and *stage*. The corresponding chronological divisions are *era*, *period*, *epoch* and *age*", (Gilbert, 1887, p. 432). It appears that the word *stage*, a newly adopted term, was intended to replace the term *formation*, because Gilbert states that its introduction "was necessitated by the restriction of the word *formation* to a special meaning—the designation of mineral masses with reference to their origin", (Gilbert, 1887, p. 432). The third Congress also proposed that the names of the individual stratigraphic ranks be distinguished by means of suffixes; those of the same rank having the same ending. *Group* terms would end in *ary* (Tertiary, Primary), *system* names in *ic* (Carbonic, Siluric), *series* names in *ian* (Trentonian, Laramian), and *stage* names in *in*.

By the time the Third Geological Survey of Missouri was established in 1889, these proposals and propositions of the International Geological Congress had begun to affect the writing and thinking of many American geologists, and an orderly system of dual nomenclature in classification was beginning to appear in the literature. The U. S. Geological Survey, under the directorship of J. W. Powell, realizing at this time how rapidly the course of events in this as well as in all phases of geological work was developing, decided to formulate a policy which would standardize geologic taxonomy, nomenclature, and map notation for Federal geologists; the Federal Survey's immediate concern being the adoption of an editorial code for the publication of a new series of geologic atlases. In January 1889, a committee of U. S. Geological Survey geologists, under the chairmanship of J. W. Powell, established a set of rules for stratigraphic taxonomy and nomenclature as well as for a series of directives for application of the rules to geologic mapping. The rules and directives were published in the "Tenth Annual Report of the Director of the U. S. Geological Survey", 1889.

It is important to recognize the fact that the rules adopted by the U. S. Geological Survey were formulated primarily for the purpose of standardizing map notation on a scale of 1/125,000 (approximately 2 miles to the inch), and this directly affected the definition of the term designating the basic unit of the Survey's classification, "formation". The rules state that for "cartographic purposes and for use in the maps published by the Geological Survey four great classes of rocks, viz: (a) fossiliferous clastic rocks, (b) superficial deposits, (c) ancient crystalline rocks, and (d) volcanic rocks" were to be recognized. These classes were divided into two divisions: "structural divisions and time divisions". The structural divisions were defined as "units of cartography" and were designated as "formations". Formations were to be "based upon the local sequence of rocks" with "lines of separation being drawn at points in the stratigraphic column where lithologic characters change". Each formation was to contain "between its upper and lower limits either rock of uniform character or rock uniformly varied in character; as for example, a rapid alternation of shale and limestone". Correlation was to be based on lithologic characteristics, aided by stratigraphic association and contained fossils. The formations were to be designated binomially, the first term being geographic and the second being lithologic with both terms capitalized. It may be noted that some of the recommendations of the International Geological Congress were not accepted in that rock units greater or smaller than formations were not mentioned in the rules, and that the term "formation" was given an entirely different definition than that given to it by the Congress. Time divisions were defined "primarily by paleontology and secondarily by structure" and were called "periods". Formations were grouped according to the periods in which they were deposited. Again it may be noted that smaller and larger time units recommended by the International Congress were omitted from the rules. In fact, the rules stated specifically that all taxonomic divisions except periods and formations were to be excluded from the atlas sheets, but that this prohibition applied only to the sheets.

Despite the effectiveness of such a directive on the work of many geologists in the country other than those employed by the Government, it is obvious from the papers published by the Missouri Geological Survey during the period of 1890 to 1904 that more than one system of classification was operative. An article on "The Clay, Stone, Lime, and Sand Industries of St. Louis City and County", by G. E. Ladd, published December 1890 in Bulletin No. 3 of the Missouri Geological Survey, indicates a direct influence of the U. S. Geological Survey ruling. The general geologic section which it contains is divided into "three grand time divisions . . . Quaternary, Carboniferous, and Silurian" and several formations. In the article both time and binominal formation terms are capitalized. A paper by S. A. Miller on "A Description of Some Lower Carboniferous Crinoids from Missouri," published in February 1891 as Bulletin No. 4 of the Missouri Geological Survey, indicates a combined influence of both the recommendations of the International Geological Congress and Dana's system of classification as established in 1855. Miller used the term "system" informally as a rock term as "Sub-Carboniferous system"—series rank was the formal status for Sub-Carboniferous at that time—and the term "group" as a formal rock term for the next higher rank above formation, as "Chouteau group". In 1894, when C. R. Keyes was appointed to the position of State Geologist, he published his work on the "Paleontology of Missouri" as Volume 4, 1st series, of the Missouri Geological Survey. In it is a table of the geologic formations of the state that is divided into four units, "Age, Series, Stage, and Formation". Except for the use of the word "Age" in what should have been the column for "System", this classification is the same as the one proposed by the International Geological Congress. During Keyes' administration (1894-1898), this procedure was followed except for the adoption in 1898 of the term "System" in its formal usage as prescribed by the Congress. The time terms "Era, Period, and Epoch" were also used in accordance with the Congress' recommendations as shown in Volume 7, 1st Series, of the Missouri Geological Survey which was also published in 1894.

In 1895, Dana published the fourth edition of his "Manual of Geology" as a completely rewritten version of his earlier work, and in it he included a revised form of his previous system of stratigraphic and time classification. Essentially, he adapted the recommendations of the International Geological Congress to his original classification, and in doing so made several significant changes which possibly tended to confuse the situation more than to clarify it. He stated that "the several grades of subdivisions of geological time are named (1) Aeons, (2) Eras, (3) Periods, (4) Epochs; and the corresponding terms applied to the formations are Series, Systems, Groups, Stages" (Dana, 1895, p. 406). In his text he substituted the word "time" for "aeon". A comparison of the two systems in the following table gives some idea of the taxonomic confusion confronting the geologic student or worker of that period.

Rock terms—Group	System	Series	Stage	Internat. Geol. Cong. 1885
Time terms—Era	Period	Epoch	Age	
Rock terms—Series	System	Group	Stage	Dana, 1895
Time terms—Aeon	Era	Period	Epoch	

During the period of 1890 to 1904, the U. S. Geological Survey held to its own system of classification and nomenclature, but after 14 years of experience in publishing geologic atlases it decided to revise its rules in accordance with new requirements. These new rules were published in 1903 in the "Twenty-fourth Annual Report of the Director of the U. S. Geological Survey". Emphasis was still placed on cartographic purposes. The rules established three great classes of rocks (sedimentary, igneous, and metamorphic), the cartographic units of which were to be called "formations". The definition of the term "formation" remained unchanged from the earlier rules, but two other subformational units were recognized, "member and lentil". The lithologic part of binomial formation names was no longer to be capitalized. The terms "system, series, and group" were recognized and defined as follows: "Through correlation all formations are referred to a general time scale, of which the units are periods. The formations made during a period are collectively designated a system . . . Within the systems smaller aggregates of formations may be recognized, which shall be called *series*, and these may be divided into subordinate *groups* of formations". Provision was made in the rules for changing the rank of a name without changing its stratigraphic inclusion. This factor had a decided influence on the future development of provincial stratigraphic columns throughout the country, especially in the classification of Pennsylvanian units in the midcontinent.

The Series which the Federal Survey recognized under the rules as applicable to North America were as follows: "In the Quaternary, Recent and Pleistocene; in the Tertiary, Pliocene, Miocene, Oligocene, and Eocene; in the Carboniferous, Permian, Pennsylvanian, and Mississippian; in the Cambrian, Saratogan, Acadian, and Georgian". In other Systems, subdivisions of the rank of Series were to be "temporarily distinguished as upper and lower, or upper, middle, and lower".

1903-1933.—The effect of the U. S. Geological Survey rules upon the statigraphic policy of the Missouri Geological Survey is obviously indicated in the geologic tables and statements published in the Survey's reports from 1903 to about 1917. It was not until about 1918 that the Missouri Geological Survey swung away from U. S. Geological Survey policy and adopted the recommendations made in 1907 by Chamberlin and Salisbury to raise the Permian, Pennsylvanian and Mississippian Series to the rank of System.

In 1911, E. O. Ulrich, then a member of the Federal Survey, published with the permission but not the sanction of the Director of the U. S. Geological Survey his treatise on the "Revision of the Paleozoic Systems". Among the several major revisions which he recommended was one which had a direct affect on the provincial stratigraphic section of Missouri for a number of years. Ulrich proposed that two Systems, the Ozarkian and Canadian, be interposed between the Cambrian and Ordovician Systems. As originally defined, the Ozarkian System in Missouri included all formations from the top of what was then known as the Elvins formation to the base of the St. Peter formation—Ulrich believed that the Everton was absent in all except southern Missouri—and the Canadian System included the Yellville formation of Arkansas which Ulrich considered to be absent in Missouri. Thus, he believed that Canadian time was represented in the state by a haitus between the Jefferson City and St. Peter formations as they were defined by him at that time. In 1913, when Wallace Lee published his report on the "Geology of the Rolla Quadrangle" as Volume 12, 2nd Series of the Missouri Survey, the boundary between the Ozarkian and Canadian Systems was lowered to a position between the Gasconade and Roubidoux formations. According to Lee (1913, p. 7), this was an "authorized modification . . . based on unpublished work in the State by Dr. Ulrich in 1912". This is the only published account in which the change is authorized. Ulrich never did publish his reasons for it. The change again appears in a correlation table published in Bulletin 92 of the U. S. National Museum, "Bibliographic Index of American Ordovician and Silurian Fossils," by Ray S. Bassler (1915, pl. 2). Bridge (1930, Table 2) ascribes this situation in Bassler's work to Ulrich. Ever since Lee's publication appeared, Ulrich's Ozarkian and Canadian Systems have been variously treated by the Missouri Geological Survey. Some authors have recognized them officially, others have accorded them semiofficial status by including the names in the discussion of Cambrian and Ordovician formations, and still others have chosen to disregard them entirely. It is herein considered that the weight of evidence is insufficient for the Missouri Geological Survey to continue to recognize the Systems in its stratigraphic succession.

Other than the above mentioned major modifications to the State's stratigraphic column, the Missouri Geological Survey's stratigraphic policy remained similar to that of the U. S. Geological Survey until 1933. At that time, the so-called "Ashley, et al. report" or "Stratigraphic Code" was published as an official statement of a joint committee representing the American Association of Petroleum Geologists, Association of American State Geologists, Geological Society of America, and U. S. Geological Survey. The Code has since served as a general guide for the Missouri Geological Survey as well as for most geologists in the country, and it is still officially recognized by the U. S. Geological Survey.* The Code was originally published in 1933 both in the Bulletin of the Geological Society of America, volume 44, pp. 423-459, and in the Bulletin of the American Association of Petroleum Geologists, volume 17, pp. 843-868, under the title of "Classification and Nomenclature of Rock Units". It was published again in 1939 in the Bulletin of the American Association of Petroleum Geologists, volume 23, pp. 1068-1099.

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*In May 1961, while this publication was in final preparation for the press, the American Commission on Stratigraphic Nomenclature published its new "Code on Stratigraphic Nomenclature" in the Bulletin of the American Association of Petroleum Geologists, volume 45, number 5, pp. 645-665. This new Code was officially adopted by the U. S. Geological Survey in June 1961.

Classification and Nomenclature

It was not until 1949 that a multiple system of classification was informally adopted by the Missouri Geological Survey for the purpose of systematically arranging rock and time terms. Until that time, a rather incomplete dual system had been used in which the major rock terms *system*, *series*, and *group* were augmented by a parallel arrangement of the time terms *period* and *epoch*. The latter term was used with either *series* or *group*, and the time term *era* was used to designate the largest divisions of geologic time and had no counterpart in rock classification. Time reference for formations and members was made informally, there being no general agreement on specific terms to designate their time factor, although such terms as subepoch, age, stage, substage, phase, chron, and hemera had been proposed by a number of authorities and were available. Most geologists either used the general term *time* or projected the use of the term *epoch*. The elements of this dual system of classification are tabulated as follows:

ROCK TERMS	*TIME TERMS*
	Era
System	Period
Series } Group }	Epoch
Formation	——
Member	——

In 1949, Greene and Searight published as Report of Investigations 11 of the Missouri Geological Survey, a revision of the post-Cherokee Pennsylvanian beds of Missouri. In this report, the elements of a multiple system of classification were first adopted by the Survey. This adoption was essentially a result of an interstate conference held in 1947 by representatives of the Iowa, Kansas, Missouri, and Nebraska Geological Surveys. The third element which was added to the already existing dual system was the concept of time-rock or time-stratigraphic units, a concept first proposed by Schenck, Hedberg, and Kleinpell in 1935, clarified by Schenck and Muller in 1941, and reiterated by Moore (1947) in Note 2 of the American Commission on Stratigraphic Nomenclature just prior to the date of the interstate conference.

Time-stratigraphic units as defined by Moore are "divisions of rocks segregated on the basis of their relation to determined segments of geologic time" (Moore, 1947, p. 520). In the light of this definition he states that the major rock units, *System* and *Series*, are examples of time-rock or time-stratigraphic units and as such are distinct from sedimentary rock units which are normally designated by the terms *group*, *formation*, and *member*. It was not until 1948 that the time term *age* was proposed by the Commission (Flint and Moore, 1948, p. 373) as the corresponding time unit for the time-stratigraphic unit *Stage*. The elements of this multiple system may be tabulated as follows:

	ROCK TERMS for Rock-stratigraphic units	TIME-ROCK TERMS for Time-stratigraphic units	TIME TERMS for Chronologic units	
	—	—	Era	Chronologically defined
	—	System	Period	
	—	Series	Epoch	
	—	Stage	Age	
Physically defined	Group	—	—	
	Formation	—	—	
	Member	—	—	

Rock-Stratigraphic Classification

Rock unit.—Any natural body or mass of mineral matter which constitutes a part of the earth's crust is regarded as a rock unit. Genesis is of no consequence in such a definition; therefore, a rock unit can be of sedimentary, of metamorphic, or of igneous origin. It is recognized and defined by its inherent and observable physical characteristics and inclusions. Its spatial extent is limited only by contained definitive physical features of all types, and the number of configurations of its discernible boundaries is unlimited. By definition, a rock unit is independent of a time scale, even though it is recognized that a certain amount of time is involved with the creation of any rock unit.

The lateral extent, thickness, and shape of a rock unit is related to the bulk of the original material, to the capabilities and character of the distributing agency, to the presence or absence of physical obstructions, to the type, rate, and degree of tectonic activity in the area of distribution, to the rate and length of time of formation, and to the degree of preservation. Because of active operation of many of these conditions during and after the course of formation, the shape of the rock mass and the physical aspect of its lateral boundaries may be very complex and correspondingly difficult to determine. Recognition of these factors in recent years has led to an intensive study of the nature of lateral contacts and to an extensive and controversial literature on the subject especially in the field of sedimentary rock units.

Selected time horizons may or may not correspond to the vertical boundaries of a sedimentary rock unit. The age of any one part of the unit may be different from that of another part because of differences in time of accumulation, and the unit may, over wide areas, transgress a time horizon.

Because a rock unit is defined and recognized by its physical features, it is necessary for correlation purposes first to establish locally the criteria needed for recognition of any one given unit. The amount and choice of the criteria will depend on the circumstances under which observations are made. For field observation, the criteria may consist of a group of physical elements which together represent the immediately observable gross lithology of a unit, and the choice of the unit's upper and lower boundaries will be determined by the extent of the total effect. Or, the criteria may be specific structures which are included in and are characteristic of the selected unit. In this case, the upper and lower boundaries may be indefinite because of a lack of sharply defined breaks between associated criteria of adjacent units. In subsurface work, such criteria as insoluble residues, electrical characteristics, transmission of seismic waves, and other properties may be determining factors of recognition and the boundaries determined by such criteria may not be sharp and distinct. In any event the particular criteria chosen must be persistent and readily apparent so that the unit may be traced or correlated as far as its definitive physical features can be recognized.

Rock-stratigraphic Units

The concepts for the ranking of rock-stratigraphic units have been derived primarily from studies of the nature and association of stratified rock units formed from sediments deposited by aqueous agencies. Application of these concepts can be (and has been) extended to the study of other types of sedimentary rock units and to other classes of rocks. When such extension is made, however, it must be realized that there are limitations to the system and that the ranks of units as defined below may not fit all cases of unit distinction.

Formation.—The formation is the fundamental unit of rock-stratigraphic classification. When the term *formation* is used, it designates the classificatory rank which a rock unit or group of contiguous rock units have within the system of stratigraphic classification. In this respect, the term is divorced from natural affinities.

A rock unit is an isolated objective entity. A formation is a subjective classificatory entity. When a rock unit or a succession of rock units is selected and designated as a formation, it is given a special significance by virtue of the fact that it is placed in an arbitrary system of classification where it is relative and comparable to other elements in the same system. Even the acts of selection and designation in themselves are of a subjective nature. By itself, a rock unit is a physical mass that is regarded as a lithologic genetic unit. A formation may be composed of one or more such units. Accordingly, as stated in Report 4 of the American Commission on Stratigraphic Nomenclature, "A formation, which is the fundamental unit in the local classification of rocks, may represent a long or short period of time, may be composed of material from different sources, and may include breaks in the stratigraphic sequence" (Cohee and others, 1956, p. 2006). This statement of the Commission actually emphasizes the fact that a formation is a *fundamental unit of a classificatory system* that may contain one or several *lithologic genetic units.* Because of the above reasoning, the Missouri Geological Survey believes that the limits (both vertical and lateral) of a formation must be *selected* so that the formational unit will have a maximum practical unity of constitution which will best express the geologic development and structure of the region in which the formation is present. Thus, a formation may contain laterally, rock of one or more lithologic types (facies), and vertically, a succession of rocks of one or more lithologic types. The formation may be a completely homogeneous unit, or it may be marked by extreme heterogeneity which in itself may constitute a form of unity. It may also be the expression of a lithologic pattern which in itself constitutes a unit.

Because of the variable constitution of some formations, more attention must be given to the character and continuity of the criteria chosen to ascertain their upper and lower boundaries than to the extension of the formations as initially defined at their type localities to assure the success of tracing them laterally. The importance of this statement is readily apparent in cases where formations consist laterally of two or more facies, or where formations expand or contract vertically because of the inclusion or exclusion of one or more rock units with or from the rock units originally assigned to the formations at their type localities. Thus, the relationships of adjoining formations at their contacts are of prime importance in the definition, distinction, and recognition of many formational units. The chosen boundaries must be defined on the basis of readily recognizable or attestable criteria definitive of the adjoining formations at their points of contact. If the contact is vertically gradational or indeterminate laterally because of interfingering relationships, it may be necessary to separate adjoining formations by an arbitrary boundary somewhere within the zone of gradation.

The criteria used for the definition of a formational boundary need not be restricted to the physical characteristics of the adjoining rock units. The boundary between adjoining formations of similar lithologies may represent a break in the geologic record which may be marked by a recognizable break in the continuity of the faunal record. It therefore follows that any type of criteria, physical or organic, may be used so long as the criteria satisfy the requirements of definitive utility.

Because of advancements in mapping technology and the availability of accurate large scale maps for most of the United States, thickness can no longer be regarded as one of the primary determining features in the discrimination of a formation. Seventy years ago when the U. S. Geological Survey laid the groundwork for the publication of its geologic atlas sheets by formulating rules of stratigraphic classification and nomenclature, it was realized that the intended map scale for the atlas (1:125,000) would definitely restrict any definition proposed for the term *formation*. In fact, the rules stated the following:

> The structural divisions [one of the two classes of divisions into which clastic rocks were divided, the other being time divisions] shall be units of cartography, and shall be designated *formations*. Their dis-

crimination shall be based upon the local sequence of rocks, lines of separation being drawn at points in the stratigraphic column where lithologic characters change. It will be impossible to delineate on maps of the scale selected for the atlas sheets the limits of each lithologic change, and the geologist must select for the limitation of formations such horizons of change as will give to the formations the greatest practicable unity of constitution. (Powell, 1890, p. 64).

In 1903, after 14 years of experience in publishing the atlas sheets, the rules were revised by the U. S. Geological Survey, but the definition of the term *formation* remained essentially unchanged. Even the wording of the rules was left intact (Walcott, 1903, p. 23).

Thirty years later when the "Ashley Code" was published, emphasis on the mappability function of a formation was shifted very slightly in deference to a genetic concept which had been alluded to by Powell as early as 1888. Otherwise, the wording of the definition and its original intent remained the same as when it was given in 1890. The fact, however, that a formation might be conceived of as a genetic unit led the formulators of the code to append the following significant remark to their definition:

Although the practicability of mapping is usually an essential feature, and, indeed, may be the chief factor, in the discrimination of a formation, it may, under exceptional conditions, be waived. It may be impracticable to show separately, even on a fairly detailed map, thin rock units which, by various other criteria, are valid formations. (Ashley and others, 1933, p. 431).

Following this corollary to its logical conclusion, they then stated that "The thickness of a formation is not a determining feature in its discrimination" (Ashley and others, 1933, p. 431). This statement was repeated in 1956 by the American Commission on Stratigraphic Nomenclature (Cohee and others, 1956, p. 2006).

Cyclic formation*.—Within the Pennsylvanian System in Missouri, lithologic units, in the main, are relatively thin. Working with similar thin units in Illinois, many of them the same as those in Missouri, Udden in 1912 directed attention to the orderly vertical arrangement of the beds of sandstone, clay, coal, and limestone in a pattern which he called a cycle of deposition or sedimentary cycle (Udden, 1912, pp. 47-50, Fig. 2).

The exposed sections of the coal-bearing rocks present an unusual persistence of 21 recognizable divisions that have been described and these may be grouped into an almost perfect quadruple repetition of a sedimentary cycle. Each cycle may be said to present four successive stages, namely: (1) accumulation of vegetation; (2) deposition of calcareous material; (3) sand importation; and (4) aggradation to sea level and soil making."

Three years later Hinds and Greene (1915, pp. 211-212) observed similar cyclic conditions in Missouri, and stated that:

*Prepared by Walter V. Searight.

During the later part of the Cherokee epoch several thin marine limestones were formed, closely associated with coal beds. There seem to have been cycles of sedimentation similar to those in Illinois which are described by Udden. The cycles began with (1) the growth of coal-forming plants; followed by (2) an invasion of the sea which killed the vegetation, but was favorable to marine animal life; then (3) an increase in sediment killed most of the limestone-forming animals, and the basin filled to the surface with muck and sand; and finally (4) soil was formed and plant life began to flourish. In Missouri a second interval favorable to marine life often intervened between stages (3) and (4), so that the soil and plants of the final stage were laid upon a thin limestone.

Later, in Illinois, Weller (1930, 1931) and Wanless (1931) emphasized the utility of considering the cycle as of formational significance and named each cyclic sequence a cyclothem (Weller, 1930). However, the base of the cyclothem or cyclic formation of Weller and Wanless was placed at the bottom of sandstone which lies approximately midway within the cycle of Udden and of Hinds and Greene. Later studies of many hundreds of successions in Missouri afford ample support for the concept of cyclic or repetitive deposition as is displayed in Pennsylvanian beds. The unit cycle also satisfies the proper requirement to make it the most useful and satisfactory fundamental unit of classification in Pennsylvanian strata. Above the base of the Marmaton, key beds, particularly limestones, by priority and long usage, are the basis for formational assignment.

In Pennsylvanian beds below the Marmaton, however, particularly in the Cherokee group, cyclic successions and the repetition of cyclic successions are conspicuous. The Missouri Geological Survey accordingly recognizes a cyclic succession in the Cherokee group as a formation, and a formal name, with certain exceptions, is applied to each of them. Coal beds have been chosen to mark the proper vertical limits of such a formation, which is defined as extending from the top of one coal bed to the top of the next higher coal bed, inasmuch as a coal bed is present or is represented in each successive cycle. Several coal beds of limited lateral distribution are assigned to well marked formations of wide distribution in order to avoid useless addition of named formations. The Seville formation and the Excello, although only parts of cycles, are given formational rank owing to their terminal positions within a group or subgroup.

Formational subdivisions.—As a classificatory unit, a formation may contain single or multiple components depending upon the definitive criteria selected for determination of its boundaries. If it contains multiple components, and if it is desirable for scientific or economic reasons to recognize them individually, each such component may be regarded as a *member*. It is not necessary that all such members be given a name for purposes of distinction.

By definition, a member is regarded by the Missouri Geological Survey as a classificatory subdivision of a formation. As such, it need not be restricted to the distinction of single rock units. A member may contain several rock units, but such units are generally regarded as being closely similar in character, whereas the rock units within a formation may be very dissimilar in character.

The classificatory term *bed* is used to designate the smallest division of stratigraphic classification and may be applied to individual stratigraphic rock units. A bed is a unit of informal rank and customarily is not named except in some instances when it may serve a useful purpose for economic reasons or for correlation.

The terms *lentil* and *tongue* have been used in the literature in a formal sense in that names have been applied to particular lentils and tongues. The American Commission on Stratigraphic Nomenclature, however, considers that they are formational subdivisions equal in rank to members, their distinction being based on shape and geographic extent. A lentil is a lenticular rock unit of relatively small geographic extent. A tongue is that part of a rock unit which wedges out laterally in one direction. A cautionary remark may be added that in some cases when a cross section of a tongue is observed normal to its direction of extension, it may be mistaken for a lentil.

Group and subgroup.—When two or more formations are considered together to form a naturally related unit within a particular region or province, the unit is termed a *group*. The upper and lower boundaries of the group are therefore formational boundaries, and as in the correlation of a formation, so long as these boundaries can be recognized the group as a unit can be traced laterally from the region in which it was originally defined.

A *subgroup* is a succession of formations which together express an integral natural relationship within a local region, and such a unit is subordinate to the total natural affinity of all the formations within the group.

Rock-stratigraphic Nomenclature

Naming a rock unit or a grouped vertical succession of rock units implies in all cases except for a *bed* formal recognition, and when named the unit or grouped units of necessity must be ranked within the system of rock-stratigraphic classification as a group, a subgroup, a formation, or a member or some coordinate division such as lentil or tongue.

Nomenclature.—A binomial system of nomenclature is used for naming formal rock-stratigraphic units. Current usage and general agreement have established that the unit is first given a distinctive name which is usually the name of a geographic feature at or near the locality where the unit is typically developed. In the past, names based on petrographic or paleontological features, as *Magnesian*, *Crinoidal*, and *Saccharoidal*, had been used, but this practice is no longer acceptable, and most such names have since been replaced by geographic names. The current custom of many geologists and geologic organizations is to use rank terms for the second part of the names of groups and subgroups, as *Cherokee group*, *Krebs subgroup*, and either a descriptive lithologic term or a rank term for the second part of a formation name depending upon the dominance and homogeneity of the lithology most characteristic of the named unit. If one type of lithology is dominant and characteristic of the formation, the lithologic term is used, as *Jefferson City dolomite.* If the formation contains several different types of rock and no one lithology is characteristic of the unit, the term *formation* is used, as *Bandera formation.* Because most established formational units are now known to be more or less multilithic in character, the Missouri Geological Survey considers that use of the rank term is preferable to the use of the lithologic term for a formation. Also, the Survey believes that the names of members and coordinate divisions should be treated in the same manner as the names of formations in that the rank term, *member*, *lentil*, or *tongue*, should accompany the geographic term, as *Mine Creek member.* The Missouri Geological Survey intends to follow this practice except in those instances when reference is made in its publications to rock-stratigraphic names that are used by other institutions.

Application of an identical geographic name to a minor unit of a formation or a member is considered by the Survey as informal nomenclature, as the *Mineral coal* of the *Mineral formation.*

Punctuation.—The Missouri Geological Survey believes that the geographic terms of accepted formations should be joined by a hyphen where such formations cannot be separated because of the difficulty of determining an obscure boundary, as in the case of the *Burlington-Keokuk formations.*

If a rock-stratigraphic name has become obsolete and has been replaced by a new name, the obsolete name should always be enclosed by quotation marks when written, and the status of the name should be made clear by some such term as *abandoned* or *obsolete.* Any Missouri rock-stratigraphic name that has not been officially adopted or recognized by the Missouri Geological Survey is also to be enclosed in quotation marks when written as "Lafayette" formation. If it is essential to show the relation of an obsolete petrographic or paleontologic name to the geographic name which has replaced it, the older name should be enclosed in quotation marks and parentheses, as *Burlington ("Crinoidal") formation.*

Capitalization.—The Missouri Geological Survey believes that neither the lithologic part of a rock-stratigraphic name nor the words *group*, *formation*, *member*, *lentil*, *tongue*, or *bed* should be capitalized. This axiom was adopted by most American geologists as early as 1870 when they broke away from the British custom of capitalizing all parts of rock-stratigraphic names. Recently, the suggestion has been made by the American Commission on Stratigraphic Nomenclature (1956, p. 2007) that the old American and British practice of capitalization be readopted. Reception of the suggestion has been mixed and both styles of capitalization have appeared in various publications.

The reason for the Missouri Geological Survey's intention of retaining lower-case initial letters for the rank terms of rock-stratigraphic units is the same as that proposed by Moore in 1947 (p. 520) in Note 2 of the American Commission on Stratigraphic Nomenclature. It is for the purpose of emphasizing the essential distinction between rock-stratigraphic units and units defined by time (time units and time-stratigraphic units). The initial letters of the classificatory terms of the latter are capitalized.

Time-stratigraphic Classification

Time-stratigraphic unit.—According to the American Commission on Stratigraphic Nomenclature (1952, p. 1629), a time-stratigraphic unit is defined as follows:

> Time-stratigraphic units are material units, each of which comprises all rocks formed in an interval of geologic time defined by the beginning and ending of the deposition or other mode of origin of those rocks contained in the type section or otherwise designated type of unit. They are sometimes known as chronolithic or time-rock units. Although they are material rock units, their boundaries, as extended geographically from the type section, are essentially isochronous surfaces, representing everywhere the same horizon in geologic time; thus, ideally, these boundaries are independent of lithology, fossil content, and any other material bases of stratigraphic division.

Analysis of this definition indicates that it is not entirely in accord with stratigraphic facts. First, it must be admitted that the rock units, which are selected for inclusion in a given time-stratigraphic unit at a given type locality may be the only existing records of some but not of all the events that occurred at that locality within the span of time delimited by the extremities of the selected sequence. There is also no reason to assume that any one sequence of stratified rocks at any one type locality records in a continuous sequence all the events which are assignable to the segment of time so selected and defined. Therefore, the limits of the time-stratigraphic unit at the type locality need not necessarily coincide with the maximum limits required to accommodate all of the recorded events relatable to those present at the type locality. Thus, it is not true that the interval of time involved for the creation of an entire time-stratigraphic unit is defined by "the beginning and ending of the deposition or other mode of origin of those rocks contained in the type section," and, if it is assumed, as stated in the Commission's definition, that the boundaries of time-stratigraphic units are "extended geographically from the type section" as isochronous surfaces which represent everywhere the same horizon in geologic time, it would be impossible to incorporate in such time-stratigraphic units any other rock unit away from the type locality that could not be exactly correlated with the rock units in the type section.

Secondly, in actual practice, the boundaries of a time-stratigraphic unit are not always and in many cases are not established at the locality of the type section. The thing that is established by the type section is the general *character* of the time-stratigraphic unit, primarily in terms of the fossils contained in the rocks composing the unit. It is this general physical and faunal aspect of the unit which identifies it, and helps to serve as a standard of correlation and relation. If the characters of geographically isolated time stratigraphic units are correlative, the foreign units are assumed to be equivalent to those at the type section. If the characters are related, the foreign units are assumed to be assignable to the time-stratigraphic unit which is represented by the rock units in the type section. Thus, a time-stratigraphic unit actually contains the total number of rock units ultimately assigned to it, whether all those units are originally present at the type locality or not.

It therefore follows that the boundaries of a time-stratigraphic unit cannot be frozen or permanently fixed at the positions assigned to them at the type locality. Although the boundaries themselves are isochronal, "representing everywhere the same horizon in geologic time", the span between them must of necessity be expandable. Because of this, the term *interval* rather than *unit* is more explanatory of the true nature of time-stratigraphic limits. An interval is more indicative of a nonobjective span between assigned limits than a unit which implies an objective restriction of limits of a determinant amount or quantity.

The above considerations indicate that in view of the incompleteness of the stratigraphic record of events which have occurred throughout geologic time, a time-stratigraphic interval can only be conceived of as a subjective entity, an interval of geologic history which is defined in terms of physical rock units and their contained fossils; the fortuitously preserved records of past events. If an unbroken rock record of *all* events which have occurred throughout geologic history did exist at any one locality, it then would be measurable in terms of time, itself an unbroken absolute sequence. Then and only then would it be possible to establish a material, an objective, time-stratigraphic unit with fixed isochronal boundaries.

In view of the above statements, the Missouri Geological Survey recognizes the flexibility of time-stratigraphic boundaries and regards a time-stratigraphic interval as a conceptual interval in which time is an implicit factor but which is defined in terms of a *collective* sequence of physical rock units and their contained fossils and/or datable elements which by virtue of some one or more common characteristics can be said to be related and representative of some particular part of geologic history.

Geologic-time unit.—For all practicable stratigraphic work, geologic-time units may be considered as essentially the same as time-stratigraphic units, because a geologic-time unit is defined in terms of a time-stratigraphic unit; in terms of rock units. Geologic-time units thus denote the particular intervals of geologic time in which took place the particular events recorded by the rock units. This close relationship of geologic-time units and time-stratigraphic units is implied in the use of the same names for the corresponding units.

Time-stratigraphic and Geologic-time Units

It has been recognized from very early in the study of stratigraphy that geologic history is divisible into two major segments, the events of the older segment being represented by rocks that do not contain any known remains of life, and the events of the younger segment being represented by rocks that contain fossilized organisms in varying amounts. The divisions are separated at the beginning of the fossil record in rocks assigned to the Cambrian System and were named Cryptozoic and Phanerozoic, respectively, by Chadwick (1930, p. 48). They are regarded as major divisions of geologic time, and the time term "eon" is used to designate them.

Because of the lack of known fossils in rocks formed during the Cryptozoic Eon and because of the inadequate quality and quantity of age determinations based on radioactive methods, many authorities and organizations including the Missouri Geological Survey have deemed it impractical for the present to divide these rocks in Missouri into time-stratigraphic units similar to those used for division of rocks formed in the Phanerozic Eon, a suggestion which has been made by the American Commission on Stratigraphic Nomenclature (1955, p. 1860).

For purposes of utility and global to regional standardization, rocks formed in the Phanerozoic Eon have been subdivided into time-stratigraphic and corresponding geologic-time units. These units are ranked according to their magnitude and geographic extent. In order of diminution, they are as follows:

Time-stratigraphic Units	*Geologic-time Units*	*Geographic Extent*
——	Era	——
System	Period	Global
Series	Epoch	Continental
Stage	Age	Regional

Era.—An Era is regarded as the largest division of the Phanerozoic Eon. Because there is no known succession of rock to be found in any one area that is extensive enough to represent all of the events which took place within the span of any one of the three designated Eras (Paleozoic, Mesozoic, and Cenozoic), most geologists regard it as impracticable to designate for it a corresponding time-stratigraphic unit. However, the term "group" had been proposed for such a purpose by the International Geological Congress in 1885, but the proposal was never generally adopted.

Period and System.—The Period is regarded as the largest subdivision of an Era. Each Period is defined by a corresponding time-stratigraphic unit known as a System which is an assemblage of rock units which together record all related events occurring anywhere on earth within the span of a Period. Thus, each System in theory contains all related events that are assignable to it, whether records of those events are present at the type locality or not. Systems are extendable by correlation throughout the world, but their magnitude in terms of time is indefinite for the following reasons: 1) there is no assurance that all the records for the events of every Period have been discovered or recognized, 2) many of the Systems have been inexactly defined at their type localities, 3) disagreement as to what criteria is definitive for the establishment of systemic boundaries away from the type locality, and 4) the fragmentary nature of the criteria used for global correlation.

Circumstantially, all of the systemic type localities were originally established in Europe, and ideally the use of System in Missouri implies correlation with these type localities except where the type localities for the Mississippian and Pennsylvanian Systems have been subsequently established in North America.

Epoch and Series.—An Epoch is a subdivision of a Period and is defined by those rocks within a System that record closely related events which are assignable to a given Series. Systems have been divided into as many as six Series, with each Series being designated by a particular name which is usually indicative of some geographic locality. Recently there is a tendency to recognize only a two or threefold division for all Systems, with the divisions being designated as parts of a System, as Lower and Upper, or Lower, Middle, and Upper. The time terms Early and Late, or Early, Middle, and Late are used in speaking of the corresponding Epochs. The Missouri Geological Survey at this time chooses not to follow this tendency in those instances where there is reasonable assurance either in past or present studies that correlation with the regional type sections for the Series can be established. Thus, the retention of traditional geographic names for Series designation continues to serve the useful purpose of relating correlative extensions of a Series to specified and known type sections. It is believed that this purpose is destroyed when portional terms are used.

As for a System, the magnitude of a Series in terms of time is indefinite, but the degree of indefiniteness in most cases is proportionally lessened by the decrease in the extent of correlation. Most Series are extendable by correlation within continental limits, but some are imbued with sufficiently recognizable criteria to be extended as worldwide units. The recognition of Series in Missouri implies a reasonable assurance of correlation with accepted type sections within the eastern or midcontinent areas of North America.

Age and Stage.—An Age is now generally accepted as a subdivision of an Epoch and is defined by those rock units which together form a Stage and record very closely related events that have taken place locally within a restricted geographic area. A Stage is defined on the basis of a designated interval in a type section, and the limits of the interval are determined by any type of criteria, physical or organic, that are sufficient for definitive correlation within the local area of the type locality. The magnitude of a Stage is usually determinable, because in most cases its limits will coincide with those of locally defined rock-stratigraphic units such as formations. As here defined, a Stage is not to be regarded as a biostratigraphic unit or as a zonal unit definitive of a mineral zone.

Time-stratigraphic and Geologic-time Nomenclature

Period and System.—Even though there has never been any consistent procedure in forming the names of Systems and their corresponding Periods, the names that have developed have come to be accepted by most geologists throughout the world. Modifications of the names have been proposed in the past but never entirely accepted, such as the recommendation by the International Geological Congress that the names of Systems and Periods should end in *-ic*. Another practice which has become traditional is that both a System and its corresponding Period are given the same proper name, as Devonian System and Devonian Period.

Epoch and Series.—The names of Series and their corresponding Epochs have been derived in the past from geographic place names that are indicative of the locality or area of a type section. In many instances, the names had been directly transposed from rock-stratigraphic names used for the designation of groups and formations. In recent years, there has been a tendency to replace the geographic place names of Series with the portional terms Lower, Middle, and Upper. As previously stated, the staff of the Missouri Geological Survey prefers the geographic name for a Series unless there is reasonable doubt concerning the correlation of Missouri's time-stratigraphic units with the regional type sections for those units.

The names of Series and their corresponding Epochs are distinguished as time-stratigraphic and geologic-time units by the addition of the adjectival suffixes *-ian* or *-an*. This device is necessary because the names of rock-stratigraphic units are also adopted geographic place names. Without the adjectival suffix or without the use of a modifying classificatory term, a Series or Epoch name would be indistinguishable from a group or formation name. There are no specific guides to follow for the spelling of the adjectival names other than those of individual euphonic taste or editorial policy. For example, both of the following spellings have been used by reputable authors: *Osagean* or *Osagian*, *Chesteran* or *Chesterian*. However, in most instances, if the geographic place name ends with a consonant, the suffix *-ian* is used, as Virgilian, and in some instances, when a name is spelled with a final unpronounced *e*, as *Cygne*, the *e* is dropped and the *-ian* suffix is appended, as *Cygnian*. If the name ends with a pronounceable vowel, as Cincinnati, the suffix *-an* is usually used.

Age and Stage.—All Stage and corresponding Age names are derived from geographic place names which are indicative of the locality of a type section. More so than in the case of Series, many Stage names have been based on the names of rock-stratigraphic units (groups and formations) and bear the names of those units. Because of the large number of such names that are currently in use, it is undesirable to eliminate them and replace them with previously unused geographic names merely to denote the time-stratigraphic significance of a Stage name, a suggestion that has been tentatively made by the American Commission on Stratigraphic Nomenclature (1952, p. 1635).

Sometimes an author may use a Series name without its accompanying classificatory term because the adjectival form distinguishes it as a time-stratigraphic term, but he cannot use a Stage term in the same way without its classificatory term except with confusion to the reader. As a precaution against such confusion, the classificatory term should always follow a Stage or Age name.

Classification of Precambrian Rocks*

In applying stratigraphic nomenclature to rocks that are older than those of the Paleozoic Era, certain modifications are necessary because of the absence of fossils and the inadequacies of present radioactive methods of dating.

The Precambrian rocks of Missouri are represented by exposures of felsitic flows, tuffs and pyroclastics, welded tuffs, granitic and felsitic intrusives, and basic intrusives and extrusives. Metamorphic rocks whose original sedimentary origin is relatively certain, and low rank metamorphic rocks which are believed to have been igneous rocks originally are known to be present in the subsurface.

To date, the Survey's studies of Missouri Precambrian rocks have been mostly restricted to surface exposures. In these studies, the terms Archean and Algonkian have been used in preference to Archeozoic and Proterozoic.

Several rock units of Precambrian age have been formally named in Missouri Geological Survey publications. In 1894, Keyes (p. 30) named the Pilot Knob conglomerate and assigned it to the Algonkian. The Iron Mountain porphyry and the Knob Lick granite were assigned to the Archean (Keys, 1894, p. 18). In 1912, Crane (p. 39) referred to the Pilot Knob iron formation. Keys (1914, p. 3) listed the Pilot Knob and the overlying Ironton unit as belonging to the Proterozoic and the Skrainka diabase as Archeozoic.

Haworth (1894, p. 98) assigned the crystalline rocks to the Archean and mentioned that the slate and conglomerates have been referred to the Algonkian, but if so, a far greater hiatus exists than has been commonly adopted between the sedimentary and igneous rocks of Missouri. Dake (1930, p. 26) assigned the Precambrian rocks to the Algonkian. Bridge (1930, p. 59) assigned the Precambrian rocks of the Eminence-Cardareva area to the Algonkian (?).

It is recommended that the Missouri Geological Survey follow the suggestions made in 1955 by the American Commission on Stratigraphic Nomenclature in regard to a twofold division of the Precambrian into Early and Late Precambrian. The basement complex in the state consists in part of sedimentary and igneous rocks that have been metamorphosed. These are tentatively assigned to Early Precambrian. Rocks such as those exposed in the St. Francois Mountains (granites, felsites, basic rocks, and tuffs) are tentatively assigned to the Late Precambrian.

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*Prepared by William C. Hayes.

Age dating of Precambrian rocks found in Missouri gives results from 1,260 to 1,670 million years. None of these dates has been obtained from the metamorphic rocks which are believed to be older and to constitute the floor upon which the volcanic sequence was extruded. Until more detailed information on age determinations is obtained, it is also recommended that time-stratigraphic units of System and Series rank not be used as suggested by the Commission in 1955. Rock-stratigraphic units from group to the smallest rank may be employed where advantageous.

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