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The Stratigraphic Succession in Missouri

by
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MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey

Volume 40 (2nd Series) Revised

THE STRATIGRAPHIC SUCCESSION IN MISSOURI (REVISED - 1995)

Revised (1995) by
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Original preparation (1961) coordinated by
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Edited (1961) by
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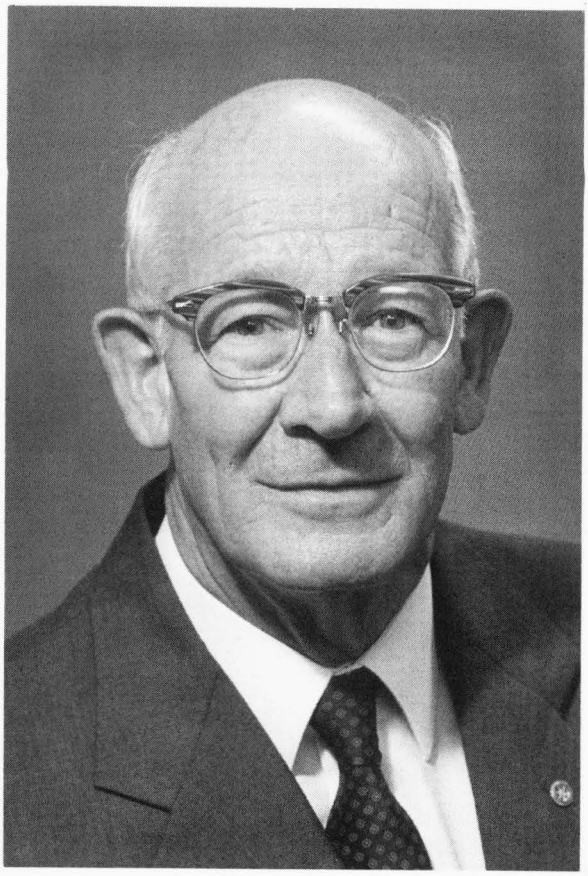

This edition of *The Stratigraphic Succession in Missouri* is dedicated to the memory of **Wallace B. Howe** (1926-1995) who served as Missouri State Geologist and Director of the Missouri Department of Natural Resources' Division of Geology and Land Survey from 1971 to 1986. In doing so, he completed the second longest tenure in office for both positions in the Survey's 142-year history. Wally joined the staff of the agency in 1947.

Wally coordinated the development of the original version of *The Stratigraphic Succession in Missouri,* which was published as Volume 40 in 1961. He also authored sections on the Missourian and Virgilian Series of the Pennsylvanian System. During Wally's tenure as State Geologist, work on detailed revisions of Volume 40 was initiated, to be published as a series of separates under *Report of Investigations Number 70, Paleozoic Succession in Missouri.*

Wallace B. Howe was considered an authority on the Pennsylvanian stratigraphy of Missouri. His dedication to the understanding of Missouri geology set the example by which all succeeding reports on the stratigraphy of Missouri have been developed.

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ABSTRACT

This report summarizes information pertaining to the stratigraphic succession in Missouri. The most prominently exposed systems in the state are the Cambrian, Ordovician, Mississippian, and Pennsylvanian. Rocks of the Precambrian, Silurian. Devonian, Cretaceous, and Tertiary Systems are less extensively exposed. Deposits of the Quaternary System overlie older strata over much of northern Missouri. 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. Today, the principles of stratigraphic nomenclature are defined by the ***North American Stratigraphic Code*** *(1983), and these principals define the nomenclatural policy of the Missouri Department of Natural Resources' Division of Geology and Land Survey.*

INTRODUCTION

This report is designed to meet the basic need of a stratigraphic reference for the geology of Missouri. It describes the important physical characteristics and stratigraphic relations of the rock formations present within the State. The classification, nomenclature, distribution, lithology, and thickness of the rock units are discussed briefly.

The original 1961 report, *Volume 40–The Stratigraphic Succession in Missouri,* was a compilation of chapters, each chapter covering a single system and written by separate authors. The overall effort was coordinated by Wallace B. Howe, then edited by John W. Koenig.

This 1995 revision of *Volume 40* was undertaken to continue to offer a publication of intermediate detail on the rock formations in Missouri. The original *Volume 40* is out of print, and no longer available for sale to the general public. Only the very detailed individual reports of the series of separates, published as parts 1 through 5 of *Report of Investigations No. 70*, or the very brief list of formation names in *Information Circular No. 31*, were available when this revision was initiated. The information presented in this revised edition of *Volume 40* draws in large part from, but is less detailed than, that presented in the series of reports combined and published under the title *PALEOZOIC SUCCESSION IN MISSOURI* (Report of Investigations 70). Those completed are: Part 2, *Ordovician System* (Thompson, 1991); Part 3, *Silurian and Devonian Systems* (Thompson, 1993); and Part 4, *Mississippian System* (Thompson, 1986).

The Cambrian and Pennsylvanian revisions have not yet been completed. Most of the discussion of the Cambrian System is that originally prepared by Hayes and Knight (1961). However, two post-1961 reports on Cambrian strata in Missouri (Howe, et al., 1972; Kurtz et al., 1975) provide a more modern classification for Cambrian formations in Missouri, and this scheme is utilized where appropriate in this revision.

Pennsylvanian units are presently under study by geologists of several Midcontinent geological surveys, including Missouri. Until such time as the Pennsylvanian (Part 5) chapter of Missouri Department of Natural Resources' Division of Geology and Land Survey's *Report of Investigations No. 70* is completed, the classification defined in the original *Volume 40* (Howe and Koenig, 1961) will be used. The only changes are to upgrade this nomenclature to conform to the rules established by the *North American Stratigraphic Code* (1983). This nomenclature, as outlined in Information Circular 31, is the most recent stratigraphic nomenclature adopted for use in Missouri.

Rock units of Precambrian age in Missouri have been reviewed in several reports collectively published in the series *Contributions to Precambrian*

Geology. The classification developed in this series, considerably different from that presented by Hayes (1961), is outlined in this report.

Within the text of this report, the symbol "^^^^" is used to locate the beginning and ending of a **group**, "^^" designates boundaries of a **subgroup**.

ACKNOWLEDGMENTS

I wish to especially thank Mark Middendorf and Charles E. Robertson for their careful reviews of the manuscript, and suggestions for improvement or changes. The illustrations and final compilation of this report were the purview of Susan C. Dunn, and reflect the high quality of her work as previously exhibited in the Report of Investigations 70 series. Dwight Weaver and Jerry D. Vineyard were the final reviewers of the manuscript.

PRECAMBRIAN ROCKS

by

Charles E. Robertson

The Precambrian of Missouri comprises four distinct terranes. The definition of terrane as used herein, was defined by Sims (1990, p. 40) as "...a geologic entity of regional extent that is characterized by a geologic history that differs from adjacent terranes..."

The oldest rocks known to occur in Missouri are early Proterozoic, 1.6-1.8 Ga (1Ga = 1 billion years ago), metamorphic and granitic rocks of the **Central Plains Orogen** (Fig. 1). These rocks originated as an oceanic arc complex, which was subsequently accreted to the previously existing North American Continent. This terrane does not crop out but occupies a subcrop belt beneath Paleozoic and volcanic rocks approximately 150 miles wide from the northwest corner of the state to at least as far as southeast Missouri where, according to Hayes (1961), it represents the floor complex upon which the acidic ash-flow tuffs and flows of the St. Francois (and Spavinaw) terranes were extruded. The subcrop belt is bounded on the southwest by the Bolivar Mansfield Tectonic Zone.

The overlying middle Proterozoic **St. Francois and Spavinaw granite-rhyolite anorogenic terranes** formed by the rifting and partial melting of the existing crust which comprised the metamorphic and igneous rocks of the Central Plains Orogen. The **St. Francois terrane** consists of an 1.4 to 1.5 Ga anorogenic granite-rhyolite terrane which crops out in southeast Missouri forming the St. Francois Mountains. It extends southwestward to approximately the Bolivar Mansfield Tectonic Zone.

The 1.35 to 1.40 Ga old anorogenic **Spavinaw granite-rhyolite terrane** abuts against the St. Francois terrane at the Bolivar-Mansfield Tectonic Zone although the contact is somewhat transitional. It underlies southwest Missouri and extends into the adjacent states of Kansas, Oklahoma, and Arkansas. It is known only in the subsurface in Missouri, but crops out at Spavinaw, Oklahoma. The rocks of this terrane are very similar to those of the St. Francois terrane.

A fourth, as of yet unnamed Precambrian terrane which consists of a small area of granites and associated rocks of uncertain age occurs in the subsurface in northeast Missouri northeast of the Northeast Missouri Tectonic Zone and extends into Iowa.

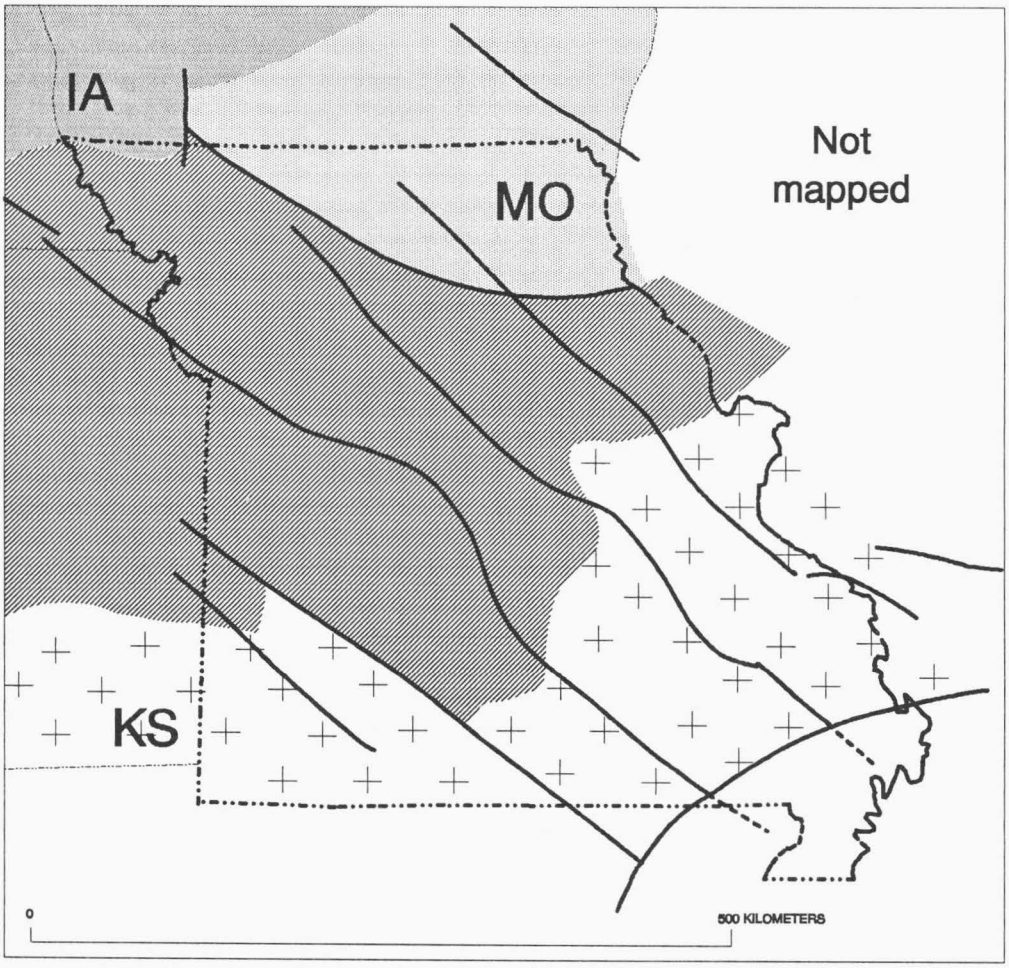

Fig. 1. *Precambrian terranes in Missouri and adjacent states; modified from Sims (1985).*

Stratigraphy and Character of the St. Francois Terrane

According to Kisvarsanyi (1990, p. 49) the St. Francois terrane "...consists of more than a dozen overlapping ring complexes, cauldron subsidence structures with ring volcanoes and ring plutons, and resurgent calderas with central plutons." Rocks of the St. Francois terrane were produced by the partial melting of the older Central Plains Orogen terrane and "...their emplacement and distribution are controlled by structures in the older terrane."

Volcanic rocks are predominantly rhyolitic ash-flow tuffs with lesser amounts of intermediate and mafic flows. There are three types of granitic rocks: (1) subvolcanic granite massifs, (2) ring intrusions, and (3) central plutons.

The subvolcanic **granite massifs** are the most widespread, being coeval with ash-flow tuffs which they produced. As stated by Kisvarsanyi (1990, p. 50): "They are typical epizonal rocks having granophyric textures and containing perthitic alkali feldspar. Biotite is the characteristic mafic mineral and magnetite is ubiquitous..."

"The **ring intrusions** [bold added] are intermediate- to high-silica rocks whose emplacement was controlled by ring fractures related to caldera collapse and cauldron subsidence." They range in composition from trachyandesite through trachyte and syenite to amphibole-biotite granite.

The **central plutons** are inferred to have filled resurgent calderas and are high-silica, two-mica granites.

The following stratigraphic classification was developed in the western St. Francois Mountains, in the vicinity of the Taum Sauk Caldera where the St. Francois terrane has been most thoroughly studied. Stratigraphic nomenclature and descriptions of volcanic rocks are from Berry (1976) and Sides (1976). Formal names and descriptions of intrusives are from Tolman and Robertson (1969).

TABLE I

Beginning with studies in the mid-1960s, geologists began formalizing some of the Precambrian units. Kisvarsanyi et al. (1981) presented the following chart of Precambrian stratigraphic units defined from exposures in the St. Francois Mountain region:

St. Francois Mountains Volcanic Supergroup	**St. Francois Mountains Intrusive Suite*** **	
	Hypabyssal Rocks (H)	**Plutonic Rocks (P)**
Taum Sauk Group*		
Cope Hollow Formation		
Johnson Shut-Ins Rhyolite	Graniteville Granite (**P**)	
Proffit Mountain Formation		
Taum Sauk Rhyolite		
Royal Gorge Rhyolite		
Bell Mountain Rhyolite	Buford Granite Porphyry (**H**)	
Wildcat Mountain Rhyolite	Munger Granite Por. (**H**)	
Russell Mountain Rhyolite	Carver Creek Gr. Por. (**H**)	
Lindsey Mountain Rhyolite		
Ironton Rhyolite		
Buck Mountain Shut-Ins Formation		
Pond Ridge Rhyolite		
Cedar Bluff Rhyolite		
Shepherd Mountain Rhyolite		
Butler Hill Group**		
Pilot Knob Felsite		Silvermine-Knoblick Granites (**P**)
Grassy Mtn. Ignimbrite	Brown Mtn. Rhy. Por. (**H**)	Slabtown-Stono Granites (**P**)
Lake Killarney Formation		Butler Hill-Breadtray Granites (**P**)

* Volcanic units defined by Berry (1976).
** Volcanic units defined by Sides (1976).
***Formal names from Tolman and Robertson (1969).

Stratigraphy of the St. Francois Mountains Volcanic Supergroup

Taum Sauk Group (Berry, 1976)

Cope Hollow Formation - The Cope Hollow Formation consists of interbedded maroon ash-flow tuffs and dark gray to black cross-bedded air-fall tuffs. A dark gray air-fall tuff containing lithophysae is a good marker horizon. The formation crops out at Johnson Shut-ins State Park in Reynolds County where it is greater than 130 ft thick. The type section is in the SW¼, NW¼, sec. 16, T. 33 N., R. 2 E.; Johnson Shut-ins Quadrangle.

Johnson Shut-ins Rhyolite - A gray ash-flow tuff with 15-20 percent quartz and feldspar phenocrysts and abundant lithophysae marks the top of the Johnson Shut-ins Rhyolite. This bed is about 90 ft thick. The remainder of the formation consists of cross-bedded water laid tuff and maroon ash-flow tuff with abundant lithophysae. The total thickness of the formation is greater than 170 ft. The type section is in the NW¼, SW¼, sec. 16, T. 33 N., R. 2 E.; Johnson Shut-ins Quadrangle.

Proffit Mountain Formation - The Proffit Mountain Formation consists of interbedded red to gray air-fall tuffs and maroon to gray ash-flow tuffs. The ash-flow tuffs contain abundant (20-30 percent) quartz and feldspar phenocrysts. The lower 50 ft of the formation is vividly lineated. The formation is more than 450 ft thick. The type section is in the SW¼, sec. 16, T. 33 N., R. 2 E.; Johnson Shut-ins Quadrangle.

Taum Sauk Rhyolite - The Taum Sauk Ryolite is a red to dark maroon ash-flow tuff containing up to 30 percent phenocrysts of alkali feldspar and quartz; fiamme may or may not be present. The formation is widely exposed in the Proffit-Wildcat-Taum Sauk mountain area. Although its maximum thickness has not been established, it is greater than 3,000 ft thick. The type section is in sec. 15, T. 33 N., R. 2 E.; Johnson Shut-ins Quadrangle.

Royal Gorge Rhyolite - The Royal Gorge Rhyolite is a red to maroon to gray lava flow containing 5 percent or more quartz and alkali feldspar phenocrysts. It is vividly banded red and white in many localities but may be massive. It is as much as 2,000 or more ft thick in some localities but may be much thinner or even absent in others. The type section is in the SE¼, SE¼, sec. 3, T. 33 N., R. 3 E.; Ironton Quadrangle.

Bell Mountain Rhyolite - The Bell Mountain Rhyolite is a maroon to dark maroon air-fall tuff containing lapilli and a 6-15 ft thick zone containing lithophysae. The formation is nearly 100 ft thick and is widely exposed in the Taum Sauk area. The type section is in the SE¼, NE¼, sec. 2, T. 33 N., R. 1 E.; Edge Hill Quadrangle.

Wildcat Mountain Rhyolite - The Wildcat Mountain Rhyolite is a deep-maroon ash-flow tuff containing 5-10 percent quartz and feldspar phenocrysts

and many white stringers of microcrystalline quartz and feldspar. It is widely exposed in the Taum Sauk area where it is nearly 300 ft thick. The type section is in the S½, NE¼, sec. 6, T. 33 N., R. 3 E.; Johnson Shut-ins Quadrangle.

Russell Mountain Rhyolite - The Russell Mountain Rhyolite is a brick-red to dark maroon ash-flow tuff with abundant large fiamme and 2-5 percent white feldspar phenocrysts. It is widely exposed in the Taum Sauk area where it is nearly 1,000 ft thick. The type section is in the NE¼, SW¼, sec. 2, T. 33 N., R. 3 E.; Ironton Quadrangle.

Lindsey Mountain Rhyolite - The Lindsey Mountain Rhyolite is a violet-gray, blackish or light maroon ash-flow tuff with 5-20 percent quartz and feldspar phenocrysts, and conchoidal fracture. It ranges in thickness between 1,600 and 2,300 ft. It is widely exposed in the western part of the Taum Sauk area, especially on Lindsey and Bell Mountains. The type section is in the S½, NW¼, sec. 4, T. 33 N., R. 3 E.; Ironton Quadrangle.

Ironton Rhyolite - The Ironton Rhyolite is a dark maroon to black ash-flow tuff with conchoidal fracture containing 5-15 percent phenocrysts of quartz and alkali feldspar. Total thickness is not known, but it is more than 1,000 ft. The type section is the SW¼, sec. 33, T. 34 N., R. 3 E.; Ironton Quadrangle.

Buck Mountain Shut-ins Formation - The Buck Mountain Shut-ins Formation consists of a sequence of black, andesitic lava flows containing white plagioclase phenocrysts, interbedded with bedded air-fall tuffs and at least one rhyolitic ash-flow tuff. The formation ranges in thickness between 260 and 3,000 ft. The type section is in the SE¼, sec. 33, T. 34 N., R. 3 E.; Ironton Quadrangle.

Pond Ridge Rhyolite - The presence of many large, reddish fiamme is a distinguishing characteristic of the Pond Ridge Rhyolite. It is a dark maroon to gray ash-flow tuff containing up to 20 percent white to pinkish feldspar phenocrysts and a few quartz phenocrysts in addition to fiamme. It is approximately 400 ft thick. The type section is in the NE¼, NW¼, sec. 3, T. 33 N., R. 3 E.; Ironton Quadrangle.

Cedar Bluff Rhyolite - The Cedar Bluff Rhyolite is a brownish-maroon to gray ash-flow tuff containing 25-50 percent white plagioclase phenocrysts. The formation is exposed on Shepherd Mountain and Pond Ridge. It is approximately 1,900 ft thick. The type section is in the NE¼, NW¼, sec. 3, T. 33 N., R. 3 E., Ironton Quadrangle.

Shepherd Mountain Rhyolite - The Shepherd Mountain Rhyolite is a brick-red to dark maroon ash-flow tuff containing white to slightly pink plagioclase phenocrysts and many fiamme. It is well exposed on Shepherd Mountain. It is approximately 2,000 ft thick. The type section is in sec. 31, T. 34 N., R. 4 E.; Ironton Quadrangle.

Butler Hill Group (Sides, 1976)

Pilot Knob Felsite - This formation was described by Sides (1976) as a sequence of rhyolitic flows with an abundance of lithophysae, local autobreccias, and flow lineation. Fresh rocks are porphyritic with reddish feldspar and a few small quartz phenocrysts in a dark red to maroon matrix. There are small amounts of fine-grained, iron-rich banded tuff near the base. Outcrops of the Pilot Knob Felsite are restricted to the northwestern part of the Lake Killarney Quadrangle. Field work indicates that the thickness of the Pilot Knob is between 500 and 1,100 ft.

Grassy Mountain Ignimbrite - The homogenous distinctive appearance of the Grassy Mountain Ignimbrite makes it an excellent stratigraphic marker. It is widely exposed on Grassy Mountain and in adjacent areas. It has a black to very dark maroon matrix with prominent phenocrysts of quartz and reddish alkali feldspar. Pumice fragments are not common, but when present, are weathered to a pinkish color and thus stand out. Prominent compaction foliation is sometimes visible. The formation ranges in thickness from approximately 900 to more than 6,000 ft.

Lake Killarney Formation - According to Sides (1976, p. 110): "The Lake Killarney Unit, named for typical exposures in the vicinity of Lake Killarney is the most difficult volcanic-rock unit [of the Butler Hill Group] to characterize." An upper zone, which is from 0 to 50 ft thick, is characterized by a prominent breccia. However, at some localities it consists of a dark gray to dark maroon tuff with up to 25% lithic fragments.

The middle zone of the Lake Killarney Formation consists of (Sides, 1976, p. 111): "...a porphyritic, light maroon ash-flow tuff with locally abundant fiamme and with phenocrysts of quartz and pink alkali feldspar." No thickness is given for the middle zone.

The lower zone is similar to the middle zone except that fiamme are much less abundant and the feldspars may be altered to nearly the same color as the matrix and appear less abundant.

The thickness of Lake Killarney is probably between 1,600 and 5,000 ft.

St. Francois Mountains Intrusive Suite

Kisvarsanyi (1990) identified three major types of intrusive rocks in the St. Francois terrane; these are 1) subvolcanic massifs, 2) ring intrusions, and 3) central plutons. She stated (p. 50): "The subvolcanic [biotite alkali] granite massifs are comagmatic with the rhyolites and are their intrusive equivalents." Subvolcanic massifs include the Butler Hill and Breadtray Granites.

She continued (p. 50): "The ring intrusions are intermediate- to high-silica rocks whose emplacement was controlled with ring-fractures related to caldera collapse and cauldron subsidence." The Knoblick, Slabtown, and Silvermine Granites constitute a complex ring intrusion. Other ring intrusives include the Buford Granite Porphyry, the Munger Granite Porphyry, the Carver Creek Granite Porphyry, and the Brown Mountain Rhyolite Porphyry.

Kisvarsanyi (1990, p. 50) stated the central plutons "...typically are high-silica, two-mica granites..." The Graniteville granite is the only exposed central pluton

in the St. Francois Mountains although fourteen others have been identified in the subsurface.

Plutonic Rocks

The following descriptions are adapted from Tolman and Robertson (1969, p. 34-51):

Graniteville Granite - The Graniteville Granite (p. 49) "...is medium to coarse grained, red, and composed of potash, [sic.] feldspars, and quartz with a small percent of albite, biotite, and pyrite. In thin section, both orthoclase and microcline microperthite are abundant." The Graniteville is a central pluton that was intruded into a resurgent collapsed caldera. The Graniteville crops out near the town of Graniteville in sections 10, 11, 14, and 15, T. 34 N., R. 3 E.

Breadtray Granite - The Breadtray and Butler Hill Granites are facies of a single subvolcanic massif (Kisvarsanyi, 1981). The Breadtray Granite (p. 40) "...is usually a light red, fine- to medium-grained granophyric kaligranite or kalialaskite. There is a predominance of red potash feldspar and quartz. Light colored plagioclase grains are sparsely and inconspicuously developed while chlorite and magnetite are the mafic minerals which rarely comprise as much as 2 percent of the rock...Fluorite is a very important accessory mineral and is found filling miarolitic cavities, in small veinlets, and disseminated in the granite generally." According to Kisvarsanyi (1981, p. 21), the Breadtray facies "...forms an onion-like skin on the tops of subvolcanic massifs..." It grades into the medium- to coarse-grained Butler Hill Granite with depth.

Butler Hill Granite - The Butler Hill Granite (p. 42) "...is a medium to coarsely-medium grained light red to pink granite composed chiefly of red potash feldspar and quartz, but with significant amounts of light gray to buff plagioclase, green to dark brown biotite, and (rarely) hornblende...Miarolitic cavities are occasionally developed, as in the Breadtray granite, and they are similarly lined with quartz and feldspar and often partially filled with fluorite." The Butler Hill was named for exposures on Butler Hill in sec. 7, T. 34 N., R. 6 E.

Silvermine Granite - The Silvermine Granite together with the Knoblick and Slabtown Granites comprise a complex ring structure. The Silvermine Granite (p. 47) "...has a medium grained texture and is usually porphyritic. Color varies from mottled gray and buff to mottled gray and red. Pink potash feldspar and light gray to buff plagioclase are often in about equal proportions, along with lesser amounts of quartz and mafic minerals. Biotite and hornblende occur in small, indistinct clusters in the granite and comprise from 10 to (rarely) as much as 25 percent of the rock." The Silvermine is widely exposed along the St. Francis River from Silvermines to a point several mines northwest.

Knoblick Granite - (p. 44) " The Knoblick granite shows greater variations in mineralogy and texture over relatively shorter distances than any of the other

granites. A wide range in mineral composition - from the mottled gray and red contact granite on Knob Lick Mountain to the 'blue' granite exposed north of the Knob Lick-Syenite road...The 'blue' granite, from which the name Syenite may have been derived, is considered typical...

"The granite is a mottled light pinkish-gray to bluish-gray, fine to medium grained rock with small pinkish-gray potash feldspar phenocrysts. Quartz is sparsely developed, megascopically. Hornblende and biotite are more abundant in this rock than any of the other granites and occur disseminated throughout the rock in small clusters, normally accounting for not less than 10 percent of the rock." Numerous xenoliths occur in this unit. The Knoblick (spelling as proposed by Tolman and Robertson) is well exposed on the southeast and east flanks of Knob Lick Mountain.

Slabtown Granite - The Slabtown Granite (p. 34) "...is fine grained, usually porphyritic, and mottled pink and green. The phenocrysts and the feldspar in the groundmass are pink; the fine grained mafic minerals are distinctly green. As the grain size of the groundmass decreases, the rocks usually appear to be more femic and take on brownish and purplish hues. In the coarser phases, the mafic minerals show a distinct tendency to form in poorly defined clusters throughout the rock." Feldspar and quartz predominate and compose nearly 100 to rarely as little as 70 percent of the rock. Orthoclase microperthite varies from 40 to 60 percent, quartz 10 to 30 percent, and plagioclase accounts for about 10 percent of the rock.

The Slabtown Granite is named for exposures southwest and east of Slabtown in sec. 1, T. 33 N., R. 6 E.

Stono Granite - (p. 36) "The Stono and Slabtown granites are very similar. The Stono granite is typically a fine grained, mottled, dull reddish-brown and green granite, in places porphyritic. Light red feldspar and inconspicuous quartz are the principal minerals with small amounts of biotite and hornblende, usually much finer grained than the felsic minerals." The Stono Granite is named from exposures on Stono Mountain in sec. 25, T. 35 N., R. 4 E., St. Francois County.

Hypabyssal Rocks

The following descriptions are adapted from Tolman and Robertson (1969):

Buford Granite Porphyry - The Buford Granite Porphyry (p. 37) "...is a dense, very fine grained, mottled brown and green porphyritic rock with abundant small light brown orthoclase phenocrysts. [Groundmass] Textures range from microgranular...to aphanitic." This unit crops out on Buford Mountain and in the Wing Lake area in Iron County, and is named for exposures on Buford Mountain in sec. 27, T. 35 N., R. 3 E.

Munger Granite Porphyry - The Munger Granite Porphyry (p. 38) "...is very similar to the Buford granite porphyry in composition, but is generally coarser grained with orthoclase phenocrysts up to 8 mm in length and quartz up to 4 mm in diameter. The rock is brownish-red with greenish mottling due to fine-

grained mafic minerals. Quartz comprises about 30 percent; orthoclase, 33 percent; oligoclase, 33 percent; and extensively altered biotite and hornblende, about 4 percent. Magnetite, fluorite, apatite, zircon, and (rarely) rutile were noted as accessory minerals." The Munger crops out extensively in northeastern Reynolds County where it occurs as a sill in secs. 4, 6, 21, and 27, T. 33 N., R. 2 E.

Carver Creek Granite Porphyry - The Carver Creek Granite Porphyry (p. 39) "...is very fine grained with a green and purple mottled groundmass containing fine-grained clusters of mafic minerals. Phenocrysts are quite large, up to 10 mm in length, and consist of dark pink orthoclase. The phenocrysts comprise about 5 percent of the rock in a microgranitic groundmass." The Carver Creek crops out along Carver Creek in secs. 27, 28, and 29, T. 33 N., R. 3 E.

Brown Mountain Rhyolite Porphyry - (p. 50) "The groundmass of the [Brown Mountain] rhyolite ranges from aphanitic to very fine grained porphyritic. Its color is a salmon red with feldspar phenocrysts of the same color, and clear quartz. A very small amount of altered biotite is locally observed. Small miarolitic cavities, often lined with quartz, are occasionally encountered on the exposures." This unit was named for exposures on Brown Mountain in sec. 1, T. 33 N., R. 4 E.

Mineral Resource Potential

The Precambrian rocks of Missouri have produced more than 700 million dollars worth of ore since 1815. An estimated 600 million dollars worth of ore remains in the ground (Kisvarsanyi, 1984; Sims et al., 1987, p. 28)

Most of the deposits are high temperature replacement and fissure filling deposits of hematite and magnetite (Hayes, 1961). In addition to iron deposits, the various Precambrian terranes of Missouri have the potential to contain undiscovered deposits of copper, zinc, gold, silver, lead, and tungsten.

PALEOZOIC ERA

Exposed bedrock over 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, particularly in the northern and/or northwestern half of the state . Relatively limited exposures of Silurian and Devonian rocks are present in northeastern, southeastern, and central Missouri.

The aggregate thickness of Paleozoic rocks within the state is approximately 10,000 ft, 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 ft 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 ft 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 Tertiary rocks.

The structural attitude of the Paleozoic rocks throughout the state is controlled principally by the shape of the Ozark Uplift, the center of which forms the Precambrian 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, Mineola Arch in central Missouri, Cap au Gres Fault north of St. Louis, Ste. Genevieve Fault system of southeastern Missouri, Little Saline Fault complex in Ste. Genevieve County, and the Chesapeake and Bolivar-Mansfield Fault Zones, Seneca Graben, and other structures in southwestern Missouri.

CAMBRIAN SYSTEM

by

William C. Hayes and Robert D. Knight (1961)

revised by

Thomas L. Thompson (1995)

Upper Cambrian Series

As noted by Hayes and Knight (1961), all of the Cambrian strata in Missouri are regarded as Late Cambrian (Croixian Series) in age. The unconformity at the base of the Series is particularly striking in the St. Francois Mountain area

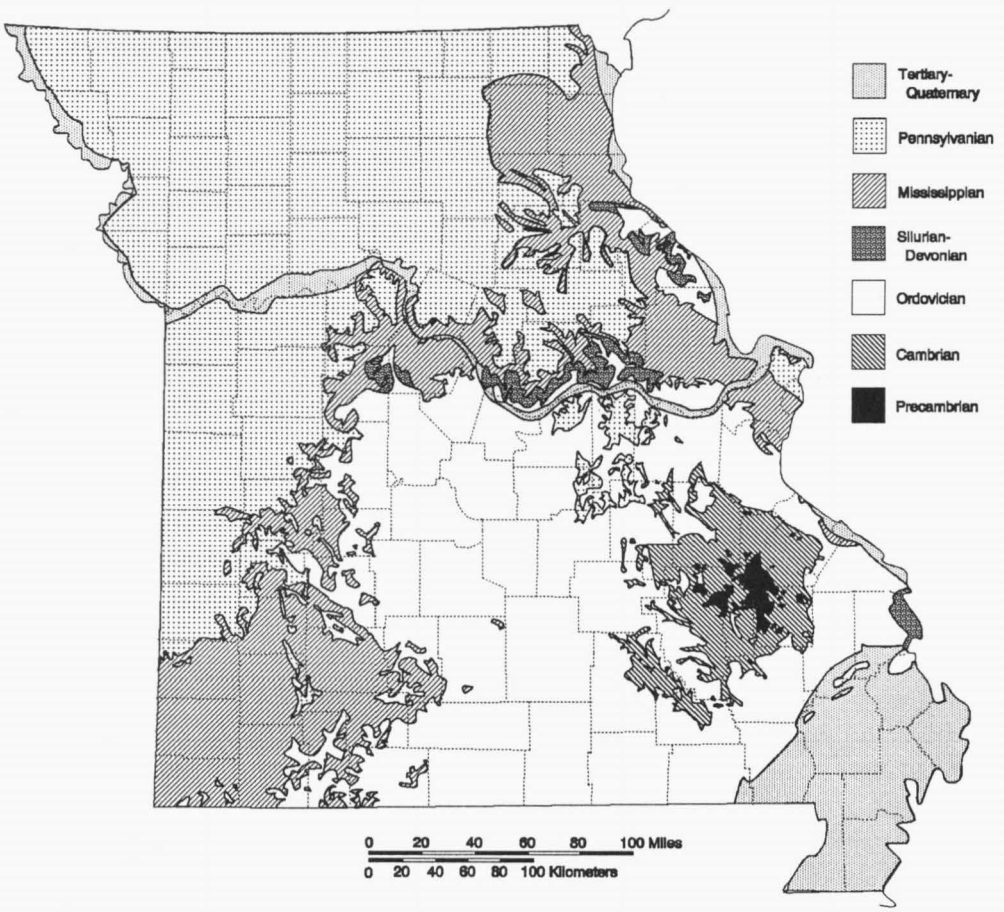

Fig. 2. *Generalized geologic map of Missouri.*

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 core area of the Ozark Uplift, where they onlap the flanks of Precambrian knobs (Fig. 2). Outcrops of successively higher (younger) units occur in peripheral, annular patterns around the uplift area. Away from the uplift, Upper Cambrian formations dip beneath younger Paleozoic strata and are present in the subsurface throughout the state except where they have been removed by erosion to expose the underlying Precambrian strata.

The combined thicknesses of the strata which form the Upper Cambrian Series in Missouri (Fig. 3) total approximately 2,000 ft. The Series contains six formations (in ascending order); the Lamotte Sandstone, Bonneterre Formation, Davis Formation, and the Derby-Doerun, Potosi, and Eminence Dolomites. The Davis and Derby-Doerun together constitute the Elvins Group.

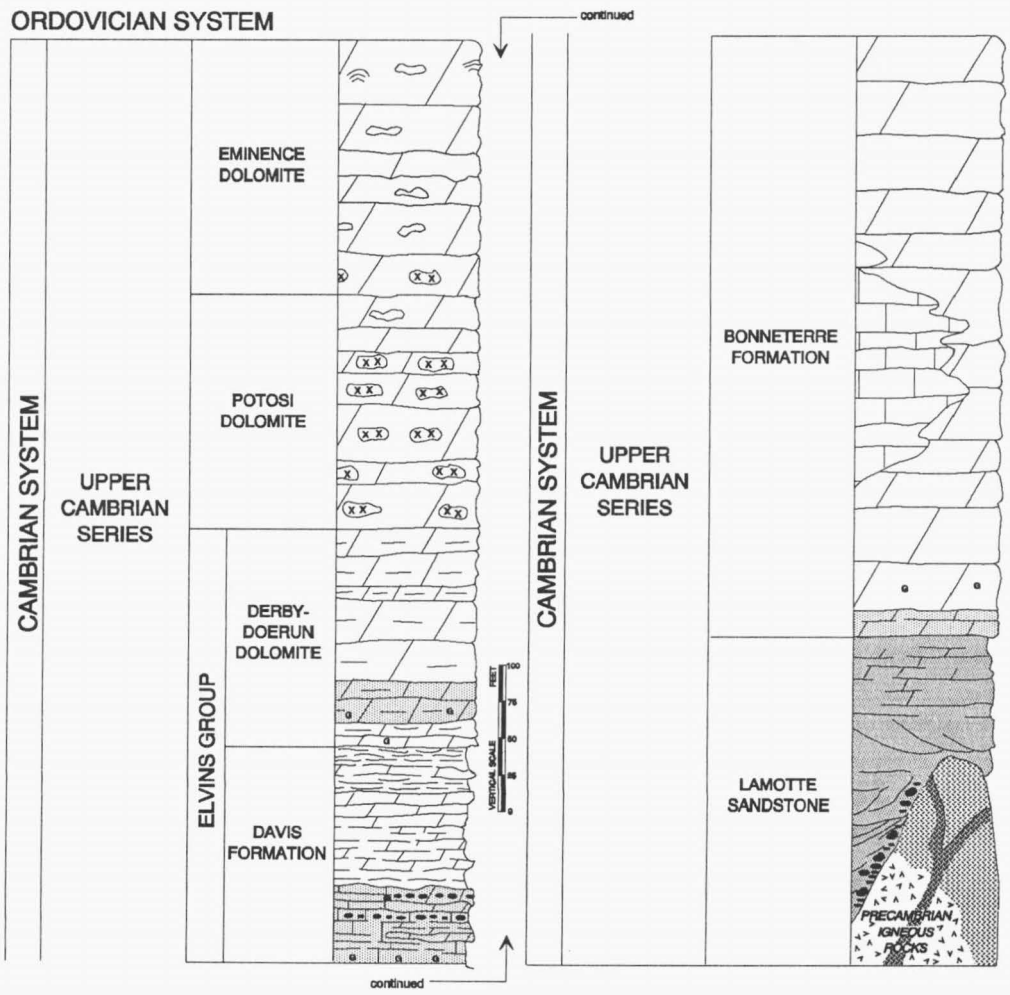

Fig. 3. *Cambrian System, Upper Cambrian Series.*

Lamotte Sandstone - The Lamotte Sandstone 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 ft 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: 200 ft in Howell County; 300 ft in Laclede County; 125 ft in Barry County; and 340 ft in Ralls County. In Nemaha County, Nebraska, across the Missouri River from Atchison County in northwestern Missouri, the Lamotte is 65 ft thick.

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

Reagan Sandstone - Kurtz et al. (1975, p. 15) stated: "This unit is a nearshore facies of the Bonneterre and Davis Formations and is also known to be the nearshore equivalent of formations as young as the Roubidoux Formation, of Early Ordovician age in Tulsa County, Oklahoma. It is generally a poorly sorted unit, made up of a mixture of shale, silt, and poorly sorted sandstones, and may be slightly dolomitic...In general, the lower part is dominated by rounded to subangular, coarse quartz grains, with some weathered feldspar grains. The sands tend to fine upward and are mixed with quartz silt and gray shale in the upper part of the unit, but silt, shale, and glauconite can occur anywhere in the section..."

The Lamotte/Bonneterre - Reagan Sandstone facies change represents a highly diachronous basal Upper Cambrian clastic unit that became progressively younger westward as it lapped onto the Precambrian surface.

Bonneterre Formation - The Bonneterre Formation is typically a light-gray, medium- to finely crystalline, medium-bedded dolomite, but also consists of relatively pure limestone in some areas. In places it is very coarsely crystalline, 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 in. 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

and the Viburnum Trend, 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, or 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 Doe Run'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 Sandstone is one of conformity. The lower part of the Bonneterre consists of alternating beds of dolomite and arenaceous dolomite with the amount of sand increasing toward the base. This sandy zone (often called the "**Bonneterre-Lamotte transition zone**") is usually 10 to 20 ft thick, but may approach a thickness of 200 ft. 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 ft in the subsurface in Pemiscot County. Westward it changes facies to the nearshore Reagan Sandstone. In the Lead Belt and the Viburnum Trend area, the formation has an approximate thickness of from 375 to 400 ft.

Sullivan Siltstone Member - Kurtz et al. (1975, p. 13) stated: "This unit is a variably micritic, generally laminated siltstone. Local layers of calcarenites and mud-chip conglomerates are present. The high volumes of quartz silt with local concentrations of fine quartz sand and glauconite are believed to more strongly reflect the provenance of the sediment than any significant changes in water depth. The base of the unit is usually in sharp contact with the subjacent stratum...This contact is interpreted as profoundly diachronous, being coincident with the boundary between the *Aphelaspis* and *Crepicephalus* Zones..."

"The lower part of the siltstone is unique in showing a nearly complete absence of burrowing. The upper part of the siltstone may change facies to a moderately burrowed micrite unit containing some shale beds...The Sullivan Siltstone Member is the 'upper marker bed' in the Bonneterre Formation referred to by Gerdemann and Myers (1972, p. 430; fig. 5, p. 431)."

Whetstone Creek Member - The uppermost unit of the Bonneterre Formation, the Whetstone Creek Member, represents changing depositional conditions from the carbonate Bonneterre "platform" to the conditions prevalent in the deposition of the Davis shales and carbonates. Whetstone Creek sedimentation is defined by Kurtz et al. (1975, p. 13) as "shifting sites of deposition" with numerous paraconformities represented by zones of reworked acrotretid brachiopods at several different horizons.

Whetstone Creek strata gradually thicken southwestward from only 8 ft thick in Crawford County, Missouri, to a maximum of 74 ft in Douglas County. West of Taney County, southwestern Missouri, Whetstone Creek strata begin to pinch out against the clastics of the Reagan Sandstone, although uppermost Whetstone Creek has been identified in Carroll County, Arkansas.

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 St. Francois Mountain area but becomes predominantly dolomitic to the south. The upper part of the Elvins consists of finely crystalline, thin-to medium-bedded, shaly dolomite.

Davis Formation - The Davis Formation is the older of the two formations which make up the **Elvins Group**. The Davis is conformable with the underlying Bonneterre and contains shale, siltstone, fine-grained sandstone, dolomite, and limestone conglomerate. Shale is more prevalent in the St. Francois Mountain area 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 ft thick that lies 30 or 35 ft below the top of the formation.

"Flat-pebble" and "edgewise" conglomerates are characteristic of the Davis. The "flat-pebble" conglomerates consist of rounded disc-like pebbles of finely crystalline limestone that are embedded in a medium-crystalline 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 finely crystalline 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, finely crystalline, mottled limestone are present about 60 ft below the top of the Davis in the St. Francois Mountain area. This horizon is informally referred to as the "**Marble boulder bed**."

The Davis Formation averages 170 ft in thickness. Its maximum recorded thickness is 225 ft, but it thins to a featheredge wherever it onlaps Precambrian knobs.

Derby-Doerun Dolomite - The Derby and overlying Doe Run were originally defined (1908) as separate formations from exposures in the vicinity of mines operated by the Derby Lead Company and the Doe Run Lead Company in what was then the Lead Belt area. However, the conformable relationship and similar lithology of the two units have 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 Dolomite.

In its outcrop area in southeastern 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 finely crystalline, 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 ft of the formation. About 50 ft 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 ft; however, its range in thickness is from 0 to 200 ft.

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Potosi Dolomite - The Potosi Dolomite is a massive, thickly bedded, medium- to finely crystalline 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 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 Potosi and the underlying Derby-Doerun are conformable.

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. Barite occurs in the residual clay and drusy mantle of the weathered formation as well as in bedrock. 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 ft to a maximum of 300 ft. Its average thickness is 200 ft. 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 ft thick. In northern Missouri its thickness ranges from 0 to 75 ft.

Eminence Dolomite - The Eminence Dolomite is composed principally of medium- to massive-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 Dolomite contains large massive chert boulders and blocks as much as 6 ft 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 upper contact with the Gasconade Dolomite is marked, over most of the state, by sandy dolomite or sandstone of the Gunter Sandstone Member of the Gasconade Dolomite. However, if the Gunter characteristics are not identifiable, the Eminence is difficult to distinguish from the lower Gasconade low-chert "Van Buren member."

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 ft. Like the Potosi, it thins or is absent over local structural features. In the south-central part of the state, it is locally as thick as 350 ft. 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

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Rocks of Ordovician age are exposed over approximately one-third of the state of Missouri (Fig. 4) and attain an aggregate thickness of about 3,800 ft. 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 St. Francois Mountains (Ozark Uplift), outside of the of Upper Cambrian strata, and dip away from it.

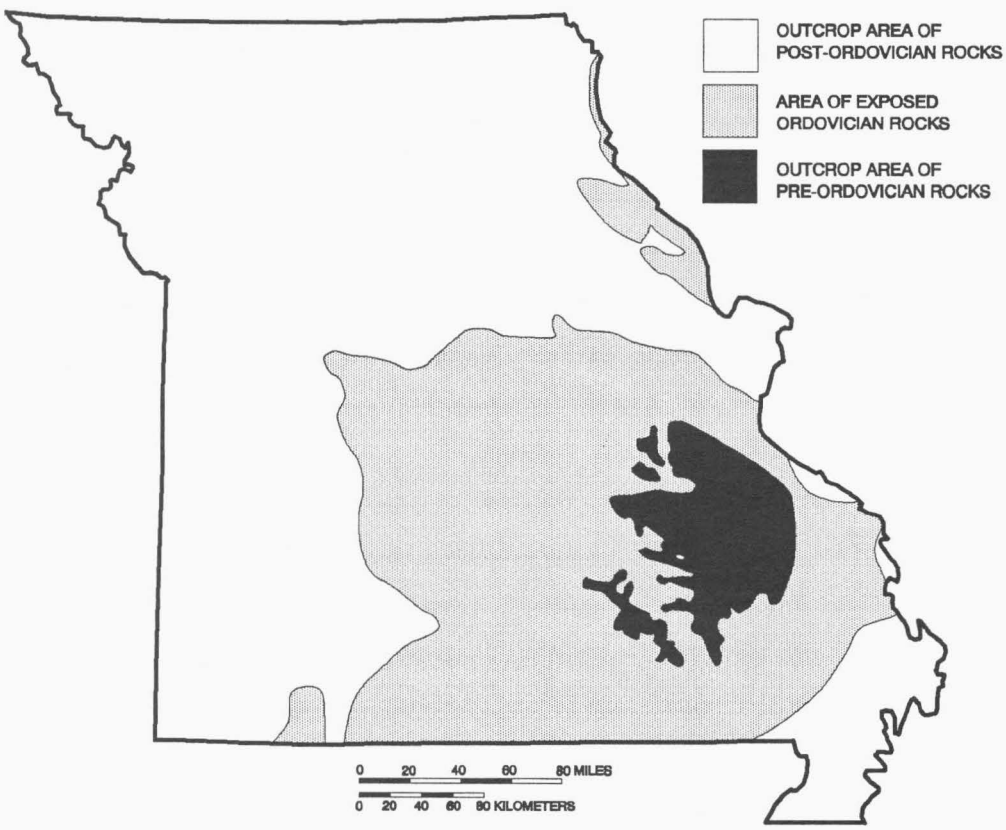


Fig. 4. *Areas of exposed Ordovician formations in Missouri.*

The Canadian (Ibexian; Ross et al., 1993), Whiterockian, Mohawkian, and Cincinnatian Series are all represented in the state, with the Canadian and Mohawkian Series being the most extensive. The strata of these series are composed predominantly of dolomite and limestone, but several important sandstone and/or shale units are also present. An unconformity is conspicuous at the top of the System, with many significant unconformities being recognized as series and stage boundaries within the System. Ordovician strata may be unconformable to conformable on the underlying Upper Cambrian strata, and in some places may unconformably overlie the Precambrian. They 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.

Canadian (Ibexian) Series

The rocks of the Canadian Series in Missouri (Fig. 5) are principally arenaceous and cherty dolomite and sandstone. They are exposed at the surface in a large part of the state south of the Missouri River (Fig. 6) and extend

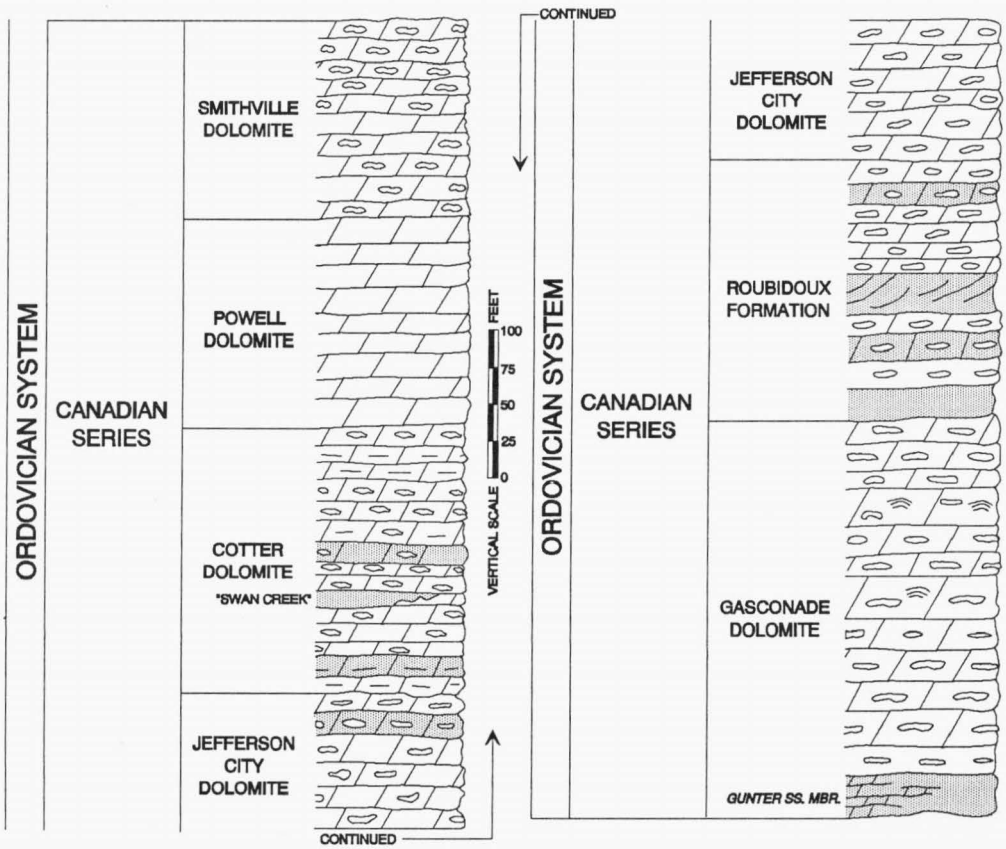


Fig. 5. *Ordovician System, Canadian (Ibexian) Series; from Thompson (1991)*

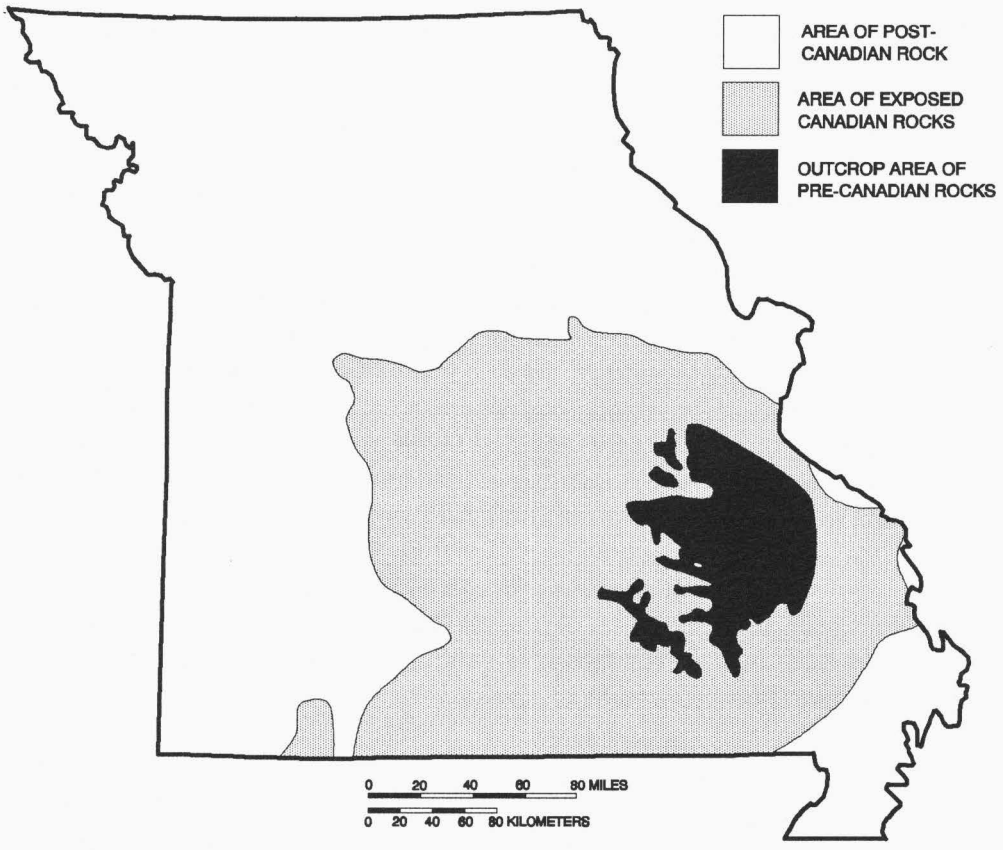


Fig. 6. *Areas of exposed Lower Ordovician Canadian formations in Missouri.*

westward from the Mississippi River to Cedar County. The base of the Series appears to be conformable with the Upper Cambrian in some areas, but may be locally unconformable in others. The unconformity at the top of the Canadian is one of the most extensive unconformities within the Paleozoic succession. In Missouri, formations of Canadian age are (in ascending order): Gasconade, Roubidoux, Jefferson City, Cotter, and possibly 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 Dolomite - The Gasconade Dolomite is predominantly a light-brownish-gray, cherty dolomite. The formation contains a persistent sandstone unit in its lowermost part that is designated the **Gunter Sandstone Member**. The upper part of the formation ("**upper Gasconade**") is dominantly medium-crystalline and contains relatively small amounts of chert (sometimes identified as the "**Richland**"). The part of the formation below the "upper Gasconade" and above the Gunter Member is identified as the "**lower Gasconade**," which is generally coarsely crystalline and may have up to 50 percent chert by volume. In some areas, the lower part of the "lower Gasconade," above the Gunter Member, is separately identified as the "**Van Buren**." The "Van Buren" is

generally a low-chert, finely crystalline dolomite similar to the "upper Gasconade."

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 ft 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 ft below the top of the formation, and locally mark the contact between the "upper" and "lower" Gasconade.

Many of the nearly vertical bluffs and cliffs along streams in south-central Missouri 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 south-central Missouri, the average thickness of the Gasconade is 300 ft. Data from wells in southeastern Missouri indicate a maximum thickness of 700 ft for the Gasconade in that area.

Gunter Sandstone Member - From central Missouri south to Taney County, the Gunter Sandstone Member of the Gasconade Dolomite is a medium-grained, quartzose sandstone from 25 to 30 ft thick. To the east and to the west, it is a thinner arenaceous (sandy) 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, and a number of deep municipal water wells produce from the Gunter.

Roubidoux Formation - The Roubidoux Formation consists of dolomite, cherty dolomite, sandy dolomite, dolomitic sandstone, and sandstone. In central Missouri, it contains a prominent 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 are predominant on weathered surfaces, but the color of 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, 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 each near the base, middle, and top.

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. Thickness of the Roubidoux ranges from 100 to 250 ft. 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. The sandstone units in the formation are quarried for building stone at many places in Missouri.

Jefferson City Dolomite - The Jefferson City Dolomite 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. An equally important rock type found in many exposures is thick- to massive-bedded, brown, medium-crystalline dolomite that weathers to a coarsely pitted surface. This is informally designated the "**Quarry Ledge,**" and is usually 25 to 40 ft above the base of the formation. In the past, rock obtained from this ledge 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 ft; its average thickness is 200 ft.

Cotter Dolomite - The major part of the Cotter Dolomite is composed of light-gray to light-brown, medium- to finely crystalline, cherty dolomite. It is normally medium- to thin-bedded and contains thin intercalated beds of green shale and sandstone. A 15- to 20-ft 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 within the Cotter Dolomite.

The lower part of the Cotter Dolomite 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 sometimes difficult to differentiate the two formations they are often designated as a combined unit, as **Jefferson City-Cotter Dolomite**.

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 as in west-central and northwestern Missouri. The average thickness of the Cotter is 200 ft, but its maximum thickness is in the subsurface of southeastern Missouri where it is 450 ft thick. It is over 350 feet thick in the region of Branson, in southwestern Missouri. The Cotter is absent in St. Clair County where the Mississippian lies unconformably on the Jefferson City Dolomite.

Powell Dolomite - The Powell Dolomite has been identified in several areas in Missouri. However, some doubt exists as to whether this is truly Powell, or upper Cotter strata. Rocks identified as Powell are composed of medium- to finely crystalline dolomite with thin beds of green shale and fine-grained sandstone. In Ste. Genevieve County this unit 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.

Strata called Powell crop out in eastern Missouri from Cape Girardeau County northward to St. Charles County and may also be present in extreme southwestern Missouri. It has been identified 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 ft.

Smithville Dolomite -The Smithville Dolomite 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, Missouri, in Cape Girardeau County.

The formation has been identified in the subsurface south and east of Cape Girardeau, and in some areas it is at least 150 ft thick. Because the formation is lithologically similar to the underlying Powell Dolomite, 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 Smithville rocks, but older than Everton rocks present within Missouri. The succession is fossiliferous and contains about 80 percent 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.

Middle Ordovician

The two Middle Ordovician series (Whiterockian and Mohawkian) are represented in Missouri by 13 formations (Fig. 7). Whiterockian strata are represented only by the Everton Formation. The Mohawkian includes the St. Peter Sandstone, Dutchtown Formation, Joachim Dolomite, "Pecatonica Formation," Plattin Limestone (or Plattin Group), the Spechts Ferry Formation, Kings Lake and Guttenberg Limestones of the Decorah Group, and the Kimmswick Limestone. The boundary between these two series is between the Everton Formation and overlying St. Peter Sandstone; the boundary between the Mohawkian Series and underlying Canadian rocks, where the Everton is absent, is between the uppermost Canadian unit and the St. Peter Sandstone.

In southeastern Missouri Middle Ordovician rocks crop out in a continuous belt 2 to 20 miles wide (Fig. 8) 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, Middle Ordovician rocks are present at the surface along the Lincoln Fold. The outcrop belt of Middle Ordovician

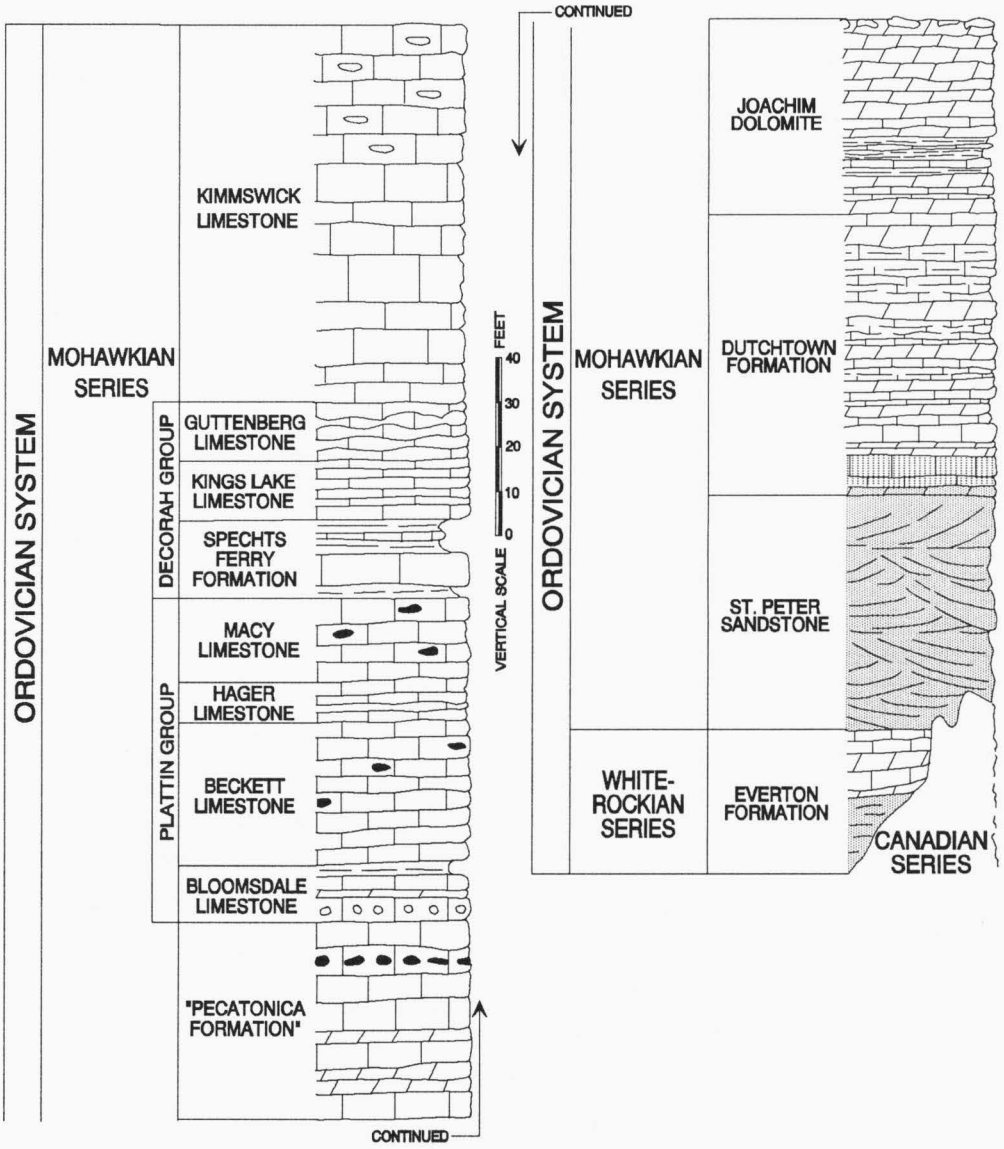


Fig. 7. *Ordovician System, Whiterockian and Mohawkian Series; from Thompson (1991).*

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 Middle Ordovician age 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.

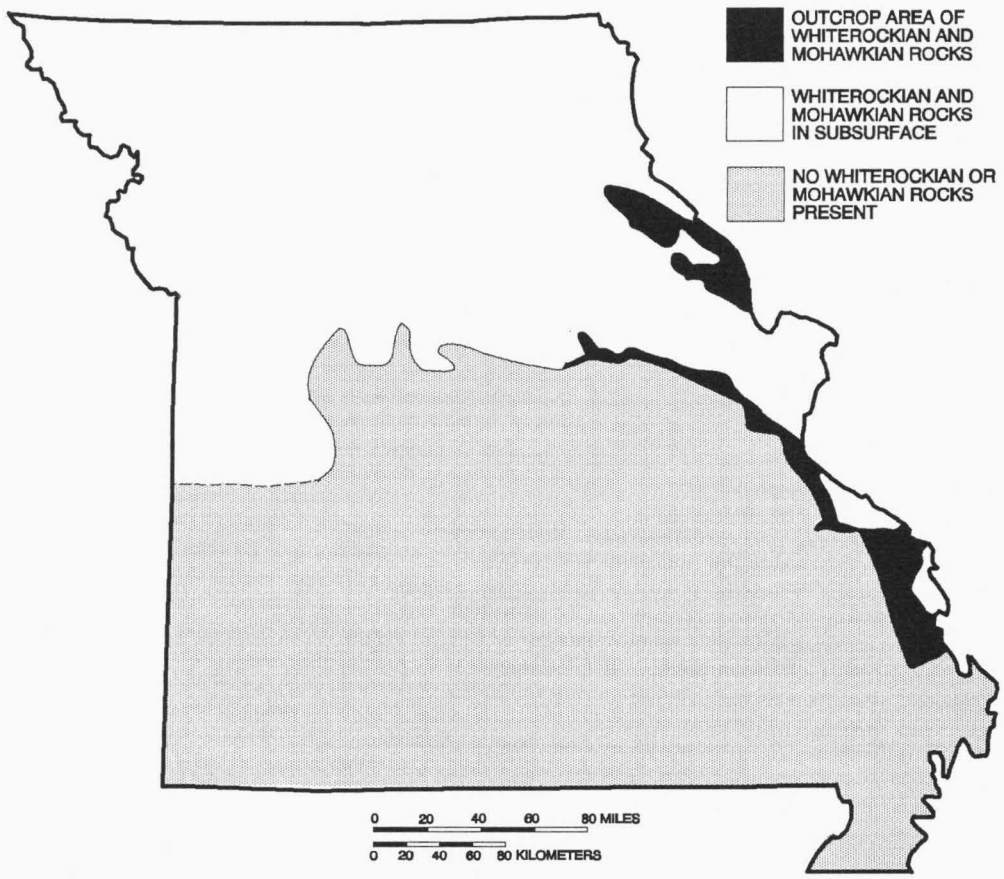


Fig. 8. *Areas of exposed Whiterockian and Mohawkian formations in Missouri; modified from Thompson (1991).*

Whiterockian Series

Everton Formation - The Everton Formation is the basal Middle Ordovician formation and rests unconformably on Canadian strata. It consists of two units; an undulating algal-appearing dolomite, often sandy, overlying a thicker, massive sandstone. The upper dolomite 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 from one another. 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, where it has been observed to pinch out. It has not been definitely recognized elsewhere in the state. It is approximately 400 ft thick in Scott County but thins rapidly northward and is probably absent north of Jefferson County.

Mohawkian Series

St. Peter Sandstone - The St. Peter Sandstone is typically a well-sorted, friable, 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 rests, possibly conformably, on the Everton. North of Jefferson County, the formation is disconformable on the eroded surface of the Canadian Series. In some parts of the subsurface of northern Missouri two members, the **Starved Rock Member** and **Tonti Member,** have been identified. The Starved Rock is an elongate barrier bar overlying the more wide-spread "sheet-sand" of the Tonti Member. A third member, the **Kress Member**, was named for the detrital unit on the eroded surface of the Canadian Series. Although intended as an Ordovician-aged unit, it is being used throughout the state of Missouri to define the residual Canadian detrital zone when directly overlain by younger Paleozoic strata, regardless that the age of the overlying formation be Ordovician, Devonian, Mississippian, or Pennsylvanian.

The St. Peter Sandstone is continuous throughout the Middle Ordovician 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 post-Canadian Ordovician 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. It also is used for underground natural gas storage in the St. Louis area.

The thickness of the St. Peter Sandstone is variable, ranging from less than 10 to more than 100 ft, thickest where it fills pre-St. Peter sink holes. Its general thickness is between 60 and 80 ft.

Kress Member - The Kress Member is a coarse, basal conglomerate of chert and residual Canadian material along with a matrix of sand, clay, or chert. The Kress can be 50 to 100 ft thick in the subsurface of west-central Missouri.

Tonti Member - The Tonti Member of the St. Peter Sandstone consists chiefly of fine-grained, well-sorted friable sandstone, that usually is the typical St. Peter that covers much of the Midcontinent region. It rests unconformably on Everton or Canadian strata, and is overlain by Joachim Dolomite, or in parts of northern Missouri, by the Starved Rock Member.

Starved Rock Member - The Starved Rock Member of the St. Peter Sandstone consists of sandstone that closely resembles the underlying sandstone of the Tonti Member, but is consistently coarser grained. It usually lacks the cross-bedding common in the Tonti Member. This unit is present as a northeast-southwest trending elongate sand body through the subsurface of northern Missouri (see Thompson, 1991).

Dutchtown Formation - The Dutchtown Formation is composed dominantly of medium- to thin-bedded dolomite and calcareous 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 asphalt-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 ft in southern Cape Girardeau County, thinning northward, being only 20 ft 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 were interpreted in 1961 to indicate that pre-Dutchtown erosion had removed part or all of the St. Peter Sandstone in some places, and that the Dutchtown thus overlaps the older St. Peter and Everton formations. However, subsequent evidence (Templeton and Willman, 1963) suggests that the Dutchtown, and also possibly the Joachim Dolomite, are southern facies of the St. Peter Sandstone in that region, and the St. Peter was never deposited prior to Dutchtown deposition.

Joachim Dolomite - The Joachim Dolomite is predominantly a yellowish-brown, argillaceous dolomite which contains interbedded limestone, sandstone, 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 in the middle. Fossils are scarce in the Joachim in Missouri.

The Joachim Dolomite has been informally subdivided into three parts (Thompson, 1991):

"***upper Joachim Dolomite***" - massive algal dolomite; the **Metz** and **Matson Members**;

"***middle Joachim Dolomite***" - thin-bedded, shaly dolomite; the **Defiance** and **Boles Members;**

"***lower Joachim Dolomite***" - thin-bedded dolomite interbedded with sandstone and sandy dolomite; either the **Abernathy** or **Augusta Member**.

The Joachim extends throughout the Middle Ordovician 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 ft in Cape Girardeau and Scott counties, to less than 50 ft in Ralls and Montgomery counties.

In Scott, Cape Girardeau, and Perry counties, the Joachim conformably overlies the Dutchtown Formation. North of this area, the Dutchtown is absent, and the Joachim rests on the St. Peter Sandstone. The St. Peter-Joachim contact appears to be transitional.

"Pecatonica Formation" - Although recognized as a formation in southeastern Missouri, the "Pecatonica Formation" was named from exposures in southern Wisconsin. The name is placed in quotes to indicate that a more local name would be desired, as the distance from the type area to southeastern Missouri is very long, and the unit is not exposed between the regions.

In Missouri, the "Pecatonica" includes beds that were formerly assigned to the **Rock Levee Formation** in the vicinity of Cape Girardeau, southeastern Missouri. Elsewhere in Missouri the "Rock Levee" comprised strata that are now included in the upper Joachim and lower Plattin. Only in the type area of the "Rock Levee," near Cape Girardeau, can the "Pecatonica" be distinguished from Joachim and Plattin rocks. 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 redefined Joachim. However, the upper "Pecatonica" is massive limestone similar to Plattin, the lower unit interbedded dolomite and shaly dolomite similar to the underlying Joachim.

The "Pecatonica Formation" is approximately 270 ft thick in Cape Girardeau County. It appears to be conformable with both the underlying Joachim and overlying Plattin in the limited area it can be recognized. But, there is a major lithologic change within the "Pecatonica" that is quite abrupt, from Joachim-like to Plattin-like rocks.

One prominent member, the **Medusa Member**, is present in the middle of the upper "Pecatonica" limestone. It is easily recognizable because it is highly burrowed, the burrows being small and filled with yellow-brown matrix.

PLATTIN GROUP (Plattin Limestone) - The Plattin consists of even-bedded, light-gray to dark-gray to light-tan, finely crystalline to sublithographic limestone (calcareous mudstone) which contains minor amounts of intercalated shale. The basal unit is composed of a shale and chocolate-brown, lithographic, oolitic limestone interbedded with brown to blue-gray dolomite and dolomitic shale. Tubular or fucoidal structures, which are commonly filled with light-brown, saccharoidal dolomite or white calcite, are distinctive features above the basal shale and oolitic units. Thin metabentonite ("K-bentonites") beds are present in the upper part and at the top 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.

The Plattin thins to less than 100 ft in Ralls and Montgomery counties. In Cape Girardeau County, it is approximately 450 ft thick, and it thins northward from there to about 200 ft in Jefferson County. Plattin rocks lie on the Joachim Dolomite everywhere except for the Cape Girardeau area, where they rest on the "Pecatonica Formation." The basal contact may be conformable. It is overlain unconformably by rocks of the Decorah Group, the contact marked by a prominent, very wide-spread, volcanic ash bed (K-bentonite).

Thompson (1991) proposed that the Plattin in Missouri south of the Missouri River be subdivided into a number of formational units, these originally defined by Larson (1951). Thus, the **Plattin Group** comprises four formations (from base upward): the Bloomsdale, Beckett, Hager, and Macy Limestones. These in turn are divided into members. North of the Missouri River most of these units are not identifiable, and the entire unit is identified as the **Plattin Limestone**.

Bloomsdale Limestone - The Bloomsdale Limestone is a thin (5-10 ft) unit of distinctive chocolate-brown to brown, partially oolitic, sublithographic to lithographic limestone beds with alternating thinner bluish-gray dolomitic shales and dolomites. The top is marked by a green shale (Establishment Shale Member).

Brickeys Member - The Brickeys Member of the Bloomsdale Limestone comprises beds of chocolate- brown to brown, oolitic, sublithographic limestone alternating with thinner beds of dolomitic shale to dolomite. This unit is prominent at the base of the Plattin succession in the well log files at DGLS/DNR.

Establishment Shale Member - The Establishment Shale Member of the Bloomsdale Limestone consists of green clayey shale ranging in thickness from a few inches in east-central Missouri to 4 or more ft in southeastern Missouri. The Establishment Member often contains thin limestone beds interbedded with shale where the member is several feet thick It can be referred to as the Establishment Shale Member of the Plattin Limestone if the group designation is not used..

Beckett Limestone - The Beckett Limestone is light-gray, burrowed (fucoidal), sublithographic limestone (calcareous mudstone). The burrows are filled with tan to dark-gray, more coarsely crystalline carbonate material that often comprise nearly 50% of the rock by volume. The base is at the top of the Establishment Shale Member of the Bloomsdale Limestone. The top is marked by the base of the white to light-gray, lower member of the Hager Limestone. The Beckett Limestone ranges from around 25 to over 125 ft thick, and is thickest in southeastern Missouri.

Hager Limestone - The Hager Limestone is characterized by massive, unburrowed, light-gray sublithographic limestone. The formation is much thinner than the underlying Beckett, or overlying Macy Limestones, but the massive nature of two of the three members make it very prominent on outcrop. The average thickness of the Hager Limestone is between 10-15 ft, although it may be thicker or thinner than this at specific sections. The Hager Limestone is divided into three members (from bottom up): the Glaize Creek, Hely, and Victory Members.

Glaize Creek Member - The Glaize Creek Member of the Hager Limestone comprises one or more thick beds of unburrowed, very light-gray, sublithographic limestone. It is not present north of Jefferson County, but thickens southward from there to around 8 ft or more in southeastern Missouri. The unburrowed beds stand out prominently within the Plattin succession due to their lighter color and massive appearance. The Glaize Creek and Victory Members are very similar in appearance, separated by the burrowed ("typical" Plattin) Hely Member.

Hely Member - The Hely Member of the Hager Limestone is a thinner, dark-gray, burrowed limestone between the massive unburrowed, light-gray to white Victory and Glaize Creek Members. Its appearance is more like that of "typical" Plattin. If the Glaize Creek Member is not present, as along I-44, the Hely cannot be separated from the underlying Beckett.

Victory Member - The Victory Member of the Hager Limestone is usually a single, thick bed of unburrowed, very light-gray, sublithographic limestone. The surface is rough due to the inclusion of small dolomite rhombs in the limestone. This limestone is defined as supratidal in origin, indicating a short period of sea level lowering during the otherwise steady deepening interval of the Plattin succession. The Victory, the only member of the Hager present in east-central Missouri (along Interstate 44), is absent north of St. Charles County, and thickens from 1 ft to over 7 ft in southeastern Missouri.

Macy Limestone - The Macy Limestone is lithologically similar to the Beckett Limestone: a burrowed, gray, very finely crystalline to sublithographic limestone, from 25 to over 40 ft thick. The Macy is divided into two members, the lower Hook Member and upper Zell Member, differentiated on the type and size of burrowing. Locally light-yellow-brown K-bentonite clay beds (volcanic ash beds) are present in this unit. The top of the Macy Limestone (the top of the Plattin Group) is at the base of the wide-spread prominent **Deicke K-bentonite bed**, that may be over 6-in. thick.

Hook Member - The Hook Member of the Macy Limestone is much like the underlying Beckett Limestone. Burrowing is predominately vertical or unoriented.

Zell Member - The Zell Member of the Macy Limestone is characterized by prominent horizontally oriented burrows, usually filled with a tan to brown finely crystalline carbonate. Upon weathering, the Zell appears more slabby-bedded than the Hook.

DECORAH GROUP - The Decorah Group consists of three formations (in ascending order): the Spechts Ferry Formation, Kings Lake Limestone, and Guttenberg Limestone. The Decorah varies in thickness from a few feet to more than 40 ft. In the subsurface of northern Missouri, the Decorah is almost entirely a cherty dolomite or limestone with minor amounts of shale.

Spechts Ferry Formation - The Spechts Ferry Formation consists of two members, the lower Castlewood Limestone Member, and upper Glencoe Shale Member. Two beds of metabentonite, one at the base of the formation, the other within the Glencoe Shale Member, are wide-spread throughout the midwest.

The shale of the Spechts Ferry (Glencoe) is the unit that has previously been regarded as "Decorah." The Kings Lake and Guttenberg Limestones were first used formally in Missouri by Templeton and Willman (1963), who regarded the Decorah as a "subgroup." Thompson (1991) followed this concept, but defined the Decorah as a "group."

Castlewood Limestone Member - The Castlewood Limestone Member of the Spechts Ferry Formation is the basal unit of the Decorah Group, and is a single 2-6-ft bed of light-gray, finely crystalline limestone above a thin, yellow-brown clay (**Deicke K-bentonite bed**). The limestone is very similar to that of the underlying Plattin, but included fossils show an

unconformity present between the Plattin and basal Decorah rocks, marked by the Deicke K-bentonite.

Glencoe Shale Member - The Glencoe Shale Member of the Spechts Ferry Formation consists of green shales and numerous, thin, interbedded limestone layers. The limestone beds are highly fossiliferous, comprised predominately of the brachiopods *Pionodema subaequata* and *Rafinesquina*. A prominent, thin, yellow-brown clay bed beneath a nodular limestone bed is the **Millbrig K-bentonite bed,** a wide-spread volcanic ash bed that has been traced as far east as the state of New York (Willman and Kolata, 1978).

Kings Lake Limestone - The Kings Lake Limestone is a light-gray, very finely crystalline to sublithographic, thin- to medium-bedded, fossiliferous limestone which contains thin, fossiliferous shale partings. Fossils are numerous, and include those from the underlying Glencoe Shale. The beds are thinner and usually less pure than those of the overlying Guttenberg Limestone. Average thickness is 10 to 15 ft.

Guttenberg Limestone - The Guttenberg Limestone has medium, even beds of fossiliferous, sublithographic, very light-gray limestone (mudstone). Brachiopods and trilobites are numerous in this formation. The contact with the overlying Kimmswick Limestone is unconformable, with fragments of Guttenberg reworked into the lower few inches of the basal Kimmswick bed. The Guttenberg is a purer limestone, and more even-bedded than the underlying Kings Lake Limestone. Present only in northeastern Missouri (Lincoln to Ralls County), the Guttenberg averages around 10 ft thick.

Kimmswick Limestone - The Kimmswick Limestone is typically a coarsely crystalline, bioclastic, white to light-gray, medium- to massive-bedded limestone. Although generally coarsely crystalline, it is nonetheless highly burrowed, and the weathered surface of the rock is distinctive in that it is notably pitted or "honeycombed," the burrow-fill material having weathered out. 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," *Fisherites oweni* (originally named *Receptaculites oweni)*, characterizes the Kimmswick in Missouri.

Regionally, the Kimmswick is unconformable on the Decorah Group, lying on the Guttenberg Limestone in northeastern Missouri, on the Kings Lake Limestone in east-central and southeastern Missouri.

The contact with overlying strata is also unconformable. Uppermost beds of the Kimmswick in northeastern Missouri may be as young as early Late Ordovician, lying beneath the mid-Late Ordovician Maquoketa Shale. Southward, the upper beds of the Kimmswick were progressively eroded, so that in and south of St. Louis County to Cape Girardeau County, only the lower half of the original unit is preserved beneath the early Late Ordovician Cape Limestone (and/or Maquoketa Shale).

In northeastern Missouri, where the greatest percentage of original Kimmswick is preserved, Thompson (1991, p. 211) informally divided the succession into "...**1)** a '**lower Kimmswick Limestone**,' a heavily burrowed, bioclastic, coarse grainstone, represented by the type Kimmswick [in eastern Jefferson County],

and the lower part of the Kimmswick throughout its extent; and **2)** an '**upper Kimmswick Limestone,**' a heavily burrowed, bioclastic, fine to medium grainstone to mudstone, that overlies the coarse-grained 'lower Kimmswick' in northeastern Missouri..." The boundary between the "upper" and "lower Kimmswick" is a thin K-bentonite bed (altered volcanic ash bed) exposed on U.S. Highway 61 in eastern Ralls and northern Pike counties.

In the type area and in east-central and southeastern Missouri, a prominent K-bentonite bed occurs approximately 3 ft above the base of the Kimmswick. Kolata et al. (1986, p. 23) named it the **House Springs K-bentonite Bed**.

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 also has been dolomitized 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, and has yielded oil in St. Louis and Atchison Counties.

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

Cincinnatian Series

Cincinnatian (Upper Ordovician) strata in Missouri (Figs. 9 and 10) comprise nine formations (in ascending order): the Maquoketa Shale and the Noix and Cyrene Limestones in northeastern Missouri; and the Cape Limestone, Maquoketa Group (Cape La Croix Shale, Thebes Sandstone, Orchard Creek Shale, and Girardeau Limestone), and Leemon Formation in southeastern Missouri. In east-central Missouri, only the Cape Limestone and Maquoketa Shale represent the Cincinnatian Series.

Thompson (1991) reported that in northeastern Missouri, uppermost Kimmswick Limestone may be as young as Early Cincinnatian.

Cape Limestone - The name Cape Limestone was proposed by Gudstadt (1958) to replace the name "**Fernvale**" in Missouri. The formation is a coarsely crystalline, highly fossiliferous, argillaceous limestone, usually gray, although fresh exposures have a distinctive purple or brown tinge. The beds are thin to medium in thickness, and are wavy and irregular. Thin beds of shale are present in the lower part of the formation which becomes massive toward the top. 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 Cape Limestone are intermittently distributed, with exposures being present in Cape Girardeau, Perry, Ste. Genevieve, and Jefferson counties. In its outcrop area in southeastern Missouri, the formation ranges from a maximum thickness of about 15 ft in Cape Girardeau County, to less than 1 ft

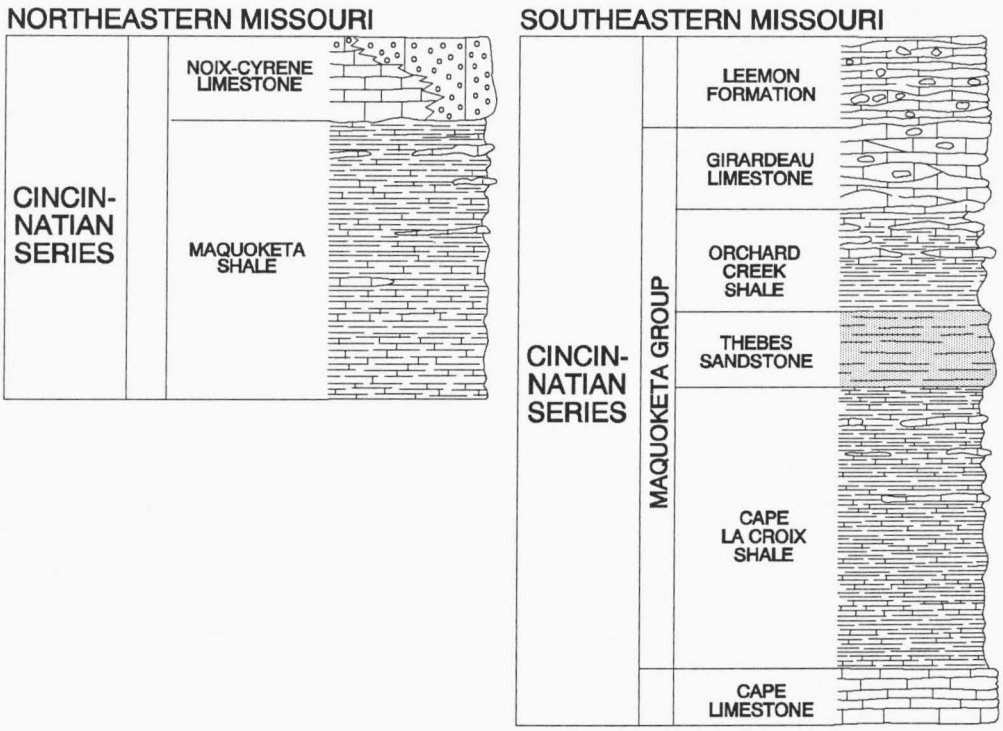


Fig. 9. *Ordovician System, Cincinnatian Series; from Thompson (1991).*

in Ste. Genevieve and Jefferson counties. The Cape lies unconformably upon the Kimmswick Limestone, although the contact is very difficult to see in Jefferson and Ste. Genevieve counties ("welded"). It is unconformably overlain by the Maquoketa Shale in east-central Missouri, and by the lower shale of the Maquoketa Group in southeastern Missouri (Cape La Croix Shale).

In the subsurface of northwestern Missouri, beneath Holt and DeKalb counties, a white crystalline dolomite, 10 to 40 ft thick, has been questionably identified as Cape.

MAQUOKETA GROUP (Maquoketa Shale) - 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 formation in the Forest City Basin of northwestern Missouri ranges from 20 to 70 ft.

On outcrop, the Maquoketa in Missouri occurs as two different units. In east central and northeastern Missouri, the **Maquoketa Shale** is typically a thinly laminated, clayey, 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

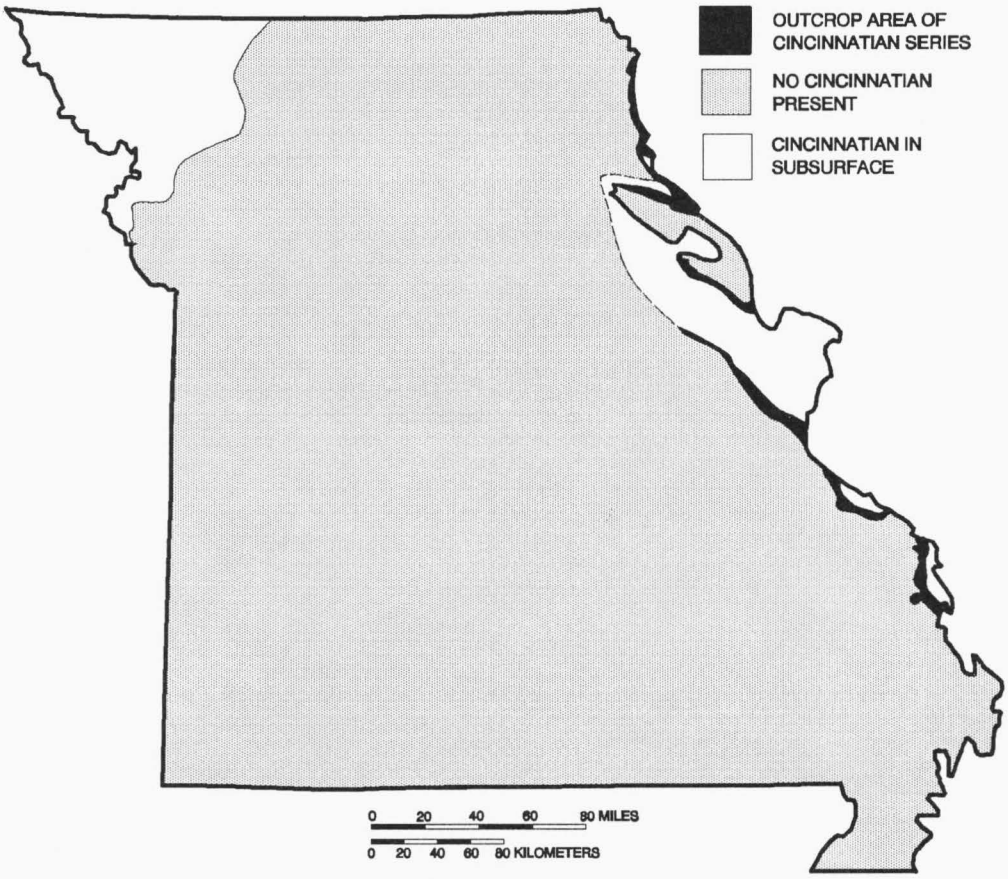


Fig. 10. *Areas of exposed Cincinnatian formations in Missouri; modified from Thompson (1991).*

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 average thickness in northeastern Missouri is 100 ft, but it ranges from 30 to 140 ft.

The Maquoketa Shale disconformably overlies the Kimmswick Limestone in northeastern Missouri. In southeastern Missouri, in Cape Girardeau and southern Perry counties, the interval equivalent to the Maquoketa Shale of north-central and northeastern Missouri, the **Maquoketa Group**, contains rocks divided into four formations (in ascending order): the Cape La Croix Shale, Thebes Sandstone, Orchard Creek Shale, and Girardeau Limestone. The thickness of the Maquoketa in southeastern Missouri ranges from 10 to 60 ft. Basal Maquoketa strata in southeastern Missouri rest unconformably on the Cape Limestone.

Cape La Croix Shale - Thompson (1991) proposed this name for the basal shale of the Maquoketa present between the Cape Limestone and the Thebes Sandstone exposed around Cape Girardeau in southeastern Missouri. The

Cape La Croix Shale is similar to the Maquoketa Shale of northeastern Missouri, greenish to gray clay and silty shale beds with several nodular to continuous thin limestone beds in the middle part. This shale ranges from 10 to 55 ft thick.

Thebes Sandstone - The Thebes Sandstone 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 ranges from less than 5 to as much as 25 ft thick.

Orchard Creek Shale - The Orchard Creek Shale lies above the Thebes Sandstone and below the Girardeau Limestone. It 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 Limestone. Fossils are present in both the limestone and shale, but are not abundant. The contact of the Orchard Creek with the underlying Thebes Sandstone is generally gradational, but locally it is sharp and distinct. The average thickness of the formation is 50 ft. The formation's contact with the overlying Girardeau appears transitional. The unit is present in Cape Girardeau, Perry and Ste. Genevieve counties.

Girardeau Limestone - The Girardeau Limestone is a dark-to medium-gray limestone which weathers to a light-bluish-gray. The texture of the limestone is dense to sublithographic (a calcareous mudstone), 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 inches to a maximum of 40 ft.

The upper boundary of the Girardeau is marked by an erosional unconformity. Clasts of Girardeau have been found in basal beds of the Leemon Formation in Cape Girardeau County. The basal beds of the Girardeau are transitional with uppermost Orchard Creek beds. For this reason, Girardeau is included within the Maquoketa Group.

Most early workers considered Girardeau to be Silurian in age, as did Martin et al. (1961) in the original Volume 40. However, Thompson and Satterfield (1975) identified the Girardeau as Late Ordovician in age, and described the transitional association of the Girardeau Limestone with the limestone beds in the upper part of the underlying Orchard Creek Shale.

Leemon Formation - The Leemon Formation is a sparsely oolitic, often very fossiliferous, gray, thin- to massive-bedded, argillaceous to calcarenitic limestone, often containing small clasts of Girardeau Limestone in the basal part. Some sections have shale interbedded with the limestone, and it appears as small bioherms in others. This unit rests on the Orchard Creek Shale at most localities (the Girardeau Limestone removed prior to deposition of the Leemon), and is overlain by the Silurian Sexton Creek Limestone.

Identified in 1961 (Martin et al.) as the "Cyrene member of the Edgewood formation," Silurian in age, this formation was assigned to the Late Ordovician by Thompson and Satterfield (1975) and renamed the Leemon Formation. They restricted the units within the Edgewood (Group) to rocks exposed in northeastern Missouri.

EDGEWOOD GROUP -The Edgewood Group comprises four formations exposed in Pike and Ralls counties of northeastern Missouri: two Late Ordovician (Cincinnatian), and two Early Silurian, in age. The Late Ordovician formations are the Cyrene and Noix Limestones.

Cyrene Limestone - The Cyrene Limestone is a gray to blue-gray, argillaceous, fossiliferous limestone restricted to a small area east of the town of Bowling Green, Missouri. It rests, possibly conformably, on the Maquoketa Shale, and is unconformably overlain by the Silurian-aged Bowling Green Dolomite. The upper 6 in. contains scattered oolites that were swept from the region of deposition of the Noix Limestone to the east and southeast and deposited in the Cyrene.

Noix Limestone - The Noix Limestone is a light-gray to brown, fossiliferous, highly oolitic limestone. At most localities, the oolite lies on upper Ordovician Maquoketa Shale, but in a few places in Pike County, several feet of non-oolitic limestone (Cyrene) lie between the oolite and the Ordovician rocks. Noix is unconformably overlain by the Silurian Bowling Green Dolomite or the Bryant Knob Formation. The Noix oolite is from 3 to 5 ft thick at most exposures, but a maximum of 10 ft has been reported.

SILURIAN SYSTEM

by

James A. Martin, Kenneth G. Larsen, and Garrett A. Muilenburg (1961)

revised by

Thomas L. Thompson (1995)

Outcrops of Silurian strata are restricted to two widely separated areas in the state (Fig. 11); 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.

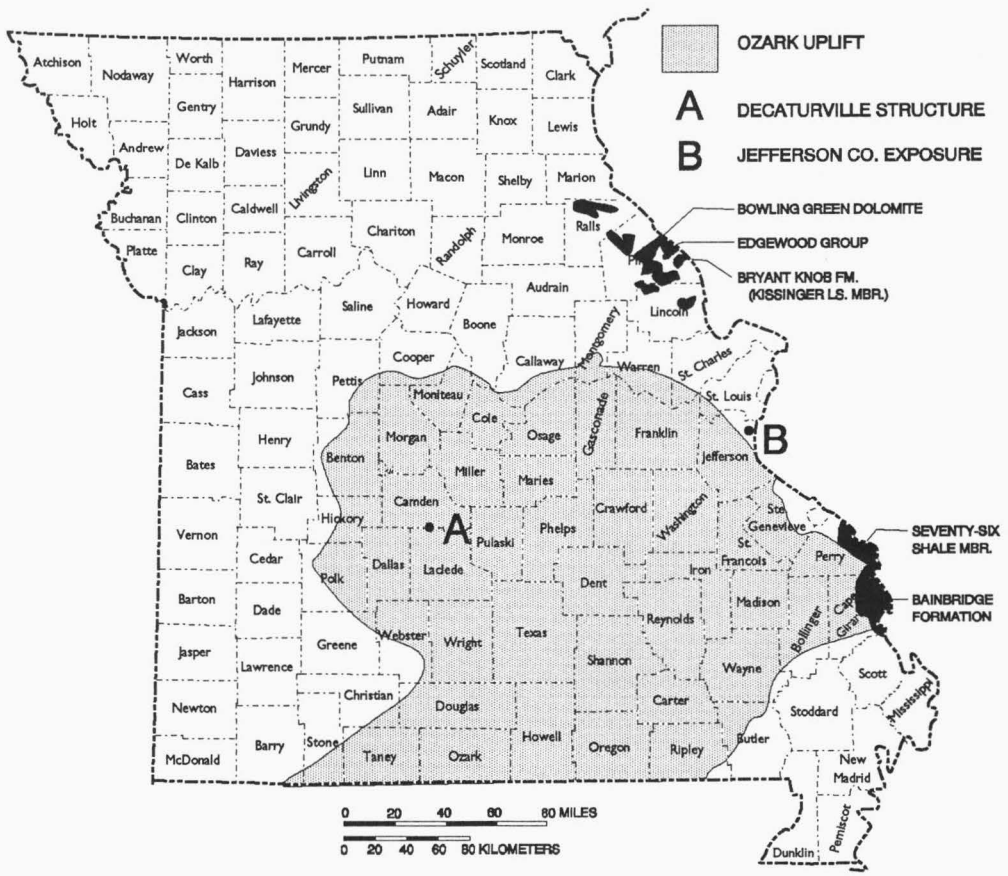


Fig. 11. *Areas of exposed Silurian formations in Missouri, and locations of type sections of Silurian formations named within the state; from Thompson (1994).*

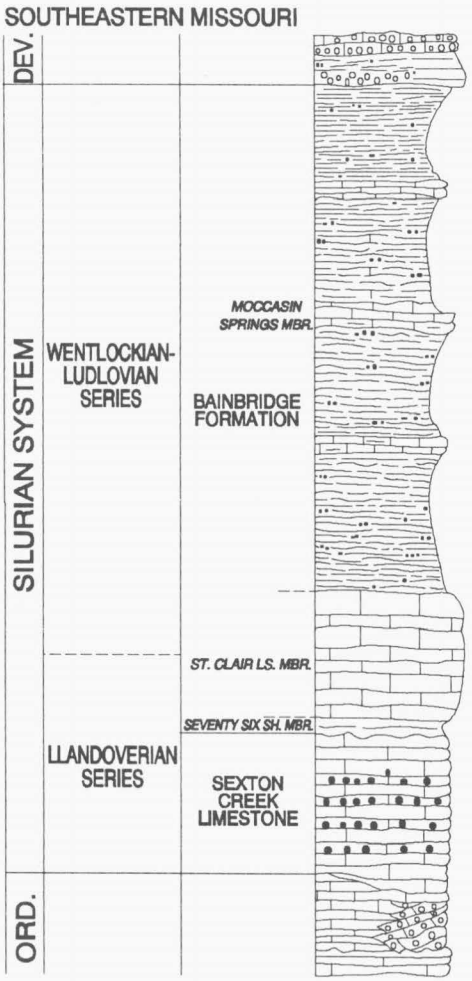


Fig. 12. *Silurian System in southeastern Missouri; from Thompson (1994).*

Charles counties in eastern Missouri and from wells in the Forest City Basin in northwestern Missouri. A few isolated exposures of Silurian rocks have been identified in Jefferson County, east-central Missouri, and Silurian rocks were identified in an isolated crypto-volcanic structure in Laclede County, central Missouri by Offield and Pohn (1979)

In southeastern Missouri (Fig. 12), Silurian strata crop out in eastern Ste. Genevieve, Perry, Cape Girardeau, and Scott counties. East of the outcrop area, the Silurian dips beneath younger strata into the southern part of the Illinois Basin. The Middle and Upper Silurian consist predominantly of limestone, shaly limestone, and shale. The Lower Silurian limestones contain minor amounts of chert.

The Silurian outcrop area in northeastern Missouri (Fig. 13) is along the northeastern flank of the Lincoln Fold in Ralls, Pike, and Lincoln counties. A few exposures in Lincoln County are situated near the crest of the fold and along its southern flank. In this area of the state, only the Lower Silurian Series is present, and it is composed largely of limestone and dolomite.

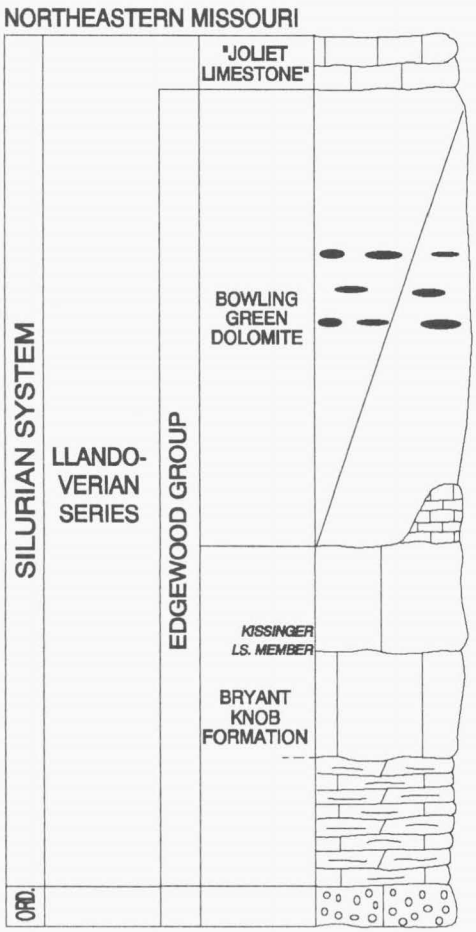


Fig. 13. *Silurian System in northeastern Missouri; from Thompson (1994).*

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 Lower and lower part of the Middle Silurian of eastern Missouri and western Illinois.

The total thickness of Silurian strata is approximately 200 ft in southeastern Missouri, 100 ft or less in the northeastern part of the state, and 300 to 400 ft in northwestern Missouri. Significant unconformities mark the top and base of the System and also separate some units of series and formation rank.

Lower Silurian Series

The Lower Silurian Series in Missouri is represented by four formations (in ascending order): the Bryant Knob Formation, Bowling Green Dolomite, "Joliet Limestone," and Sexton Creek Limestone. In southeastern Missouri, only the Sexton Creek is present. The Bryant Knob, Bowling Green, and "Joliet" are in northeastern Missouri. The Bryant Knob and Bowling Green are included in the **Edgewood Group**, along with the Upper Ordovician Cyrene and Noix Limestones.

The Lower Silurian Series in the southeastern part of the state averages around 30 ft in thickness. In the northeastern part of the state, it is approximately 75 to 100 ft thick.

Northeastern Missouri

EDGEWOOD GROUP (continued from Cincinnatian Series of Ordovician System) - In the type area of the Edgewood in northeastern Missouri, the Group is subdivided into four formations (Fig. 11), two Late Ordovician in age (Cyrene and Noix Limestones), and two Early Silurian (Bryant Knob and Bowling Green).

Bryant Knob Formation - Identified as the "Cyrene member of the Edgewood formation" by Martin et al. (1961a), the Bryant Knob Formation was named by Thompson and Satterfield (1975) from exposures in Pike County. They stated (p. 98): "We define the Bryant Knob Formation as the bioclastic limestone and dolomitic limestone and shale between the Noix Limestone and the Bowling Green Dolomite. The predominate rock type is the bioclastic limestone, and this is named the Kissenger Limestone Member of the Bryant Knob Formation."

The original Cyrene, as proposed by Savage (1913), was a Late Ordovician limestone associated with the Noix Limestone, which is stratigraphically beneath the Bryant Knob. It is a completely different unit from, and younger than, the unit called "Cyrene" by later workers (including Martin et al., 1961a). The thickness of the Bryant Knob does not exceed 20 ft, and throughout its extent it lies unconformably on Ordovician strata (Noix Limestone).

Kissenger Limestone Member - Thompson and Satterfield (1975, p. 98) stated: "The Kissenger Limestone Member [of the Bryant Knob Formation] consists of light-gray, massively bedded, coarsely crystalline, bioclastic limestone, and light-brown bioclastic limestone is not uncommon." This is the unit called "Cyrene" in 1961.

Bowling Green Dolomite - The Bowling Green Dolomite, which is exposed on the flanks of the Lincoln Fold in Pike County, is characteristically a medium- to thick-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 ft 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 ft to as much as 60 ft. In places it is unconformable on upper Ordovician beds, such as the Cyrene and/or Noix Limestones; elsewhere it lies on the Bryant Knob Formation.

"Joliet Limestone" - Identified as the Sexton Creek Limestone in northeastern Missouri by Martin et al. (1961b), the distribution of the "Joliet Limestone" was described as (p. 35) "...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 that area, but it is believed, on the basis of outcrops in Illinois, that the formation is unconformably overlain by Devonian strata..."

Thompson (1993) correlated this unit with the Joliet Limestone immediately across the Mississippi River in west-central Illinois, rather than with the Sexton Creek Limestone of southeastern Missouri, which is correlative with the underlying Bryant Knob and/or Bowling Green formations.

SOUTHEASTERN MISSOURI

Sexton Creek Limestone - The Sexton Creek Limestone 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. The olive to dull green-brown waxy 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 reentrants 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 ft. An erosional unconformity is present at its base.

Middle and Upper Silurian Series

The youngest Silurian rocks presently recognized in Missouri were formerly assigned to the Niagaran Series (Martin et al., 1961). Silurian rocks in Missouri younger than Lower Silurian have been recognized only in the southeastern part of the state where they are represented by one formation, the Bainbridge.

Bainbridge Formation - Exposed in a narrow band in southeastern Missouri, from southeastern Cape Girardeau County to southeastern Perry County, the Bainbridge Formation is a succession of finely crystalline limestone, argillaceous to silty limestone, and shale that in places may reach 300 ft thick. Bainbridge limestones are characteristically dark-red to brick-red, although gray to greenish-gray to reddish-gray limestone also occurs. The thicker, gray shales in the upper part of the formation can be confused with shales of the Upper Ordovician Maquoketa Group, particularly where these strata are within isolated parts of fault blocks.

Lowenstam (1949) proposed a two-fold division for the Bainbridge: **St. Clair** ("comparatively pure, commonly pink crinoidal limestone"), and overlying **Moccasin Springs** ("a thicker sequence of dominantly reddish and purplish high-clastic limestone and calcareous siltstone, commonly with greenish mottling"). The base of the limestone sequence of the Bainbridge Formation is separated from the underlying Sexton Creek Limestone by a thin, highly glauconitic, red and green, calcareous, "algal" shale that was named the **Seventy-Six Shale Member** of the Bainbridge Formation by Satterfield and Thompson (1975). This shale is rarely over 1 ft thick in its outcrop area, but may be several feet thick in the subsurface of the Illinois Basin.

Therefore, in Missouri, the Bainbridge Formation is divided into three members: the Seventy-Six Shale, St. Clair Limestone, and Moccasin Springs.

Seventy-Six Shale Member - Satterfield and Thompson (1975, p. 115) stated: "... the Seventy-Six [Shale Member of the Bainbridge Formation] is a green and brick-red, calcareous, partly fissile shale that is extremely glauconitic and contains hematitic 'buttons' that may have been algal in origin. At the type section, the shale is 9 inches thick, the lower 2 inches green, the upper 7 inches brick-red. The hematitic 'buttons' appear to be confined to the upper part, whereas the glauconite is distributed throughout. The thickness of the Seventy-Six Shale Member ranges from a few inches near McClure, Illinois, to near one foot at the type section and up to 2 to 4 feet in the subsurface."

St. Clair Limestone Member - The St. Clair Limestone Member of the Bainbridge Formation is a relatively pure, red and gray, finely crystalline to sublithographic, fossiliferous, glauconitic, medium- to thick-bedded limestone up to 30 ft thick. The contact between the St. Clair and overlying Moccasin Springs is abrupt, but conformable.

Moccasin Springs Member - The Moccasin Springs Member of the Bainbridge Formation is a succession of red to grayish-green, thin- to medium-bedded, argillaceous to silty limestones, and gray to reddish-gray, calcareous shales. The Moccasin Springs is over 120 ft thick in its type region.

DEVONIAN SYSTEM

by

John W. Koenig (1961)

revised by

Thomas L. Thompson (1995)

Devonian rocks in Missouri consist almost entirely of limestone and dolomite. Shale, sandstone, and chert are secondary in quantity and prominence. The rocks of this System are present in nearly all parts of the state (Fig. 14), and have been assigned to 20 formations. The formations range in age from Early to Late Devonian. The older Devonian formations are present in

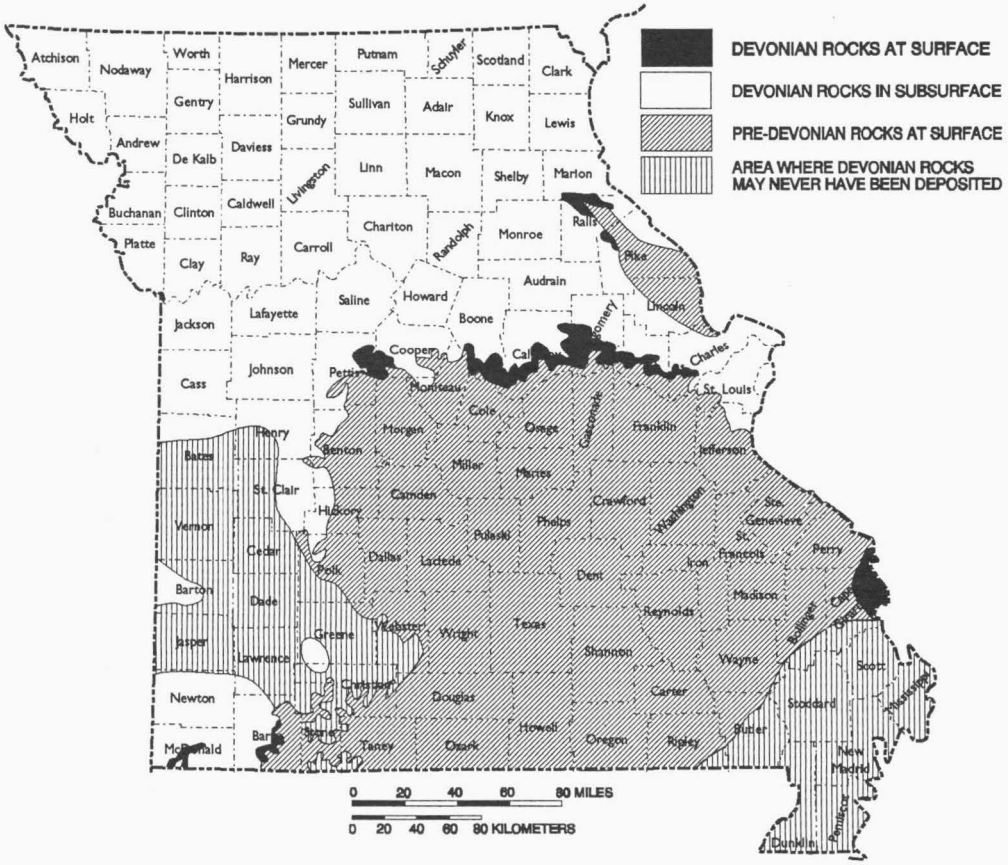


Fig. 14. *Devonian System in Missouri; from Thompson (1993).*

southeastern Missouri, and outliers of Middle Devonian rock occur at a few localities within the area of the Ozark Uplift.

In southeastern Missouri, Devonian rocks are exposed in the area of Ste. Genevieve, Perry, Cape Girardeau, and Scott counties (Fig. 15). They are Early and early Middle Devonian in age and comprise seven formations (in ascending order): the Bailey, Grassy Knob, Little Saline, and Clear Creek (Lower Devonian); and the Grand Tower, Beauvais, and St. Laurent (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. The oldest Devonian formation in Missouri, 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

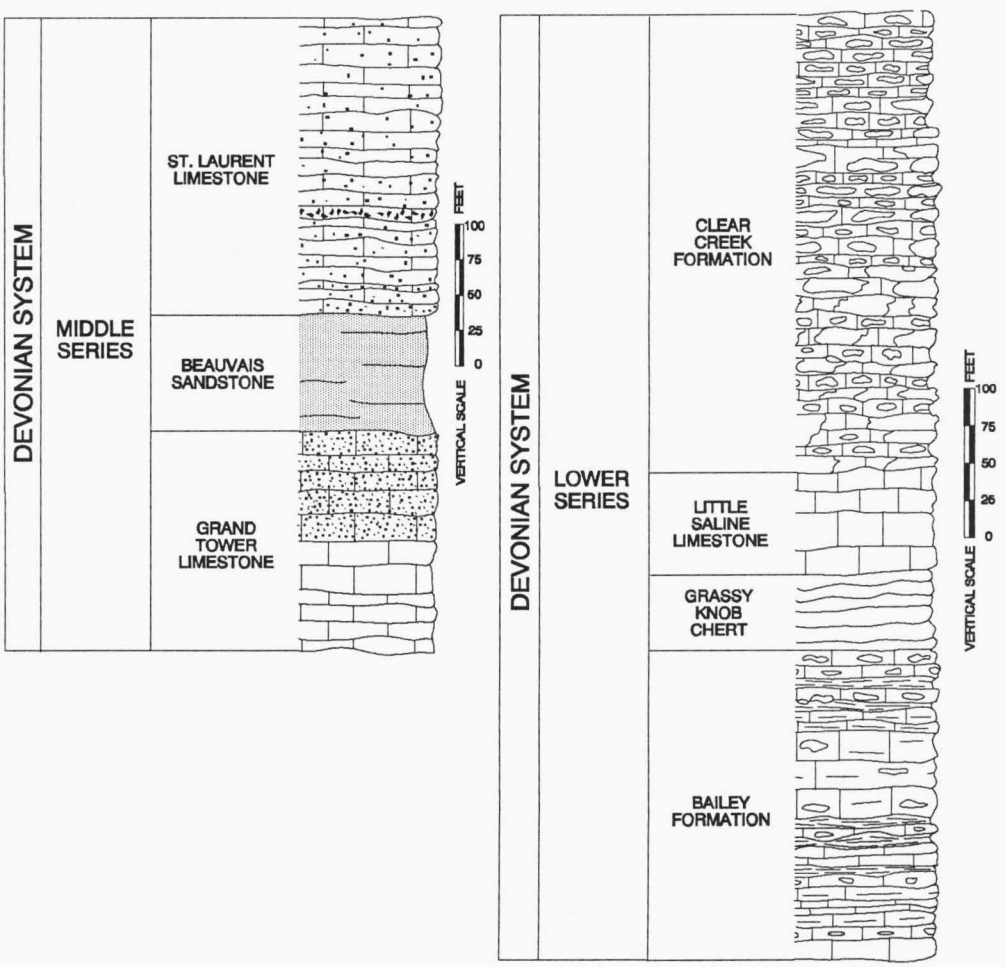


Fig. 15. *Lower and Middle Devonian formations in southeastern Missouri; modified from Thompson (1993).*

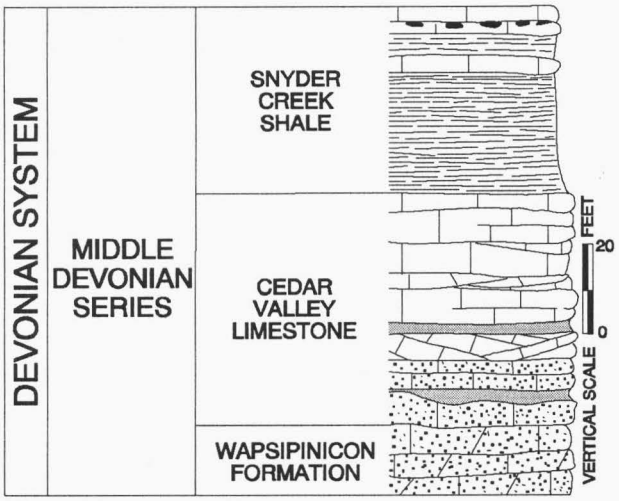
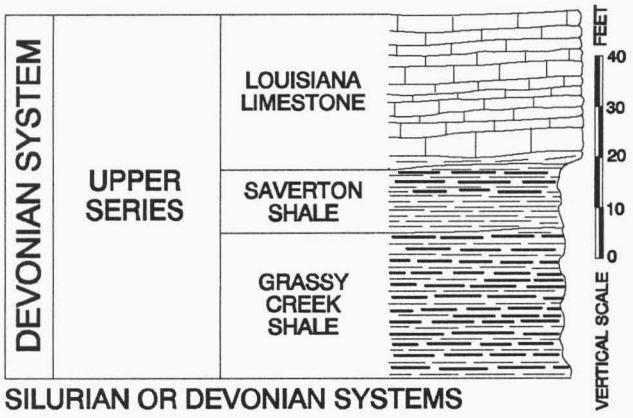


Fig. 16. *Middle Devonian formations in central and east-central Missouri.*

Fig. 17. *Upper Devonian formations in northeastern Missouri; modified from Thompson (1986).*



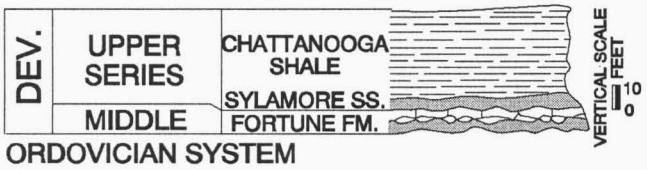


Fig. 18. *Middle and Upper Devonian formations in southwestern Missouri.*

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 ft.

The Devonian rocks of central and east-central Missouri (Fig. 16) are late Middle Devonian and Late Devonian in age. The late Middle Devonian is represented by the Cedar Valley Limestone which is exposed in a narrow belt north of the Missouri River, and in peripheral exposures around the northwest plunging nose of the Lincoln Fold in Ralls County. The early Late Devonian formation, the Snyder Creek Shale, is exposed in a limited area in Callaway and Montgomery counties. The total thickness of the Devonian in these outcrop areas rarely exceeds 50 ft, but in the subsurface where these Devonian beds extend into Iowa and Illinois, the System attains a thickness of about 200 ft.

In northeastern Missouri (Fig. 17), the Late Devonian Grassy Creek, Saverton, and Louisiana formations are present in Ralls and Pike counties, and in the subsurface north and west of these exposures.

In southwestern Missouri, the Devonian System is represented in a small area of central Barry County by the Middle Devonian Fortune Formation, which rarely exceeds a thickness of 6 ft, and in McDonald County by the Late Devonian Chattanooga Shale (Fig. 18).

Missouri's 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 Cedar Valley Limestone 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, thin-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 streaks and blotches. The upper part is a tan , thin- and even-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 ft. 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.

Bailey residuum is present over much of the Cape Girardeau County area, and can be over 100 ft thick. This material may be difficult to distinguish from the Grassy Knob or Clear Creek Cherts.

Grassy Knob Chert - Amos (1985) introduced the name **Grassy Knob** into Missouri by mapping it in the southeastern region. He stated (1986, unpublished manuscript): "...A light- to medium-gray, fine-grained limestone and white, thick-bedded, novaculitic chert...overlies transitionally the Bailey. The

unit, which is deeply leached and weathered, yields a thick residuum of white, unfossiliferous, angular chert fragments. Earlier workers (Flint, 1925, Weller and St. Clair, 1928) failed to recognize the Grassy Knob in the study area [Perry County] and identified it as the Clear Creek Chert. It is about 210 feet thick in the southeastern part of the area but it thins rapidly to the northwest and pinches out in the vicinity of Lithium. This rapid northward thinning and pinching out indicates major post-Grassy Knob – pre-Little Saline erosion in and north of the study area."

As it occurs in isolated outcrops, it is difficult to distinguish Grassy Knob Chert from Clear Creek Chert, or even from residual Bailey chert. Amos' identifications are the only positive ones made, so far. Much study is still required to clear up this stratigraphic puzzle.

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

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

Apparently, some outcrops identified as Clear Creek may, in the sense of Amos, be Grassy Knob. Koenig (1961) placed the Clear Creek as the lowest formation of the Middle Devonian Series, instead of the uppermost Lower Devonian formation, in southeastern Missouri.

Middle Devonian Series

SOUTHEASTERN MISSOURI

Grand Tower Limestone - 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 Grand Tower Limestone is light-gray to almost white, finely to coarsely crystalline, and even-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 very finely 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 ft thick, but in Perry County it thins to about 100 ft. It lies unconformably on the Clear Creek Chert in eastern Perry County and apparently is unconformable on the Little Saline Limestone in Ste. Genevieve County. It merges with no observable sedimentary break with the overlying Beauvais Sandstone.

Beauvais Sandstone- The Beauvais Sandstone is nearly white to yellowish-brown quartzose sandstone which is remarkably similar to the sandstone of the St. Peter (Ordovician). It is about 80 ft 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 Limestone - The limestone of the St. Laurent is gray or bluish-gray, dense, brittle, and thin-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 ft. Its relationship with the underlying Beauvais Sandstone is believed to be conformable. It is unconformably overlain by the Fern Glen Formation (Mississippian) or by sandstone blocks thought to be Bushberg Sandstone.

Central and Northeastern Missouri

Wapsipinicon Formation - As stated by Thompson (1993, p. 108): "The Wapsipinicon in Iowa (Witzke et al., 1988) comprises unfossiliferous dolomite, vuggy dolomite (some with fossil casts), and unfossiliferous and fossiliferous dolomite (Otis and Spillville Formations) associated with breccia zones, gypsum, and anhydrite (Pinicon Ridge Formation). Wapsipinicon rocks are present in the subsurface of northwestern Missouri, as attested by a thick sequence of evaporites identified in the 'Silurian-Devonian' ('Hunton') section in several wells drilled north and east of Kansas City. Wapsipinicon is also present in northeastern Missouri (Woodruff, 1990). At this time, no exposures of the Wapsipinicon are known from Missouri."

The Wapsipinicon Formation can be clearly distinguished from and is not a facies of the Cedar Valley. All Wapsipinicon is older than the base of the Cedar Valley, the latter overstepping the depositional edge of the Wapsipinicon in northern Missouri.

Cedar Valley Limestone - Thompson (1993) proposed to place all strata in Missouri previously called "Callaway Formation" within the Cedar Valley Limestone. He stated (p. 129-130): "The several facies that compose the Cedar Valley Limestone in Missouri have each at some time been given a separate name. The three most widespread facies, **Callaway**, **Cooper**, and **Mineola**, were initially regarded as separate formations (Branson, 1923, 1944a, 1944b).

However, their interbedded nature and areal distribution has led present stratigraphers to regard them as facies within a single formation..."

"Unklesbay (1952) appears to be the first to use a single name for the entire complex, **Callaway Formation**, and identified the facies (including **Ashland**) as members of the Callaway Formation. However, Callaway is itself one of the facies of the Callaway Formation; thus, 'Callaway' stands both for the formation and for one of the facies of the formation..."

(p. 132) "Fraunfelter (1967a) regarded the Callaway Limestone of central Missouri to be a direct correlative of the **Cedar Valley Limestone** of Iowa, and proposed the name **Cedar City Formation** (named from a section just north of Jefferson City, in Callaway County, central Missouri) to reflect this relationship. However, the close similarity of 'Cedar City' to 'Cedar Valley' led the Missouri Geological Survey to reject 'Cedar City' to avoid possible confusion.

"In view of the recent work on Cedar Valley strata in Iowa (Bunker et al., 1986; Witzke et al., 1988), it is herein proposed to identify the complex of Middle Devonian carbonate facies, previously collectively called 'Callaway Limestone,' as the **Cedar Valley Limestone**, thus, clearly defining its relationship to the same-named unit in the type area of Iowa. At this time, Cedar Valley is the most useful name for the unit as a whole, and the reports of Fraunfelter (1964, 1967a, 1967b) are the most definitive on Cedar Valley ('Cedar City') strata in Missouri.

"The Cedar Valley Limestone is present over much of the northern half of the state, and, is over 500 ft (165 m) thick when combined with other limestones of the 'Hunton Group' in the subsurface of northwestern Missouri. However, in Iowa the Cedar Valley has a maximum thickness from 80 to 120 m (Witzke, personal communication, 1990).

"The Cedar Valley in Missouri has generally been considered to be upper Middle Devonian in age. However, Schumacher (1972) identified the uppermost Cedar Valley Limestone and lowermost Snyder Creek Shale to be within the early Late Devonian..."

As defined by Koenig (1961, p. 39-40), "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... 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." The **Callaway facies** a very finely crystalline to sublithographic (mudstone) massive-bedded limestone with numerous fossils, particularly corals (*Hexagonaria*).

A white, friable, quartzose sand cemented with calcium carbonate generally lies at or near the base of the Cedar Valley (**Hoing Sandstone Member** of western Illinois). 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 Cedar Valley is sandy. The thickness of this sand varies from 1 to 5 ft, averaging 2 ft, and the sand is persistent in the Devonian outcrop area in Callaway County. It has been tentatively traced northeastward in the subsurface to exposures in Ralls County.

The lithic characteristics of the Cedar Valley 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 "Devonian limestone" in the subsurface.

In central and northeastern Missouri, the Cedar Valley Limestone lies on an erosion surface and rests on Ordovician formations ranging from Jefferson City to Maquoketa. It is conformably overlain by the Upper Devonian Snyder Creek Shale, or unconformably by younger Upper Devonian shales, but where these are absent, it is overlain by beds of Early Mississippian age. Its thickness is variable. In the outcrop area, it ranges from less than an inch to as much as 60 to 70 ft thick. In the subsurface the Devonian (Cedar Valley in part) thickens to the northwest. In the Forest City Basin, undifferentiated Devonian limestones attain a maximum thickness of about 700 ft.

Southwestern Missouri

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. 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 12 ft, as seen at its type section in southwestern Missouri.

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 Dolomite (Ordovician). It is unconformably overlain in different places by both the Chattanooga (Late Devonian) and the Bachelor and Compton formations (Early Mississippian).

Over most of its extent, the Fortune consists only of 3 to 5 ft of well cemented, highly brecciated white to light gray chert. The carbonate portion of the formation has been leached out, and the residual Fortune chert collapsed to form this resistant bed of chert breccia.

Conodonts and a few fragmentary brachiopods and fish teeth in the formation indicate possible equivalence to the Clifty Formation of northwestern Arkansas, and to the Cedar Valley Limestone.

Upper Devonian Series

CENTRAL AND NORTHEASTERN MISSOURI

Snyder Creek Shale - The Snyder Creek Shale 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, cherty 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 ft to a minimum of less than 10 ft. 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 conformably upon the underlying Cedar Valley Limestone. 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.

Holts Summit Sandstone - Mehl (1960, p. 79) stated: "The Holts Summit [Sandstone] consists of alternating beds of sandstone and noticeably arenaceous shale. In most places the lowest sandstone, the base of the formation, is the most conspicuous, ranging from 6 to 18 inches thick. It is very light gray or white in fresh exposures but weathers to a slightly brown, case hardened surface. It consists of moderately uniform medium size quartz grains that show marked crystal regrowth. The sandstone is well cemented, massively cross bedded, and on its under surface records mud cracks and worm borings. The first sandstone is normally followed by a thickness of 5 to 25 inches of arenaceous clay shale or poorly cemented argillaceous sand, the quartz grains of which are similar to those of the first sandstone. This second unit is color banded, blue-green to brown or light gray. In some exposures this unit contains sandstone lenses or one or more continuous thin sandstone beds. In most places a third sandstone bed is recognized which is very similar to the lowest unit except that the upper sandstone is uniform in thickness, ranging from 5 to 8 inches, and has a somewhat irregular upper surface."

Thompson (1993, p. 158) added: "Mehl (1960) identified Holts Summit over a 30-square mile region in southwestern Callaway County, Missouri. He also recognized a single outcrop in Benton County, and one in Boone County. He gave the average thickness as about 4 ft, with a maximum of not more than 8 to 10 ft. Variations are generally due to irregularities in the lower beds; 5-18 in. differences in a short distance.

"Although roughly the same age as the Turpin Sandstone and Grassy Creek and Saverton Shales (Famennian), the Holts Summit appears to be of local derivation, and has not been linked directly with the other Late Devonian clastic units to the east. Mehl (1961, p. 92) indicated on a correlation chart that the Holts Summit was younger than the Chattanooga-Grassy Creek sequence, equivalent to the Glen Park Limestone of eastern Missouri. The sand grains were most likely derived from the St. Peter Sandstone. At the type section, Holts

Summit strata rest disconformably on the early Late Devonian (Frasnian) Snyder Creek Shale, and are overlain by the Early Mississippian (Kinderhookian) Bachelor Formation and limestones of the Chouteau Group. The lower part of the basal sandstone is conspicuous in that the black and gray cross-bed laminae are composed almost entirely of conodonts; including the form-genera *Palmatolepis, Ancyrodella, Ancyrognathus, Nothognathus*, and *Icriodus*."

Turpin Sandstone - The Turpin Sandstone is a pale-buff, brown, to reddish-brown sandstone at the base of the Grassy Creek Shale in northeastern Missouri, which Mehl (1960) named the **"Turpin sandstone member of the Grassy Creek shale."** He proposed that use of the name "Sylamore" be suppressed in Missouri because of some doubt he had about correlation of the Sylamore Sandstone at its type section in Arkansas with that in Missouri.

In areas of Missouri where the "Sylamore" is definitely of Mississippian age, and is not correlative with the Late Devonian Sylamore at its type section in Arkansas, Mehl (1960) proposed the name **Bachelor Formation. Sylamore Sandstone** has been retained for those sands in southwestern Missouri and northwestern Arkansas that are related to the Late Devonian Chattanooga Shale (Thompson and Fellows, 1970). The name **Turpin Sandstone** was used in a study of strata in northeastern Missouri by Thompson and Satterfield (1975).

Over most of its extent, the Turpin Sandstone is represented by a very thin (0.5-1 in.) sand and conglomerate beneath the Grassy Creek. Only locally is it very thick, such as around 5 ft at the type section. The Turpin rests unconformably on rocks ranging from the Late Ordovician Maquoketa Shale to Early Silurian Bowling Green Dolomite (Thompson and Satterfield, 1975), and is always overlain by the Late Devonian Grassy Creek Shale.

The relationship of the Turpin Sandstone to the Grassy Creek Shale appears to be analogous to the Sylamore-Chattanooga Shale relationship, the sandstone (Turpin-Sylamore) a near-shore facies of the deeper-water black, carbonaceous shale (Grassy Creek-Chattanooga).

Grassy Creek Shale - The Grassy Creek Shale 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 in. 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 1-3 ft thick (Turpin) or by a soft, arenaceous, greenish-gray shale approximately 1 ft 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 ft. 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 Shale of Iowa. Well cuttings of the Grassy Creek are indistinguishable from cuttings from the overlying Saverton Shale; 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 Shale is conformable. The Grassy Creek extends into west-central Illinois and is generally considered to be equivalent to part of the Chattanooga Shale of Tennessee and to the New Albany Shale of Indiana and Kentucky. It is possibly equivalent in part to 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 of southwestern Missouri, Arkansas, and Oklahoma.

Saverton Shale -The Saverton Shale is a greenish-gray or bluish-gray, fissile, silty, and sandy clay 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 in. to 2 ft thick. In northern Pike County, in the type area of the Grassy Creek Shale, the Saverton is 14 ft thick. From there 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 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 Limestone. However, in those areas where the sandstone of the Saverton lies directly beneath the Louisiana, the contact is sharp. In areas where the Louisiana is absent the Hannibal Shale rests upon the Saverton, and the contact is obscure.

Louisiana Limestone - The Louisiana Limestone in its type area is typically a dense to lithographic, bluish-gray, hard, brittle limestone which breaks with conchoidal 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 dolomitic limestone. The dolomitic limestone is interbedded with silty clay-like dolomitic partings. Scattered irregular masses of clear, very coarsely crystalline calcite

2 to 3 in. in diameter are common throughout the formation. The lowest bed of the Louisiana is about 15 in. 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 in. 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 ft. 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 ft 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 is conformable with the underlying Saverton Shale because the adjacent mudstones of the two formations appear to merge one into the other and to have similar faunas. However, 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, 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. In this latter case, however, faunal evidence indicates a disconformity.

Southwestern Missouri

Sylamore Sandstone - The name Sylamore was originally proposed for sandstones associated with the Late Devonian Chattanooga Shale in northern Arkansas. As described by Manger et al. (1988) it is "...a white to brown, medium- to coarse-grained orthoquartzite with abundant phosphatic detritus and chert sand and gravel. It usually is thin to medium bedded, nonresistent and ranges in thickness from 0 to more than 20 feet across northern Arkansas."

Several tongues of this sandstone interfinger with the Chattanooga. In some exposures the shale is absent, and the various tongues of sandstone rest on one another, so that two or three different ages of Late Devonian sandstones are present in one section (Thompson and Fellows, 1970). The thin basal sandstone of the **Bachelor Formation**, generally light-green and often including phosphatic material, sometimes rests on the Chattanooga Shale or Sylamore Sandstone, and on older (Early Ordovician) strata elsewhere.

Thompson and Fellows (1970) have shown that the previously reported widespread distribution of the Sylamore Sandstone actually reflects that of the Bachelor. The Sylamore is much more restricted in Missouri, primarily to just a few sections in southwestern Missouri counties (Thompson and Fellows, 1970; Thompson and Satterfield, 1975), and scattered exposures in eastern Missouri.

The **Turpin Sandstone** of northeastern Missouri contains the same conodont fauna, and is in the same position relative to the Grassy Creek Shale, as the Sylamore is to the Chattanooga Shale in southwestern Missouri and

Arkansas. The Turpin has been identified as "Sylamore Sandstone" in western Illinois (Collinson and Atherton, 1975, p. 122).

Regionally, the base of the Sylamore is conformable in the small area of southwestern Missouri where it is underlain by the Chattanooga. Often, however, Sylamore rests unconformably on Early Ordovician dolomites. The upper contact is unconformable with the overlying Middle Kinderhookian (Early Mississippian) Bachelor. Thickness varies from 0 to 6 ft in southwestern Missouri.

Chattanooga Shale -The Chattanooga Shale 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 ft in the vicinity of the town of Noel and along Mill Creek. It may be as thick as 50 ft in the vicinity of Powell, in eastern McDonald County, but it thins eastward to 10 or 12 ft in Barry County and feathers out in the subsurface near the eastern 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 ft thick are recorded in the well records of Greene County and western Christian County, and a few exposures 2 to 3 ft thick occur along the James River in Christian County a few miles southwest of Nixa.

The black shale rests unconformably on Lower Ordovician dolomite (Jefferson City and/or Cotter Dolomites) in southwestern Missouri. It is unconformably overlain by the Bachelor and Compton formations of Early Mississippian age. 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 present as part of the "Kinderhook shale" sequence of Missouri.

EAST-CENTRAL AND CENTRAL MISSOURI

SULPHUR SPRINGS GROUP - Thompson (1993, p. 195) stated: "The Sulphur Springs Group comprises three formations, two of which are Late Devonian (unnamed lower shale and Glen Park Limestone), and one that has been identified as either Early Mississippian? or Late Devonian in age (Bushberg Sandstone). Although at least two of the three formations of the Sulphur Springs (Bushberg and Glen Park, [Fig. 19]) have been frequently referred to, the unnamed lower shale at the base has been referred to only a few times. Weller and St. Clair (1928) proposed a fourth member for the formation, a black shale above the Bushberg Sandstone.

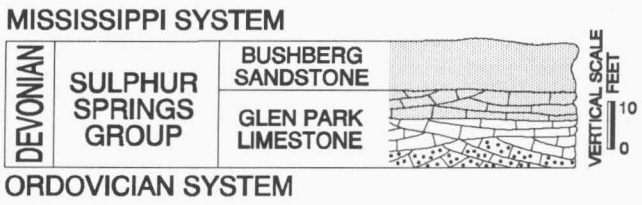


Fig. 19. *Upper Devonian Sulphur Springs Group of east-central Missouri; modified from Thompson (1986).*

"Both the Bushberg and Glen Park have been problematic units over the years, their stratigraphic positions within either the Devonian or Mississippian vacillating with changing view points. At some sections ... the Glen Park appears to be a sandy and sparsely oolitic limestone in the base of the Bushberg; conodonts do indicate a definite Late Devonian age for this limestone. However, attempts to recover a definitive conodont fauna from the Bushberg have been futile. Those specimens recovered are highly worn and broken fragments of Late Devonian forms. The only useful fauna, cited from the Bushberg by Branson and Mehl (1934), was actually recovered from the Early Mississippian Bachelor Formation, which directly overlies the Bushberg (see p. 73, fig. 65, of Thompson, 1986)."

"unnamed lower shale" - The "unnamed lower shale" of the Sulphur Springs Group is usually less than 5 ft thick, and is probably equivalent to the Grassy Creek Shale of northeastern Missouri. In the type region of eastern Jefferson County, this shale rests on the Kimmswick Limestone (Middle Ordovician) or the Maquoketa Shale (Upper Ordovician)

Glen Park Limestone - The Glen Park Limestone is a light- to medium-gray or yellowish-gray, oolitic, arenaceous 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, cross-bedded, and 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. 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 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 Ste. Genevieve County, the cross-bedded, oolitic limestone is about 14 in. thick. It crops out as a single bed 2.5 ft thick at the type locality in Jefferson County. In west-central St. Charles County, it is approximately 30 ft thick with a 6-ft 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 (Horton Creek Limestone) which lies between the Louisiana and Hannibal formations in southwestern Illinois.

Bushberg Sandstone- The term Bushberg was applied to several different sandstones of different ages, some Mississippian, others Devonian. Koenig (1961) restricted the name to the sandstone which occurs in the immediate area of the formation's type locality in eastern Jefferson County. Here, the formation is approximately 14 ft 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 Bushberg Sandstone can be recognized from exposures in St. Charles County south to Jefferson County. Regionally, it conformably overlies the Glen Park Limestone, but is unconformably overlain by the Bachelor Formation of Kinderhookian (Early Mississippian) age.

The lower part of this sandstone is gradational with Glen Park sandy limestone in St. Charles County. Here, the Glen Park is definitely Late Devonian in age. Thus, by inference, the Bushberg is also considered Late Devonian.

MISSISSIPPIAN SYSTEM

by
Alfred C. Spreng (1961)
revised by
Thomas L. Thompson (1995)

Rocks of Mississippian age are widely exposed in the northeastern, central, and southwestern parts of Missouri (Fig. 20). 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; Kinderhookian, Osagean, Meramecian, and Chesterian. The series are separated by unconformities (except for the Osagean-Meramecian boundary) that are not particularly noticeable at any one locality or local area; therefore, the series have been defined almost entirely on the basis of paleontologic data.

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

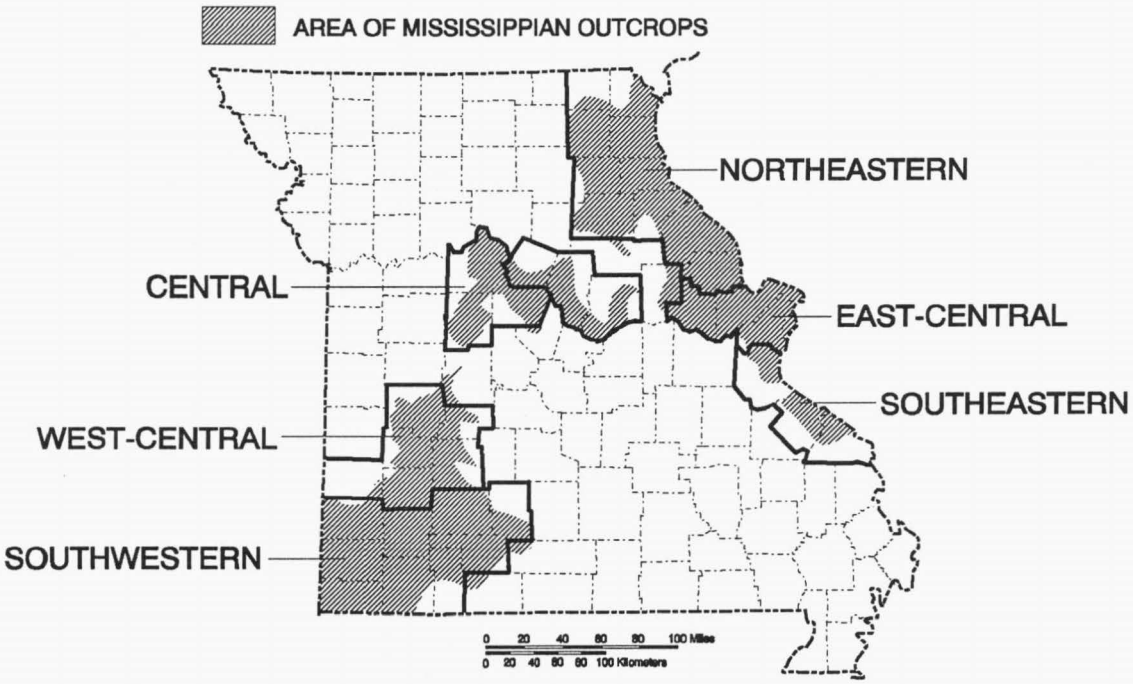


Fig. 20. *Areas of exposure of Mississippian formations in Missouri.*

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, such as the Grand Falls Chert, 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 (Fig. 20): northeastern, east-central, southeastern, central, southwestern, and northwestern.

In **northeastern Missouri** (Fig. 21) the Mississippian System is represented by 10 formations which are assigned to the series as follows: Horton Creek, Hannibal, Chouteau Group undifferentiated, and "McCraney Limestone" (Kinderhookian), Burlington and Keokuk (Osagean), and Warsaw, Salem, and St. Louis (Meramecian), and Ste. Genevieve (Chesterian). Except for the

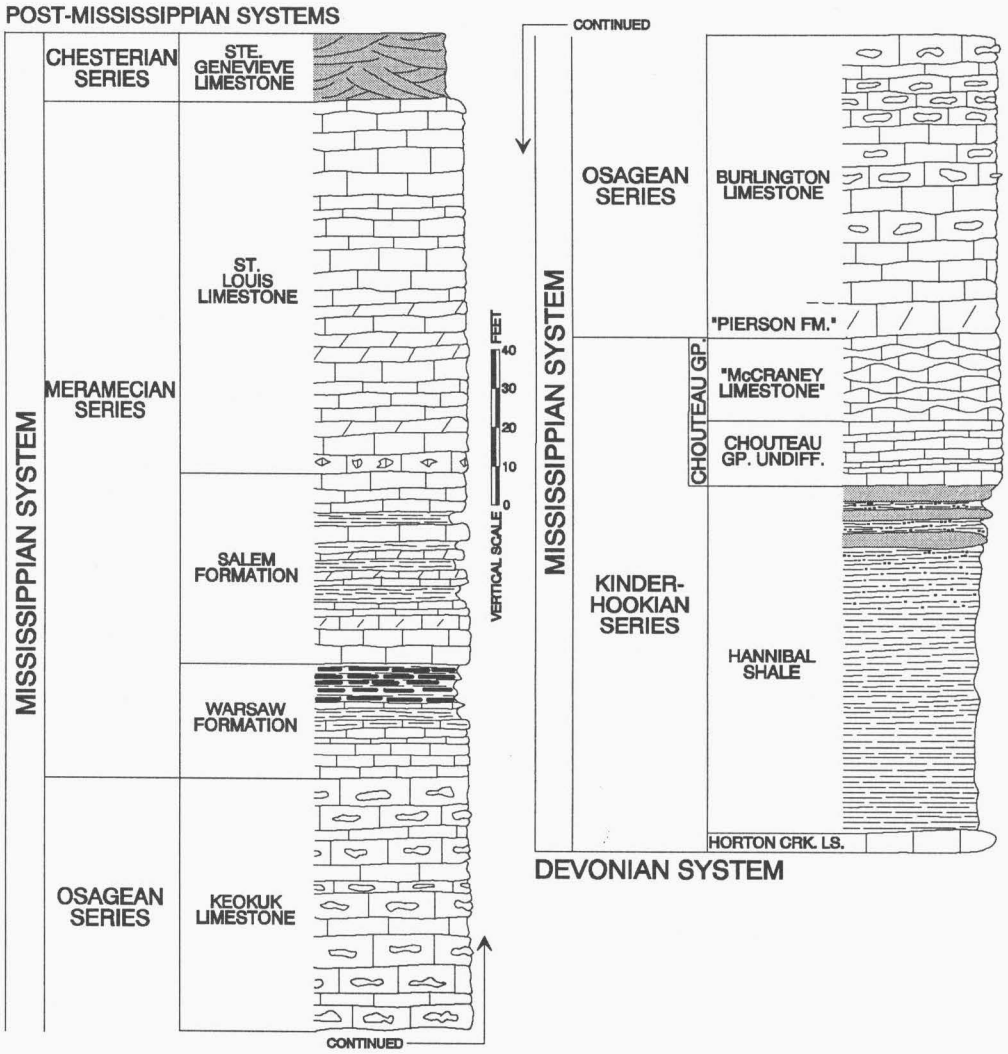


Fig. 21. *Mississippian formations in northeastern Missouri; from Thompson (1986).*

Hannibal Shale which is composed of shale and siltstone, the Mississippian 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 ft.

All the major time-stratigraphic divisions of the Mississippian System are represented in the **east-central and southeastern** areas of the state (Figs. 22 and 23). The Bachelor and Chouteau (Kinderhookian); the Fern Glen, Burlington, and Keokuk (Osagean); the Warsaw, Salem, St. Louis (Meramecian); and the Ste. Genevieve, Aux Vases, Renault, Yankeetown, Paint Creek, Cypress, Golconda, Hardinsburg, Glen Dean, Tar Springs, and Vienna (Chesterian). The aggregate thickness of the Mississippian in this part of the state is about 1,250 ft.

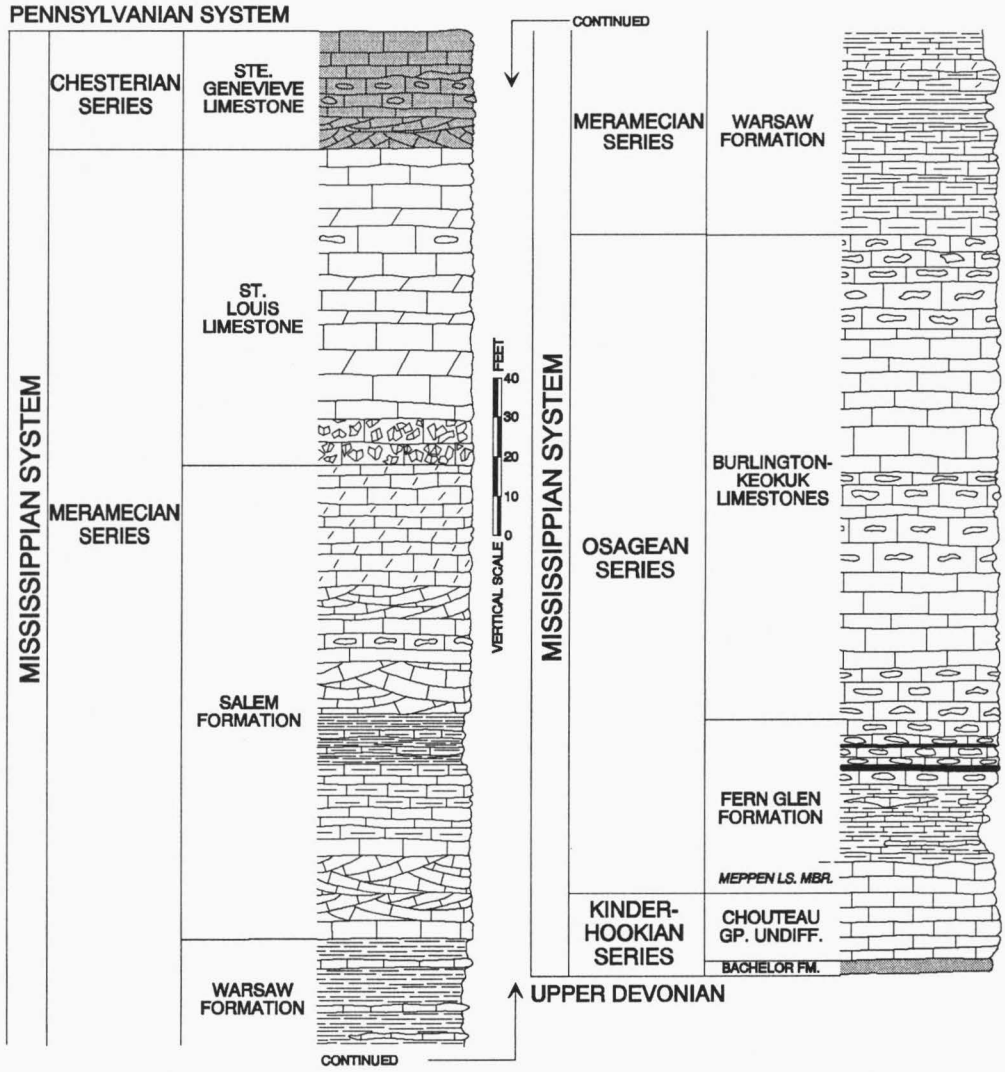


Fig. 22. *Mississippian formations in east-central Missouri; modified from Thompson (1986).*

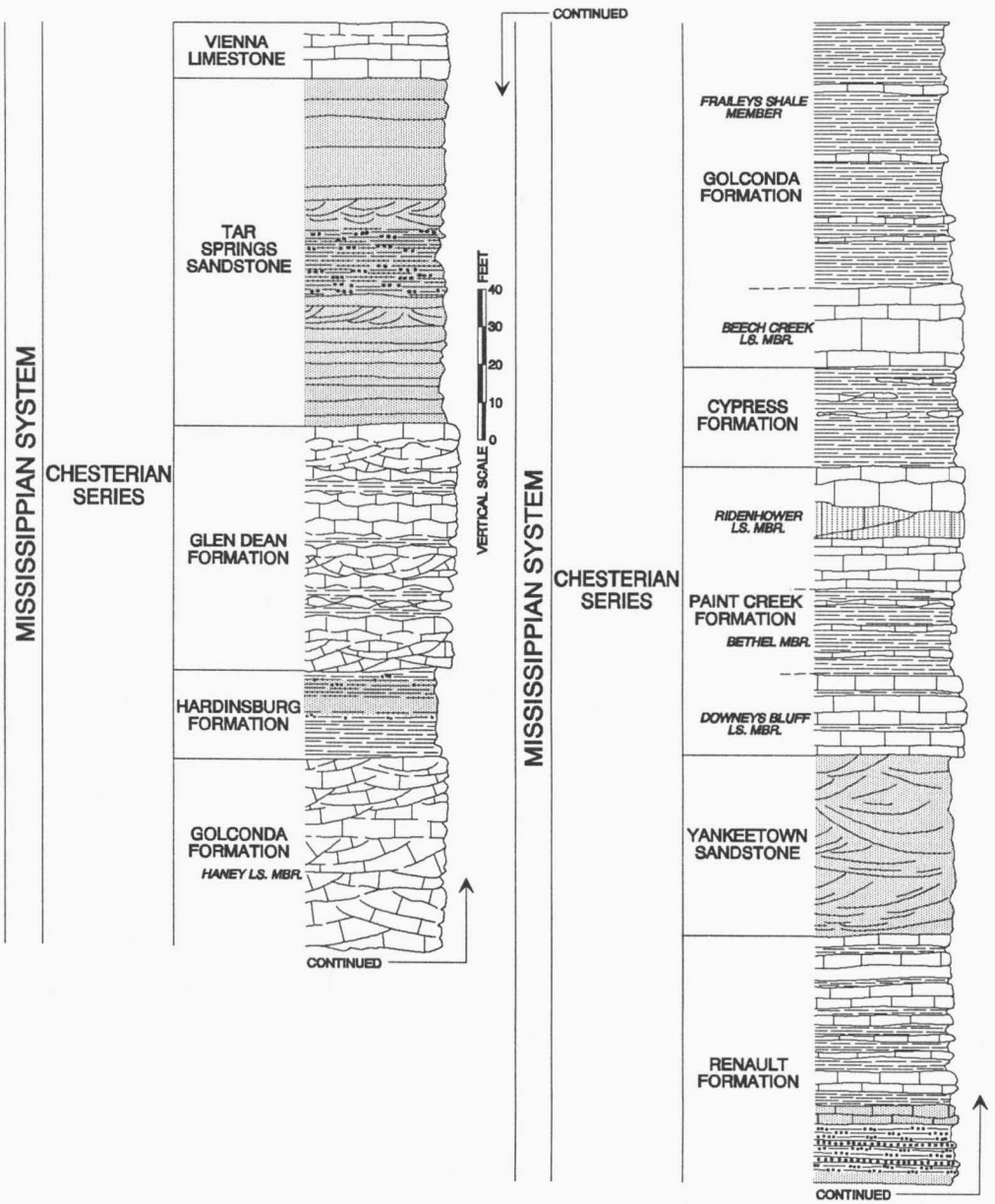
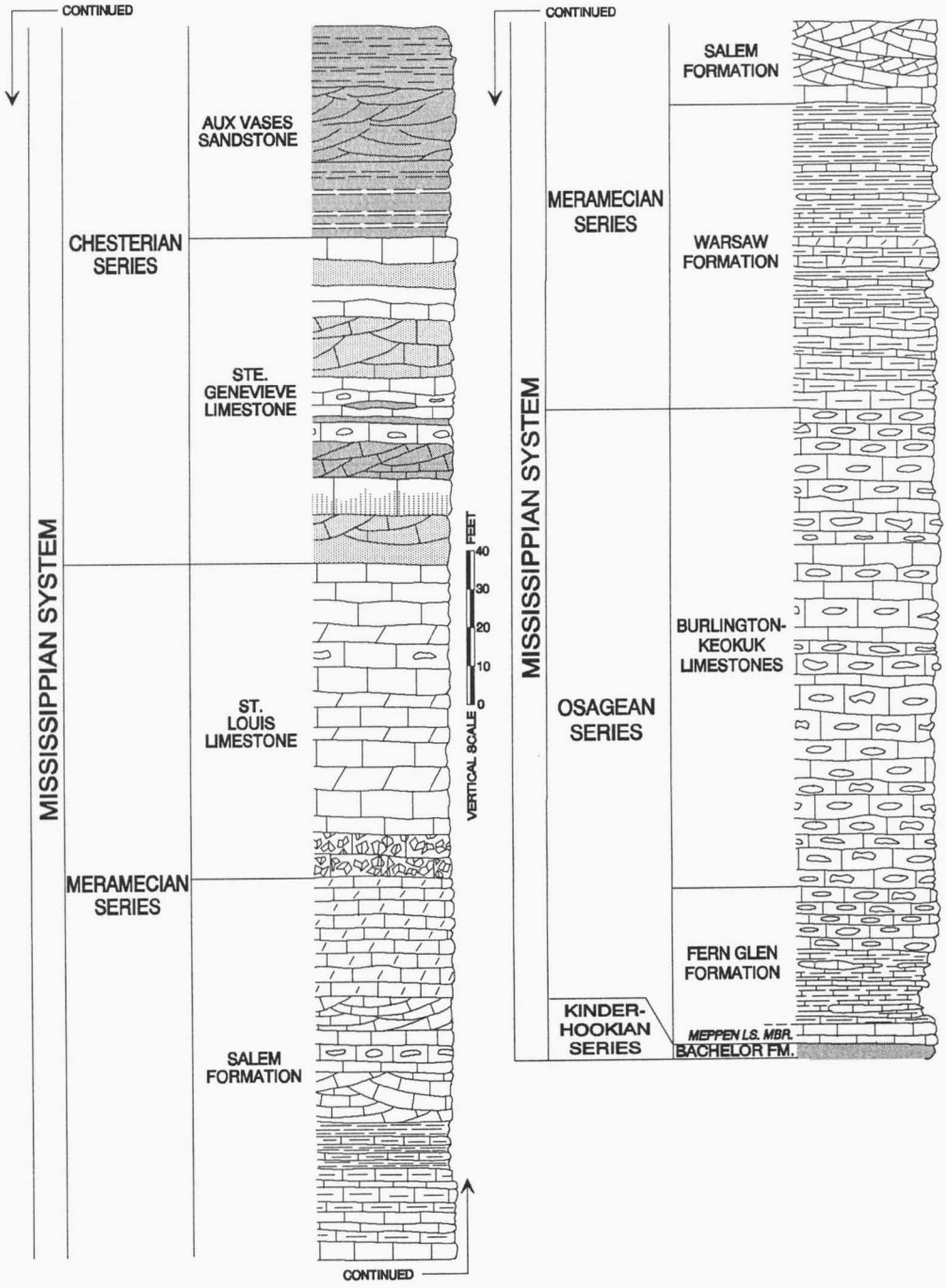


Fig. 23. *Mississippian formations in southeastern Missouri:*


CONTINUED
MISSISSIPPIAN SYSTEM
CHESTERIAN SERIES
MERAMECIAN SERIES
AUX VASES SANDSTONE
STE. GENEVIEVE LIMESTONE
ST. LOUIS LIMESTONE
SALEM FORMATION
VERTICAL SCALE FEET
40
30
20
10
0
CONTINUED
CONTINUED
MISSISSIPPIAN SYSTEM
MERAMECIAN SERIES
OSAGEAN SERIES
KINDER-HOOKIAN SERIES
SALEM FORMATION
WARSAW FORMATION
BURLINGTON-KEOKUK LIMESTONES
FERN GLEN FORMATION
MEPPEN LS. MBR.
BACHELOR FM.

The Mississippian System in **central Missouri** (Fig. 24) is about 400 ft thick and is composed mostly of carbonate rocks and chert; the Compton, Sedalia, and Northview, together form the Chouteau Group (Kinderhookian); the Pierson, Burlington, and Keokuk (Osagean), and the Warsaw and Salem (Meramecian). 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 (Fig. 25) 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 this region, the Kinderhookian is represented by the Bachelor Formation, and the Compton, Sedalia, and Northview formations of the Chouteau Group. Southward, the Sedalia appears to eventually pinch out so that at the southern limit of the region only the Bachelor, Compton, and a thin Northview remain. The lower part of the

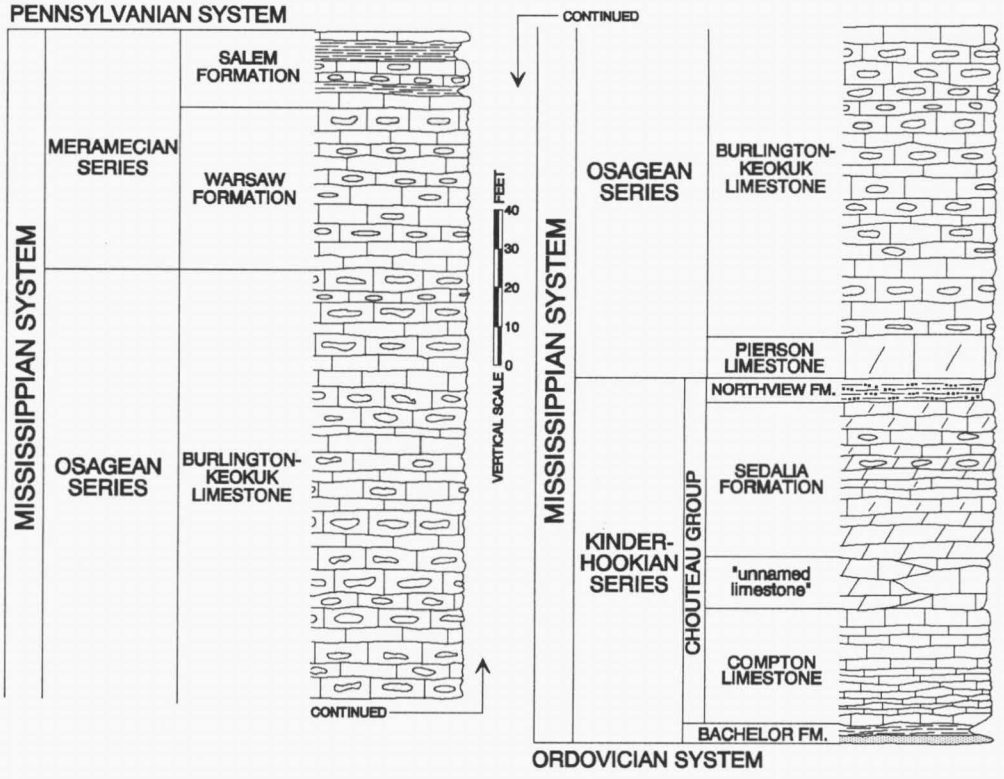


Fig. 24. *Mississippian formations in central Missouri; from Thompson (1986).*

Osagean Series is represented in the northern part of this region by the Pierson Limestone which is here a thin bed of silty, dolomitic limestone. Southward, the Pierson thickens and changes to a limestone and cherty limestone, and as it approaches the southern limits of the region, it becomes a thick, varicolored red and green, argillaceous limestone which in many respects resembles the Fern

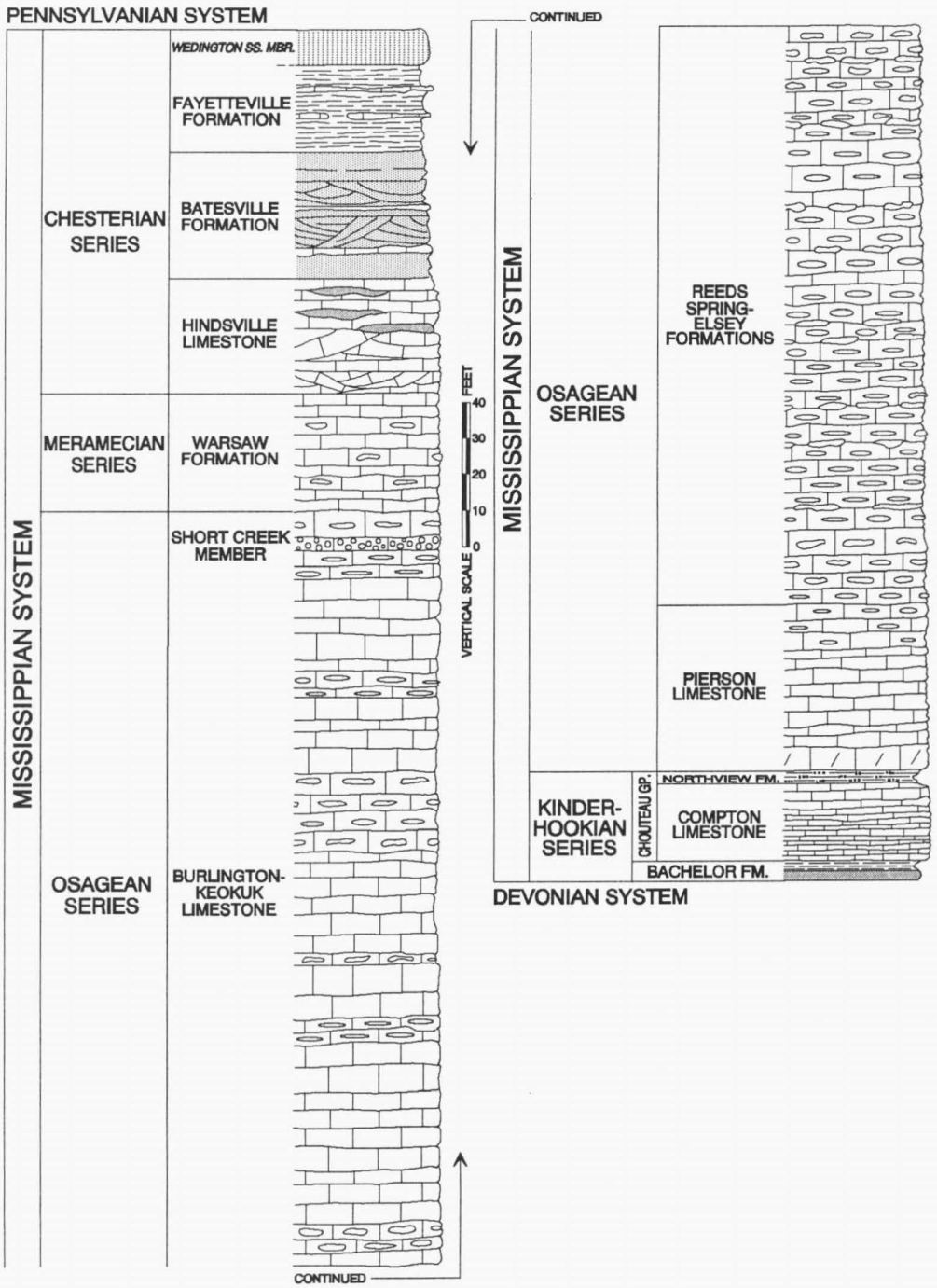


Fig. 25. *Mississippian formations in southwestern Missouri; from Thompson (1986).*

Glen Formation of southeastern Missouri. The balance of the Osagean Series consists of four formations; two cherty limestone units (Reeds Spring and Elsey) overlain by two units predominantly of limestone, the Burlington, and Keokuk Limestones. The Burlington and Keokuk are very similar in their lithologies. Their formational contacts are difficult to determine. Throughout most of southwestern Missouri, it is becoming more useful to group these formations into two collective units; the Reeds Spring-Elsey and the Burlington-Keokuk. In adjacent parts of Arkansas and Oklahoma, all four units have been collectively designated as comprising the "**Boone Formation;**" the Compton through Pierson interval identified as the "**St. Joe Limestone Member of the Boone**" (or "**St. Joe Limestone**"). The Meramecian Series is represented principally by the Warsaw, which is lithologically similar to formations in the underlying Osagean, but is somewhat less cherty. The Salem is questionably present, and the St. Louis is restricted to the relatively small area of eastern Barton and western Dade counties.

The Chesterian Series in southwestern Missouri is represented by outliers of a more extensive region of outcrop in Arkansas and Oklahoma. A limestone ("Carterville formation") in the area of Joplin is interpreted as being composed of local filled-sink deposits in older Mississippian rocks. It is also known from isolated exposures to the south, and has been interpreted to be outliers of the Hindsville Limestone. 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). The aggregate thickness of the Mississippian System in the southwestern region is about 1,000 ft.

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, and St. Louis, are readily differentiated. Formations of Chesterian age, except for Ste. Genevieve, have not been identified in the area. The aggregate thickness of the System in northwestern Missouri is about 515 ft.

Kinderhookian Series

The type area for the Kinderhookian Series is in northeastern Missouri (Fig. 26) and in adjacent parts of Illinois and Iowa. Here, the Series is represented by the Hannibal Shale, which is a thick shale and siltstone unit, and by an overlying limestone unit, the Chouteau Group, that is more commonly referred to in older reports as the "Chouteau limestone."

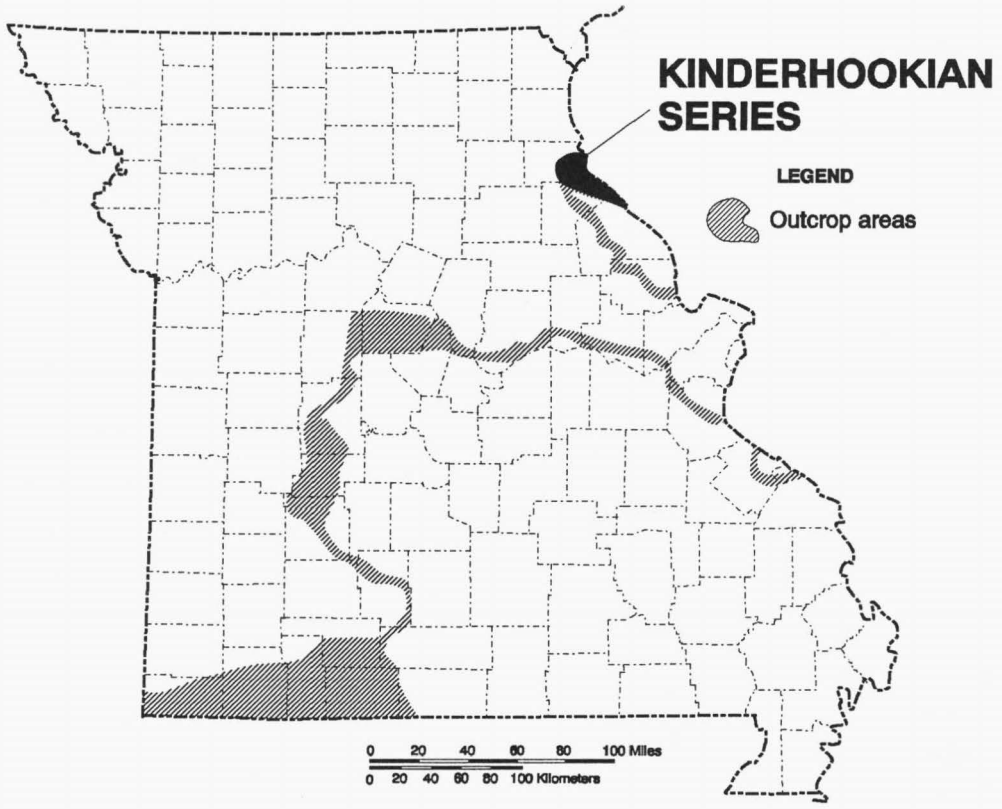


Fig. 26. *Areas of exposed Kinderhookian rocks in Missouri (shaded areas) and location of type area for the Kinderhookian Series.*

South and west of the northeastern area, the Hannibal is absent, but the limestone of the 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, occur above the "Chouteau limestone." Together, these three units form the Chouteau Group, and the lower unit is herein referred to as the Compton Limestone. In older reports this lower 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 to a shaly limestone, and the Compton becomes thinner.

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 and is identified as the Bachelor Formation, which is usually composed of a lower sandstone and upper shale. In extreme southwestern Missouri, only the shale member is present.

"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 Missouri Department of Natural Resources' Division of Geology and Land Survey 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 (1946) and Lee to the **Boice Shale** 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 dark-red shale. This interval may also include irregular-shaped, hematitic oolites in the upper part. The thickness of the unit varies between 25 and 50 ft. Below the lower hematitic oolite zone, there is a black, fissile, carbonaceous shale which is micaceous, and contains spores 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 ft in Holt and Atchison counties.

The "Kinderhook shale" contains both Late Devonian (Chattanooga or Grassy Creek equivalents) and Early Mississippian (Hannibal equivalent) shales.

Horton Creek Limestone - Originally identified as the "**Hamburg oolite**" (Weller, 1906), and later as the **"Glen Park" formation** (Collinson, 1961, the quotes to distinguish this unit from the Glen Park Limestone of the Sulphur Springs Group), Conkin and Conkin (1973) identified a limestone unit between the Louisiana Limestone and Hannibal Shale as the Horton Creek Limestone ("Member of the Hannibal Shale"). It consists of a basal siltstone, succeeded by silty shale, and usually a dolomitic limestone or limestone that is oolitic, and often conglomeratic, at its base. The Horton Creek, exposed in several places in west-central Illinois, is not well-known from exposures in Missouri, but limestone lenses and beds in the lower part of the Hannibal Shale in Missouri may be equivalent to the Horton Creek of west-central Illinois.

Hannibal Shale - The Hannibal Shale ranges from a clay shale to silty shale to siltstone; often the upper part is a very fine-grained, argillaceous sandstone. It is typically light-gray to bluish-green, 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 Hannibal crops out throughout the northeastern Mississippian region. Its thickness is variable and reaches a maximum of approximately 100 ft in southeastern Pike County. It thins westward and southward from this area, but has been identified from core in Randoph County.

Fossils are sparse and are generally pyritized; brachiopods and pelecypods are major constituents of the fauna. However, well preserved ammonoids have been recovered from Hannibal at some sites. "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 Shale was originally named the "Vermicular shale and sandstone."

The Hannibal appears to be disconformable on the Late Devonian Louisiana Limestone. Locally it is in contact with the Grassy Creek (Late Devonian), Cedar Valley (Middle Devonian), or Maquoketa (Late Ordovician). It is overlain by limestone of the Chouteau Group in a few places, but where the Chouteau is absent, particularly in the eastern part along the Mississippi River Valley, the Hannibal is overlain by the Burlington Limestone.

Bachelor Formation - The Bachelor Formation comprises a characteristic thin (3-in. to 1 ft), light-green to tan, quartzose sandstone, with a calcareous "glint" (poikilitic) cement. It usually contains phosphatic debris and nodules, and often chert fragments from underlying strata. In central, western, and southwestern Missouri, a thin sandy gray to green calcareous shale overlies this sandstone and underlies the basal carbonate (Compton Limestone), forming a two-member unit for the Bachelor. In extreme southwestern Missouri and northeastern Oklahoma, the shale persists, while the sandstone member disappears.

The sandstone member has been variously correlated with the Sylamore Sandstone of Arkansas (a facies of the Upper Devonian Chattanooga Shale) and with the Upper Devonian Bushberg Sandstone of eastern Missouri. Mehl (1960, 1961) proposed the name Bachelor to replace "Sylamore" for the basal Mississippian sandstone.

CHOUTEAU GROUP - The Chouteau Group, as it is defined at its type locality in central Missouri, is composed of (in ascending order): the Compton, a fine- to medium-crystalline limestone; an unnamed, sublithographic limestone; the Sedalia dolomitic limestone; and the Northview shale and siltstone.

Within the type area (Pettis, Saline, Howard, and Cooper counties), the Chouteau attains a maximum thickness of more than 100 ft. Exposures 50 to 75 ft 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 "unnamed limestone" and the Sedalia merge.

In northeastern Missouri this combined unit has been designated as "Chouteau Group undifferentiated." This unit consists of bluish-gray, finely crystalline limestone which becomes more dolomitic and more massive-bedded in the upper part and thus resembles the Sedalia lithology of the type area. At some localities the lower limestone is finely to medium-crystalline. The upper part is an almost lithographic mudstone called "McCraney Limestone" by Thompson (1986). 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 ft, but in parts of Pike, Ralls, and Marion counties, it is much thinner or absent.

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 ft, and the Northview thickens at the expense of the "unnamed limestone" and the Sedalia. 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 to an argillaceous limestone 1 to 2 ft thick, and the Compton also thins to less than 10 ft in this same area.

Compton Limestone - The Compton Limestone is a finely crystalline to sublithographic limestone with scattered small crinoid segments. It is characteristically very even-bedded, and weathers to thin incipient nodular or wavy beds, separated by green shale partings. Thus, weathered exposures of the formation are characteristically slabby or hackly in appearance, and exhibit an abundance of small crinoid columnals which stand out in relief on the surface of the rock. Where the formation is locally dolomitic, it is brown and massive. Chert is locally present, but not abundant. Chert usually is present only in southwestern counties, in the vicinity of small dome-shaped bioherms. The chert is bluish-gray to bluish-black to pink.

The Compton lithology is consistent at the base of the Mississippian carbonate succession from extreme southwestern Missouri through central Missouri (type Chouteau - Cooper County) into east-central Missouri (St. Charles County). In central Missouri the Compton is the basal formation of the Chouteau Group, and the entire Chouteau in St. Charles County appears to be Compton.

In the type area of the Chouteau Group in Cooper County, the Compton is less dolomitic than the Sedalia, and usually is chert-free. Compton is also thinner and more even-bedded and fossiliferous than the Sedalia. Within this area it has an average thickness of less than 20 ft.

In central Missouri, east of Pettis County, and in northeastern Missouri, the Compton, "unnamed limestone," and Sedalia lithologies interfinger and form an indivisible unit of limestone and dolomitic limestone - the "Chouteau Group undifferentiated."

"unnamed limestone" - In the type region of the Chouteau Group (Cooper County, central Missouri), is a succession of interbedded lithographic limestone and dolomitic limestone. There is no chert in this zone, and it is identifiable as a separate unit between Compton below and the cherty dolomitic limestone of the Sedalia above. Clark and Beveridge (1952) called this unit the "Sedalia-Compton transition beds." This unit is about 10 ft thick in the vicinity of Sedalia, in Pettis County.

Sedalia Formation -The Sedalia Formation is typically a medium- to thick-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 in west-central Missouri is about 50 ft. 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. Farther south it is absent or unrecognizable. East of Pettis County, the "unnamed limestone" disappears, leaving only the Compton and Sedalia formations.

Northview Formation-The Northview Formation consists of brown to buff, and 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 ft 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. The formation is locally fossiliferous, the fauna consisting chiefly of pyritized and limonitized internal molds of brachiopods. The lithologic character of the Northview, together with the formation's tubular-shaped perforations (worm burrows) and abundant "rooster tail" markings (*Taonurus caudagalli*), were causal factors for the formation being named the "Vermicular siltstone" in earlier reports (as was the Hannibal Shale in northeastern Missouri). Northward, in the area of Cedar County, the formation laterally interfingers with the underlying Sedalia. Farther north the Sedalia thickens at the expense of the Northview.

In central Missouri the thickness of the Northview ranges from 2 to 3 ft, 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 disconformable.

The Northview extends from the Missouri River, in central Missouri, southward into Arkansas. Its maximum thickness of 80 ft occurs along a northwest trend through Greene to Barton County. It thins eastward from Pettis County to a few inches thick in Montgomery County. The Northview cannot be traced into northeastern Missouri; its stratigraphic position is somewhere within the Hannibal Shale.

In southwestern Missouri the Northview thins rapidly from a maximum of about 80 ft in Greene County, to less than 6 ft in Christian County, and to as thin as 1-2 ft in McDonald and Barry counties. In Stone and Taney counties, the Northview is around 10 ft thick, being primarily calcareous shale and shaly limestone. The upper 2 to 4 ft is a distinctive dark-brick-red, and is predominantly a limestone. This red, upper part of the Northview is very widespread across the southwestern tier of Missouri counties into northern Arkansas. It was named the Baird Mountain Limestone Member of the Northview Formation by Thompson and Fellows (1970).

Baird Mountain Limestone Member- Thompson (1986, p. 59) stated: "Near the Missouri-Arkansas border, the grayish-green Northview calcareous shale (or argillaceous limestone) is capped by a dark-red fossiliferous argillaceous limestone 1 to 3 ft thick...Because this thin unit is transitional with the Northview beneath it and distinctly older than the immediately overlying Osagean Pierson Limestone, it was designated the Baird Mountain Limestone Member of the Northview Formation by Thompson and Fellows."

"Chouteau Group undifferentiated" - In northeastern Missouri, limestones of the Chouteau Group have not been identified as separate formations. Where present between the Hannibal Shale and Burlington Limestone, these limestones are designated "Chouteau Group undifferentiated."

Two facies are present. One is a very finely crystalline to sublithographic, dark-gray mudstone, usually appearing as wavy-bedded units with thin undulating shale partings. The other is a finely to medium-crystalline, light-gray limestone. The mudstone was designated the "**McCraney Limestone**" by Thompson (1986). He stated (p. 63): "A limestone of peculiar blocky bedding and very dense, compact ('sublithographic') lithology, the McCraney Limestone of western Illinois, was...regarded as equivalent to the Chouteau of eastern Missouri..."

"In Missouri, rocks of McCraney-like lithology, herein called 'McCraney Limestone,' are known from quarries in northeastern Missouri, where they overlie a crystalline limestone of the 'Chouteau group undifferentiated.' These McCraney-like rocks may be related to, or [are] a western continuation of, the restricted McCraney Limestone of western Illinois...In Knox County, it lies on the previously described crystalline facies of the Chouteau Group, whereas in Montgomery County it appears to represent the entire Chouteau Group, with a thin Compton Limestone at the base."

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Osagean Series

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

The series (Fig. 27) contains the following formations: Pierson, Fern Glen, Reeds Spring, Elsey, Grand Falls, Burlington, and Keokuk. All of these formations, however, do not occur together in any one particular section. The most complete Osagean sequence in the state is in southwestern Missouri south and west of Springfield, where the Pierson, Reeds Spring, Elsey, Burlington, and Keokuk occur together.

In Arkansas the term "**Boone Formation**" has been applied to the entire sequence. Predominantly chert free and varicolored, red and green, crinoidal, argillaceous limestone in the lower part of the "Boone Formation" has been designated in earlier reports as the **St. Joe member**. This unit is now regarded by some workers as a formation in Arkansas and Oklahoma (**St. Joe Limestone**), and is equivalent to the Compton, Northview, and Pierson succession of southwestern Missouri.

In central Missouri, and in the subsurface of northwestern Missouri, the Osagean Series is represented by only the Pierson, Burlington, and Keokuk; in northeastern Missouri by the Burlington and Keokuk; and in east-central

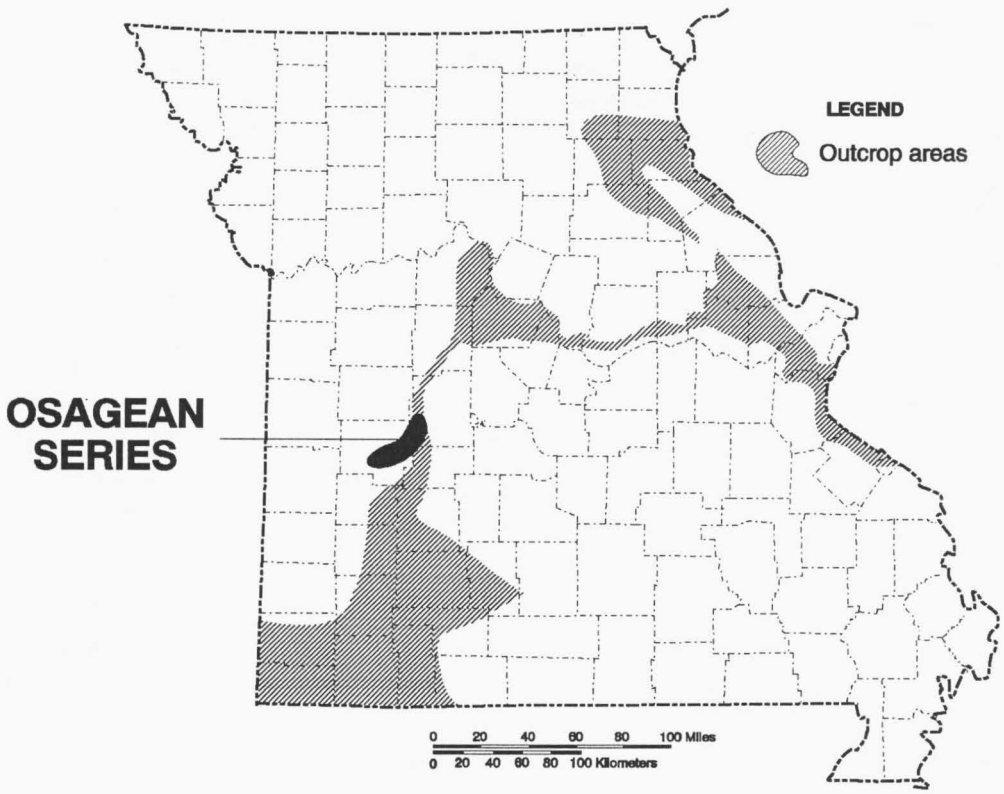

Fig. 27. *Areas of exposed Osagean rocks in Missouri (shaded areas) and location of type area for the Osagean Series.*

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 often 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 strata of Arkansas and Oklahoma. Its upper part, which is cherty, is regarded as equivalent in part to the Reeds Spring Formation of southwestern Missouri.

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 ft thick, in the east-central part about 200 ft thick, and in the southwestern part about 250 ft thick. However, in some areas of the Tri-State district, the thickness of the series exceeds 400 ft.

Southwestern Missouri

Pierson Limestone - In the type area of the Pierson Limestone, in southern Greene County of southwestern Missouri, the formation is a medium- to massive-bedded, brown, dolomitic limestone, 35 to 40 ft thick. Cream-colored

chert is present in the form of nodules in the lower part and as discontinuous beds in the upper part. Northward from Greene County, the lower part of the Pierson thins to less than 10 ft 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 Limestone. Southward from Greene County, the formation becomes less dolomitic, the lower part becomes more calcareous, thin-bedded, and except in sections of the red "St. Joe" facies, essentially chert-free. In the vicinity of southern Stone and Barry counties, the limestone becomes crinoidal, with a pronounced argillaceous zone in the upper 10 to 20 ft. The chert in the upper part is more like that of the overlying Reeds Spring Formation, usually dark-bluish-gray to blue, irregular nodules and discontinuous beds. Around Table Rock Lake Dam, much of the lower Pierson is the "St. Joe" facies, mottled with shades of greenish-gray and brick-red, with scattered nodules of brick-red to black chert. In this area of southwestern Missouri, the formation is about 50 ft thick.

In many places the limy shale of the Northview Formation is much too thin to map as a formation. The two formations above and below the Northview, the Compton and Pierson Limestones, are quite similar lithologically. Because of this, Clark and Beveridge (1952) proposed that the Compton-Northview-Pierson succession of extreme southwestern Missouri be designated the "**St. Joe Group.**" As thus defined, the group straddles the Kinderhookian-Osagean Series boundary. They recognized the persistence of the Compton and Northview, refuting the idea that the Northview and Compton disappeared southward in southwestern Missouri. They stated (p. 77) "...that previous workers have overlooked the intervening Northview shaly beds and considered the St. Joe to be a single limestone unit..."

Although not necessary in Missouri, the concept of the St. Joe Group is very useful in northern Arkansas and northeastern Oklahoma, where the lithology of the Northview is lost into the red "St. Joe" limestone facies, and a single unit exists (Thompson and Fellows, 1970).

The Pierson in the western part of central Missouri is not as fossiliferous as it is in southwestern Missouri 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 all of its extent in west-central and southwestern Missouri. In all of the area north of Springfield, the Pierson is overlain by the Burlington Limestone, but south of this area the Reeds Spring and Elsey Formations intervene between it and the Burlington.

Reeds Spring Formation - As stated by Thompson (1986, p. 84): "The Reeds Spring Formation consists of alternating beds of dense, very fine-grained, gray or bluish-gray, slightly argillaceous limestone, and bluish-black to grayish-white, nodular and irregularly bedded chert. The chert has a distinctive light-gray border. The chert beds often appear to be **within** the

limestone beds, not just between them. On weathered surfaces from which the limestone has been removed, a box-work, or lattice structure, in the chert is exposed as horizontally and vertically anastomosing beds. Chert constitutes over 50 percent of the formation.

"The northern limit of Reeds Spring distribution [identification] appears to be in a region that extends from just south of Springfield, in Greene County, Missouri, to northwest of Springfield. North of this line, the lithologic characteristics of the Reeds Spring become indistinguishable from those of the overlying Elsey, a similar limestone and chert formation. These characteristics include grain size of the limestone and the type of chert, whether as beds of nodules (Elsey) or as interconnected beds and bands of chert (Reeds Spring). Southwestward, the Reeds Spring extends in Arkansas and Oklahoma where it is called the '**Boone chert**.' In its type area the Reeds Spring averages less than 100 ft thick, but it thickens southward and westward. It is 100 to 150 ft thick in the Joplin area, and has been reported up to 225 ft thick in the extreme southern part of the state.

"Throughout the area, the Reeds Spring apparently lies conformably on the Pierson Limestone. It is also conformable with the overlying Elsey Formation..."

"At the northern limit of its extent, the Reeds Spring is indistinguishable from the Elsey, and farther north, where the chert content decreases and limestone is dominant, the Reeds Spring-Elsey interval becomes part of the Burlington Limestone. Similar changes occur in the cherty upper portion of the Fern Glen Formation in eastern Missouri, a unit correlative with the Reeds Spring."

Elsey Formation - As described by Thompson (1986, p. 87-88): "The Elsey Formation is present only in southwestern Missouri and in adjacent parts of Arkansas, Oklahoma, and Kansas. It consists of finely to medium-crystalline gray limestone and white chert, which occurs as ellipsoidal nodules, discontinuous beds, and nodular massive beds. Crinoidal lenses, usually finely crystalline, are common in the limestone. The chert is usually mottled white and gray and contains abundant fossil fragments, including spicules. A type of chert that is brecciated, with a gnarly structure, is widespread but does not appear to be confined to any particular stratigraphic horizon. When weathered, much of the chert breaks into sharp slivers; in this form, it is commonly called 'butcher-knife flint.'

"The Elsey, which is approximately 30 ft thick, conformably overlies the Reeds Spring Formation or Pierson Limestone, and is immediately below the Burlington-Keokuk Limestone. In southern Greene County, Missouri, the Reeds Spring and Elsey appear to merge, the Reeds Spring characteristics being lost, into a single formation between the underlying Pierson and overlying Burlington. The Reeds Spring appears to be a southern facies of the lower Elsey. Where the Elsey lies on Pierson, the contact is sharp. Further northward the Elsey merges into lower Burlington, through loss of diagnostic chert and coarsening of the limestone."

Grand Falls Chert- As stated by Thompson (1986, p. 89-90): "Robertson (1967) described the Grand Falls at its type section as a silicified sequence of

strata that were formerly part of the Reeds Spring and Elsey Formations, and the lower Keokuk Limestone; he could recognize chert types of all three formations in the Grand Falls. 'Grand Falls' is restricted to this local chert unit along Shoal Creek and in the general vicinity of Joplin, Missouri. The formation is 24 to 40 ft thick in its type area, in western Jasper and Newton counties, where exposures are numerous.

"Distribution of the Grand Falls Chert is discontinuous. It may be well developed close to outcrops of the Reeds Spring, Elsey, and Keokuk, the units that make up the Grand Falls Chert; thus, transition from normal limestone formations to chert may occur in very short distances."

EAST-CENTRAL AND SOUTHEASTERN MISSOURI

Fern Glen Formation - Although the lower limestone of the Fern Glen Formation and the southwestern extension of the Pierson Limestone are closely similar in lithology and age, they are separated by almost the entire width of the state. The Fern Glen is present 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. It is also present in west-central Illinois.

Throughout this area, the formation consists of gray to tan, grayish-green, and/or red limestone, and green and red, calcareous shale, overlain by finely crystalline to sublithographic, greenish-gray, cherty limestone. 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, non-cherty, brown, thick-bedded, dense to crinoidal limestone, 4 to 15 ft thick, which contains a few quartz geodes in places (**Meppen Limestone Member**); a middle, distinctively red and/or green, fossiliferous, calcareous shale, 10 to 20 ft thick; and an upper, nodular, cherty, very finely crystalline to crinoidal limestone, 12 to 30 ft thick which contains some quartz geodes. The total thickness of the formation ranges from 20 to 45 ft. 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 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 Limestones. 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 southwestern

Missouri, and the lower part resembles the Pierson Limestone. Because of this and faunal similarities, the Fern Glen is considered a correlative of the Pierson-Reeds Spring succession of southwestern Missouri.

In the area of St. Charles County, the Fern Glen overlies limestone of the Chouteau Group. Southward into St. Louis County, and down through Ste. Genevieve County, Chouteau rocks disappear, and Fern Glen rests on the Kinderhookian Bachelor Formation and underlying Late Devonian Bushberg Sandstone.

Meppen Limestone Member - Thompson (1986, p. 75) stated; "Named to replace the 'Sedalia' in Illinois, the Meppen Limestone [Member of the Fern Glen Formation] is equivalent to the lower Fern Glen limestone in Missouri, and also to the 'lower brown beds of the Burlington' [Pierson] in central Missouri...The Meppen Limestone in many places is a brick-red, very fossiliferous limestone that breaks down readily on weathering...Typically it is a dense, hard, buff limestone that forms resistant ledges."

STATEWIDE

Burlington Limestone - Thompson (1986, p. 91-92) stated: "The Burlington Limestone is characteristically a white to gray, medium-to coarsely crystalline, medium-to coarsely crinoidal, medium-to thick-bedded, often cross-stratified, chert-free to sparsely cherty limestone. Chert occurs in zones 1 to 10 ft thick, separated by chert-free zones 30 to 50 ft thick...The lower 20 to 30 ft in the St. Louis area contains 50 percent chert and has been called the 'lower Burlington Limestone'...The 'lower Burlington Limestone' is considered equivalent to the Elsey Formation of southwestern Missouri, which is recognized as a facies of the lower part of the Burlington Limestone to the north of Springfield..."

The contact of the Burlington with underlying formations varies considerably. In northeastern Missouri, it lies unconformably on the Hannibal Shale at some sections, on the "Chouteau Group undifferentiated" at others; in east-central and southeastern Missouri, it is conformable on the Fern Glen; in central Missouri, it is unconformable on both "Chouteau Group undifferentiated" and Northview; and in southwestern Missouri, it lies conformably either on Pierson or on the Reeds Spring-Elsey or Elsey Formations.

Thompson (1986, p. 92) added: "The contact with the overlying, lithologically similar Keokuk Limestone is transitional and often difficult or impossible to identify; hence, the sequence of Osagean limestones is sometimes identified as the '**Burlington-Keokuk Limestone**' [bold added]. The thickness of the Burlington Limestone, however, is believed to be fairly uniform throughout the state, seldom exceeding 100 ft. The formation is absent in the immediate Joplin area and has not been identified south of southern Barry County, in southwestern Missouri."

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. In northeastern Missouri, the formation is arbitrarily divided into a sparsely-cherty lower part, 20 to 30 ft thick, which is informally designated as the "**White Ledge**," and a cherty upper part 50 to 70 ft thick. In this area the lower part contains from 95 to 99 percent calcium carbonate ($CaCO_3$), and because of this, numerous agricultur-

al 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.

In northeastern Missouri the formations's thickness ranges from 70 to 100 ft; in central, east-central, and southeastern Missouri, it ranges from 75 to 100 ft; and in southwestern Missouri, it is about 100 ft thick.

Keokuk Limestone - The Keokuk Limestone is widespread throughout the state and like the Burlington 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 abundant 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**) at the top of the formation contains calcareous areas which when weathered give the chert a matted appearance.

A unit similar in appearance to the Short Creek is present in St. Louis County. Basically a single cross-stratified bed of oolitic grainstone, this unit was named the **Peerless Park Member** of the Keokuk Limestone by Kammer et al. (1990). The base of the Warsaw in eastern Missouri is not right at the top of the Peerless Park, but is not too many feet above.

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 Limestone, 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 ft. Of this amount, about 50 ft belongs to the Keokuk. In northeastern Missouri the thickness of the formation ranges from 60 to 70 ft. In central and southwestern Missouri, it is about 100 ft 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 unconformably overlain by the Hindsville

Limestone (Chesterian). The Keokuk conformably overlies the Burlington in all areas of the state except in the immediate Joplin area and in parts of Barry County where it lies conformably on the Elsey or Reeds Spring-Elsey Formations. 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 Oolite Member - Throughout southwestern Missouri and adjacent areas of Kansas and Oklahoma, a thin, persistent bed of oolitic limestone, 2 to 8 ft thick is present at the top of the Keokuk. This unit is the Short Creek Oolite Member of the Keokuk Limestone. 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, the top of the Short Creek Member has been arbitrarily designated as the base of the Warsaw. 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*.

Peerless Park Member - The Peerless Park Member of the Keokuk Limestone is a single, thick bed of cross-stratified grainstone (or calcarenite) containing scattered oolites and fossil fragments. It has been identified only in St. Louis County and while it is not as oolitic as the Short Creek Oolite of western Missouri, it had a similar depositional environment, and is essentially in the same stratigraphic position.

Meramecian Series

Because of redefinition of the position of the Meramecian-Chesterian boundary within the Midcontinent succession (Maples and Waters, 1987) , the Meramecian Series no longer includes the Ste. Genevieve Limestone. It now comprises three formations, the Warsaw, Salem, and St. Louis. These formations (Fig. 28), 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 the formations. All three formations are present in east-central Missouri which is regarded as the type area for the Series and the St. Louis Limestone. 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, Salem, and St. Louis has been established in a small area of western Dade County and eastern Barton County. 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 250 and 400 ft thick. The Series thins northward to 150 ft in northeastern Missouri. In central and southwestern Missouri where the Series is incomplete, thicknesses range from 60 ft in central Missouri to 185 ft in southwestern Missouri.

The position of the boundary between the Meramecian and Osagean Series has long been disputed. Thompson (1986, p. 96) stated: "Because there is no faunal evidence for a Meramecian-Osagean boundary in western and southwestern Missouri, the Short Creek Oolite designates the top of the Osagean

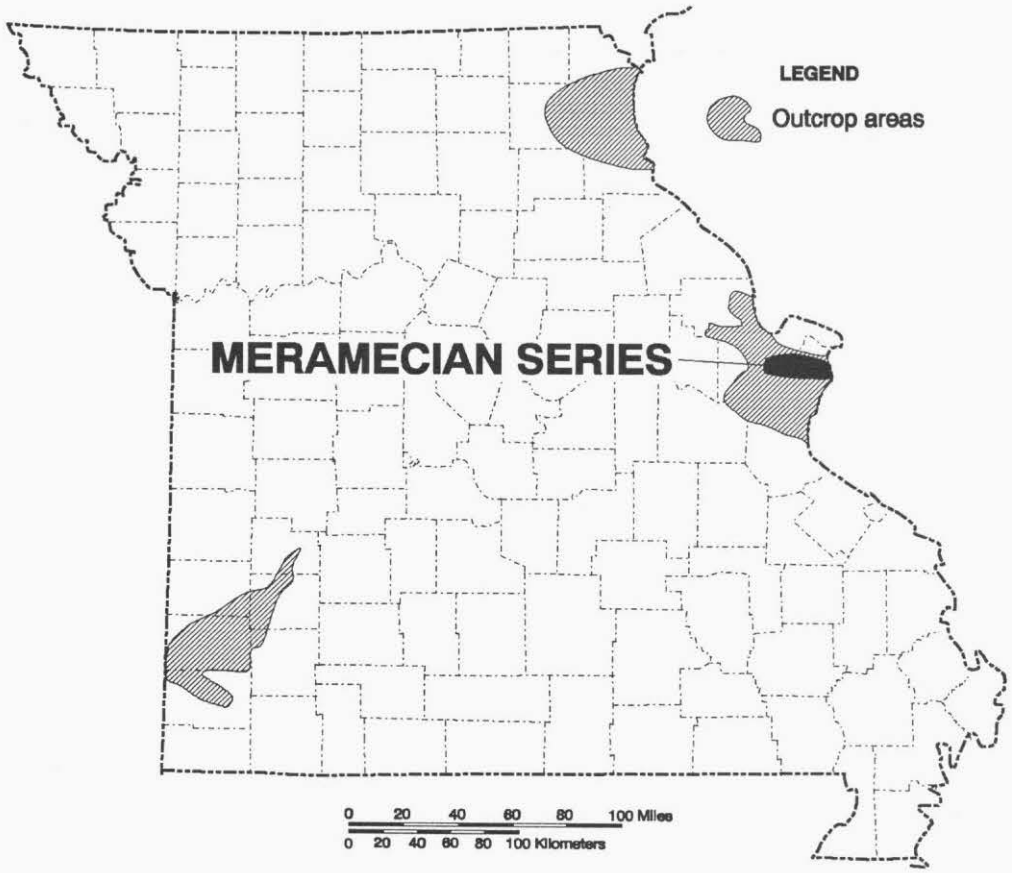

Fig. 28. *Areas of exposed Meramecian rocks in Missouri (shaded areas) and location of type area for the Meramecian Series.*

Series in that region. It also defines the Keokuk-Warsaw contact for regional mapping purposes, because the lower Warsaw strata are lithologically similar to upper Keokuk limestones. Regionally, the Short Creek is a member of the Keokuk limestone, and the top is the marker for the base of the Warsaw Formation." Kammer et al. (1990) stated: "Analysis of fossil occurrences in late Osagean-early Meramecian stratotype beds of the upper Mississippi River Valley shows that major faunal changes occur within the Warsaw Formation not at the underlying Keokuk-Warsaw formational contact where the Osagean-Meramecian serial boundary is presently placed..." They recommended that the Osagean-Meramecian boundary be redefined to occur **within** the Warsaw Formation at a horizon that corresponded to a major faunal change. The Illinois Geological Survey side-stepped this problem by assigning all formations within the Osagean and Meramecian Series to the **Valmeyeran Series.**

For practical purposes 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 in southwestern Missouri, less so in east-central Missouri. 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 ft 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 northern Perry County. In these areas, the Warsaw is about 80 to 100 ft 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 ft 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 and in Newton and Jasper counties, the formation is over 150 ft 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. It is about 50 ft 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 Warsaw is differentiated from the underlying Keokuk by the presence of these thin shale partings and by abundant bryozoan fragments in the chert. It is separated from the Keokuk Limestone in west-central and southwestern Missouri by the Short Creek Oolite. There, the lower Warsaw is much like the underlying Keokuk. However, the upper Warsaw limestone is calcarenitic (a calcareous sandstone), much like the Warsaw limestone of northeastern and east-central Missouri.

Salem Formation - The most characteristic lithology of the Salem Formation is a sucrosic (calcarenitic), often cross-stratified limestone or grainstone, the limestone beds made up of sand-sized calcareous fragments (a calcareous sandstone). This is similar to the calcarenitic Warsaw limestones, but the Salem limestone is usually purer. Warsaw calcarenites are usually quite muddy, or contain some clay.

Thompson stated (1986, p. 110): "The Salem Formation, which is more restricted in distribution than the underlying Warsaw, crops out principally in central and eastern Missouri..."

"A distinctive 'cannonball,' or 'bulls-eye,' chert zone occurs near the top of the Salem in the St. Louis area, and indicates proximity to the Salem-St. Louis contact. The chert occurs as concentrically banded, spherical nodules, 4 to 6 in. in diameter..."

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 ft 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 ooid 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 is usually picked at the base of the lowest lithographic, very light-gray to white limestone that marks the base of the overlying St. Louis Limestone. This is usually not too far above the occurrence of the "cannonball" chert nodules. The insoluble residue from the upper 50 ft 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 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 ft in thickness. It is composed of buff-weathered limestone, dolomitic limestone, and shale in this part of the state, and its contact with the underlying Warsaw, which also is a shale, 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 *Tripophyllites*. It is 10 ft thick at the surface and thickens to 50 ft to the north and west in the subsurface. In Dade and Barton 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 ft thick.

St. Louis Limestone - The St. Louis Limestone 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 in part a white to light-

gray, lithographic to finely crystalline, medium- to massive-bedded limestone which is more than 100 ft 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 constituents. The contact between the St. Louis and Salem formations appears to be conformable, and is usually placed at the base of the lowest white to light-gray, lithographic limestone (which is often brecciated).

The thickness of the St. Louis Limestone in northeastern Missouri is generally less than 50 ft. The formation is about 50 ft 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 ft. The formation's local absence in this area is the result of pre-Pennsylvanian erosion.

The limestone from the St. Louis 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.

Chesterian Series

Maples and Waters (1987) redefined the Meramecian-Chesterian boundary such that the Ste. Genevieve Limestone and Aux Vases Sandstone, uppermost Meramecian in 1986 (Thompson), are now the basal Chesterian units. Therefore, under this definition, Chesterian rocks occur throughout the subsurface of northern Missouri beneath the Pennsylvanian rocks. The Ste. Genevieve is the only Chesterian formation present in the subsurface of northwestern Missouri.

Thompson (1986, p. 135) stated: "In Missouri, there are two geographically separated, lithologically distinct successions of Chesterian strata. One, in the southeastern part of the state, includes approximately the lower half of those formations in the type region of the Chesterian Series as exposed across the Mississippi River in southwestern and southern Illinois (Atherton et al., 1975). The other succession is in extreme southwestern Missouri, exposed in down-dropped fault blocks now appearing as northern outliers of the thick Late Mississippian-Early Pennsylvanian succession present in northwestern Arkansas and northeastern Oklahoma. These latter units show a closer correlation with Chesterian strata in Oklahoma and Texas than with those of the Illinois Basin."

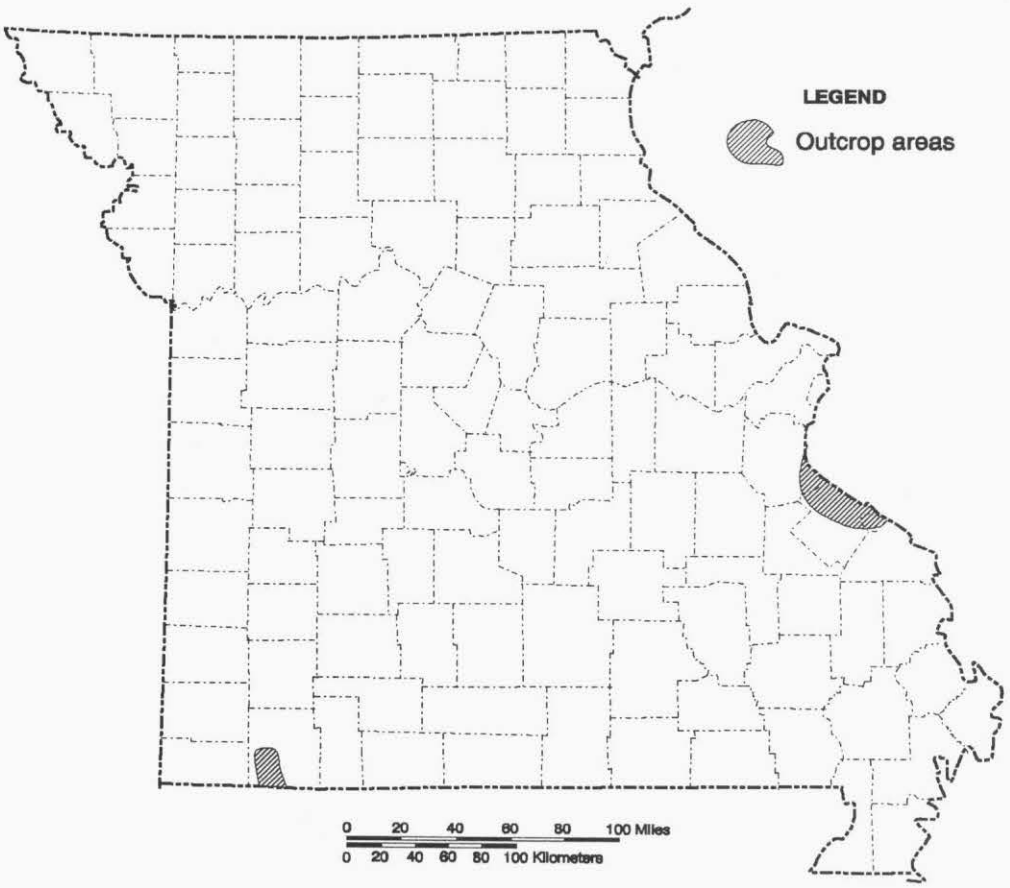

Fig. 29. *Areas of exposed Chesterian rocks in Missouri.*

The formations that make up the Chesterian Series in **southeastern Missouri** (Figs. 23 and 29) are (in ascending order): the St. Genevieve, Aux Vases, Renault, Yankeetown, Paint Creek, Cypress, Golconda, Hardinsburg, Glen Dean, Tar Springs, and Vienna. They are crudely rhythmic repetitions of sandstone, shale, and limestone which crop out in the bluffs of the Mississippi River in St. Louis, Ste. Genevieve, and Perry counties in an area of steeply dipping beds and considerable faulting. South of St. Louis County, exposures are not continuous, and identity of the formations is established only by their similarity to the better-developed sections in Illinois. The outcrops in Missouri are situated on the western edge of the thicker and more completely developed succession of Illinois and Kentucky.

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 cannot always be verified. The maximum thickness of the Series, in eastern Perry County, is 600 ft. 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 formations of the Chesterian Series occupy only a small part of the outcrop area of the Mississippian System of **southwestern Missouri** (figs. 25 and 29). In the Joplin area of Jasper, Lawrence, and Newton counties, the Series is represented only by the outliers of the Hindsville Limestone (locally called the "Carterville formation"). A more fossiliferous and better sequence of rocks 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.

Thompson (1986, p. 126) stated; "Chesterian formations of southwestern Missouri, widely separated and lithologically distinct from the Chesterian formations of southeastern Missouri and southwestern Illinois, possibly represent deposition in a basin geographically isolated from the Illinois basin during time of deposition...[Thompson (1972)] studied the conodont fauna recovered from the southwestern Missouri sequence, and was able, with some reservation, to correlate them with the faunas previously reported from the type region of the Chesterian Series, but he recognized a closer correlation with Chesterian strata in Oklahoma and Texas than with those of the Illinois basin..."

The Series lies unconformably on the Keokuk Limestone (Osagean) in the southwestern part of the state. Beneath the Pennsylvanian cover in northern Missouri, Ste. Genevieve strata are present from the northwestern to northeastern parts of the state.

Southeastern Missouri

Ste. Genevieve Limestone - The Ste. Genevieve Limestone 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, massive-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, 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. That that is retained is predominantly 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 ft, with the maximum being less than 100 ft. The formation's thickness in St. Louis County is 30 ft. The Ste. Genevieve is disconformable with the underlying St. Louis Limestone; a basal conglomerate is present in numerous places. A significant 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, 1 to 4 ft thick, containing fragments of chert and lithographic limestone, has been identified as Ste. Genevieve. This limestone is generally overlain by Pleistocene till, and faunal evidence for its age is lacking. However, in adjacent parts of southeastern Iowa, a similar sandstone is overlain by finely crystalline limestone, **the Pella beds**, which have been correlated with the type Ste. Genevieve in southeastern Missouri. The contact of this sandstone with the underlying St. Louis Limestone 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 ft of subangular, fine-to medium-grained sandstone in the upper part of the formation whose maximum recorded thickness is less than 75 ft.

Aux Vases Sandstone - The Aux Vases Sandstone is composed principally of yellow-brown to tan 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. It is coarsest in Perry County, where it superficially resembles, but differs from, the St. Peter Sandstone by being more fine-grained and 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 Limestone 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 ft and in Perry County, from 55 to 105 ft.

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 ft 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 Sandstone - Throughout most of its outcrop area, the Yankeetown is a fine-grained, light to reddish-brown, calcareous sandstone. The sandstone is irregular- and cross-bedded, exhibits 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 Sandstone and Renault Formation 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 ft, while 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 Paint Creek is divided into three members (in ascending order): the Downeys Bluff Limestone, Bethel, and Ridenhower Limestone. Crinoid and blastoid debris is common, and the crinoid *Pterotocrinus* is distinctive. The total thickness of the formation varies from 80 to 100 ft.

Downeys Bluff Limestone Member - The Downeys Bluff Limestone Member of the Paint Creek Formation consists of light-gray, coarsely to finely crystalline limestone, and interbedded shale; in all 8 to 20 ft thick.

Bethel Member - The Bethel Member of the Paint Creek Formation consists of shale with a few limestone beds in the upper part, and noncalcareous, red claystone in the lower part; in all 15 to 30 ft thick.

Ridenhower Limestone Member - The Ridenhower Limestone Member of the Paint Creek Formation contains light-buff, oolitic, cross-bedded limestone and some shale, with numerous crinoid (*Pterotocrinus*) and blastoid debris; in all 40 to 70 ft thick.

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 Creek are concealed. The Cypress 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 ft of sandstone, which may be a channel deposit. Because this facies relationship was not noted in the past, the formation was not recognized in Missouri before 1961, where the thickness of the unit probably does not exceed 30 ft.

Golconda Formation - The Golconda Formation is a limestone and shale succession that can be divided into three members (in ascending order): the Beech Creek Limestone, Fraileys Shale, and Haney Limestone. Outcrops 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.

Beech Creek Limestone Member - The Beech Creek Limestone Member of the Golconda Formation is a 5-20-ft thick, dark-gray to brown limestone, which contains an abundance of foraminifera, small gastropods, and pelecypods

Fraileys Shale Member - The Fraileys Shale Member of the Golconda Formation, 70-90 ft thick, is composed of shale, which contains beds of dark-colored, crinoidal limestone

Haney Limestone Member - The Haney Limestone Member of the Golconda Formation is a 50-ft thick, very-light-gray, oolitic, cross-bedded limestone.

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 within the unit in one Missouri exposure. This shaly succession between the Glen Dean and Golconda limestones apparently represents the westward extension of a more typical, thicker, sandy shale and sandstone of western Illinois. This shale was not differentiated as Hardinsburg in older reports of the Missouri Geological Survey (before 1961). 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 ft, but may reach 30 ft, a thickness which is comparable to that observed in wells across the Mississippi 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 Glen Dean 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 seratula* 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 65-80 ft thick and contains numerous local disconformities.

Tar Springs Sandstone - The Tar Springs Sandstone consists chiefly of sandstone and contains shale and shaly sandstone near the middle of the unit. It is buff to rust-brown and red, dominantly fine-grained, even-textured, and friable, except where it is locally an orthoquartzite. The formation is generally thin-bedded, but is medium- to thick-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 ft thick in Missouri.

Vienna Limestone - The Vienna Limestone 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 10-15 ft 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 is concealed.

Southwestern Missouri

Hindsville Limestone - The Hindsville Limestone 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, and in some sections is essentially a calcareous sandstone (calcarenite) that originated under shoaling conditions. The upper part contains lenses of sandstone which are indistinguishable from the sandstone of the overlying Batesville. 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 Limestone.

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. In Missouri, the Hindsville unconformably overlies the Keokuk. The contact is irregular and marked by chert-pebble conglomerates which contain fish teeth. The Hindsville is from 0-50 ft thick.

Once believed to be confined only to southwestern Missouri, Hindsville strata have been found as outliers over much of west-central Missouri. It has been preserved in a graben structure in southeastern Jasper County, and an exposure of confirmed Hindsville and Batesville strata has been located in south-central Pulaski County, Missouri (personal communication, M.A. Middendorf), also preserved in a structure .

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 it 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 "Carterville" is extremely variable in thickness and is believed to be composed of local filled-sink deposits in older Mississippian rocks. It is present only in Jasper, Lawrence, and Newton counties and is reported to be over 200 ft thick in some of the sinks. The "Carterville" is now regarded as northern outliers of Hindsville, preserved in sinkholes (Thompson, 1986).

Batesville Sandstone - The Batesville Sandstone is a yellowish-brown, fine-grained, calcareous sandstone which contains discontinuous, thin beds of gray, medium-crystalline, oolitic limestone. The strata of the formation are even-bedded, 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). In Arkansas the Hindsville is regarded as a member of the Batesville.

As noted under "Hindsville Limestone," an outlier in southern Pulaski County, Missouri, includes confirmed Hindsville and Batesville strata. Fossils regarded as from the Batesville have also been identified from sandstone boulders on top of knobs in Ozark County. The Batesville, 35-50 ft thick in Missouri, is regarded as equivalent in age to the lower Chesterian Series of the type area.

Fayetteville Shale - The Fayetteville Shale 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 ostracods 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 ft.

In southwestern Missouri the Fayetteville is conformable with the underlying Batesville Sandstone. The total thickness of beds identified as Fayetteville in Missouri is about 20 ft, and the formation has been correlated with the Golconda, Hardinsburg, and Glen Dean formations of southeastern Missouri.

Wedington Sandstone Member - In a few southwestern Missouri localities, particularly Oakleigh Mountain, the Fayetteville Shale is capped by a thick, resistant, 30-ft sandstone. Thompson (1986, p. 158) stated: "This sandstone, capping the outliers of Chesterian strata in southern Barry County, Missouri, was previously assumed, because of its lack of marine fossils and similarity with deposits in northeastern Oklahoma and northwestern Arkansas, to represent the basal Pennsylvanian (Morrowan) Hale Formation. However, specimens of *Lepidodendron*, collected from the Oakleigh Mountain outcrop, have been identified with certainty as representative of *L. yolkmannianum* (identified as *L. wedingtonense* by White, 1936), and are Late Mississippian (Chesterian) in age...This identification is used to designate the sandstone capping these outliers to be a northern extension of the Wedington Sandstone Member of the Fayetteville Formation..."

PENNSYLVANIAN SYSTEM

by
Walter V. Searight and Wallace B. Howe (1961)
revised by
Thomas L. Thompson (1995)

Rocks of Pennsylvanian age are present beneath surficial deposits in more than two-thirds of the counties in Missouri (see Fig. 2) 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. The Atokan 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 ft.

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** overlain by the **Bloyd Formation**. Northward in Missouri, the Morrowan (Fig 30) is represented only by calcareous siltstone preserved in a graben in McDonald County, southwestern Missouri, correlated with the **Prairie Grove Member of the Hale Formation** in Arkansas (Thompson, 1970). A sandstone body in southwestern Missouri, previously correlated with the Hale Formation in Arkansas, is now known to be the **Wedington Sandstone Member of the Fayetteville Shale**, which is Late Mississippian in age (Thompson, 1986).

Atokan Series

Fossil evidence indicates the presence in Missouri of pre-Desmoinesian rocks which are assignable to the Atokan age (Fig. 30). This includes the Burgner Formation of southwestern and west-central Missouri, 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 Formation in their lithology and position below the Warner Formation, of early Desmoinesian age.

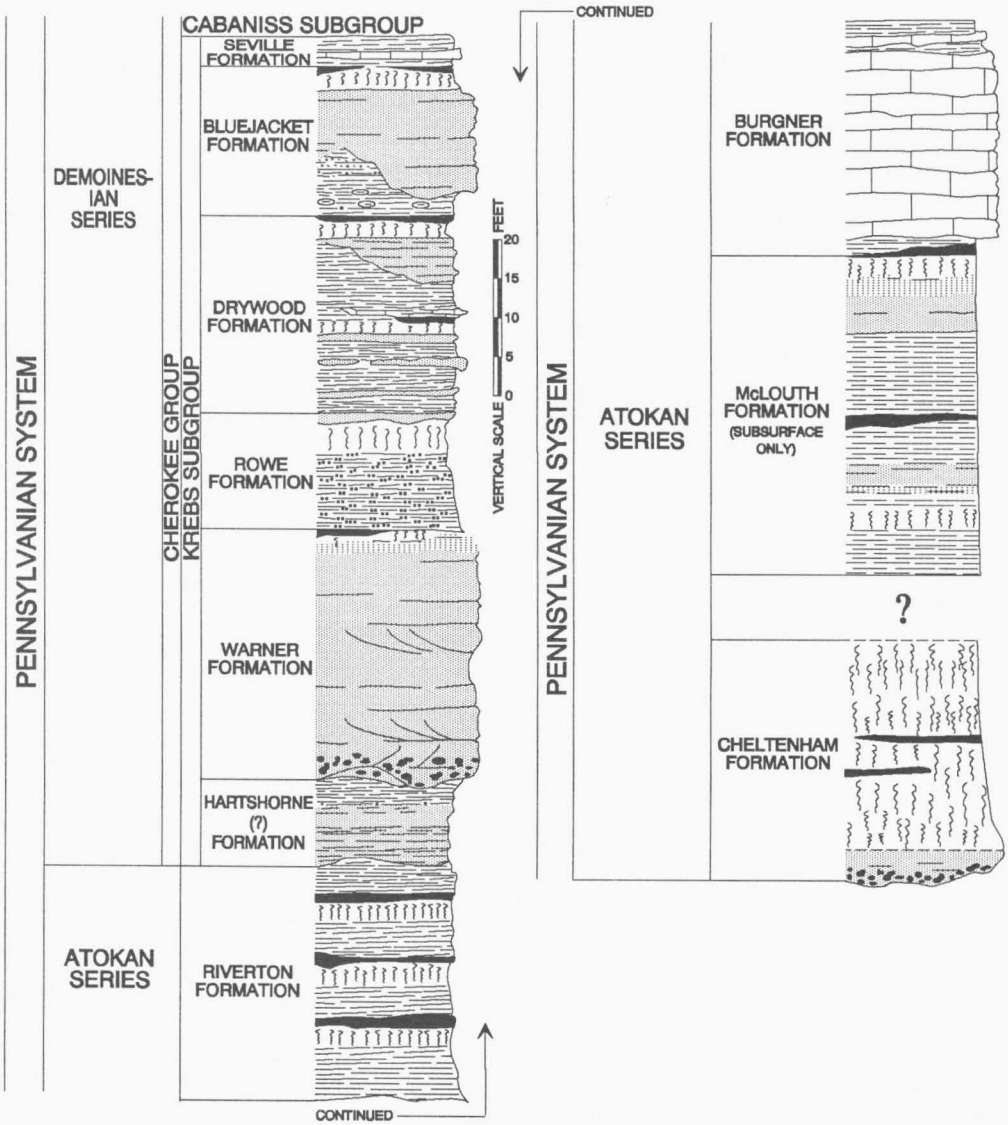

Fig. 30. *Atokan and lower Desmoinesian Krebs Subgroup of the Cherokee Group in Missouri.*

Cheltenham Formation - The Cheltenham Formation, 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. The included clays are mostly white to light- or medium-gray to purplish or red. 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 fossil, *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 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 lens 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 in Kansas that were described and named the McLouth sand by Lee (1941). 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 ft 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 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 filled-sink-type deposits in Mississippian limestone. The Burgner is as much as 16 ft 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 ft thick. The fauna in the limestone indicates that the unit is equivalent to the Burgner. Sandy limestone (**"Ladden Branch" limestone** of Lambert and Thompson, 1990), as much as 12 ft 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. Limestone in the Forest City Basin, below

the Warner, and within black shales resembling the Riverton, is likewise referred to the Burgner. The thickness of the formation varies from a featheredge to 35 ft in Jasper County and from a featheredge to 70 ft 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 in. 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 and faulted, exhibiting slickensides. Similar beds of like facies that lie below the Hartshorne (?) Formation 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 ft or more.

Graydon Conglomerate - The Graydon Conglomerate is an unsorted, often very thick and massive mixture of small to very large (3 feet and more long) rounded chert boulders cemented within a sandstone matrix. The cement is quite hard, the boulders well held together. It obviously represents very high-energy environment of deposition. The Graydon occurs in scattered areas, probably representing old channels, in west central Missouri (Cedar, St. Clair, and Polk counties), in Greene County, and in central Missouri (southern Callaway County).

Shepard (1898, p. 22-23) included coarse, friable, micaceous, ferruginous sandstone, scattered gray shale, and thin coals within the Graydon Formation. More recent work has shown confusion by different geologists on just what the lithology of Graydon actually is. Some identify the basal Pennsylvanian shales as Graydon, or basal sandstones, and others identify only the basal chert conglomerate (composed of Mississippian cherts cemented within a sandstone matrix) as the Graydon.

Consensus of presently active geologists (1994) indicates the sandstone, once called "Graydon," may be Warner, the shales may be Riverton. Thus, as used in this report, only the conglomerate remains as a distinctive unit that retains the name "Graydon."

Age of the Graydon is speculative, as it lies beneath Pennsylvanian strata of varying ages from early to late Desmoinesian. It is included here as the "**basal Pennsylvanian conglomerate**" for the Missouri Pennsylvanian succession.

Desmoinesian Series

The Desmoinesian Series contains those rocks deposited from the beginning of the Venteran Stage to the end of the Cygnian Stage, the major time subdivisions of the Desmoinesian. It includes all post-Atokan, pre-Missourian formations, and all of the Cherokee and Marmaton Groups. The boundary

formations, and all of the Cherokee and Marmaton Groups. The boundary between the Venteran and Cygnian Stages lies within the Cherokee Group.

Venteran Stage

Rocks of the Venteran Stage comprise the strata of the Krebs Subgroup of the Cherokee Group. The Venteran-Cygnian boundary is at the top of the Seville Formation.

CHEROKEE GROUP - The Cherokee Group contains most of the mineable coal beds in Missouri, and is predominantly shale, with minor carbonate, and sandstone. It is divided into the Krebs and Cabaniss Subgroups. The base is at the top of the Riverton Formation; the top is at the base of the Marmaton Group, either the base of the Excello Shale or the Blackjack Creek Limestone. Thus, the Cherokee Group contains the strata of all of the Venteran and the early part of the Cygnian Stages.

KREBS SUBGROUP - Rocks of the Krebs Subgroup (Fig. 30) include sandstone, siltstone, shale, clay, limestone, and coal beds; clastics predominate. 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 are 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 absent in many places, but attains a thickness of up to approximately 20 ft.

Warner Formation - Conglomerate composed of well-worn chert and coarse- to fine-grained sandstone commonly lies at the base of the Warner Formation. 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 ft. Conglomerates at the base are locally as much as 30 ft 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 noticeably 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 ft.

Drywood Formation - Where it is completely exposed in Barton and Vernon counties, the Drywood Formation contains (from the base upward): 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 thus expanded includes (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 discontinuous, 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 cover, multiple cycles presumably within the Drywood Formation are likewise indicated. The formation varies in thickness from a featheredge to 50 ft or more.

Bluejacket Formation - Where it is completely represented, the Bluejacket Formation consists of (from the base upward): 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, the conglomerate pebbles composed of siderite or clay ironstone "blisters" of shale; 4) an underclay; and 5) the **Bluejacket coal bed**. 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 ft 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 ft 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 ft, but because of cutouts and pinchouts, it is locally absent and apparently is as much as 70 ft 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 ft thick. Locally, as much as 3 ft of calcareous

shale below the limestone and as much as 2 ft or more of calcareous, fossiliferous shale above the limestone are included in the formation.

The Seville 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

Rocks of the Cygnian Stage range from the top of the Seville Formation to the base of the Missourian Series. 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 (Fig. 31) consist of sandstone, siltstone, shale, underclay, limestone, and coal beds. These are packaged into 11 widely-recognized successions, each of which, with certain exceptions noted in formational descriptions

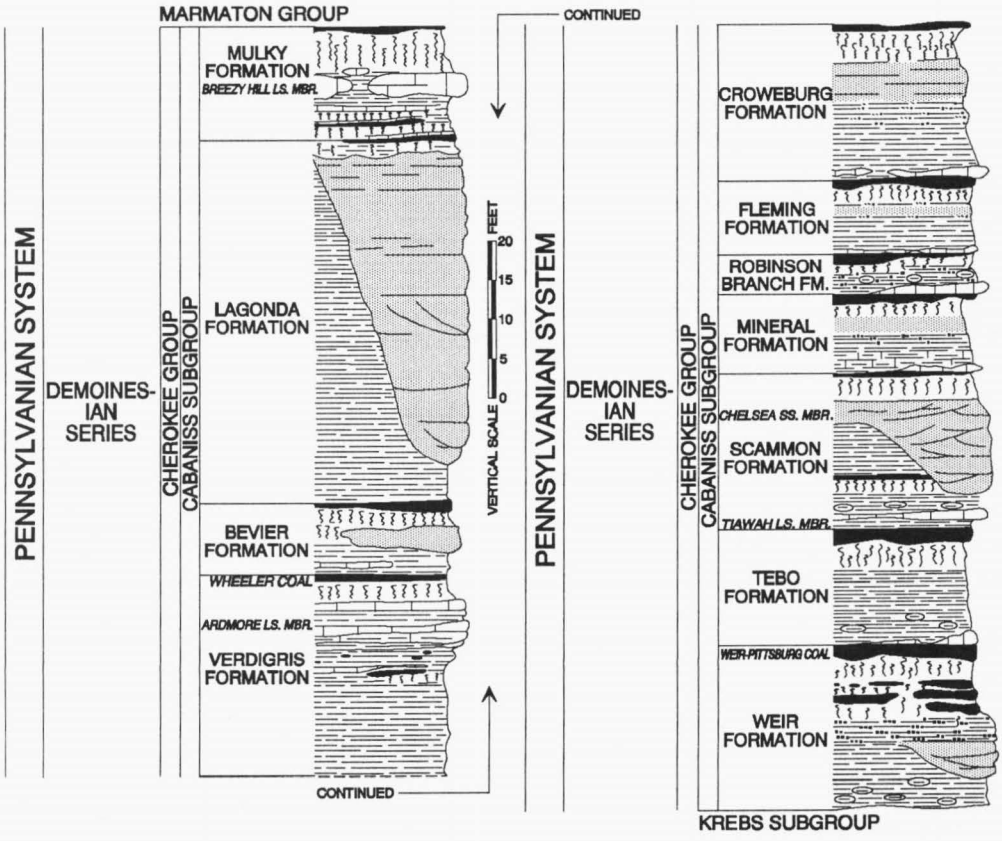

Fig. 31. Cabaniss Subgroup of the Cherokee Group in Missouri.

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.

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 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 slightly more than 280 ft in the Forest City Basin. Its average thickness in western Missouri south of the Missouri River is approximately 185 ft.

Weir Formation - Where completely represented, the Weir Formation is a composite of three cyclic successions (in ascending order): 1) shale and clay, up to 6 or more ft thick, that contains an abundance of clay-ironstone concretions; 2) a fine-grained sandstone 0-30 ft thick; 3) a micaceous siltstone up to 5 ft thick; 4) an underclay; 5) a coal; 6) a shale as much as 3 ft thick; 7) a sandstone 0-2 ft thick; 8) an underclay; 9) a coal; 10) an underclay; and 11) the **Weir-Pittsburg coal bed**.

The complete succession is developed only locally, but is 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 its strike from Henry County. Mining of this coal has been particularly active 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 ft, but it has a maximum thickness of 30 ft 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 in thick. It is too thin to be mined elsewhere.

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 Limestone Member**; 3) a black, hard, blocky shale which contains siderite concretions and which grades upward into a dark-gray mudstone; 4) the **Chelsea Sandstone Member** ; 5) a thin underclay; and 6) the thin **Scammon coal**. Locally, in southern Vernon County, another succession of thin underclay, thin coal, and shale, lies above the Tiawah and below the Chelsea sandstone. The Chelsea locally cuts out, or replaces lower beds nearly to the Weir-Pittsburg coal bed. The persistent, nodular 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 not more than 30 ft.

Tiawah Limestone Member - The Tiawah Limestone Member of the Scammon Formation 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 Missouri-Kansas line. The limestone is nodular in northeastern Missouri,

Chelsea Sandstone Member - The Chelsea Sandstone Member of the Scammon Formation is a fine-grained micaceous channel sandstone that locally cuts out lower Scammon units.

Mineral Formation - Where the Mineral Formation is complete, it consists of (in ascending order): 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 ft. This bed was mined in northern Vernon and southern Bates counties during the early part of the century. It is most recently 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 ft.

Robinson Branch Formation - The Robinson Branch Formation includes (from the base upward): 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) an underclay; 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 Missouri-Kansas line. The underclay and coal are present at widely-spaced intervals along the cropline. The formation is 0 to 10 or more ft 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 ft.

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 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 Croweburg 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 ft.

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 Limestone Member**; 4) an underclay; 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 ft 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 ft or more to a featheredge near the Lincoln Fold.

Ardmore Limestone Member - The Ardmore Limestone Member of the Verdigris Formation is a limestone or succession of limestone and interbedded shale.

Bevier Formation - From western Vernon County northward into western Henry County, the Bevier Formation consists of (from the base upward): 1) a more-or-less mottled shale, which ranges from a featheredge up to 4 ft 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

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 in 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 ft 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 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 ft and averages approximately 60 ft 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 in 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 in western Missouri, the **Breezy Hill Limestone Member** 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 ft. The formation is 3 to 8 ft thick and averages approximately 4 ft thick.

Breezy Hill Limestone Member - The Breezy Hill Limestone Member of the Mulky Formation is a hackly, nodular limestone in western Missouri that lies at the base of the underclay either as a bed or as discontinuous masses.

MARMATON GROUP - The Marmaton Group consists of a succession of shale, limestone, clay, and coal beds (Fig. 32). It contains more limestone units

than the underlying Cherokee Group, which are also thicker and more persistent. The Marmaton in Missouri has been divided into two subgroups, the Fort Scott below and the Appanoose above.

Ravn et al. (1984) redefined the base of the Marmaton Group in Iowa (top of the Cherokee Group) to coincide with the base of the Excello Shale, thus placing the base of the Marmaton at the beginning of a marine cyclothem. This concept has been followed in Kansas by Goldstein (1977). Therefore, the top of the Cherokee Group is now at the top of the Mulky Coal bed, at the base of the Excello Shale.

FORT SCOTT SUBGROUP - The Fort Scott Subgroup includes four formations (in ascending order): the Excello, Blackjack Creek, Little Osage, and

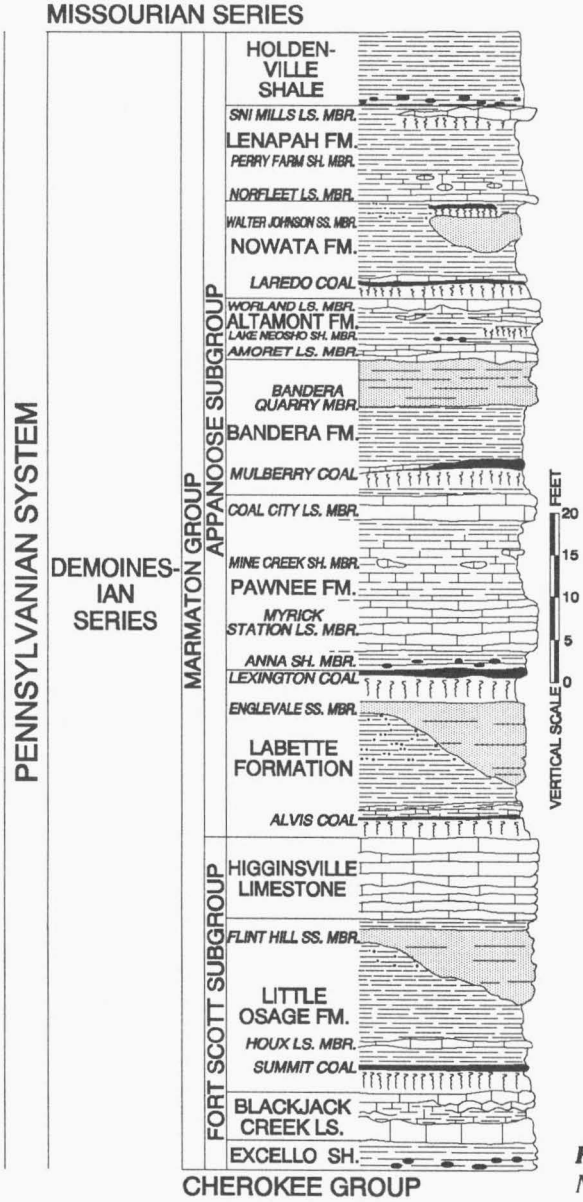

Fig. 32. *Upper Desmoinesian Marmaton Group in Missouri.*

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 units that could not otherwise continue to bear formal names.

Excello Shale - The Excello Shale 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 ft or more in diameter. In many places a bed of gray to buff, calcareous shale, 2-3 ft 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 in. and 5 ft, but probably averages 3 to 4 ft.

Blackjack Creek Limestone - The Blackjack Creek Limestone 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 uneven-bedded and becomes wavy-bedded or nodular toward the Lincoln Fold. The upper unit is absent in many places, but wherever 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 ostracods and brachiopods rarely occur. The Blackjack Creek is more than 12 ft thick in some localities, but it thins to less than 1 ft in others.

Little Osage Formation - The lower part of the Little Osage Formation 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, and followed by a black, fissile shale containing abundant phosphatic concretions. The latter is one of the most conspicuous and persistent units of 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 Limestone Member** appears above the black, fissile shale and is persistent to the Iowa line and extends eastward into northeastern Missouri to its outcrop boundary.

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 Sandstone Member**. In northern Missouri as in Putnam County, the upper foot or two of the Little Osage is a light-gray shale or clay with a carbonaceous smut 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 ft south of central Johnson County, but it attains a local maximum of more than 50 ft in northern Missouri.

Houx Limestone Member - The Houx Limestone Member of the Little Osage Formation is a single 6-in. to 1-ft dense limestone bed in north-central Missouri. It is split into thin beds of limestone by a thin shale parting which thickens northward.

Flint Hill Sandstone Member - The Flint Hill Sandstone Member of the Little Osage Formation is 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.

Higginsville Limestone - In western Missouri, where it is thickest, the Higginsville Limestone 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 poorly 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 ft. From Johnson County it thins northward and northeastward.

^^APPANOOSE SUBGROUP - The Appanoose Subgroup includes all of the Marmaton formations above the Higginsville Limestone of the Fort Scott Subgroup (in ascending order): the Labette, Pawnee, Bandera, Altamont, Nowata, Lenapah, and Holdenville. 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 (Labette Shale)- 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 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, shaly limestone that is sporadically persistent 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 Sandstone Member,** 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, and is persistent to the Iowa line. The Lexington coal has a thin, persistent clay parting that is exposed wherever the coal has been extensively mined, as 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 ft in Bates County, to less than 2 ft in western Howard County.

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

Anna Shale Member - The Anna Shale 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 from 1 to 3 ft in thickness .

Myrick Station Limestone Member - In western Missouri, the Myrick Station Limestone Member of the Pawnee Formation 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 ft thick.

Mine Creek Shale Member - The Mine Creek Shale Member of the Pawnee Formation is mostly a medium- to dark-gray shale, 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 from 5 to 30 ft.

Coal City Limestone Member - The uppermost member of the Pawnee Formation, the Coal City Limestone Member, 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*, *Neospirifer*, and *Schuchertella* are commonly present. The member is 2 to 6.5 ft 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 Missouri-Iowa state line. A shale which is commonly medium- or greenish-gray 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 Mulberry diminishes to the thickness of a smut 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 overlying Amoret Limestone Member of the Altamont Formation. The Bandera varies from 2 to 21 ft in thickness.

Altamont Formation - The Altamont Formation consists of three members; the lower and upper members, the Amoret and Worland, are mostly composed of limestone. They are separated by the Lake Neosho Shale Member.

Amoret Limestone 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 Formation is obscure. The Amoret Limestone Member of the Altamont Formation varies in thickness from 0 to 5 ft.

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

Worland Limestone Member - This persistent member of the Altamont Formation, the Worland Limestone Member, crops out from Bates and Jackson counties northeastward to the Missouri-Iowa state line in Putnam County. It is characteristically a massive bed of limestone which grades laterally into a lower light-bluish-gray limestone and upper lighter gray, algal limestone. The limestone is separated into two units by 3 ft 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 ft.

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 Sandstone Member**, which is a sandstone and siltstone, locally occupies the position of the upper Nowata and possibly cuts 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 ft thick, lies on the Laredo coal. The thickness of the Nowata averages between 10 and 15 ft.

Lenapah Formation - The Lenapah is typically composed of two limestone members, the Norfleet and Sni Mills, and an intervening shale, the Perry Farm.

Norfleet Limestone Member - The Norfleet Limestone Member of the Lenapah Formation 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, but it has been identified in many places in the western part of the state. In western Missouri the Norfleet ranges from a featheredge to 10 in. in thickness.

Perry Farm Shale 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 ft in Ray County.

Sni Mills Limestone Member - The Sni Mills Limestone 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 beds of the Perry Farm Member. The Sni Mills varies in thickness from a featheredge to 2.5 ft; it probably averages 8 in or less.

Holdenville Shale - The Holdenville Shale is the youngest recognized unit of the Marmaton Group in Missouri, and 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 in southern Cass County. The thickness of the formation ranges from a featheredge to 15 ft 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 (Figs. 33-35) 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, indicated by the absence of typical Desmoinesian fossils, and the introduction of several new fossils, among which the fusuline *Triticites* is probably the most important. The unconformity beneath the basal Virgilian, Tonganoxie Sandstone Member, marks the upper boundary of the Missourian Series.

PLEASANTON GROUP - The Pleasanton Group (Fig. 33) comprises all the strata which lie below 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, whose thick limestone beds form a prominent scarp above the less-resistant shales and sandstones of the Pleasanton. Exposures of Pleasanton lie in a belt of variable width which extends across western and northern Missouri. The group is also represented

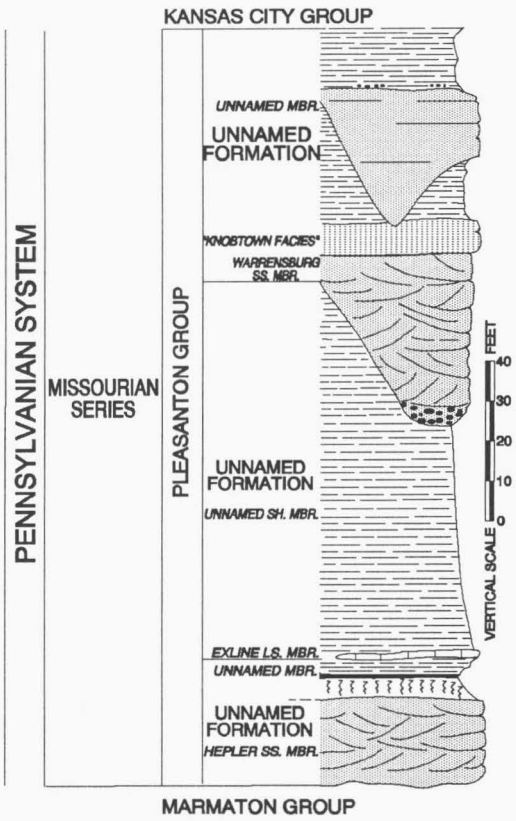

Fig. 33. *Lower Missourian Pleasanton Group in Missouri.*

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 ft. The group thins northward and westward from its cropline, and in the subsurface its minimum thickness appears to be as little as 20 ft. Its maximum thickness in areas where it includes channel-fill deposits probably exceeds 150 ft.

"lower unnamed formation" - The "lower unnamed formation" of the Pleasanton Group includes the Hepler Sandstone Member and all overlying beds up to the base of the Exline Limestone Member of the next higher formation.

Hepler Sandstone Member - The Hepler Sandstone Member is a thin-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 ft 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 ft.

"middle unnamed formation" - The Exline Limestone Member and an "unnamed shale member" which lies above it together compose the "middle unnamed formation" of the Pleasanton Group.

Exline Limestone Member - Regionally, the Exline Limestone Member is an extremely persistent, thin, crinoidal limestone, with an average thickness of less than 1 ft. 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 shale 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, even-bedded, calcareous, marine sandstone that is associated with the channel-fill sandstone. The shale member is approximately 50 ft thick where it is overlain by the widespread, marine sandstone, but it is absent where it was eroded away during deposition of the channel-fill deposits. The shale of this "unnamed shale member" is utilized for the manufacture of brick and tile at a number of places in Missouri and southern Iowa.

"upper unnamed formation" - The **Warrensburg Sandstone Member** and an overlying "unnamed member" constitute the uppermost formation of the Pleasanton group.

In western Missouri the thick shale of the "middle unnamed 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 sandstone, which has been referred to as the Warrensburg. 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 sandstone 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.

Warrensburg Sandstone Member - The strata which are assigned to the Warrensburg Sandstone 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.

"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 Group. 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. 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. The shale and sandstone of the "unnamed member" are present throughout the outcrop area 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 bed 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 unnamed 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 Shale (Fig. 34). The succession is divided into three subgroups, in ascending order: the Bronson, Linn, and Zarah. The top and base of the Kansas City Group are conformable with strata above and below, and the subgroup boundaries are also conformable. Rocks of the Kansas City 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 ft thick.

Hertha Formation - The Hertha Formation includes two limestone members, the basal Critzer and topmost Sniabar, separated by the Mound City Shale Member. The average thickness of the Hertha is approximately 15 ft.

Critzer Limestone Member - The Critzer Limestone 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 ft.

Mound City Shale Member - The Mound City Shale Member of the Hertha Formation includes the **Ovid coal** and its associated underclay in its lower part. The upper part contains beds of dark- and light-gray shale and thin, argillaceous limestone. The thickness of the member ranges from less than 5 ft to more than 10 ft.

Sniabar Limestone Member - The Sniabar Limestone Member of the Hertha Formation is the most conspicuous unit of the Hertha. It 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. 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 ft thick.

Ladore Formation (Ladore Shale) - The Ladore typically contains clay and shale, the total thickness of which is less than 5 ft 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 ft thick where it overlies bioherms in the upper part of the Sniabar. The formation is as much as 15 ft thick in Carroll and Livingston counties, where sandstone may occupy all or part of the unit. Fossils are generally scarce.

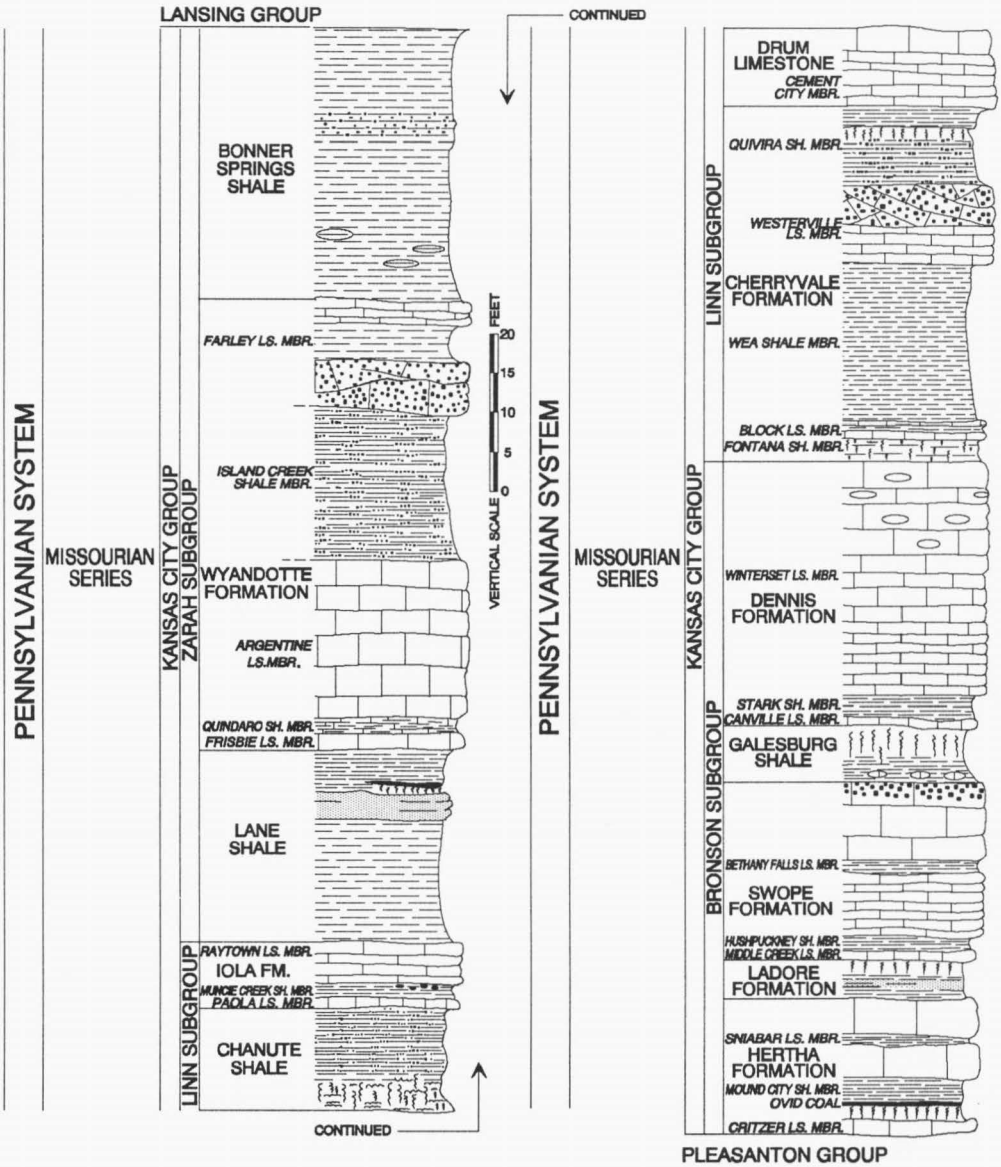

Fig. 34. *Kansas City Group in Missouri.*

Swope Formation -The Swope 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 ft.

Middle Creek Limestone Member - The Middle Creek Limestone Member of the Swope Formation 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 ft.

Hushpuckney Shale Member - The Hushpuckney Shale Member of the Swope Formation 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 ft.

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

Galesburg Shale - The Galesburg Shale 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 ft.

Dennis Formation - The Dennis Formation consists of two limestone members (Canville and Winterset) separated by a shale member (Stark). The thickness of the Dennis ranges from 30 to 40 ft in the outcrop area of Missouri.

Canville Limestone Member - The Canville Limestone Member of the Dennis Formation is found in only a few counties in western Missouri, but it is well-represented in Bates County. It is a dark-gray, thin, lenticular limestone whose maximum thickness is about 4 in.

Stark Shale Member - The Stark Shale Member of the Dennis Formation is a dark-gray to black, fissile shale that grades upward into medium-gray shale. It is about 4 ft thick.

Winterset Limestone Member - The Winterset Limestone Member of the Dennis Formation is a thin- to thick-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. 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 ft.

^^LINN SUBGROUP - The succession of strata that lies between the top of the Winterset Limestone Member of the Dennis Formation and the base of the Lane Shale is named the Linn Subgroup. This succession, except for the uppermost formation, is one of the most variable in the upper Pennsylvanian succession of Missouri. In ascending order, the formations of the subgroup are: the Cherryvale, Drum, Chanute, and Iola. The subgroup is about 70 ft thick in the Kansas City area and nearly 100 ft 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 Cherryvale contains five members (from oldest to youngest): the Fontana, Block, Wea, Westerville, and Quivira. The average thickness of the Cherryvale Formation in western and northern Missouri exposures is about 45 ft.

Fontana Shale Member - The Fontana Shale Member of the Cherryvale Formation 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 ft thick, and consists mostly of clay, but in the Kingston area of Caldwell County it is between 10 and 15 ft thick and is represented principally by the shale described above.

Block Limestone Member - The Block Limestone Member of the Cherryvale Formation is 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 ft to approximately 4 ft.

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

Westerville Limestone Member - The Westerville Limestone Member of the Cherryvale Formation is composed of a lower, relatively uniform, even-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 ft, and the total thickness of the member may be as much as 25 ft. In northern Missouri the thickness of the entire member is less than 10 ft.

Quivira Shale Member - The Quivira Shale Member of the Cherryvale Formation 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, and is silty or sandy. Its thickness varies greatly in the Kansas City area, where it ranges from an average of about 1 ft, to a maximum of about 15 ft. This thickness variation is associated with an essentially equivalent variation in the underlying Westerville. The average thickness of the Quivira in its outcrop area is about 10 ft.

Drum Limestone - In most of the northern Midcontinent area, the Drum Limestone 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 of the Drum Limestone is a gray to buff, thin-bedded limestone that is locally suboolitic in the upper part. This suboolitic limestone may possibly prove to be the Corbin City Limestone of Kansas. The member is 5 to 10 ft thick.

Chanute Shale - The Chanute Shale lies above the Drum Limestone and below the Paola Limestone 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, overlain by silty to sandy shale. 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 ft thick in the Kansas City area and thins to 5 or 10 ft in northern Missouri.

Iola Formation - The Iola Formation contains two limestone members, the lower Paola and upper Raytown, separated by the Muncie Creek Shale Member.

The succession is uniform throughout northeastern Kansas and northwestern Missouri and has an average thickness of about 8 ft.

Paola Limestone Member - The Paola Limestone Member of the Iola Formation is characteristically a single bed of dark-gray, fossiliferous limestone, which has an average thickness of about 1 ft.

Muncie Creek Shale Member - The Muncie Creek Shale Member of the Iola Formation 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 ft.

Raytown Limestone Member - The Raytown Limestone Member of the Iola Formation 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 ft.

^^ZARAH SUBGROUP - The Zarah Subgroup is the uppermost division of the Kansas City Group and includes (in ascending order): the Lane, Wyandotte, and Bonner Springs formations. In the Kansas City area, the subgroup is about 130 ft thick. In northern Missouri this division becomes somewhat thinner because of marked thinning of the Argentine Limestone Member of the Wyandotte Formation.

Lane Shale - The Lane Shale is a gray, silty, micaceous shale at most of its localities in northern and western Missouri. Thin-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 ft.

Wyandotte Formation - The Wyandotte Formation is composed of five members (from the base upward): the Frisbie, Quindaro, Argentine, Island Creek, and Farley. The Frisbie and Argentine are composed of limestone and are separated by the Quindaro, 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 Limestone Member - The Frisbie Limestone Member of the Wyandotte Formation, 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 more complex, as in the Kansas City area, where it contains several beds of limestone interbedded with calcareous shale. The thickness of the Frisbie ranges from 1 to 3 ft.

Quindaro Shale Member - The Quindaro Shale Member of the Wyandotte Formation is a dark- to medium-gray, calcareous shale. Locally, it contains calcareous, fossiliferous siltstone in the upper part. The thickness of the Quindaro varies from less than 1 ft to about 3 ft.

Argentine Limestone Member - The Argentine Limestone Member of the Wyandotte Formation 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 ft at Kansas City, to less than 1 ft 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 as well.

Island Creek Shale Member - The Island Creek Shale Member of the Wyandotte Formation is a sandy or silty shale, which averages about 30 ft in thickness in the area of

Jackson, Platte, and Clay counties, but is very thin or absent in parts of northwestern Cass County.

Farley Limestone Member - The Farley Limestone Member of the Wyandotte Formation 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 ft thick in Platte and Clay counties where the complete Farley succession is known. The upper limestone is largely composed of algal debris and ranges in thickness from a few inches to 2 or 3 ft. The member contains many gastropods and pelecypods. The average thickness of the Farley in the area noted above is about 15 ft.

Bonner Springs Shale - The Bonner Springs Shale 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 ft.

LANSING GROUP - The Lansing Group is composed of three formations (Fig. 35). 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 Lansing Group is 60 ft thick.

Plattsburg Formation - The Plattsburg Formation contains a lower and an upper limestone member and an intervening shale member (in ascending order): the Merriam, Hickory Creek, and Spring Hill. 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 Limestone Member - The Merriam Limestone Member of the Plattsburg Formation 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 ft thick.

Hickory Creek Shale Member - The Hickory Creek Shale Member of the Plattsburg Formation is a calcareous, fossiliferous shale which is generally less than 2 ft 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 Limestone Member - Where it is typically developed, the Spring Hill Limestone Member of the Plattsburg Formation contains a thin, basal, sponge-bearing, limestone bed, which is overlain by thicker limestone beds that are commonly extremely fossiliferous and 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 ft thick. It has been quarried at a number of localities in the state for riprap and road surfacing material.

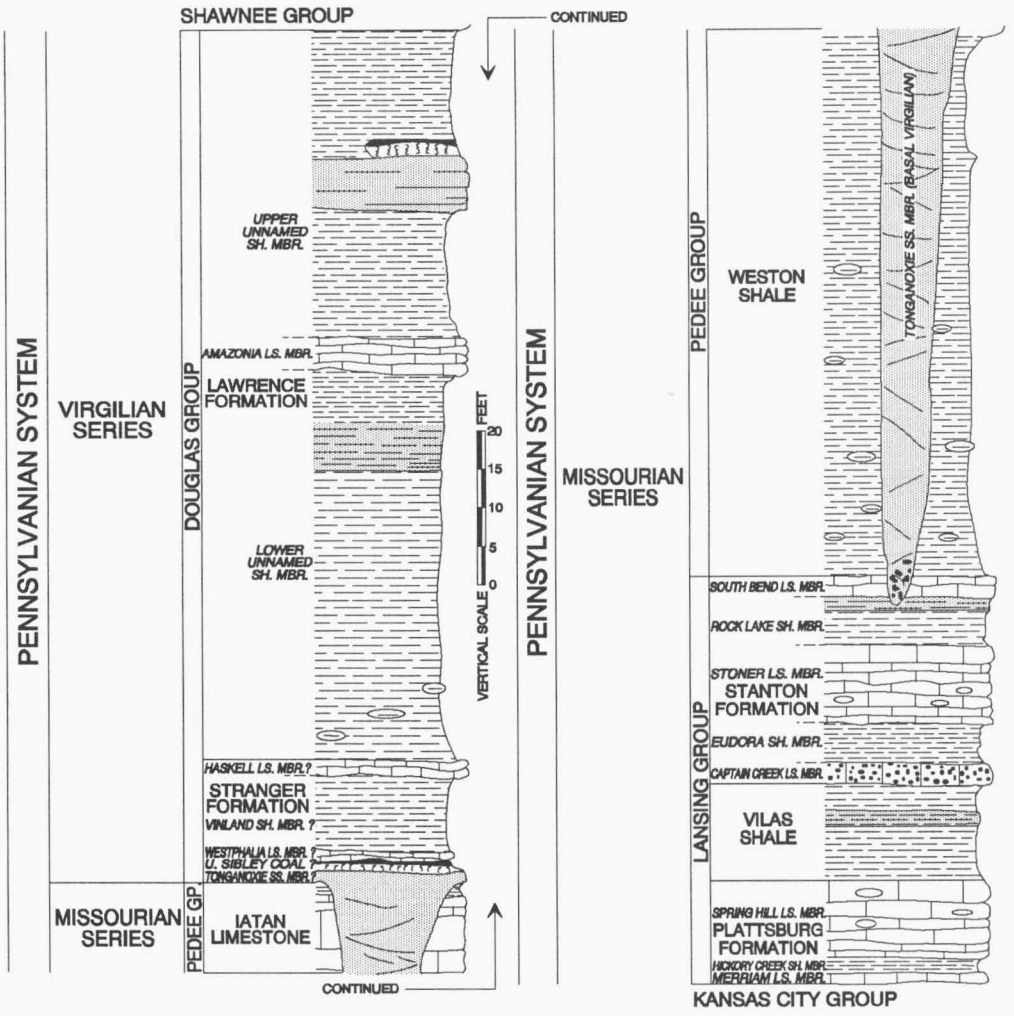

Fig. 35. *Lansing, Pedee, and Douglas Groups in Missouri.*

Vilas Shale - The Vilas Shale 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 ft thick; elsewhere, it is no more than 5 ft thick.

Stanton Formation - The Stanton Formation contains the following members (from the base upward): the Captain 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 Sandstone Member, lies upon the eroded surface. The average thickness of the Stanton is about 35 ft.

Captain Creek Limestone Member - The Captain Creek Limestone Member of the Stanton Formation consists of bluish-gray, dense limestone, which has pronounced vertical joints. The member occurs either as a thin- and even-bedded unit or as a single, massive bed. It is commonly oolitic, and ranges from 2 to 4 ft thick.

Eudora Shale Member - The Eudora Shale Member of the Stanton Formation is a fissile shale, which is black in the basal and middle parts and gray in the upper part. Its average thickness is about 5 ft.

Stoner Limestone Member - Most of the limestone beds of the Stoner Limestone Member of the Stanton Formation are light-gray and thin-bedded, but the topmost bed of the member is massive to rubbly, drab or buff limestone, 1 to 2 ft 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 ft.

Rock Lake Shale Member - The Rock Lake Shale Member of the Stanton Formation 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 ft, but averages less than 10 ft.

South Bend Limestone Member - The South Bend Limestone Member of the Stanton Formation 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 the Tonganoxie Sandstone Member of the Stranger Formation. Elsewhere in northwestern Missouri the South Bend Member is persistent and is from 3 to 5 ft thick.

PEDEE GROUP - The Pedee Group (Fig. 35) 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 Pedee varies with that of the Weston, which thickens from 60 ft in central Platte County to nearly 100 ft 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 ft. The Pedee Group is conformable with the underlying Lansing Group.

The uppermost beds of the Pedee are gray and maroon shale and clay that are locally present above the Iatan Limestone 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 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 ft in Missouri exposures.

Weston Shale - The Weston Shale is a gray shale that generally contains a great many clay-ironstone concretions. 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 Weston ranges from about 60 ft in Platte County, to approximately 100 ft in Buchanan County. North and west of Buchanan County, it thins to a thickness of only a few feet.

Iatan Limestone - The Iatan Limestone consists of a single, massive bed of light-gray, algal limestone, which has a brecciated appearance when weathered. Locally, a few inches of thin-bedded limestone overlie the thick, massive bed. The thickness of the Iatan ranges from less than 5 ft in the St. Joseph area, to more than 15 ft 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 considered to be the equivalent of the Tonganoxie Sandstone 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 (Fig. 35) is a dominantly clastic succession which extends upward from the base of the Stranger Formation to the base of the Toronto Limestone Member of the Oread Formation, 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 Douglas Group ranges from 110 to 150 ft.

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 Limestone Member. The Stranger Formation also includes a thick, channel-fill sandstone, which is considered to be equivalent to the **Tonganoxie Sandstone Member**

believed to have a maximum thickness of about 50 ft.

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 thin-bedded, shaly, fine-grained micaceous sandstone. This bed lies above the Iatan Limestone 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 ft.

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 ft 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.

Westphalia Limestone Member - The Westphalia Limestone Member of the Stranger Formation is a few inches of platy limestone, which contains carbonized plant material along the bedding planes,

Vinland Shale Member - The Vinland Shale Member of the Stranger Formation is an extremely fossiliferous, calcareous shale and claystone. It contains an abundance of gastropods and pelecypods. The unit is from 5 to 10 ft thick in Missouri exposures.

Haskell Limestone Member - The Haskell Limestone Member of the Stranger Formation, the crinoidal limestone at the top of the succession, is from a few inches to approximately 2 ft thick in Missouri

Lawrence Formation - In Missouri the strata of the Douglas Group that lie above the Haskell Limestone 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 Limestone Member. In Kansas, a sandstone unit known as the Ireland Sandstone Member is present at the base of the Lawrence; this sandstone lies disconformably on the Robbins Shale Member, which in Kansas is the highest unit of the Stranger. 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 shale 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 unnamed shale member" - The "lower unnamed shale member" 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

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 member" may be equivalent to the Robbins Shale Member of the Stranger Formation in Kansas. The thickness of the entire "lower unnamed shale member" varies. It is more than 80 ft thick in southwestern Buchanan and northwestern Platte counties, approximately 50 ft thick at St. Joseph in Buchanan County, and about 75 ft thick at Savannah in Andrew County.

Amazonia Limestone Member - The Amazonia Limestone Member of the Lawrence Formation is a light- to medium-gray, dense to finely crystalline limestone, which commonly is exposed 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 ft thick, to the St. Joseph area and Amazonia area, where it is 12 to 15 ft thick. The member is very thin, or absent in northwestern Platte County.

"upper unnamed shale member" - The "upper unnamed shale member" of the Lawrence Formation 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 "upper unnamed shale member" decreases from about 50 ft in the southwestern part of Buchanan County, to less than 20 ft 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 Limestone Member has its thickest development.

SHAWNEE GROUP - The formations of the Shawnee Group (Fig. 36) include (from the base upward) the: 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 Shawnee Group in Missouri ranges from 230 to 250 ft.

Oread Formation - The Oread Formation is composed of an alternating succession of four limestone and three shale members. From the base upward, they are: the Toronto, Snyderville, Leavenworth, Heebner, Plattsmouth, Heumader, and Kereford. 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-

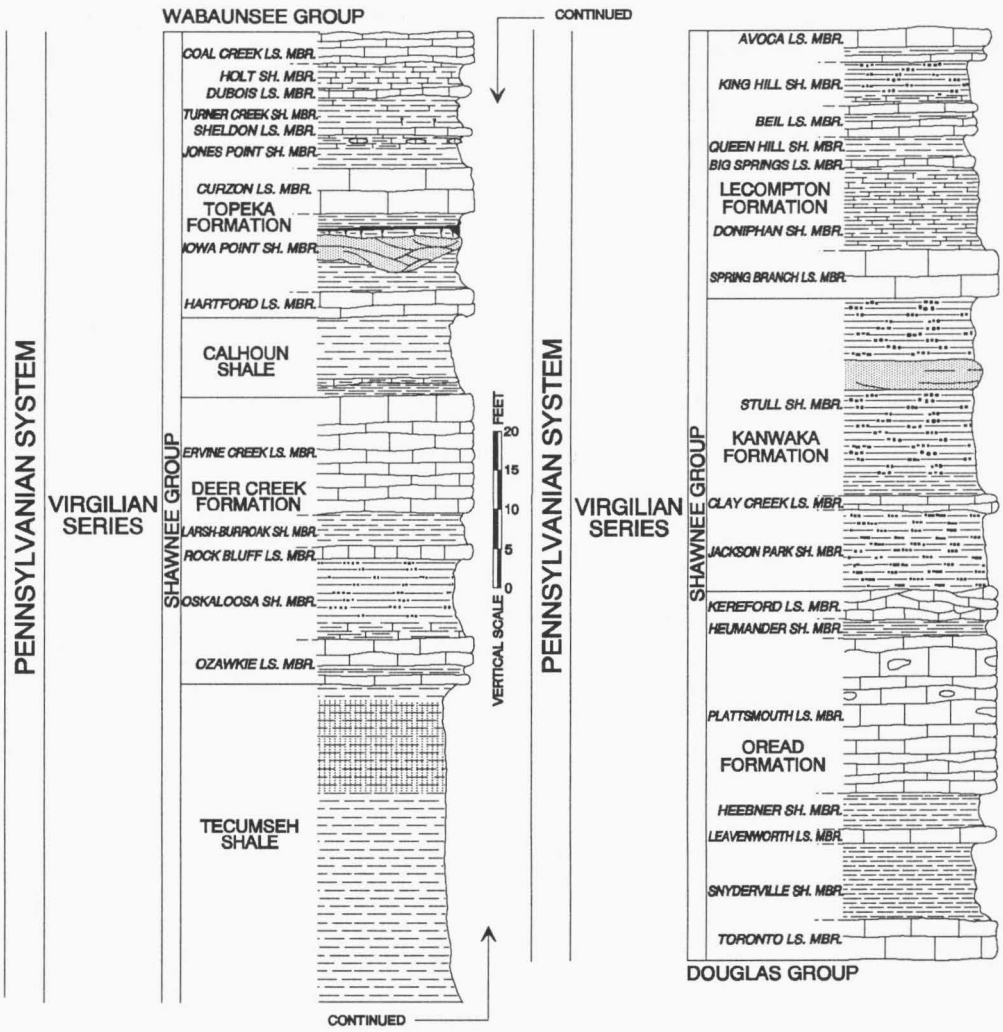

Fig. 36. *Shawnee Group in Missouri.*

exposed at several places in Buchanan and Andrew counties. The total thickness of the Oread in Missouri is about 50 ft.

Toronto Limestone Member - The Toronto Limestone Member of the Oread Formation 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 ft.

Snyderville Shale Member - The Snyderville Shale Member of the Oread Formation is a gray shale. It is reported to include a maroon zone at or near the base in Buchanan and Andrew counties. The member has an average thickness of about 10 ft.

Leavenworth Limestone Member - The Leavenworth Limestone Member of the Oread Formation is a dense, dark-gray limestone. It consists of two or more beds and is commonly 2 to 3 ft thick.

Heebner Shale Member - The Heebner Shale Member of the Oread Formation is extremely persistent. It is a dark-gray to black, fissile core-shale in the lower part, and is a lighter-gray, nonfissile shale in the upper part. The member is 4 to 5 ft thick.

Plattsmouth Limestone Member - The Plattsmouth Limestone Member of the Oread Formation 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 ft thick.

Heumader Shale Member - The Heumader Shale Member of the Oread Formation 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 ft to about 3 ft.

Kereford Limestone Member - The Kereford Limestone Member of the Oread Formation 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 thin-bedded unit or as a massive ledge. It is commonly cross-bedded. Its thickness ranges from less than 2 ft to more than 10 ft.

Kanwaka Formation.–The Kanwaka Formation is composed of two relatively thick shale beds and a thin intervening limestone unit (from the base upward): the Jackson Park, Clay Creek, and Stull Members. 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 ft thick.

Jackson Park Shale Member - The Jackson Park Shale Member of the Kanwaka Formation is a gray, silty, micaceous shale. It is 10 to 15 ft thick.

Clay Creek Limestone Member - The Clay Creek Limestone Member of the Kanwaka Formation 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 ft thick.

Stull Shale Member - The Stull Shale Member of the Kanwaka Formation 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 ft.

Lecompton Formation - The Lecompton Formation contains four limestone members alternating with three shale members (from the base upward): the Spring Branch, Doniphan, Big Springs, Queen Hill, Beil, King Hill, and Avoca Members. 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 Formation is about 35 ft.

Spring Branch Limestone Member - The Spring Branch Limestone Member of the Lecompton Formation is a dark-gray, massive, argillaceous limestone that weathers to a dark-buff. The member is 5 to 7 ft thick.

Doniphan Shale Member - The Doniphan Shale Member of the Lecompton Formation is composed of gray, calcareous shale and claystone. In southern Holt County, the member is about 16 ft thick; elsewhere it is less than 10 ft thick.

Big Springs Limestone Member - The Big Springs Limestone Member of the Lecompton Formation consists of a single bed of dark-gray, dense limestone that has an average thickness of about 1 ft.

Queen Hill Shale Member - The Queen Hill Shale Member of the Lecompton Formation 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 ft.

Beil Limestone Member - The Beil Limestone Member of the Lecompton Formation is composed of several layers of fossiliferous limestone, which are interbedded with calcareous shale. The member is 4 to 5 ft thick.

King Hill Shale Member - The King Hill Shale Member of the Lecompton Formation is a gray shale, which is silty in the upper part and calcareous near the base. Its thickness ranges from 6 to 8 ft.

Avoca Limestone Member - The Avoca Limestone Member of the Lecompton Formation 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 ft in southern Holt County and is of comparable thickness elsewhere in northwestern Missouri.

Tecumseh Shale - The Tecumseh Shale is arenaceous in the upper part. The **Ost Limestone** of Nebraska is possibly represented in Missouri by a lenticular limestone which is less than 1 ft thick near the base of the formation in a locality near Savannah in Andrew County. The thickness of the Tecumseh ranges from 40 to 50 ft.

Deer Creek Formation - The Deer Creek Formation includes three limestone members and two shale members (from the base upward): the Ozawkie, Oskaloosa, Rock Bluff, Larsh-Burroak, and Ervine Creek Members. 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 are considered as a combined unit, the **Larsh-Burroak**.

The best exposures of the Deer Creek 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 has been quarried for concrete aggregate and road surfacing material. The Deer Creek Formation is about 40 ft thick.

Ozawkie Limestone Member - The Ozawkie Limestone Member of the Deer Creek Formation is composed of several uneven beds of argillaceous, buff limestone that are separated by shaly partings. The thickness of the formation ranges from 5 to 7 ft.

Oskaloosa Shale Member - The Oskaloosa Shale Member of the Deer Creek Formation 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 ft.

Rock Bluff Limestone Member - The Rock Bluff Limestone Member of the Deer Creek Formation is a single, massive bed of dense, medium-gray limestone, which has pronounced vertical joints. It has an average thickness of approximately 2 ft.

Larsh-Burroak Shale Member - The Larsh-Burroak Shale Member of the Deer Creek Formation is comprised of dark-gray to black, fissile shale in the lower part and of gray shale in the upper part. The member is about 4 ft thick.

Ervine Creek Limestone Member - The Ervine Creek Limestone Member of the Deer Creek Formation 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 ft.

Calhoun Shale - In northwestern Missouri, the Calhoun Shale, except for a few beds of 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. Exposures range from less than 5 ft, to a maximum of 10 ft.

Topeka Formation - The Topeka Formation consists of nine alternating limestone and shale members (from the base upward): the Hartford, Iowa Point, Curzon, Jones Point, Sheldon, Turner Creek, DuBois, Holt, and Coal Creek. Except for a few scattered exposures where the Ervine Creek Member has been quarried along the One Hundred and Two River south of Maryville in Nodaway

County, exposures of the Topeka 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 ft thick.

Hartford Limestone Member - The Hartford Limestone Member of the Topeka Formation consists of one or more beds of fossiliferous, brownish-gray limestone and associated calcareous shale. The member is 3 to 4 ft thick.

Iowa Point Shale Member - The Iowa Point Shale Member of the Topeka Formation is composed of sandstone and sandy shale. A thin coal is present near the top of the member. The sandstone is locally a channel-fill deposit. The average thickness of the member is about 10 ft.

Curzon Limestone Member - The Curzon Limestone Member of the Topeka Formation consists of two beds of massive, earthy, brownish-weathering limestone that are separated by a shale parting. The member is 5 to 6 ft thick.

Jones Point Shale Member - The Jones Point Shale Member of the Topeka Formation is composed of medium-gray shale and calcareous clay, which is present in the uppermost part of the unit. The clay contains limestone concretions, and is from 3 to 5 ft thick.

Sheldon Limestone Member - The Sheldon Limestone Member of the Topeka Formation 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 ft thick.

Turner Creek Shale Member - The Turner Creek Shale Member of the Topeka Formation 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 ft.

DuBois Limestone Member - The DuBois Limestone Member of the Topeka Formation 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 ft.

Holt Shale Member - The Holt Shale Member of the Topeka Formation 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 ft.

Coal Creek Limestone Member - The Coal Creek Limestone Member of the Topeka Formation 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 ft.

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 Member 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 terminates at what is believed to be the top of the Dry Member of the Stotler Formation (Figs. 37 and 38).

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 was published in 1961 as being divided into three subgroups: the **Sacfox**, **Nemaha**, and **Richardson**. However, in late 1961 these units were deemed unnecessary by a coalition of Midcontinent geological surveys, and dropped from use.

Rocks of the Wabaunsee Group are present in Holt, Nodaway, and Atchison counties in the northwestern corner of the state. In this area the group is approximately 340 ft thick.

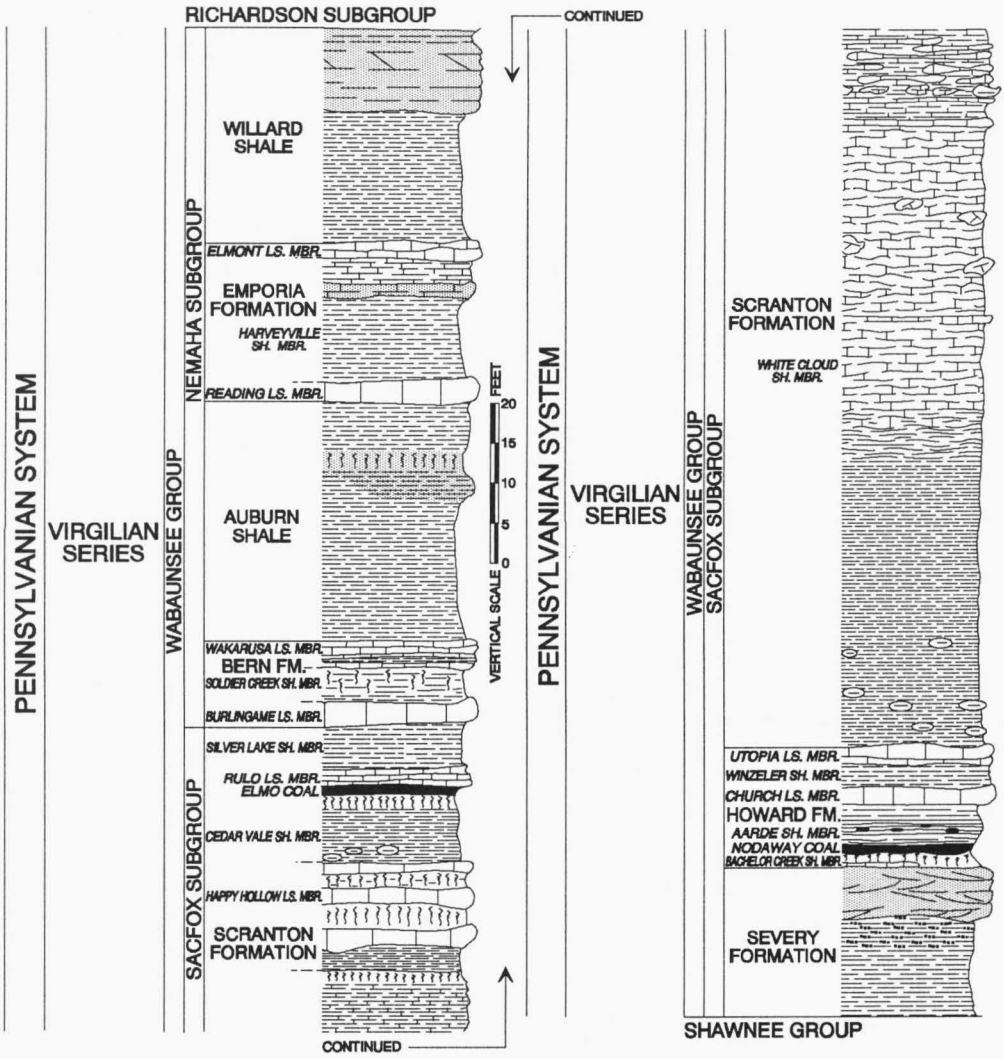

Fig. 37. *Sacfox and Nemaha Subgroups of the Wabaunsee Group in Missouri.*

Severy Formation - The Severy Formation is composed of silty, micaceous, gray shale in the lower part and thin-bedded to massive sandstone in the upper part. The average thickness of the formation is about 25 ft.

Howard Formation - Where the Howard Formation is fully developed in the northern Midcontinent region, it contains five members (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 ft.

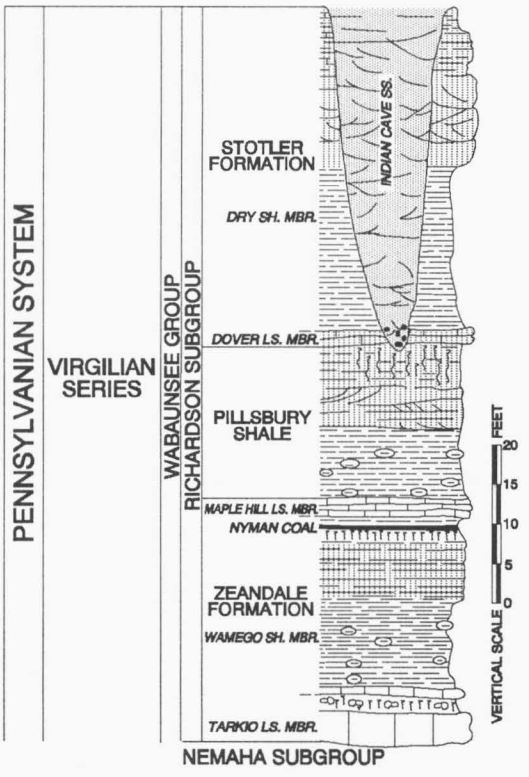

Fig. 38. *Richardson Subgroup of the Wabaunsee Group in Missouri.*

Bachelor Creek Limestone Member - The Bachelor Creek Limestone Member of the Howard Formation is present in only one locality in Holt County. Here, it is a dense, bluish-gray limestone, which is only a few inches thick.

Aarde Shale Member - The Aarde Shale Member of the Howard Formation is composed, from the base upward, of an underclay, the Nodaway coal bed, which is over 1 ft 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 ft thick.

Church Limestone Member - The Church Limestone Member of the Howard Formation is a single bed of medium- to dark-bluish-gray, brittle limestone, which weathers to rusty-brown. It is fossiliferous and contains an abundance of gastropods, brachiopods, crinoids, and bryozoans. The member is about 18 in thick.

Winzeler Shale Member - The Winzeler Shale Member of the Howard Formation is composed of dark-gray shale, which is apparently unfossiliferous. The thickness of the member ranges from 2 to 4 ft.

Utopia Limestone Member - The Utopia Limestone Member of the Howard Formation 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 ft.

Scranton Formation - The Scranton Formation is composed of a succession of beds that lies above the top of the Utopia Limestone Member of the Howard Formation and beneath the base of the Burlingame Limestone Member of the Bern Formation. The formation is divided into five members (from the base upward): the White Cloud, Happy Hollow, Cedar Vale, Rulo, and Silver Lake. The average thickness of the formation is about 130 ft.

White Cloud Member - The White Cloud Member of the Scranton Formation is composed predominantly of gray shale. The upper 20 to 25 ft of the member contains numerous, thin, silty and argillaceous beds of limestone and large, irregular-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 ft.

Happy Hollow Member - The Happy Hollow Member of the Scranton Formation contains three, rubbly beds of argillaceous limestone that 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 ft.

Cedar Vale Shale Member - The Cedar Vale Shale Member of the Scranton Formation 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 ft thick.

Rulo Limestone Member - The Rulo Limestone Member of the Scranton Formation 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 ft, to about 2 ft.

Silver Lake Shale Member - The Silver Lake Shale Member of the Scranton Formation consists of gray shale. It is thin in Nodaway County and thickens westward. Where it is exposed, the member is 5 to 10 ft thick.

Bern Formation - The Bern Formation contains three members (from the base upward): the Burlingame, Soldier Creek, and Wakarusa. The total thickness of the Bern is about 10 ft.

Burlingame Limestone Member - Where it is exposed in Atchison County, the Burlingame Limestone Member of the Bern Formation is commonly a single, massive bed of argillaceous limestone that has an average thickness of about 2 ft. 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 ft of greenish-gray, dense, algal limestone, 3 to 4 ft of calcareous claystone, and of a few inches of slabby limestone.

Soldier Creek Shale Member - The Soldier Creek Shale Member of the Bern Formation contains gray shale in the lower part and calcareous claystone in the upper part. The member is 3 to 4 ft thick.

Wakarusa Limestone Member - The Wakarusa Limestone Member of the Bern Formation is composed of three units: the lower is medium-gray, argillaceous limestone, about 6 in. thick; the middle is a thin, dark-gray shale bed; and the upper is an irregular-bedded, crinoidal limestone, about 2 ft thick. The total thickness of the member is about 3 ft.

Auburn Shale - The Auburn Shale 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 ft 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 ft.

Reading Limestone Member - The Reading Limestone Member of the Emporia Formation typically occurs as a single bed of dense limestone that contains few fossils. It is commonly dark-bluish-gray, and locally it is dolomitic. The member is 2 to 3 ft thick.

Harveyville Shale Member - The Harveyville Shale Member of the Emporia Formation 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 than that below. The member is 15 to 18 ft thick.

Elmont Limestone Member - The Elmont Limestone Member of the Emporia Formation 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 ft thick.

Willard Shale - The Willard Shale consists mostly of gray 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 ft, but in the subsurface north of Rock Port in Atchison County, it is somewhat thicker.

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 ft thick.

Tarkio Limestone Member - The Tarkio Limestone Member of the Zeandale Formation 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 rough-textured limestone concretions. Large fusuline foraminifera, which are commonly encrusted with algae, are present in the lower, 3 to 4-ft-thick bed. The total thickness of the Tarkio member ranges from 4 to 5 ft.

Wamego Shale Member - The Wamego Shale Member of the Zeandale Formation is predominantly a gray shale, which grades upward to sandy shale and sandstone. The lower and middle parts of the member contain clay-ironstone concretions. The thin persistent **Nyman coal bed** is present near the top of the member. The average thickness of the Wamego is about 20 ft.

Maple Hill Limestone Member - The Maple Hill Limestone Member of the Zeandale Formation 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 ft.

Pillsbury Shale - The lower and middle parts of the Pillsbury Shale 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 ft. The average thickness of the Pillsbury in Missouri is about 28 ft.

Stotler Formation - Where the Stotler Formation is complete, it consists of three members (from the base upward): 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 Limestone Member - The Dover Limestone Member of the Stotler Formation 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 Shale. It is exposed in Atchison County along the bluffs of the Missouri River from Rock Port northward. This member was formerly regarded as the **Grandhaven member** in Missouri. The thickness of the member ranges from 2 in to almost 2 ft.

Dry Shale Member - In Missouri the complete succession of the Dry Shale Member of the Stotler Formation 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 thin-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 ft.

Indian Cave Sandstone - In the northwestern corner of the state, in northwestern Atchison County, a few exposures of massive sandstone have been named the Indian Cave Sandstone (Fig, 38). This sandstone occupies deep channels that have been cut into upper Pennsylvanian beds . 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 ft in northwestern Missouri exposures.

In 1961, this sandstone was identified as Early Permian (Wolfcampian) in age. Today, this sandstone is considered Pennsylvanian in age, but little more is known about it.

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.

Farther north, 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 (1961)

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 (Fig. 39). These include (from the base upward): 1) an incompletely-known subsurface succession, which is provision-

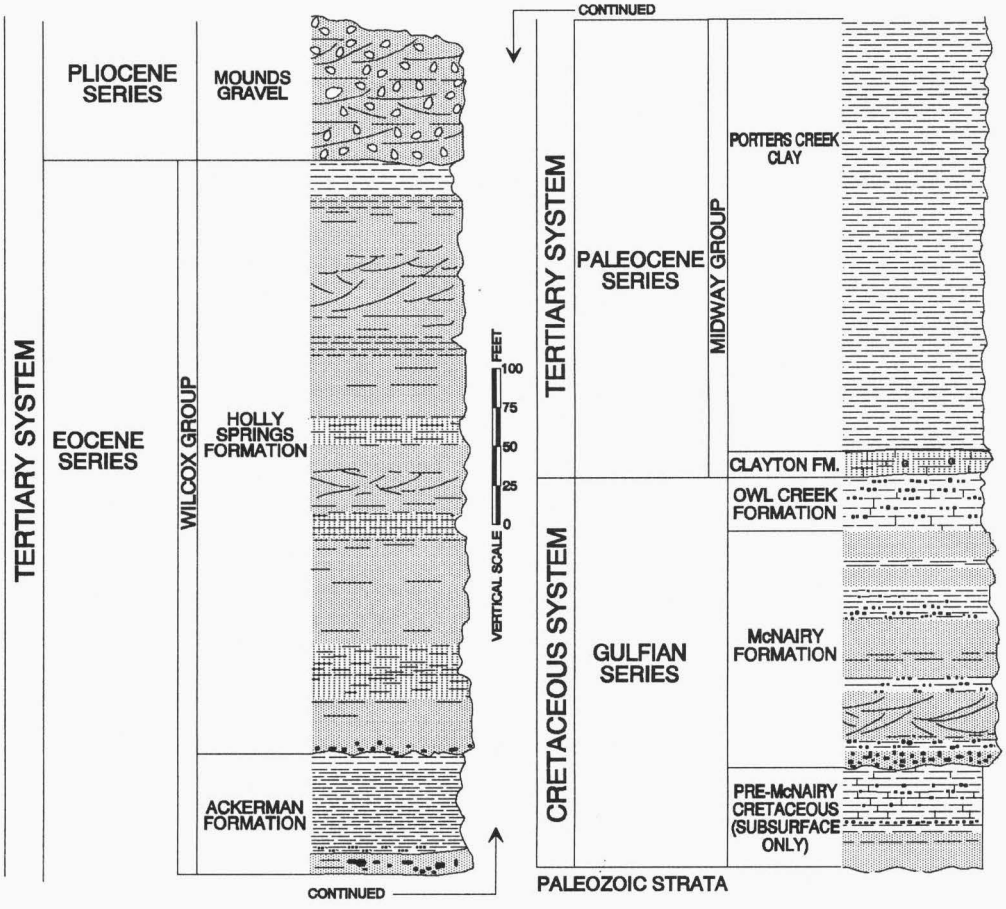

Fig. 39. *Cretaceous and Tertiary Systems in southeastern Missouri.*

ally 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 are not exposed 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 ft.

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 thin-bedded, light-gray clay, 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 cannot 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 ft.

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 is dark-bluish-gray, 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 ft in the outcrop area, to as much as 100 ft in the subsurface. The Owl Creek is unconformably overlain by Tertiary 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 ft thick, covers much of the bedrock through 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 (1961)

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 (Fig. 39).

MIDWAY GROUP - The Midway Group in Missouri is composed of two formations, the Clayton below and the Porters Creek above. The Midway Group varies in thickness from a few inches in some places in its outcrop area along Crowley's Ridge in Scott and Stoddard counties to more than 650 ft 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 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 is distinctively green, which makes it noticeable and easy to recognize in the outcrop area. In the subsurface the Clayton 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 ft in the outcrop area, to as much as 20 ft in the subsurface.

Porters Creek Clay - The Porters Creek Clay is a massive, homogeneous, dark-gray clay, that is almost black when wet. When dry, it spalls with a characteristic conchoidal fracture 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, a 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 ft thick in some places. Southeastward, in the subsurface, it thickens to 650 ft or more. In the subsurface the formation lacks sand, and its lower 50 ft commonly contains foraminifera and small pelecypods.

Eocene Series

The Eocene Series in Missouri (Fig. 39) 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 Mounds Gravel (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 its outcrop area that varies from 0, to more than 300 ft 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 ft thick. The group lies unconformably above the Midway Group and unconformably below the Mounds Gravel. The Ackerman and Holly Springs Formations of the Wilcox Group 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 ft of the formation is very plastic and is bright-red or yellow. 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, medium-grained, and has clay particles disseminated throughout the mass. At one locality boulders of quartzite 3 to 4 ft 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 Clay, are erratically incorporated in the basal lenticular sandstone of the Ackerman. The boulders range in size from a few inches to more than 4 ft 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 ft or more. The presence of the Ackerman has been noted in the

0 to 100 ft 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.

Holly Springs Formation - The Holly Springs Formation is quite 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 sandstone on weathered surfaces varies from orange to dark-red, but fresh exposures are colorless or white. The clay of the Holly Springs is erratically 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 thin-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 thickens southward. It ranges from a few inches thick along the northwestern margin of the ridge, to more than 250 ft 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 ft of rock has been referred to the Holly Springs in a test well near Caruthersville in Pemiscot County. The formation is exposed 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 Mounds (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 reports (up to 1961) referred to the gravel composing the unit or units as the **"Lafayette" Gravel** or as the "Lafayette-type gravel." In Missouri (Fig. 39), 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 Gravel** was proposed by C.F. Marbut in 1902. Recent work in the region has referred to this unit as the **Mounds Gravel**,. This name is used extensively in Illinois, and was adopted by the U.S. Geological Survey in their work in the Embayment region.

Mounds Gravel - Descriptions of the various occurrences of the Mounds Gravel (called **"Lafayette" Gravel** in 1961) throughout eastern Missouri indicate that in this area there is little variation in its composition. In most exposures the formation is composed of irregular-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 1.5 and 3 in. 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, 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 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.

Sand associated with the gravel is medium- to coarse-grained, subangular to angular, and heavily stained with iron oxide. This staining makes the formation a distinctive dark-red at most exposures. The clay in the formation is erratically distributed as thin lenses, or else it forms a matrix for the gravel. It is very sandy, plastic, noncalcareous, and varies 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 ft thick. In southeastern Missouri, where the formation caps most of the hills, it is estimated to be as much as 60 ft thick along the southeastern margin of Crowley's Ridge, with 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. (1961)
Revised By
John W. Whitfield
(1995)

Pleistocene Series

The Pleistocene Series of Missouri includes all unconsolidated post-Tertiary deposits and consist of clay, silt, sand and gravel (Fig. 40). The greatest recorded thickness of the deposits is 400 ft.

			Stage (Age)		Deposits
CENOZOIC ERA	QUATERNARY SYSTEM	PLEISTOCENE SERIES	Recent		alluvium, landslide, debris, soil
			Wisconsinan	Upper	Bignell Loess, alluvium
				Lower	Brady Geosol Farmdale Loess Peoria Loess, alluvium
			Sangamonian		Sangamon Geosol
			Illinoian		Loveland Loess Yarmouth-Sangamon soil alluvium, till
			Yarmouthian		Ferrelview Formation Yarmouth Geosol
			pre-Illinoian		alluvium till sand and gravel

Fig. 40. *Pleistocene deposits in Missouri.*

Quaternary investigations in adjoining states support an interpretation that the Kansan and Nebraskan glacial stages had a more complex history of multiple glaciation and interglacial periods than previously described. Better dating techniques also show that past age correlations were underestimated. Until the stratigraphy of the Pleistocene is resolved, the age and correlation of Kansan and Nebraskan glacial deposits in Missouri are identified as **"pre-Illinoian."**

Most of the northern part of the state, north of the Missouri River, was covered by pre-Illinoian glacial ice (Fig. 41). During this time there were several advances and retreats of the glacial ice sheet. The last surge of ice extended somewhat farther south than the earliest ice as evidenced by deposits (formerly regarded as of Kansan age) which lie just south of the Missouri River west of Jefferson City. Small areas of the state in the vicinity of the cities of St. Louis and Ste. Genevieve have deposits once thought to be Illinoian in age.

There are considerable variations in till thickness. In Putnam County, located in north-central Missouri, 45 ft of till overlies Pennsylvanian limestone in coal strip-pits. Several miles to the west, wells drilled into pre-glacial valleys that have been buried by glacial sediments penetrated over 250 ft of till. Farther south, near the glacial terminus, variable drift thickness may be partly due to postglacial erosion, but the diversity in elevation of the rolling preglacial landscape undoubtedly influenced glacial deposition. Land surfaces not

Fig. 41. *Southern extent of pre-Illinoin glaciation in Missouri.*

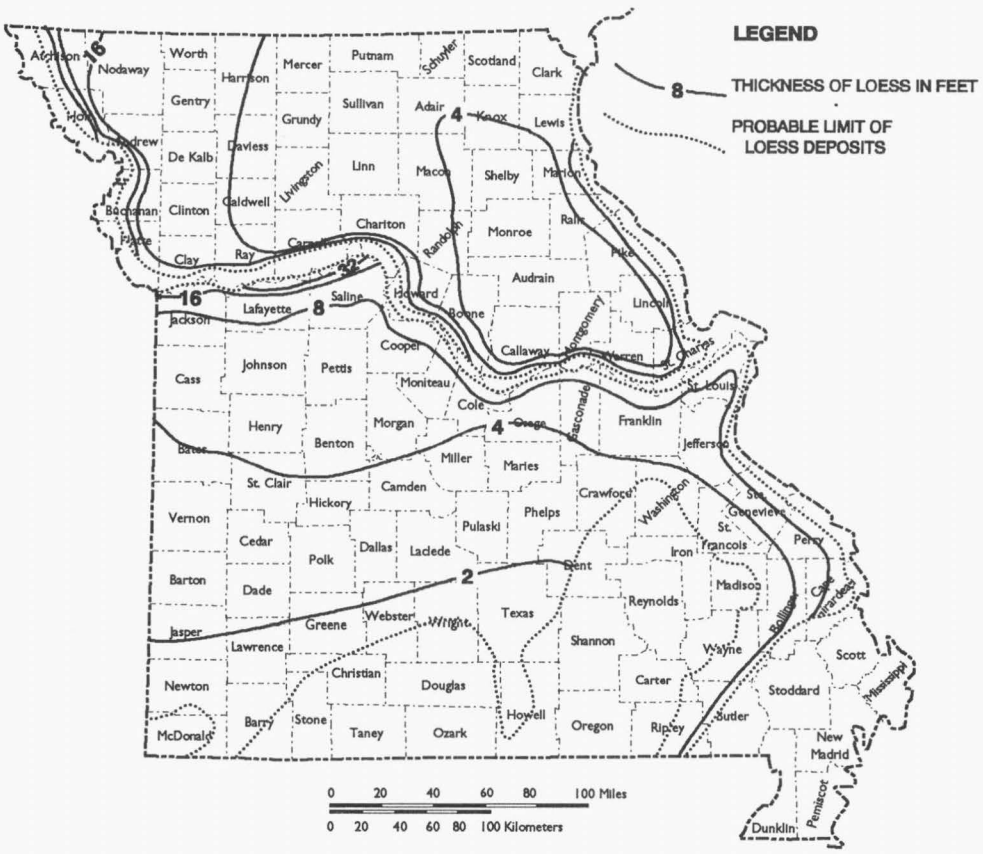

Fig. 42. *Thickness map of loess in Missouri.*

covered by drift were either high enough in elevation during pre-Illinoian times to avoid glacial encroachment or pre-Wisconsinan erosion removed glacial sediments. Possibly, the structure of the advancing glacier was not a uniformly monolithic ice mass but a ragged, uneven ice front with lobe-like protrusions. Small areas remained undisturbed between the protrusions and eventually formed windows of nonglaciated land surface as the glacier advanced toward its southern terminus.

Soils that formed during the successively younger interglacial ages (Yarmouth and Sangamon) are known to be present in Missouri. Austin, et al. (1991, p. 550) stated "The term paleosol describes a buried soil horizon or horizons developed in the geologic past without reference to a stratigraphic context. The term geosol, a buried soil in a stratigraphic context, coincides with guidelines of the North American Commission on Stratigraphic Nomenclature (1983)." Therefore, in Missouri these soils are regarded formally as the Yarmouth and Sangamon **Geosols**. Nonglacial sediments, deposited during Pleistocene and Recent ages, have been identified. Loess of the youngest (Wisconsinan) age is present throughout most of the state, but loess of an older (Illinoian) age is apparently confined to areas adjacent to the Missouri River (Fig. 42). Colluvial deposits of various ages of the Pleistocene have also been recognized within the glaciated area of the state.

On wide areas of the uplands, till is overlain by a gray, clayey silt that is considered by some to be a welded paleosol (Yarmouth-Sangamon) and by

others as a deposit (Ferrelview Formation). Deposits of gray, calcareous sand and gravel underlie unleached till in northern Missouri. Wood fragments are often present in the gravel. In many areas in northern Missouri the sand and gravel have filled pre-Pleistocene river channels; deposits of 100 ft are not uncommon in the channel-filled areas. These channel deposits are excellent sources for groundwater.

Several terrace surfaces have been identified within the state, and some of them have been named, although statewide correlations have not yet been made from them. Samples of wood from one of the terraces at Bonfils in St. Louis County, 2.5 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).

Pleistocene deposits are economically important as parent material for much of the soil in the state. They are important sources of water and large quantities of sand and gravel.

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.

Pre-Illinoian - The first recognizable sign of the glacial approach in Missouri is outwash layers of silt and sand, containing round to subangular chert and limestone pebbles, lying directly on Pennsylvanian deposits. At some locations, the presence of dense, compact silt layers interbedded with varved silt implies ice-marginal ponds and lakes formed in front of the ice mass.

The base of the till varies in lithology. In places it consists of sand and gravel beds several feet thick; in other places it is an unleached and unoxidized till (blue clay). It is commonly a very dark gray, silty clay containing many locally derived cobbles and boulders. The upper part of the unoxidized till commonly contains gypsum-filled joints. This till grades upward into unleached and oxidized till that is calcareous and contains limestone in the form of pebbles and cobbles. It 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, but lacks the limestone inclusions which are common in the underlying material. Nodules of secondary carbonate are commonly present in the pre-Illinoian till.

Probably the most distinctive erratic in western Missouri is pink Sioux quartzite.

Materials overlying the leached and oxidized pre-Illinoian till vary from loess, Yarmouth-Sangamon soil, Ferrelview clayey silt, to lacustrine silty clay.

Yarmouthian Stage

Yarmouth Geosol - Remnants of a thick, gray soil developed on the pre-Illinoian till and preserved only on primary divides in northern Missouri have been tentatively classified as Yarmouthian age.

Ferrelview Formation - According to Howe and Heim (1968), the Ferrelview consists of a thick, gray, clayey silt situated below the Loveland loess and above the youngest pre-Illinoian till. The Ferrelview is considered to

comprise deposits formed in a continuum of environments, among which those of till-plain lakes and accretion-gley formation were most important. According to the authors, the typical Ferrelview does not include a recognizable Yarmouth soil profile. Late Kansan outwash silt probably was an important constituent as lacustrine deposits, and Kansan and Yarmouthian loess may have contributed to the introduced material.

A differing point of view has been suggested by Guccione (1982) who states that what has been called Ferrelview by others has developed from parent material in place by weathering and gleying of pre-Illinoian till and Illinoian loess (Loveland silt). The silty clay is the solum of the Yarmouth-Sangamon and early Sangamon and not, in most cases, a separate deposit.

Illinoian Stage

Illinoian loess, commonly referred to as the Loveland loess, and Illinoian 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 Loveland is commonly dark-brown, 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 Geosol. Generally, the Loveland loess does not exceed a thickness of 20 ft. It is commonly found at high topographic positions near the Missouri River.

Yarmouth-Sangamon soil - The Yarmouth-Sangamon soil is intensely weathered. Guccione (1982) describes this soil occurring on north-central Missouri uplands where weathering and development of the Sangamon Geosol has extended through a thin deposit of Loveland loess and welded to the underlying Yarmouth Geosol, which formed on the pre-Illinoian till. In places the Yarmouth-Sangamon soil has at least a 4.3 meter thick leached and gleyed solum.

Illinoian alluvium - Illinoian 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 Geosol is present. The material is noncalcareous. Stratification is obscure, but jointing is common. Thicknesses of 30 ft or more are common. The alluvium is always found at low topographic position and is generally confined to stream valleys tributary to the Missouri and Mississippi rivers.

In north St. Louis County, fine sand, silt and clay, up to 100 ft in thickness, were deposited in a lacustrine environment in front of the Illinoian glacier.

Illinoian 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, clay-like 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

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

Peoria loess - The grain size, calcium carbonate content, and color of the Peoria loess varies with the distance from the river bluffs. Near the bluffs, the Peoria is a well-sorted, medium to coarse silt, which contains some very fine- to fine-grained sand. It is light yellowish-brown 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. The Farmdale 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 ft thick.

Brady Geosol - The Brady Geosol 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 ft thick.

Bignell loess - The Bignell loess overlies the Peoria loess and is differentiated from it by the presence of the underlying Brady Geosol 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 Wisconsinan 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 ft thick in terraces. Another younger terrace is very widespread. The exact age of the latter has not been determined, but possibly it is post-Thermal Maximum.

Non-glaciated areas - South of the glacial terminus soil changes from glacial origins to soil produced by the effects of weathering and solution of bedrock. Some of these soils may be as old as Pliocene or perhaps older.

In the Ozarks region of Missouri weathering of massive Ordovician formations has produced reddish, cherty residuum that in places is over 100 ft thick and may contain 50 percent chert and sandstone fragments. In western Missouri weathering of shale and limestone has formed very clayey residuum up to 10 ft thick.

Recent Stage

Recent deposits comprise the alluvium that is associated with the present streams and rivers in the state as well as 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 ft or more of silt at the top. The total thickness of this material is commonly more than 100 ft. Soils are developing on this and on all exposed material in the state.

SELECTED BIBLIOGRAPHY

Stratigraphy

PRECAMBRIAN

Berry, A.W., Jr., 1976, Proposed stratigraphic column for Precambrian volcanic rocks, western St. Francois Mountains, *in* Kisvarsanyi, Eva B., editor, Studies in Precambrian geology of Missouri (Contribution to Precambrian Geology No. 6): Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 61, p. 81-90.

Bridge, Josiah, 1930, Geology of the Eminence and Cardareva Quadrangles: Missouri Bureau Geology and Mines, Volume 24, 2nd series, 228 p., 22 pls., 10 figs.

Crane, G.W., 1912, The iron ores of Missouri: Missouri Bureau Geology and Mines, Volume 10, 2nd series, 434 p., 48 pls., 29 figs.

Dake, Charles L., 1930, The geology of Potosi and Edgehill Quadrangles: Missouri Bureau Geology and Mines, Volume 23, 2nd series, 233 p., 26 pls.

Damon, Paul E., 1950, Radioactivity and mineralization in rhyolite porphyry: Geophysics, v. 15, p. 94-101.

Graves, Howard B., Jr., 1938, The pre-Cambrian structure of Missouri: St. Louis Academy of Science Transactions, v. 29, no. 5, p. 111-164, 9 figs.

Haworth, Erasmus, 1895, Crystalline rocks of Missouri: Missouri Geological Survey, Volume 8, p. 81-224, 30 pls., Jefferson City, Missouri.

Hayes, William C., 1961, Precambrian rocks, *in*, The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources ,Volume 40, 2nd series, p. 10-12.

Kisvarsanyi, Eva B., 1981, Geology of the Precambrian St. Francois terrane southeastern Missouri (Contribution to Precambrian Geology No. 8): Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 64, 58 p.

___, 1990, General features of the St. Francois and Spavinaw granite-rhyolite terranes and the Precambrian metallogenic region of southeast Missouri, *in*

Pratt, Walden P., and Sims, P.K., editors, The Midcontinent of the United States - permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey, Bulletin 1932, p. 48-57.

___, and Hebrank, Arthur W., (1982), Guidebook A: Field Trip to the St. Francois Mountains and the Historic Bonne Terre Mine: Missouri Department of Natural Resources, Division of Geology and Land Survey, Open File Report 82-16-MR, 42 p.

___, ___, and Ryan, Richard F., 1981, Regional geologic setting, *in* Guidebook to the geology and ore deposits of the St. Francois Mountains, Missouri (Contribution to Precambrian Geology No. 9): Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 67, p. 1-4

McMillan, W.D., 1946, Exploration of the Bourbon magnetic anomaly, Crawford County, Missouri: U.S. Bureau of Mines, Report of Investigations 3961, 9 p., 8 figs.

Muilenburg, Garrett A, and Goldich, S.S., 1933, Petrography and petrology of the Mount Devon diabase porphyry: American Journal of Science, 5th series., v. 26, no. 153, p. 355-367.

Robertson, Forbes, and Tolman, Carl, 1948, High-potash volcanic rocks, St. Francois Mountains, Missouri (abstract): Geological Society of America Bulletin, v. 59, no. 12, pt. 2, p. 1347; reprinted in American Mineralogist, v. 34, nos. 3-4, p. 282, 1949.

___, and Maurer, Russell, 1951, Evidence bearing on the consanguinity of Missouri and Oklahoma Precambrian igneous rocks (abstract): Geological Society of America Bulletin, v. 62, no. 12, pt. 2, p. 1541.

Sides, J.R., 1976, Stratigraphy of volcanic rocks in the Lake Killarney quadrangle, Iron and Madison Counties, Missouri:, *in* Kisvarsanyi, Eva B., editor, Studies in Precambrian geology of Missouri (Contribution to Precambrian Geology No. 6): Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 61, p. 105-113.

Sims, P.K., 1990, Geologic setting and ages of Proterozoic anorogenic rhyolite-granite terranes in the central United States, *in* Pratt, Walden P., and Sims, P.K., editors, The Midcontinent of the United States - permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey, Bulletin 1932, p. 40-47.

___, Kisvarsanyi, Eva B., and Morey, G.B., 1987, Geology and metallogeny of Archean and Proterozoic basement terranes in the northern Midcontinent, U.S.A. – An overview: U.S. Geological Survey, Bulletin 1815, 51 p.

Skillman, Margaret W., 1948, Pre-upper Cambrian sediments of Vernon County, Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 7, 17 p., 2 pls.

Tarr, William A., 1932, Intrusive relationship of the granite to the rhyolite of southeastern Missouri: Geological Society of America Bulletin, v. 43, p. 965-992, 14 figs.: Pan-American Geologist, v. 57, p. 231-232; (abstract) Science, new series, v. 75, p. 265.

Tolman, Carl, 1933, The geology of the Silver Mine area, Madison County, Missouri: Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist to the 57th General Assembly, 1931-32, app. 1, 39 p., 6 pls.

___, 1936, Volcanic activity in southeastern Missouri (abstract): Pan-American Geologist, v. 65, no. 2, p. 160; Geological Society of America Proceedings, 1935, p. 442, 1936.

___, **and Denham, R.L.**, 1935, Granitic intrusion in the St. Francois Mountains: American Mineralogist, v. 20, no. 3, p. 203; Geological Society of America Proceedings, 1934, p. 118.

___, **and Koch, H.L.**, 1936, The heavy accessory minerals of the granites of Missouri: Washington University Studies, new series, no. 9, p. 11-50, 5 pls., 13 figs.; (abstract) American Mineralogist, v. 20, no. 3, p. 208, 1935; Geological Society of America Proceedings, 1934, p. 429, 1935.

___, **and Robertson, Forbes**, 1969, Exposed Precambrian rocks in southeast Missouri (Contribution to Precambrian Geology No. 1): Missouri Geological Survey and Water Resources, Report of Investigations 44, 68 p.,

CAMBRIAN SYSTEM

Bridge, Josiah, 1930, Geology of the Eminence and Cardareva Quadrangles: Missouri Bureau of Geology and Mines, Volume. 24, 2nd series, 228 p., 22 pls., 10 figs.

Brightman, George F., 1938, The Taum Sauk limestone member of the Bonneterre formation in Missouri: Journal of Geology, v. 46, no. 3, p. 248-267.

Buckley, E.R., 1908, Geology of the disseminated lead deposits of St. Francois and Washington Counties: Missouri Bureau of Geology and Mines, Volume 9, 2nd series, pt. 1, 259 p., pls. 1-30, 10 figs.; pt. 2, pls. 40-121.

Gerdemann, Paul E., and Myers, Harold E., 1972, Relationships of carbonate facies patterns to ore distribution and to ore genesis in the Southeast Missouri Lead District: Economic Geology, v. 67, p. 426-433.

Grohskopf, John G., 1955, Subsurface geology of the Mississippi Embayment of southeast Missouri: Missouri Geological Survey and Water Resources, Volume 37, 2nd series, 133 p., 9 pls., 3 figs., 7 tables.

___, and McCracken, Earl, 1949, Insoluble residues of some Paleozoic formations of Missouri, their preparation, characteristics, and application: Missouri Geological Survey and Water Resources, Report of Investigations 10, 39 p., 11 pls.

Hayes, William C., and Knight, Robert D., 1961, Cambrian System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 14-20.

Howe, Wallace B., Kurtz, Vincent E., and Anderson, Kenneth H., 1972, Correlation of Cambrian strata of the Ozark and Upper Mississippi Valley regions: Missouri Geological Survey and Water Resources, Report of Investigations 52, 68 p.

Kurtz, Vincent E., Thacker, Joseph L., Anderson, Kenneth H., and Gerdemann, Paul E., 1975, Traverse in Late Cambrian strata from the St. Francois Mountains, Missouri, to Delaware County, Oklahoma: Missouri Department of Natural Resources, Division of Research and Technical Information, Geological Survey, Report of Investigations 55, 112 p.

McCracken, Earl, 1955, Correlation of insoluble residue zones of upper Arbuckle of Missouri and southern Kansas: American Association of Petroleum Geologists Bulletin, v. 39, p. 47-59, 3 figs.

___, 1959, Insoluble residues provide good regional correlations: World Oil, v. 149, no. 2, p. 79-82, 110, 4 figs.

Weller, Stuart, and St. Clair, Stuart, 1928, Geology of Ste. Genevieve County: Missouri Bureau of Geology and Mines, Volume 22, 2nd series, 352 p., 15 pls., 5 figs.

ORDOVICIAN SYSTEM

Agnew, Allen, 1955, Facies of Middle and Upper Ordovician rocks of Iowa: American Association of Petroleum Geologists Bulletin, v. 39, p. 1703-52, 13 figs.

Bridge, Josiah, 1930, Geology of the Eminence and Cardareva Quadrangles: Missouri Bureau of Geology and Mines, Volume 24, 2nd series, 228 p., 22 pls., 10 figs.

Buehler, H.A., 1908, The lime and cement resources of Missouri: Missouri Bureau of Geology and Mines, Volume 6, 2nd series., 255 p., 36 pls.

Cullison, James A., 1944, The stratigraphy of some lower Ordovician formations of the Ozark uplift: University of Missouri School of Mines and Metallurgy Bulletin, Technical series, v. 15, no. 2, 105 p., 35 pls.

Dake, C.L., 1921, The problem of the St. Peter sandstone: University of Missouri School of Mines and Metallurgy Bulletin, Technical series, v. 6, no. 1, 225 p., 30 pls.

___, 1930, The geology of the Potosi and Edgehill Quadrangles: Missouri Bureau of Geology and Mines, Volume 33, 2nd series, 233 p., 26 pls.

DuBois, E.P., 1945, Subsurface relations of the Maquoketa and "Trenton" formations in Illinois: Illinois Geological Survey, Report of Investigations 105, p. 7-33.

Flint, R.F., 1925, A report on the geology of parts of Perry and Cape Girardeau Counties: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Gealy, J.R., 1955, Geology of Cape Girardeau and Jonesboro Quadrangles, southeastern Missouri: Unpublished Ph.D. dissertation, Yale University, New Haven, Connecticut.

Greene, Frank C., 1945, Recent drilling in northwestern Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 1, 153 p., 14 figs.

Grohskopf, John G., 1948, Zones of Plattin-Joachim of eastern Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 6, 15 p., 5 figs.

___, 1955, Subsurface geology of the Mississippi Embayment of southeast Missouri: Missouri Geological Survey and Water Resources, Volume 37, 2nd series, 133 p., 9 pls., 3 figs.

___, **and Hinchey, N.S.,** 1939, An Ordovician outcrop in Saline County, Missouri: Missouri Academy of Sciences, v. 4, no. 6, p. 164.

___, ___, **and Greene, F.C.,** 1939, Subsurface geology of northeastern Missouri: Biennial Report of the State Geologist to the 60th General Assembly, app. 1, 160 p., 3 pls., 3 figs.

___, **and McCracken, Earl,** 1949, Insoluble residues of some Paleozoic formations of Missouri, their preparation, characteristics, and application: Missouri Geological Survey and Water Resources, Report of Investigations 10, 39 p., 11 figs.

Gutstadt, Allan M., 1958, Upper Ordovician stratigraphy in Eastern Interior region: American Association of Petroleum Geologists Bulletin, v. 42, no. 3, pt 1, p. 513-547, 10 figs.

Heller, Robert L., 1954, Stratigraphy and paleontology of the Roubidoux formation of Missouri: Missouri Geological Survey and Water Resources, Volume 35, 2nd series, 118 p., 19 pls.

Hendriks, Herbert E., 1954, The geology of the Steelville Quadrangle: Missouri Geological Survey and Water Resources, Volume 36, 2nd series, 88 p., 9 pls.

James, Jack A., 1949, Geologic relationships of the ore deposits in the Fredericktown area, Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 8, 25 p., 5 pls., 2 figs.

Kolata, Dennis R., Frost, Joyce K., and Huff, Warren D., 1986, K-bentonites of the Ordovician Decorah Subgroup, Upper Mississippi Valley; correlation by chemical fingerprinting: Illinois Department of Energy and Natural Resources, State Geological Survey Division, Circular 537, 30 p.

Larson, Edward Richard, 1951, Stratigraphy of the Plattin group, southeastern Missouri: American Association of Petroleum Geologists Bulletin, v. 35, p. 2041-2075, 16 figs.

Laswell, Troy J., 1957, Geology of the Bowling Green Quadrangle: Missouri Geological Survey and Water Resources, Report of Investigations 22, 64 p., 1 pl., 4 figs.

Lee, Wallace, 1913, The geology of the Rolla Quadrangle: Missouri Bureau of Geology and Mines, Volume 12, 2nd series, 111 p., 10 pls., 17 figs.

McCracken, Earl, 1950, Paleozoic rocks of the northern embayment region of Arkansas: Unpublished manuscript, Arkansas Geological Survey.

___, 1955, Correlation of insoluble residue zones of upper Arbuckle of Missouri and southern Kansas: American Association of Petroleum Geologists Bulletin, vol. 39, p. 47-59, 3 figs.

McQueen, H.S., 1937, The Dutchtown, a new lower Ordovician formation in southeastern Missouri: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 59th General Assembly, app. 1, 27 p., 5 pls., 1 fig.

Martin, James A., Knight, Robert D., and Hayes, William C., 1961, Ordovician System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 20-32.

Muilenburg, Garrett A, and Beveridge, Thomas R., 1954, Kansas Geological Society, Seventeenth Regional Field Conference: Missouri Geological Survey and Water Resources, Report of Investigations 17, 63 p., 26 figs.

Ross, Reuben J., Jr., Hintze, Lehi F., Ethington, Raymond L., Miller, James F., Taylor, Michael E., and Repetski, John E., 1993, The Ibexian Series (Lower Ordovician), a replacement for "Canadian Series" in North American chronostratigraphy, Chapter B, *in* Paleozoic biochronology of the Great Basin, western United States, Michael E. Taylor, editor: U.S. Geological Survey, Open-File Report 93-598, 75 p.

Savage, T.E., 1917, The Thebes sandstone and Orchard Creek shale and their faunas in Illinois: Illinois Academy of Science Transactions, vol. 10, p. 261-275, 2 pls.

Searight, Thomas K., 1955, The geology of the Lebanon Quadrangle: Missouri Geological Survey and Water Resources, Report of Investigations 18, 33 p., 3 pls.

Templeton, J.L., and Willman, H.B., 1963, Champlainian Series (Middle Ordovician) in Illinois: Illinois Geological Survey, Bulletin 898, 260 p.

Thompson, Thomas L., 1991, Paleozoic succession in Missouri, Part 2, Ordovician System: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, pt. 2, 282 p.

___, and Satterfield, Ira R., 1975, Stratigraphy and conodont biostratigraphy of strata contiguous to the Ordovician-Silurian boundary in eastern Missouri: Missouri Department of Natural Resources, Division of Research and Technical Information (Geological Survey), Report of Investigations 57, pt. 2, p. 61-108.

Twenhofel, W.H., et al., 1954, Correlation of the Ordovician formations of North America: Geological Society of America Bulletin, vol. 65, p. 247-298, 1 pl., 2 figs.

Ulrich, E.O., 1939, The Murfeesboro limestone in Missouri and Arkansas: 13th Annual Field Conference Guidebook, Kansas Geological Society, p. 105-109.

Unklesbay, A.G., 1952, Geology of Boone County, Missouri: Missouri Geological Survey and Water Resources, Volume 33, 2nd series, 159 p., 13 pls., 1 fig.

Weller, J.M., 1940, Geology and oil possibilities of extreme southern Illinois: Illinois Geological Survey, Report of Investigations 71, 71 p., 1 pl., 1 fig.

___, and McQueen, H.S., 1939, Catalog of formation names of southwestern Illinois and southeastern Missouri: 13th Annual Field Conference Guidebook, Kansas Geological Society, p. 159-170.

Weller, Stuart, and St. Clair, Stuart, 1928, Geology of Ste. Genevieve County: Missouri Bureau of Geology and Mines, Volume 22, 2nd series, 352 p., 15 pls., 5 figs.

Williams, J.H., 1955, The geology of the Hannibal Quadrangle: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Willman, H.B., and Kolata, Dennis R., 1978, The Platteville and Galena Groups in northern Illinois: Illinois State Geological Survey, Circular 502, 75 p.

SILURIAN SYSTEM

Ball, John R., 1939a, Stratigraphy of the Silurian System of the lower Mississippi Valley: 13th Annual Field Conference Guidebook, Kansas Geological Society, p. 110-126.

___, 1939b, Type section of Bainbridge formation of southeastern Missouri: American Association of Petroleum Geologists Bulletin, v. 23, p. 595-601, 3 figs.

___, 1942, Some Silurian correlations in lower Mississippi drainage basin: American Association of Petroleum Geologists Bulletin, v. 26, p. 1-18, 3 figs.

Boucot, A.J., 1958, Age of the Bainbridge limestone: Journal of Paleontology, v. 32, p. 1029-1030.

Flint, R.F., 1925, A report on the geology of parts of Perry and Cape Girardeau Counties: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

___, and Ball, John R., 1926, Revision of the Silurian of southeast Missouri: Journal of Geology, v. 34, p. 248-256.

Gealy, J.R., 1955, Geology of Cape Girardeau and Jonesboro Quadrangles, southeastern Missouri: Unpublished Ph.D. dissertation, Yale University, New Haven, Connecticut.

Laswell, Troy J., 1957, Geology of the Bowling Green Quadrangle: Missouri Geological Survey and Water Resources, Report of Investigations 22, 64 p., 1 pl., 4 figs.

Lee, Wallace, et al., 1946, Structural development of the Forest City basin of Missouri, Kansas, Iowa, and Nebraska: U.S. Geological Survey, Oil and Gas Investigations Preliminary Map 48, 7 sheets.

Lowenstam, H.A., 1949, Niagaran reefs in Illinois and their relation to oil accumulation: Illinois Geological Survey, Report of Investigations 145, 36 p., 1 pl., 8 figs.

McQueen, H.S., and Greene, F.C., 1938, The geology of northwestern Missouri: Missouri Geological Survey and Water Resources, Volume 25, 2nd series, 217 p., 7 pls., 11 figs.

___, Hinchey, N.S., and Aid, Kenneth, 1941, The Lincoln fold in Lincoln, Pike and Ralls Counties, northeastern Missouri: 15th Annual Field Conference Guidebook, Kansas Geological Society, p. 99-110, figs. 57-59.

Martin, James A., Knight, Robert D., and Hayes, William C., 1961, Ordovician System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 20-32 (Martin et al., 1961a).

___, Larsen, Kenneth G., and Muilenburg, Garrett A, 1961, Silurian System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 32-35 (Martin et al., 1961b).

Offield, T.W., and Pohn, H.A., 1979, Geology of the Decaturville impact structure, Missouri: U.S. Geological Survey, Professional Paper 1042, 48 p.

Rowley, R.R., 1908, The geology of Pike County: Missouri Bureau of Geology and Mines, Volume 8, 2nd series, 122 p., 20 pls., 13 figs.

Savage, T.E., 1913, Alexandrian Series in Missouri and Illinois: Geological Society of America Bulletin, v. 24, p. 351-376.

___, 1917, The Thebes sandstone and Orchard Creek shale and their faunas in Illinois: Illinois Academy of Science Transactions, v. 10, p. 261-275, 2 pls.

Satterfield, Ira R., and Thompson, Thomas L., 1975, Seventy-Six Shale, a new member of the Bainbridge Formation (Silurian) in southeastern Missouri: Missouri Department of Natural Resources, Division of Research and Technical Information (Missouri Geological Survey), Report of Investigations 57, pt. 3, p. 109-120.

Swartz, Charles K., et al., 1942, Correlation of the Silurian formations of North America: Geological Society of America Bulletin, v. 53, p. 533-538.

Thompson, Thomas L., 1993 (1994), Paleozoic succession in Missouri, Part 3, Silurian and Devonian Systems: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, pt. 3, 228 p.

___, and Satterfield, Ira R., 1975, Stratigraphy and conodont biostratigraphy of strata contiguous to the Ordovician-Silurian boundary in eastern Missouri: Missouri Department of Natural Resources, Division of Research and Technical Information (Geological Survey), Report of Investigations 57, pt. 2, p. 61-108.

Weller, J.M., and Ekblaw, G.E., 1940, Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes Quadrangles: Illinois Geological Survey, Report of Investigations 70, 26 p., 1 pl., 2 figs.

DEVONIAN SYSTEM

Amos, Dewey, 1985, Geologic map of the Altenburg 7½' Quadrangle, Perry County, Missouri: Missouri Department of Natural Resources, Division of Geology and Land Survey, OFM-8-221-GI.

Branson, E.B., 1922, The Devonian of Missouri: Missouri Bureau of Geology and Mines, Volume 17, 2nd series, 279 p., 71 pls.

___, 1941, Devonian of central and northeastern Missouri: 15th Ann. Field Conference Guidebook, Kansas Geological Society, p. 81-85, pl. 9.

___, 1944a, The geology of Missouri: University of Missouri Studies, v. 19, no. 3, 535 p., 51 figs., 49 pls.

___, 1944b, Devonian of northeastern Missouri, *in* Symposium on Devonian Stratigraphy: Illinois Geological Survey, Bulletin 68, p. 174-181, figs. 40-42.

____, **and Mehl, M.G.**, 1934, Conodont studies number 4; Conodonts from the Bushberg sandstone and equivalent formations in Missouri: University of Missouri Studies, v. 8, n. 4, p. 265-300.

Bridge, Josiah, and Charles, B.E., 1922, A Devonian outlier near the crest of the Ozark uplift: Journal of Geology, v. 30, p. 450-458, 3 figs.

Bunker, Bill J., Witzke, Brian J., and Day, Jed, 1986, Upper Cedar Valley stratigraphy, north-central Iowa, Lithograph City Formation: Geological Survey of Iowa Guidebook 44, 41 p.

Collinson, Charles, and Atherton, Elwood, 1975, Devonian System, *in* Willman, H. B., et al., Handbook of Illinois stratigraphy: Illinois Geological Survey, Bulletin 95, p. 104-123.

Condra, G.E., and Reed, E.C., 1959, The geological section of Nebraska: Nebraska Geological Survey, Bulletin 14A, 82 p., 25 figs.

Counselman, F.B., 1935, The geology and stratigraphic petrography of the Auxvasse Creek Quadrangle, Callaway County, Missouri: Missouri Academy of Science Proceedings, v. 1, p. 101-119, 2 figs.

Cooper, G. Arthur, et al., 1942, Correlation of the Devonian sedimentary formations of North America: Geological Society of America Bulletin, v. 53, p. 1729-1794, 1 pl., 1 fig.

___, 1944, Remarks on correlation of Devonian formations in Illinois and adjacent states, *in* Symposium on Devonian Stratigraphy: Illinois Geological Survey, Bulletin 68, p. 217-222.

Croneis, Carey, 1944, The Devonian of southeastern Missouri, *in* Symposium on Devonian Stratigraphy: Illinois Geological Survey Bulletin 68, p. 103-131.

Flint, R.F., 1925, A report on the geology of parts of Perry and Cape Girardeau Counties: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Fraunfelter, George H., 1964, The paleontology and stratigraphy of the Cedar City Formation (Middle Devonian) of Missouri: unpublished Ph.D. dissertation, University of Missouri - Columbia.

___, 1967a, The stratigraphy of the Cedar City Formation (Middle Devonian) of Missouri: Illinois Academy of Science Transactions, v. 60, p. 9-44.

___, 1967b, Notes on the correlation of the Lingle and St. Laurent Formations (Middle Devonian) of southern Illinois and southeastern Missouri: Illinois Academy of Science Transactions, v. 60, p. 308-309.

Gealy, J.R., 1955, Geology of Cape Girardeau and Jonesboro Quadrangles, southeastern Missouri: Unpublished Ph.D. dissertation, Yale University, New Haven, Connecticut.

Grohskopf, J.G., Clark, E.L., and Ellison, S., 1943, The Fortune, a new Devonian formation: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 62nd General Assembly, app. 4, p. 5-17.

___, **and McCracken, Earl**, 1949, Insoluble residues of some Paleozoic formations of Missouri, their preparation, characteristics, and application: Missouri Geological Survey and Water Resources, Report of Investigations 10, 39 p., 10 pls.

Koenig, John W., 1961, Devonian System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 36-41.

Lee, Wallace, 1940, Subsurface Mississippian rocks of Kansas: State Geological Survey of Kansas, Bulletin 33, 114 p., 10 pls., 4 figs.

Manger, Walter L., Shelby, Phillip R., and Farris, Steve G., 1988, Devonian-Lower Mississippian lithostratigraphy, northwestern Arkansas: The Compass, v. 65, no. 4, p. 223-231.

Marshall, John Harris, 1950, Geology in and adjacent to Cape Girardeau, Cape Girardeau County, Missouri: Unpublished Master's thesis, University of Missouri, Columbia, Missouri.

Mehl, M.G., 1960, The relationships of the base of the Mississippian System in Missouri: Journal of the Scientific Laboratories, Denison University, v. 45, art. 5, p. 57-107.

____, 1961, Basal relationships of the Mississippian in northeastern Missouri, *in* Guidebook, 26th Regional Field Conference, the Kansas Geological Society, Northeastern Missouri and west-central Illinois: Missouri Geological Survey and Water Resources, Report of Investigations 27, p. 89-94.

Savage, T.E., 1925, Comparison of the Devonian rocks of Illinois and Missouri: Journal of Geology, v. 33, p. 550-558.

Schumacher, Dietmar, 1972, Conodont biostratigraphy and paleoenvironments of Middle-Upper Devonian boundary beds, Missouri: unpublished Ph.D. dissertation, University of Missouri - Columbia.

Thompson, Thomas L., 1993 (1994), Paleozoic succession in Missouri, Part 3, Silurian and Devonian Systems: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, pt. 3, 228 p.

___, **and Fellows, Larry D.**, 1970, Stratigraphy and conodont biostratigraphy of Kinderhookian and Osagean rocks of southwestern Missouri and adjacent areas: Missouri Geological Survey and Water Resources, Report of Investigations 45, 263 p.

___, **and Satterfield, Ira R.**, 1975, Stratigraphy and conodont biostratigraphy of strata contiguous to the Ordovician-Silurian boundary in eastern Missouri: Missouri Department of Natural Resources, Division of Research and Technical Information (Geological Survey), Report of Investigations 57, pt. 2, p. 61-108.

Unklesbay, A.G., 1952, Geology of Boone County, Missouri: Missouri Geological Survey and Water Resources, Volume 33, 2nd series, 159 p., 13 pls., 1 fig.

___, 1955, The geology of the Fulton quadrangle: Missouri Geological Survey and Water Resources, Report of Investigations 19, 1 pl.

Weller, Stuart, and St. Clair, Stuart, 1928, Geology of Ste. Genevieve County, Missouri: Missouri Bureau of Geology and Mines, Volume 22, 2nd series, 352 p., 15 pls., 5 figs.

Witzke, B.J., Bunker, B.J., and Rogers, F.S., 1988, Eifelian through Lower Frasnian stratigraphy and deposition in the Iowa area, central Midcontinent, U.S.A., *in* McMillan, N.J., Embry, A.F., and Glass, D.J., editors, Devonian of the World: Canadian Society of Petroleum Geologists, Memoir 14, vol. 1, p. 221-250.

Woodruff, Michael Leo, 1990, Middle and Upper Devonian (Givetian-Famennian) conodont biostratigraphy and lithostratigraphy in the subsurface of northeastern Missouri: unpublished M.S. thesis, University of Iowa - Iowa City.

MISSISSIPPIAN SYSTEM

Atherton, Elwood, Collinson, Charles, and Lineback, Jerry A., 1975, Mississippian System, *in* Handbook of Illinois Stratigraphy, Willman, H.B., et al.: Illinois Geological Survey, Bulletin 95, p. 123-193.

Bridge, Josiah, and Charles, B.E., 1922, A Devonian outlier near the crest of the Ozark uplift: Journal of Geology, v. 30, p. 450-458, 3 figs.

Beveridge, T.R., 1951, Geology of the Weaubleau Creek area: Missouri Geological Survey and Water Resources, Volume 32, 2nd series, 111 pp., 12 pls., 5 figs.

___, and Clark, E.L., 1952, A revision of the early Mississippian nomenclature in western Missouri, *in* 16th Annual Field Conference Guidebook, Kansas Geological Society: Missouri Geological Survey and Water Resources, Report of Investigations 13, p. 71-80.

Bradley, W.H., 1953, Use of Mississippian, Pennsylvanian, and Carboniferous in official reports: American Association of Petroleum Geologists Bulletin, v. 37, p. 1533.

Branson, E.B., 1944, The geology of Missouri: University of Missouri Studies, v. 19, no. 3, 535 p., 49 pls., 51 figs.

___, and Mehl, M.G., 1933, Conodont studies no. 3, Conodonts from the Grassy Creek shale of Missouri: University of Missouri Studies, v. 8, no. 3, p. 171-259, 9 pls., 3 figs.

___, et al., 1938, Stratigraphy and paleontology of the lower Mississippian of Missouri, part 1: University of Missouri Studies, v. 13, no. 3, 205 p., 23 pls., 6 figs.

Bridge, Josiah, 1917, Residual Mississippian faunas of Phelps County, Missouri: Journal of Geology, v. 25, p. 558-575.

Chakravorty, Sailendra K., 1951, Late Mississippian Bryozoa from Missouri: Unpublished Ph.D. dissertation, University of Kansas - Lawrence.

Clair, Joseph R., 1943, The oil and gas resources of Cass and Jackson Counties, Missouri: Missouri Geological Survey and Water Resources, Volume 27, 2nd series, 208 pp., 7 pls., 14 figs.

Clark, Edward L., 1937, The St. Louis formation of southwestern Missouri: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 59th General Assembly, app. 4, 13 p.

___, 1938, The Burlington formation in southwest Missouri: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

___, 1941, Geology of the Cassville Quadrangle, Barry County, Missouri: Unpublished Ph.D. dissertation, University of Missouri - Columbia.

___, **and Beveridge, Thomas R.**, 1952, Guidebook, 16th Regional field Conference, Kansas Geological Society, west-central Missouri. Missouri Geological Survey and Water Resources, Report of Investigations 13, 91 p.

Cline, L.M., 1934, Osage formations of southern Ozark region, Missouri, Arkansas, and Oklahoma: American Association of Petroleum Geologists Bulletin, v. 18, p. 1132-1159, 2 figs.

Collinson, Charles, 1961, The Kinderhookian Series in the Mississippi Valley, *in* Guidebook 26th Regional Field Conference, Kansas Geological Society, northeastern Missouri and west-central Illinois: Missouri Geological Survey and Water Resources, Report of Investigations 27, p. 100-109.

___, **Swann, D.H., and William, H.B.**, 1954, Guide to the structure and Paleozoic stratigraphy along the Lincoln fold in western Illinois: American Association of Petroleum Geologists, Field Conference Guidebook, 39th Ann. Convention, St. Louis, Missouri, 75 p.

Conkin, James E., and Conkin, Barbara M., 1973, The para-conformity and the determination of the Devonian-Mississippian boundary in the Lower Mississippian type area of North America: University of Louisville Studies in Paleontology and Stratigraphy No. 1, 36 p.

Fenneman, N.M., 1911, Geology and mineral resources of the St. Louis Quadrangle, Missouri-Illinois: U.S. Geological Survey, Bulletin 438, 73 p.

Flint, R.F., 1925, A report of the geology of parts of Perry and Cape Girardeau Counties including parts of Altenburg, Perryville, and Campbell Hill Quadrangles: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Giles, A.W., 1935, Boone chert: Geological Society of America Bulletin, v. 46, p. 1815-1867.

Gillerman, Elliot, 1937, Early Osage formations in Missouri: Unpublished Master's thesis, Washington University - St. Louis, Missouri.

Greene, Frank C., 1945, Recent drilling in northwestern Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 1, 153 p., 14 figs.

Grohskopf, J.G., Hinchey, N.S., and Greene, F.C., 1939, Subsurface geology of northeastern Missouri: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 60th General Assembly, app. 1, 100 p., 3 pls, 3 figs.

___, and McCracken, Earl, 1949, Insoluble residues of some Paleozoic formations of Missouri, their preparation, characteristics, and application: Missouri Geological Survey and Water Resources, Report of Investigations 10, 39 p., 11 pls.

Harris, Stanley E., Jr., 1947, Subsurface stratigraphy of the Kinderhook and Osage series in southeastern Iowa: Unpublished Ph.D. dissertation, University of Iowa - Iowa City.

Hinchey, Norman S., Fisher, R.B., and Calhoun, W.A., 1947, Limestones and dolomites in the St. Louis area: Missouri Geological Survey and Water Resources, Report of Investigations 5, 80 p., 4 pls., 2 figs.

Hoffman, Olive L., 1927, The Chouteau limestone in central Missouri: Unpublished Master's thesis, University of Kansas - Lawrence.

Hundhausen, Mary, 1941, Subsurface distribution of the Meramec group in northern Missouri: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Kaiser, Charles Philip, 1950, Stratigraphy of the lower Mississippian rocks in southwestern Missouri: American Association of Petroleum Geologists Bulletin, v. 34, p. 2133-2175, 8 figs.

Kammer, Thomas W., Brenckle, Paul L., Carter, John L., and Ausich, William I., 1990, Redefinition of the Osagean-Meramecian boundary in the Mississippian stratotype region: Palaios, v. 5, p. 414-431.

Laswell, Troy J., 1957, Geology of the Bowling Green Quadrangle, Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 22, 64 pp., 1 pl., 4 figs.

Laudon, L.R., 1937, Stratigraphy of the northward extension of the Burlington limestone in Missouri and Iowa: American Association of Petroleum Geologists Bulletin, v. 21, p. 1158-1167.

___, 1948, Osage-Meramec contact: Journal of Geology, v. 56, p. 288-302, 3 pls., 12 figs.

Lee, Wallace, 1943, The stratigraphy and structural development of the Forest City basin in Kansas: State Geological Survey of Kansas, Bulletin 51, 140 p., 22 figs.

___, 1956, Stratigraphy and structural development of the Salina basin: State Geological Survey of Kansas, Bulletin 121, 167 p., 12 pls., 23 figs.

___, **et al.**, 1946, Structural development of the Forest City basin of Missouri, Kansas, Iowa, and Nebraska: U.S. Geological Survey, Oil and Gas Investigations, Preliminary Map 48, 7 sheets.

Malott, C.A., 1952, Stratigraphy of the Ste. Genevieve and Chester formations of southern Indiana: Edwards Letter Shop, Ann Arbor, Michigan, 105 pp.

Maples, Christopher G., and Waters, Johnny A., 1987, Redefinition of the Meramecian/Chesterian boundary (Mississippian): Geology, v. 15, p. 647-651.

McQueen, H.S., and Greene, F.C., 1938, The geology of northwestern Missouri: Missouri Geological Survey and Water Resources, Volume 25, 2nd series, 217 p., 7 pls., 11 figs.

McQueen, Henry S., Hinchey, Norman S., and Aid, Kenneth, 1941, The Lincoln fold in Lincoln, Pike, and Ralls Counties, northeast Missouri: 15th Annual Field Conference Guidebook, Kansas Geological Society, p. 99-110, figs. 57-59.

Mehl, M.G., 1960, The relationships of the base of the Mississippian System in Missouri: Journal of the Scientific Laboratories, Denison University, v. 45, art. 5, p. 57-107.

___, 1961, Basal relationships of the Mississippian in northeastern Missouri, *in* Guidebook, 26th Regional Field Conference, the Kansas Geological Society, Northeastern Missouri and west-central Illinois: Missouri Geological Survey and Water Resources, Report of Investigations 27, p. 89-94.

Moore, Raymond C., 1928, Early Mississippian formations in Missouri: Missouri Bureau Geology and Mines, Volume 21, 2nd series, 283 pp., 13 pls.

___, 1935, The Mississippian System in the upper Mississippi Valley region: 9th Annual Field Conference Guidebook, Kansas Geological Society, p. 239-243.

Murdock, James Neil, 1931, The physical composition of the Sylamore sandstone: Unpublished Master's thesis, University of Missouri - Columbia.

Noble, James Eugene, 1957, A limited geologic reconnaissance of Clark and Lewis counties, Missouri: Unpublished Master's thesis, University of Missouri - Columbia.

Reed, E.C., 1946, Boice shale, new Mississippian subsurface formation in southeast Nebraska: American Association of Petroleum Geologists Bulletin, v. 30, p. 348-352.

Robertson, Charles E., 1967, The Elsey Formation and its relationship to the Grand Falls Chert: Missouri Geological Survey and Water Resources, Report of Investigations 38, 26 p.

Rowley, R.R., 1908, Geology of Pike County, Missouri: Missouri Bureau of Geology and Mines, Volume 8, 2nd series, 122 p., 20 pls., 13 figs.

Rubey, W.W., 1952, Geology and Mineral Resources of the Hardin and Brussels Quadrangles (in Illinois): U.S. Geological Survey, Professional Paper 218, 179 p., 21 pls., 17 figs.

Short, Nicholas M., 1954, Ste. Genevieve formation at its type locality: Unpublished Master's thesis, Washington University - St. Louis, Missouri.

Siebenthal, C.E., and Mesler, R.D., 1908, Tripoli deposits near Seneca, Missouri: U.S. Geological Survey, Bulletin 340, p. 429-437.

Smith, William C., 1940, The petrography of the Bushberg sandstone: Unpublished Master's thesis, University of Missouri - Columbia.

Smith, W.S.T., and Siebenthal, C.E., 1907, Description of the Joplin District, Missouri-Kansas: U.S. Geological Survey, Atlas, Folio 148, 20 p.

Spreng, A.C., 1952, The lower Pierson fauna of west-central Missouri, *in* 16th Annual Field Conference Guidebook, Kansas Geological Society: Missouri Geological Survey and Water Resources, Report of Investigations 13, p. 81-86.

___, 1955, Post-Keokuk Mississippian of Dade and Barton Counties, Missouri: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Thompson, Thomas L., 1972, Conodont biostratigraphy of Chesterian strata in southwestern Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 50, 48 P.

___, 1986, Paleozoic succession in Missouri, Part 4, Mississippian System: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, pt. 4, 182 p.

___, **and Fellows, Larry D.**, 1970, Stratigraphy and conodont biostratigraphy of Kinderhookian and Osagean rocks of southwestern Missouri and adjacent areas: Missouri Geological Survey and Water Resources, Report of Investigations 45, 263 p.

Ulrich, E.O., 1904, Preliminary notes on classification and nomenclature of certain Paleozoic rock units in eastern Missouri, *in* The quarrying industry in Missouri, by E.R. Buckley and H.A. Buehler: Missouri Bureau of Geology and Mines, Volume 2, 2nd series, p. 109-111.

Unklesbay, A.G., 1952, Geology of Boone County, Missouri: Missouri Geological Survey and Water Resources, Volume 33, 2nd series, 159 p., 13 pls., 1 fig.

Van Duym, D.P., 1954, The mineralogy of the Grassy Creek and Saverton formations: Unpublished Master's thesis, University of Missouri, School of Mines and Metallurgy - Rolla.

Van Tuyl, F.M., 1922, Stratigraphy of the Mississippian formations of Iowa, *in* Annual reports, 1921 and 1922: Iowa Geological Survey, AR-30, p. 33-374, 6 pls., 16 figs.

Weller, J.M., 1939, Mississippian System: 13th Annual Field Conference Guidebook, Kansas Geological Society, p. 131-137.

___, **et al.**, 1948, Correlation of Mississippian formations of North America: Geological Society of America, Bulletin, v. 59, p. 91-196.

Weller, Stuart, 1906, Kinderhook faunal studies: IV. The fauna of the Glen Park limestone: Transactions of the Academy of Science of St. Louis, v. 16, p. 435-471.

___, **and St. Clair, Stuart**, 1928, Geology of Ste. Genevieve County, Missouri: Missouri Bureau of Geology and Mines, Volume 22, 2nd series, 352 p., 15 pls.

Williams, James Steele, 1943, Stratigraphy and fauna of the Louisiana limestone of Missouri: U.S. Geological Survey, Professional Paper 203, 133 p., 9 pls.

Winslow, Arthur, 1894, Lead and zinc deposits: Missouri Geological Survey, Volumes 6 and 7, 673 p., Jefferson City, Missouri.

Workman, L.E., and Gillette, Tracey, 1956, Subsurface stratigraphy of the Kinderhook Series in Illinois: Illinois Geological Survey, Report of Investigations 189, 46 p., 2 pls., 20 figs.

Wright, Leo M., 1952, The paleontology of the Chester Series of southwestern Missouri: Unpublished Ph.D. dissertation, University of Missouri - Columbia.

PENNSYLVANIAN SYSTEM

Broadhead, G.C., 1868, Coal measures in Missouri: St. Louis Academy of Science Transactions (1861-1868), vol. 2, no. 2, p. 311-333. (Read May 5, 1862 and released as separate in 1866).

___, 1895, The coal measures of Missouri, *in* Annual report for 1894, C.R. Keyes: Missouri Geological Survey, Volume 8, p. 353-395.

___, **and Potter, W.B.**, 1873, Geology of northwestern Missouri and of Lincoln County: Missouri Geological Survey, Preliminary report on iron ores and coal fields from the field work of 1872, pt. 2, p. 1-402, app. B, 116 figs.

Clark, Edward L., 1941, Geology of the Cassville Quadrangle, Barry County, Missouri: Unpublished Ph.D. dissertation, University of Missouri - Columbia.

Cline, L.M., 1941, Traverse of upper Des Moines and lower Missouri Series from Jackson County, Missouri, to Appanoose County, Iowa: American Association of Petroleum Geologists Bulletin, v. 25, p. 23-72, figs. 1-2.

___, **and Greene, Frank C.**, 1950, A stratigraphic study of the upper Marmaton and lowermost Pleasanton groups, Pennsylvanian, of Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 12, 74 p., 1 fig., 7 correlation charts.

Condra, G.E., 1949, The nomenclature, type localities, and correlation of the Pennsylvanian subdivisions in eastern Nebraska and adjacent states: Nebraska Geological Survey, Bulletin 16, 67 p.

Greene, Frank C., and Searight, Walter V., 1949, Revision of the classification of the post-Cherokee Pennsylvanian beds of Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 11, 22 p., 4 figs.

Hinds, Henry, 1912, Coal deposits of Missouri: Missouri Bureau Geology and Mines, Volume 11, 2nd series, 503 p., 97 figs.

___, and Greene, F.C., 1915, The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bureau Geology and Mines, Volume 13, 2nd series, 407 p.

___, and ___, 1917, The description of the Leavenworth and Smithville Quadrangles (Missouri-Kansas): U.S. Geological Survey Atlas, Leavenworth-Smithville, Folio 206, 13 p.

Hoare, Richard David, 1957, Desmoinesian Brachiopoda and Mollsuca from southwest Missouri: Unpublished Ph.D. dissertation, University of Missouri - Columbia; (abstract) American Association for the Advancement of Science, Program and abstracts, Sec. E., p. 11, December 1957; (abstract) Geological Society of America Bulletin, v. 68, no. 12, pt. 2, p. 1893, December 1957.

Howe, Wallace B., 1953, Upper Marmaton strata in western and northern Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 9, 29 p., 3 pls.

___, 1956, Stratigraphy of pre-Marmaton Desmoinesian (Cherokee) rocks in southeastern Kansas: Kansas State Geological Survey, Bulletin 123, 132 p., 10 pls., 8 figs.

___, (coordinator), and Koenig, John W. (editor), 1961, The stratigraphic succession in Missouri. Missouri Geological Survey and Water Resources, Volume 40, 2nd series, 185 p.

,

Jewett, John Mark, 1945, Stratigraphy of the Marmaton group, Pennsylvanian, in Kansas: Kansas State Geological Survey, Bulletin 58, 148 p., 4 pls.

Lambert, Lance L., and Thompson, Thomas L., 1990, Age and significance of the "Ladden Branch" limestone (Riverton Formation, Pennsylvanian), west-central Missouri (abstract): Geological Society of America, 1990 Abstracts with Programs, v. 22, no. 1, p. 13.

Lee, Wallace, 1941, Preliminary report on the McLouth gas and oil field, Jefferson and Leavenworth Counties, Kansas: Kansas State Geological Survey, Bulletin 38, pt. 10, p. 261-284, pls. 1-3.

McQueen, H.S., 1943, Geology of the fire clay districts of east-central Missouri, with chapters on the results of X-ray analyses and firing behavior tests, by Herold, P.G.: Missouri Geological Survey and Water Resources, Volume 28, 2nd series, vol. 28, 250 p., 39 pls., 6 figs.

___, and Greene F.C., 1938, The geology of northwestern Missouri: Missouri Geological Survey and Water Resources, Volume 25, 2nd series, 217 p., 7 pls., 11 figs.

Moore, Raymond C., 1948, Classification of Pennsylvanian rocks in Iowa, Missouri, Nebraska, and northern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 32, p. 2011-2040, 6 figs.

___, and Mudge, Melvin R., 1956, Reclassification of some lower Permian and upper Pennsylvanian strata in northern Mid-Continent: American Association of Petroleum Geologists Bulletin, v. 40, p. 2271-2278.

Oakes, Malcolm C., 1953, Krebs and Cabaniss groups, of Pennsylvanian age, in Oklahoma: American Association of Petroleum Geologists Bulletin, v. 37, p. 1523-1526, 1 fig.

Ravn, R.L., Swade, J.W., Howes, M.R., Gregory, J.L., Anderson, R.R., and Van Dorpe, P.E., 1984, Stratigraphy of the Cherokee Group and revision of Pennsylvanian stratigraphic nomenclature in Iowa. Iowa Geological Survey, Technical Information Series No. 12, 75 p.

Searight, Thomas K., 1959, Post-Cheltenham Desmoinesian sedimentation in the Columbia-Hannibal region, Missouri (abstract): Geological Society of America Program, 1959 Annual Meetings., p. 114A, November 1959; Geological Society of America Bulletin, v. 70 no. 12, pt. 2, p. 1672.

Searight, Walter V., and Howe, Wallace B., 1961, Pennsylvanian System, *in* The stratigraphic succession in Missouri, Howe, Wallace B. (coordinator), and Koenig, John W. (editor): Missouri Geological Survey and Water Resources, Volume 40, 2nd series, p. 78-122

___, 1955, Field Trip Guidebook, Second Annual Meeting Association of Missouri Geologists: Missouri Geological Survey and Water Resources, Report of Investigations 20, 44 p., 21 figs.

___, 1959a, Pennsylvanian (Desmoinesian) of Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 25, 46 p., 2 pls., 30 figs.

___, 1959b, Pre-Marmaton Pennsylvanian deposits of the Forest City basin (abstract): Geological Society of America Program, 1959 Annual Meetings, p. 115A, November 1959; Geological Society of America Bulletin, v. 70, no. 12, pt. 2, p. 1673.

___, and Jeffries, N.W., 1958, Alvis and Lexington coals of Missouri and associated beds (abstract): Geological Society of America Program, 1958 Annual Meetings., p. 137, November 1958; Geological Society of America Bulletin, v. 69, no. 12, pt. 2, p. 1641.

___, and Palmer, E.J., 1957, Burgner formation, pre-Desmoinesian Pennsylvanian deposit in southwestern Missouri: American Association of Petroleum Geologists Bulletin, v. 41, p. 2127-2131, 2 figs.

___, et al., 1953, Classification of Desmoinesian (Pennsylvanian) of the northern Mid-Continent: American Association of Petroleum Geologists Bulletin, v. 37, p. 2747-2749.

Thompson, Thomas L., 1970, Lower Pennsylvanian conodonts from McDonald County, Missouri. Journal of Paleontology, v. 44, p. 1041-1048.

Unklesbay, A.G., and Palmer, E.J., 1958, Cephalopods from the Burgner formation in Missouri: Journal of Paleontology, v. 32, p. 1071-1075, pl. 138, 2 figs.

Wanless, Harold R., 1956, Classification of the Pennsylvanian rocks of Illinois as of 1956: Illinois State Geological Survey, Circular 217, 14 p., 1 pl.

CRETACEOUS AND TERTIARY SYSTEMS

Cooke, C. Wythe, Gardner, Julia, and Woodring, Wendell P., 1943, Correlation of the Cenozoic formations of the Atlantic and Gulf Coastal Plain and the Caribbean region: Geological Society of America Bulletin, v. 54, p. 1713-1723, 1 pl.

Farrar, Willard, Grenfell, Donald S., and Allen, Victor T., 1935, The geology and bleaching clays of southeast Missouri: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 58 General Assembly, 1933-34, app. 1, p. 1-35, 8 pls., 5 figs.

___, and McManamy, Lyle, 1937, The geology of Stoddard County, Missouri: Missouri Geological Survey and Water Resources, Biennial Report of the State Geologist to the 59th General Assembly, 1935-36, app. 6, 92 p., 12 pls., 2 figs.

Fisk, H.N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Mississippi River Commission, 78 p.

Grohskopf, John G., 1955, Subsurface geology of the Mississippi Embayment of southeast Missouri: Missouri Geological Survey and Water Resources, Volume 37, 2nd series, 133 p., 9 pls., 3 figs.

Lamar, J.E., and Sutton, A.H., 1930, Cretaceous and Tertiary sediments of Kentucky, Illinois, and Missouri: American Association of Petroleum Geologists Bulletin, v. 14, p. 845-866, 4 figs.

McQueen, H.S., et al., 1939, Third day of field conference - Guide to field study in the vicinity of Cape Girardeau, Missouri: 13th Annual Field Conference Guidebook, Kansas Geological Society, p. 59-76, figs. 16-28.

Marbut, C.F., 1902, The evolution of the northern part of the lowlands of southeastern Missouri: University of Missouri Studies, v. 1, no. 3, 63 p., 7 pls.

Matthes, F.E., 1933, Cretaceous sediments in Crowley's Ridge, southeastern Missouri: American Association of Petroleum Geologists Bulletin, v. 17, p. 1003-1015, 1 fig.

Potter, Paul E., 1955a, The petrology and origin of the Lafayette gravel–Pt. 1, Mineralogy and petrology: Journal of Geology, v. 63, p. 1-38, 18 figs.

___, 1955b, The petrology and origin of the Lafayette gravel–Pt. 2, Geomorphic history: Journal of Geology, v. 63, p. 115-132, 5 figs.

Pryor, Wayne A., 1960, Cretaceous sedimentation in upper Mississippi Embayment: American Association of Petroleum Geologists Bulletin, v. 44, p. 1473-1504, 19 figs.

Rubey, William W., 1952, Geology and mineral resources of the Hardin and Brussels Quadrangles (in Illinois): U.S. Geological Survey, Professional Paper 218, 179 p., 21 pls., 17 figs.

Stearns, R.G., 1957, Cretaceous, Paleocene, and lower Eocene geologic history of the northern Mississippi Embayment: Geolgical Society of America Bulletin, v. 68, p. 1077-1100, 21 figs.

Stephenson, L.W., 1914, Cretaceous deposits of the eastern Gulf region and species of *Exogyra* from the eastern Gulf region and the Carolinas: U.S. Geological Survey, Professional Paper 81, 77 p., 21 pls., 2 figs.

___, **and Monroe, W.H.**, 1937, Prairie Bluff chalk and Owl Creek formation of eastern Gulf region: American Association of Petroleum Geologists Bulletin, v. 21, p. 806-809.

___, **King, P.B., Monroe, W.H., and Imlay, R.W.**, 1942, Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas: Geological Society of America Bulletin, v. 53, p. 435-448, 1 pl.

Stewart, D.R., 1942, The Mesozoic and Cenozoic geology of southeastern Missouri: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Wade, Bruce, 1926, The fauna of the Ripley formation on Coon Creek, Tennessee: U.S. Geological Survey, Professional Paper 137, 272 p., 72 pls., 2 figs.

Wells, F.G., 1933, Groundwater resources of western Tennessee, with a discussion of the chemical character of the water by F.G. Wells and M.D. Foster: U.S. Geological Survey, Water-Supply Paper 656, 319 p., 16 pls., 18 figs.

Willman, H.B., and Frye, J.C., 1958, Problems of Pleistocene geology in the greater St. Louis area: Geological Society of America, Field Trip Guidebook, St. Louis Meeting., 1958, p. 9-11, figs. 1-2.

QUATERNARY SYSTEM

Austin, William J., et al., Quaternary geology of the Lower Mississippi Valley, *in* Morrison, R.B., editor, Quaternary nonglacial geology; Conterminous U.S.: Boulder, Colorado, Geological Society of America, The Geology of North America, V. K-2.

Condra, G.E., and Reed, E.C., 1950, Correlation of the Pleistocene deposits of Nebraska: Nebraska Geological Survey Bulletin 15A, 74 p., 15 figs.

Davis, Stanley N., Jr., Howe, Wallace B., and Heim, George E., 1960, The geology of Platte County, Missouri: Unpublished manuscript, Missouri Department of Natural Resources, Division of Geology and Land Survey - Rolla.

Flint, R.F., 1957, Glacial and Pleistocene geology: xiii + 553 p., 5 pls., 133 figs., John Wiley & Sons, Inc., New York.

___, et al., 1959, Glacial map of the United States east of the Rocky Mountains: Geological Society of America, 2 sheets, east and west, scale 1:1,250,000.

Frye, J.C., and Leonard, A.B., 1952, Pleistocene geology of Kansas: Kansas Geological Survey, Bulletin 99, 230 p., 19 pls., 17 figs.

___, Shaffer, P.R., Willman, H.B., and Ekblaw, G.E., 1960, Accretion-gley and the gumbotil dilemma: American Journal of Science, v. 258, p. 185-190.

___, and Willman, H.B., 1960, Classification of the Wisconsinan Stage in the Lake Michigan glacial lobe: Illinois Geological Survey, Circular 285, 16 p., 1 fig.

Gamble, Erling E., 1993, Geomorphic study in the Upper Gasconade River Basin, Laclede and Texas Counties, Missouri: US Department of Agriculture, Soil Conservation Service, Soil Survey Investigation Report No. 43.

Goodfield, Alan Granger, 1965, Pleistocene and surficial geology of the city of St. Louis and the adjacent St. Louis County, Mo.: unpublished, PhD Dissertation, University of Illinois-Urbana.

Greene, F.C., and Trowbridge, R.M., 1935, Pre-glacial drainage pattern of northwest Missouri: Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist to the 58th General Assembly, 1933-34, app. 7, 7 p., 1 pl.

Guccione, M. J., 1982, Mineral weathering, soil development, and stratigraphy of Quaternary deposits, Midcontinent U.S.A.: unpublished PhD Dissertation, University of Colorado.

Holmes, C.D., 1943, Nebraskan-Kansan drift boundary in Missouri: Geological Society of America Bulletin, v. 53, p. 1479-1490, 3 figs.

___, 1944, Pleistocene glacial drifts and loess of Missouri, *in* The geology of Missouri: University of Missouri Studies, vol. 19, no. 3, p. 337-346.

Howe, W. B. and Heim, G. E., Jr., 1968, The Ferrelview Formation (Pleistocene) of Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 42, 32 p.

Kay, G.F., and Apfel, E.T., 1929, The pre-Illinoian Pleistocene geology of Iowa: Iowa Geological Survey, Volume 34, p. 1-304, 3 pls., 63 figs.

___, **and Graham, J.B.**, 1943, The Illinoian and post-Illinoian Pleistocene geology of Iowa: Iowa Geological Survey, Volume 38, p. 11-262, 89 figs.

Missouri Geological Survey, 1977, The resources of St. Charles County, Missouri, land, water, and minerals: Missouri Department of Natural Resources, for the St. Charles County Planning and Zoning Commission.

Leighton, M.M., and Willman, H.B., 1950, Loess formations of the Mississippi Valley: Journal of Geology, v. 58, p. 599-623.

Rueff, Myrna, 1992, Surficial materials investigation at the Weldon Springs Training Area, St. Charles County, Missouri: Prepared for the United States Department of the Army, Kansas City District, Corps of Engineers, Kansas City, Missouri.

Schmaltz, Lloyd John, 1959, Pebble lithology of Nebraskan and Kansan tills in north-central Missouri: Unpublished Ph.D. dissertation., University of Missouri - Columbia.

Thorp, James, and Smith, H.T.U., 1952, Pleistocene eolian deposits of the United States, Alaska, and parts of Canada: Geological Society of America, 2 sheets, east and west, scale 1:2,500,000.

Whitfield, John W., 1986, Surficial materials map of the Springfield 1o x 2° Quadrangle, Missouri, Missouri Department of Natural Resources, Division of Geology and Land Survey, US Geological Survey Miscellaneous Field Studies Map MF-1830B.

Williams, James Hadley, 1975, Classification of surficial materials: unpublished Ph Dissertation, University of Missouri - Rolla.

Willman, H.B., and Frye, J.C., 1958, Problems of Pleistocene geology in the greater St. Louis area: Geological Society of America, Field Trip Guidebook, St. Louis Meeting., 1958, p. 9-11, figs. 1-2.

Classification and Nomenclature

Division of Geology and Land Survey Stratigraphic Commitee, 1993, Stratigraphic nomenclature adopted for use by the Missouri Department of Natural Resources' Geological Survey, DNR-DGLS Information Circular 31, 24 p.

Howe, Wallace B. (coordinator), and Koenig, John W. (editor), 1961, The stratigraphic succession in Missouri. Missouri Geological Survey and Water Resources, Volume 40, 2nd Series, 185 p.

Code of Stratigraphic Nomenclature, by American Commission on Stratigraphic Nomenclature: American Association of Petroleum Geologists Bulletin, vol. 45, no. 5, pp. 645-665, May, 1961.

North American Stratigraphic Code: American Association of Petroleum Geologists Bulletin, v. 67, p. 841-875. (1983)

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