The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States—Missouri

By THOMAS L. THOMPSON

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Historical review and summary of areal, stratigraphic, structural, and economic geology of Mississippian and Pennsylvanian rocks in Missouri

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THE MISSISSIPPIAN AND PENNSYLVANIAN (CARBONIFEROUS) SYSTEMS IN THE UNITED STATES—MISSOURI

By THOMAS L. THOMPSON[1]

ABSTRACT

Carboniferous rocks crop out over approximately two-thirds of the State of Missouri, although much of this region is partially covered by either Pleistocene drift and loess (northern part) or residual material from deeply weathered bedrock. Mississippian (lower Carboniferous) strata are predominantly limestone, although some shale is present in eastern and southwestern Missouri. Mississippian limestone is an economically important resource to the State and has been the host rock for lead and zinc. Pennsylvanian (upper Carboniferous) rocks consist of thin beds of limestone, shale, and sandstone; limestone and shale beds, although thin, are very widespread laterally persistent units. Coal is an increasingly important resource associated with Pennsylvanian strata, and many of the limestone beds are thick enough to be quarried in some regions of the State. In restricted parts of central Missouri, Pennsylvanian clay has been mined for its refractory properties.

INTRODUCTION

Rocks of Carboniferous age in North America have been divided into two systems, the Mississippian and Pennsylvanian. These systems were proposed in a review of Carboniferous strata of North America by Williams (1891), who described the "Mississippian series" of the upper Mississippi River valley (cited by Williams, 1891, p. 136, to have been originally named the "Mississippi limestone series, or Mississippi group" by Winchell 1872), and the "coal measures or Pennsylvanian series" of the Appalachian province of Pennsylvania. Although not immediately adopted by all North American Carboniferous stratigraphers, these names received general acceptance soon after the turn of the century. By the period 1935–1940, they seem to have been accepted by most, if not all, North American Carboniferous stratigraphers, and the general correlation of Pennsylvanian for upper Carboniferous and Mississippian for lower Carboniferous became common usage. Missouri contains at least part of the type areas for all four of the formally recognized series in the Mississippian System (fig. 1) and includes the type area for one of the five recognized midcontinent Pennsylvanian series.

The stratigraphic nomenclature used in this paper has not been reviewed by the Geologic Names Committee of the U.S. Geological Survey. The nomenclature used here conforms with the current usage of the Missouri Department of Natural Resources, Division of Geology and Land Survey.

GEOLOGIC SETTING

The dominant factor in the present distribution of Paleozoic strata in Missouri is the Ozark "dome" (or "uplift"). Rocks dip away from the region of maximum uplift (in east-central Missouri, the St. Francois Mountains) in all directions, and the amount of strata eroded decreases away from the center. Uplift and erosion before Carboniferous deposition (but apparently after Late Devonian deposition) produced an arcuate distribution of pre-Carboniferous formations. Basal Carboniferous rocks rest on strata ranging from Early Ordovician to Late Devonian in age; strata are progressively younger away from the uplift center.

The basal contact of the Carboniferous is unconformable, with the possible exception of that in northeastern Missouri, where the uppermost late Upper Devonian Louisiana Limestone underlies basal Carboniferous strata (Hannibal Shale) with little or no unconformity. The hiatus at the basal Carboniferous contact increases rapidly westward, however, as the Louisiana Limestone disappears and the Hannibal thins markedly. The region of Devonian-Carboniferous transition is restricted to that along the Mississippi River valley in Marion, Pike, and Ralls Counties, Mo.

Except for a sandstone (Indian Cave Sandstone) in northwestern Missouri of questionable Permian

[1] Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, MO 65401.

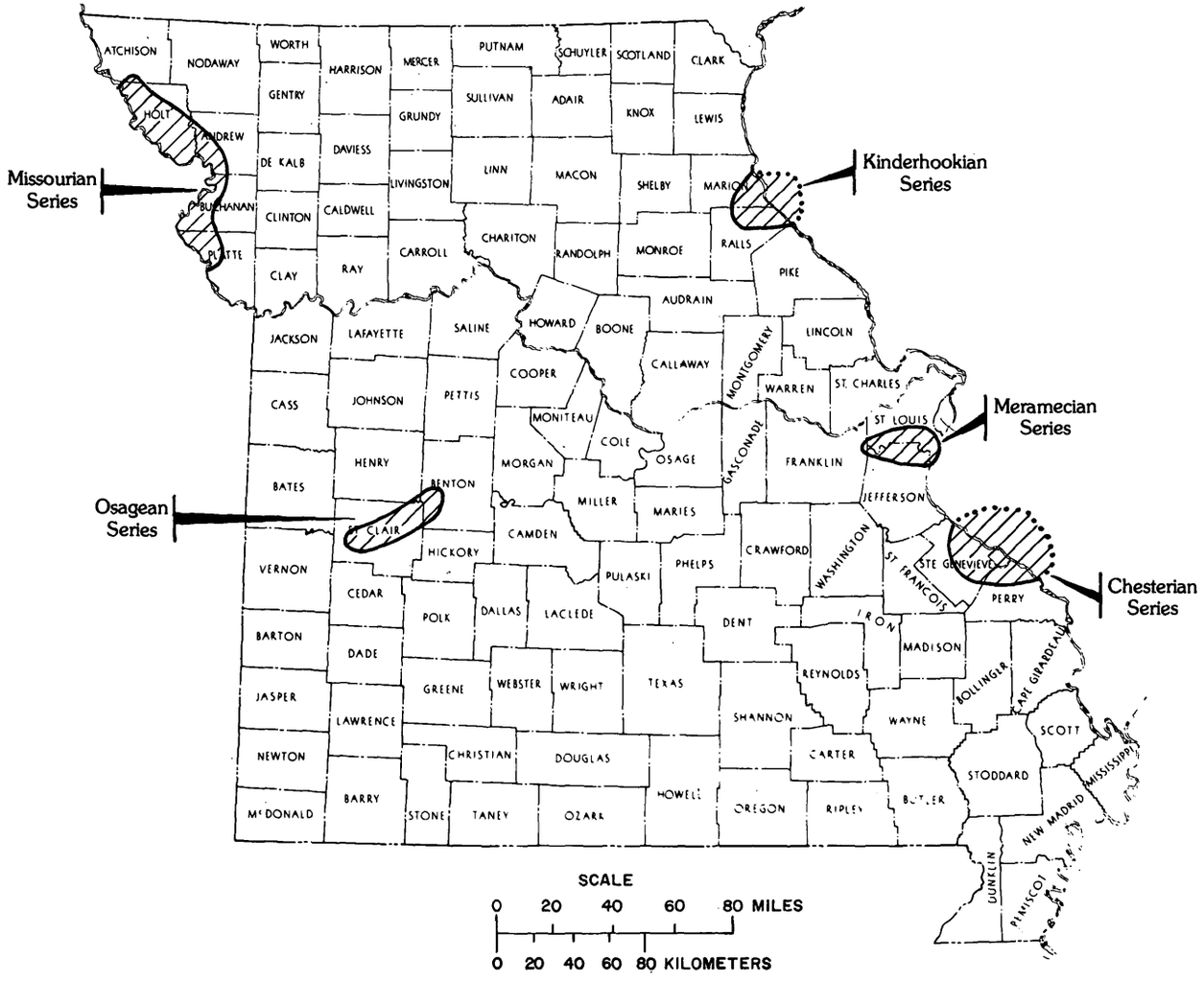


FIGURE 1.—Type areas of Mississippian and Pennsylvanian Series.

age, upper Carboniferous rocks constitute the youngest consolidated strata in Missouri except for the Cretaceous embayment region of southeastern Missouri. Thus, sediments overlying the Carboniferous consist primarily of Pleistocene glacial and other deposits north of the Missouri River and residual products derived by in situ weathering of bedrock south of the Missouri River.

Structural events were relatively minor throughout early Carboniferous time until late Meramecian and early Chesterian deposition. Increased clastic content in eastern Missouri and removal of Meramecian and upper Osagean strata by erosion before initial deposition of Chesterian strata (Hindsville Limestone) in western Missouri indicate late Mississippian uplift and associated activity. After Mississippian deposition, uplift and erosion removed considerable amounts of Mississippian strata before the start of Pennsylvanian deposition. Chesterian strata have been preserved in downdropped fault blocks in southeastern and southwestern Missouri. Elsewhere, erosion removed strata down to middle Mississippian and, in the Ozark uplift region south of the Missouri River, to Lower Ordovician strata.

Most of the Ozark "mountains" lie inside the belt of Mississippian outcrop. In western Missouri, the Mississippian marks the location of a broad, highly dissected upland (Springfield Plateau); the sharp eastern margin (often termed the "Eureka Springs escarpment") of this plateau forms a distinctive topographic feature above the Ordovician outcrops to the east. This plateau is less distinct north of Springfield because it has been highly dissected by tributaries of the Missouri River system.

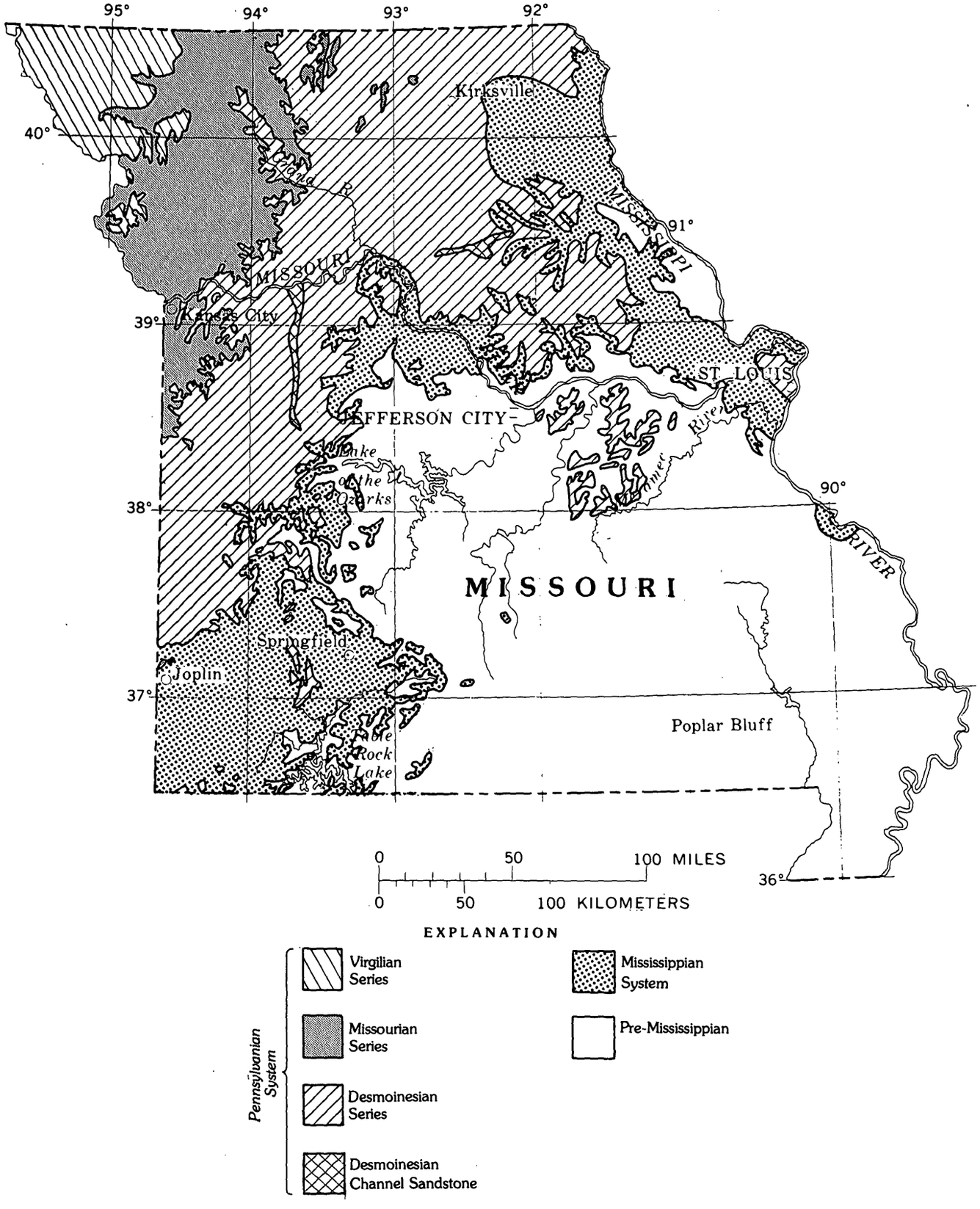
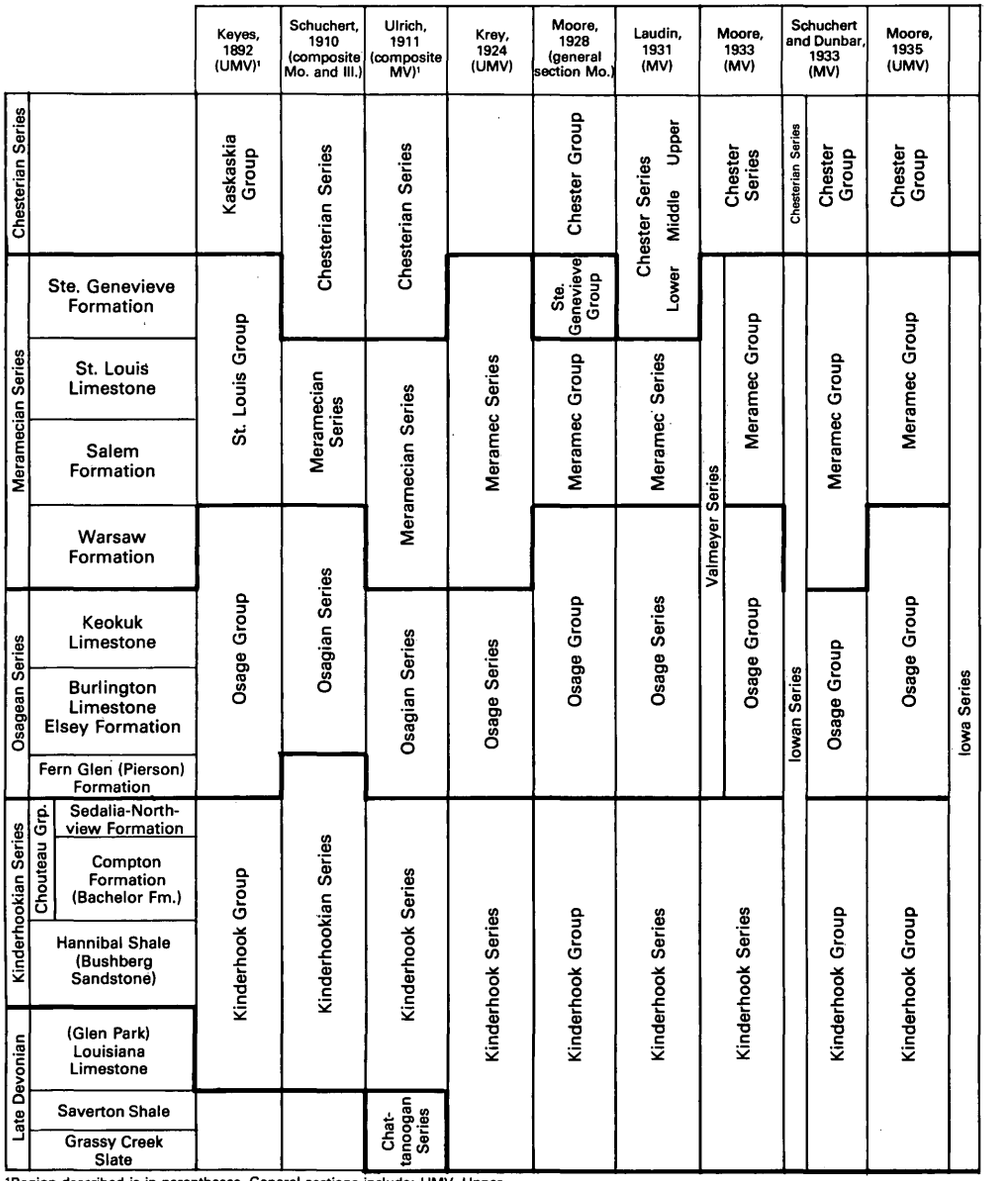


FIGURE 2.—Distribution of outcropping Mississippian and Pennsylvanian strata.

Carboniferous strata crop out over almost two-thirds of the State (fig. 2). Rocks south of the Missouri River valley (approximately the 39th parallel) are generally well exposed except where covered by loess (for example, in areas immediately adjacent to major river valleys) and (or) residual materials produced by weathering of the carbonate terrane. Outcrops are less common north of the Missouri River valley owing to cover by glacial drift deposited during the Kansan and Nebraskan episodes of Pleistocene ice advance. Here, best exposures are found where streams have cut down through the drift to re-expose the Paleozoic strata.

MISSISSIPPIAN SYSTEM

Rocks of the Mississippian System have been divided into four series: Chesterian Series (Worthen, 1866); Meramecian Series (Ulrich, 1904); Osagean (or Osagian) Series (Williams, 1891); and Kinderhookian Series (Meek and Worthen, 1861). Weller and others (1948, chart 5) stabilized this nomenclature as the "standard stratigraphic section" for the Mississippian System in North America (a condition lacking in nomenclature of Pennsylvanian stratigraphy). Figure 3 depicts the conceptual changes of the four Mississippian series



[1]Region described is in parentheses. General sections include: UMV, Upper Mississippi River Valley; MV, Mississippi River Valley.

FIGURE 3.—Development of nomenclature of Mississippian series in Missouri and surrounding midcontinent region.

from 1892 to the present. (See Thompson and Anderson, 1976, for synonymies of Mississippian nomenclature published for strata in Missouri.) Locations for the type areas of the four Mississippian series are shown on figure 1.

Although the four-part division of the Mississippian is more or less standard for North America, inability to agree on the placement of the Osagean-Meramecian boundary (whether it is above or below the Warsaw Formation or even whether such a boundary exists) led to a three-part division of the Mississippian in some States; Valmeyeran Series (Weller and Sutton, 1933; fig. 3) replaced Osagean and Meramecian in Illinois and Indiana. Kansas (Jewett and others, 1968) recognized "Lower Mississippian" and "Upper Mississippian" Series (fig. 3), the former composed of the Kinderhookian and Osagean Stages, the latter of the Meramecian and Chesterian Stages. However, this is nomenclatural variation and does not change the overall concept of time-stratigraphic correlation of the Mississippian System in the midcontinent region.

Rocks of the Mississippian age crop out extensively across Missouri (fig. 2). They are or have been economically important as a limestone resource where exposed and as host rock for lead and zinc

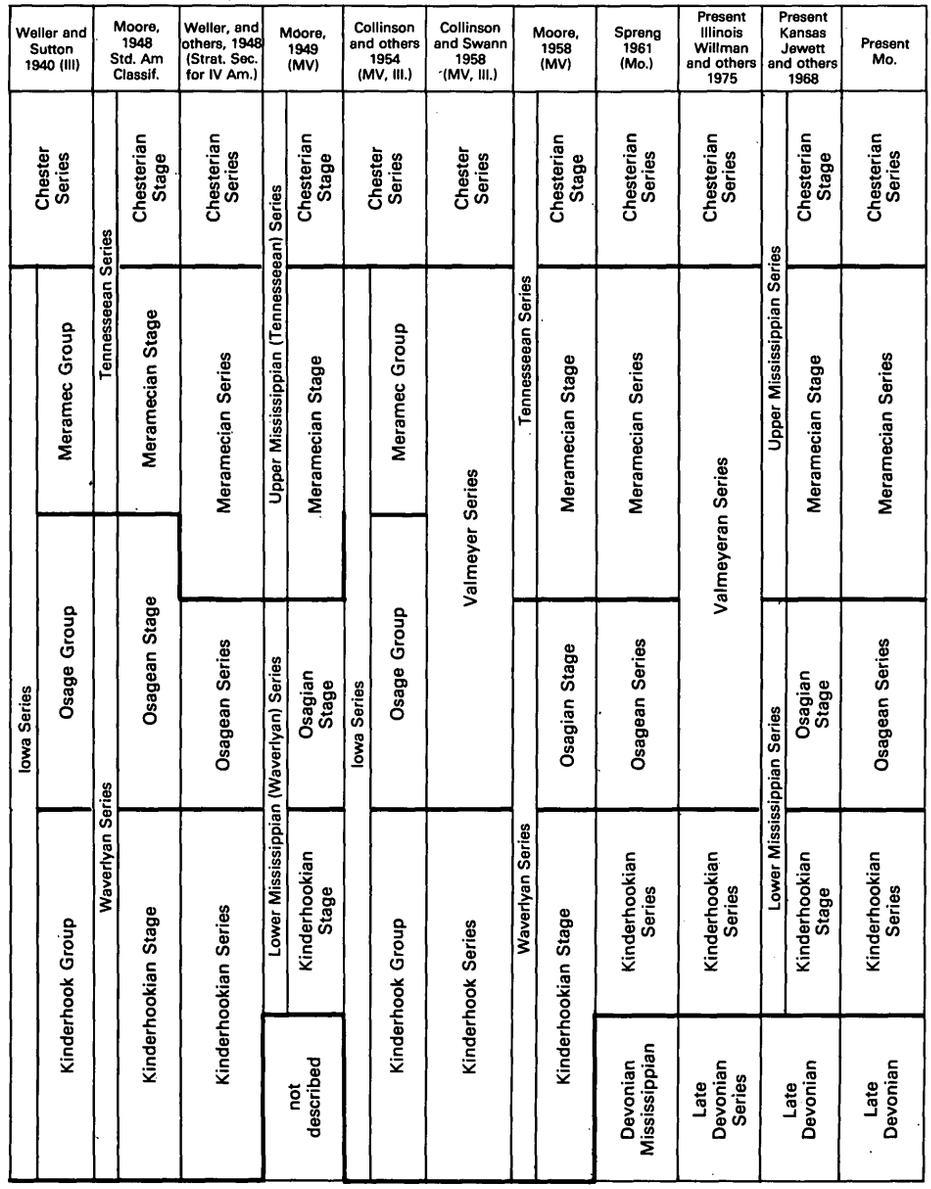


FIGURE 3.—Continued

deposits in the presently inactive Tri-State mining district of Missouri-Kansas-Oklahoma.

KINDERHOOKIAN SERIES

The "Kinderhook group" was named by Meek and Worthen (1861, p. 288) for strata exposed in the east bluffs of the Mississippi River valley immediately north of the small town of Kinderhook, Pike County, Ill. Formations identified within the Kinderhookian Series in Missouri include

Western and southwestern	*Northeastern*
Chouteau Group:	Chouteau Limestone
Northview Formation	
Sedalia Formation	
Compton Formation	Hannibal Shale
Bachelor Formation	

Originally this series also included strata later determined to be Late Devonian in age (Grassy Creek and Saverton Shales, Louisiana Limestone) and other rocks now assigned to the Osagean Series (Fern Glen Formation: see Weller, 1909, and Schuchert, 1910). As late as 1948 (Weller and others), the Grassy Creek, Saverton, and Louisiana formations were still identified as Kinderhookian in age. Scott and Collinson (1961) determined that the Devonian-Mississippian boundary was between the Louisiana Limestone and the overlying Hannibal Shale, finally defining the base of the Kinderhookian Series as now recognized. One of the best exposures of Kinderhookian strata in the type region (fig. 1) is a section along the Burlington Northern Railroad track immediately south of the town of Hannibal, Marion County, Mo., where the entire Hannibal Shale is exposed (the entire Kinderhookian interval in this region), along with the underlying Louisiana Limestone (Koenig and others, 1961, p. 44–46, stop 11).

The basal Kinderhookian formation in most of the Missouri outcrop area, other than the northeastern (Hannibal Shale) and southeastern (Bushberg Sandstone) regions, is the Bachelor Formation (Mehl, 1960, 1961), a very thin (5–10 cm), distinctive, persistent light-green to tan calcareous-cemented quartz sandstone that overlapped all pre-Mississippian strata during middle Kinderhookian time. This sandstone and overlying thin shale lie directly on strata of Ordovician, Silurian, Devonian, and even early Kinderhookian age (Bushberg Sandstone of southeastern Missouri). Conodonts recovered from the Bachelor (Thompson and Fellows, 1970) indicate basically the same age (that is, the same conodont zone, fig. 4) for the Bachelor throughout its outcrop from northwestern Arkansas to east-central Missouri. Late Devonian conodonts have commonly been reworked into the middle Kinderhookian fauna, even where the Bachelor rests on Lower Ordovician rocks, indicating that a widespread Upper Devonian sea existed before pre-Mississippian regression. The quartz sand of the Bachelor was most likely derived from Upper Devonian sandstone (Sylamore Sandstone), a nearshore facies of the Chattanooga Shale (Freeman and Schumacher, 1969).

Older Kinderhookian is represented only in the limited outcrop region of the Hannibal Shale on the western margin of the Illinois basin. Most of Missouri was still above sea level until middle Kinderhookian, when relatively sudden inundation resulted in the deposition of the Bachelor Formation. Stability soon followed, and the basal carbonate facies of the Chouteau Group (Compton facies) and its attendant crinoid fauna were deposited over most, if not all, of the Missouri region.

Throughout Missouri, Kinderhookian strata are predominantly carbonate rocks, either limestone or dolomitic limestone, except in the type area in northeastern Missouri where introduction of argillaceous material from the east produced the Hannibal Shale. In places, chert is present in the carbonate rocks, but not in the amounts found in some of the overlying beds of Osagean limestone. North of the Ozark uplift area (generally in the subsurface north of the Missouri River), Kinderhookian shales continue westward, resting on shale and limestone

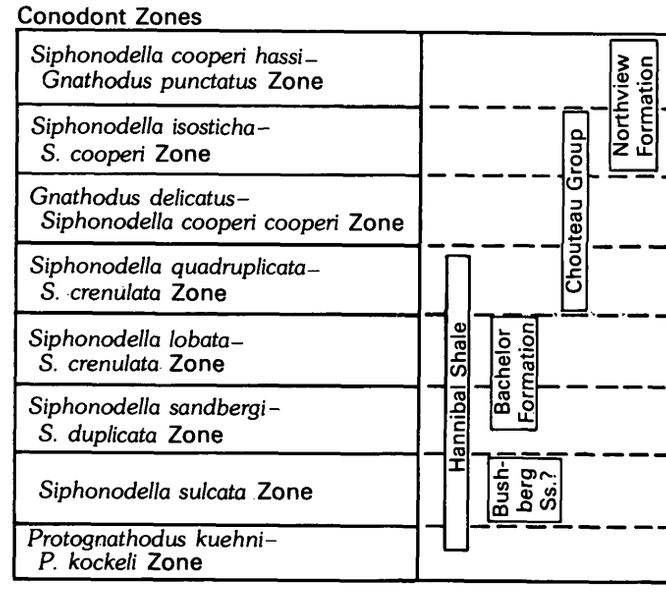


FIGURE 4.—Kinderhookian conodont zones (from Collinson, Rexroad, and Thompson, 1971) showing relative ages of Kinderhookian formations in Missouri.

of Late Devonian age. These Kinderhookian (Hannibal) shales continue in the subsurface to northwestern Missouri (Wells, 1960), where they rest on Upper Devonian shale.

Kinderhookian strata other than the basal Hannibal Shale are composed chiefly of limestone and dolomitic limestone (Chouteau Group) except for a northwest-trending "basin" of dolomitic silt and shale (Northview Formation, fig. 5) as much as 25 m thick in the vicinity of Springfield in southwestern Missouri (Clark and Beveridge, 1952; Thompson and Fellows, 1970). The Compton Formation, a limestone beneath the Northview, can be traced into Arkansas and Oklahoma and into the subsurface of eastern Kansas; Manger and Shanks (1976) recognized it as a member of the St. Joe Limestone in Arkansas. Statewide, the Kinderhookian carbonate rocks include fossiliferous limestone (with or without chert), oolitic limestone, silty and (or) argillaceous limestone, dolomitic limestone (with or without chert), dolomite, and even lithographic limestone. Interpretation of depositional environments is locally complicated by facies changes, as several of the above-mentioned lithologic types occur close together both horizontally and vertically.

The Chouteau in its type region in central Missouri, first described by Shallow (1855), is, from the base to top (fig. 6): fossiliferous limestone (Compton facies, units 3 and 4); lithographic limestone interfingering with silty, dolomitic limestone (unit 5); lithographic limestone ("Chouteau limestone", unit 6); silty, dolomitic, cherty limestone (Sedalia facies, unit 7); and dolomitic limestone (unit 8). The entire group is not more than 15 m

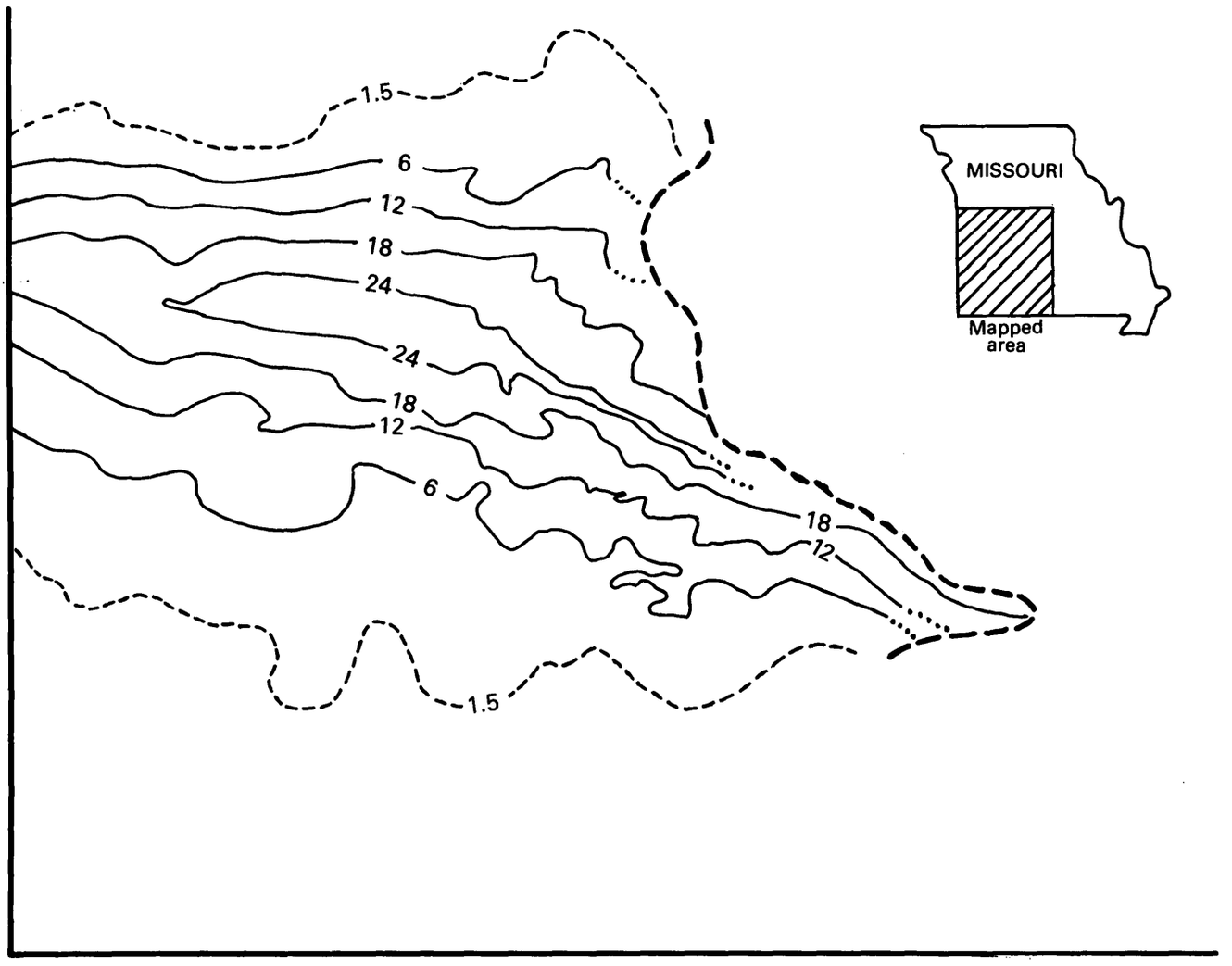


FIGURE 5.—Isopach map of the Northview Formation, southwestern Missouri (modified from Beveridge and Clark, 1952). Isopachs in meters.

thick. An isopach map of the Chouteau Group in southwestern, west-central, and central Missouri (fig. 7) shows the "Northview basin" and the increasing thickness of Chouteau strata to the northeast and north into central Missouri.

An unpublished study of the Chouteau Group of Missouri (Frey, 1967) described five carbonate facies in detail and presented a cross section of Chouteau strata from southwestern to northeastern Missouri (fig. 8). In Frey's interpretation of Chouteau strata, the Chouteau consists of the Compton, Sedalia, and Northview Formations; no "Chouteau limestone" was specifically identified by name. Frey did recognize two distinct facies, other than transitional facies, that had not been previously named formally. The "dolomitic limestone facies" (unit D, fig. 8) has been referred to in older literature as the "Chouteau limestone" in central Missouri. Facies unit E is a medium to coarsely crystalline fossiliferous limestone in northeastern Missouri and west-central Illinois; it is quite unlike the other Chouteau facies, except possibly for the Compton facies (unit F). The facies E grades into the upper part of the Hannibal Shale in northeastern Missouri, whereas the Compton facies (F) appears to be at the base of the Chouteau interval throughout its outcrop.

OSAGEAN SERIES

The "Osage group" was named by Williams (1891, p. 169) without further definition or discussion as part of his "Mississippian series." Later geologists differed in their definition of this group. Keyes (1892), Weller (1914), and Laudon (1948) included the Warsaw Formation as the upper unit of the Osagean, whereas Weller (1898), Moore (1928), and many other geologists (Weller and others, 1948) placed the top of the Osagean at the base of the Warsaw, the top of the underlying Keokuk Limestone. It was this controversy over the placement of the Osagean-Meramecian boundary that led to the establishment of the Valmeyeran Series in Illinois (Weller and Sutton, 1933) to include strata previously assigned to both former series.

The type area of the Osagean Series is the Osage River valley near Osceola, St. Clair County, west-central Missouri (fig. 1). However, in this region, Osagean exposures are poor, and only part of the series is represented. Osagean formations recognized in Missouri include, in descending order: Keokuk Limestone, Burlington Limestone, Elsey Formation ("lower Burlington" of eastern Missouri), and the Reeds Spring and Pierson Formations (Fern Glen Formation of eastern Missouri).

Strata of the Osagean Series are more than uniform in lithology than those of the Kinderhookian, and the formations are thicker. Except for a thin (2–3 m) shale or shaly limestone in the lower part near St. Louis in east-central Missouri (part of the Fern Glen Formation; Thompson, 1975), the Osagean is almost without exception a fossiliferous limestone or a cherty limestone. Lower Osagean limestones can be very cherty, and those in southwestern and east-central Missouri (Reeds Spring and Elsey Formations, upper part of the Fern Glen and lower part of the Burlington) commonly consists of more than 50 percent chert in at least part of the sequence. Upper Osagean limestones (Burlington and Keokuk Limestones) are extremely fossiliferous, the Burlington Limestone being more than 90 percent fossil debris throughout much of its outcrop. Upper Osagean limestones, more than 50 m thick, do contain some chert, but as 1 to 3-m zones separated by 10 to 15-m intervals of chert-free limestone.

MERAMECIAN SERIES

The "Meramec group" was named by Ulrich (1904, p. 110) for exposures and quarries in the "Meramec Highlands" adjacent to the Meramec River, St. Louis County, Mo. (fig. 1). Some early geologists excluded Warsaw and (or) Ste. Genevieve strata from this series, but Weller and others (1948) defined this series as it is now recognized. Meramecian formations in Missouri include, in descending order: Ste. Genevieve Formation, St. Louis Limestone, Salem Formation, and Warsaw Formation.

Meramecian rocks are, with the exception of the Warsaw and lower Salem of east-central Missouri, like the underlying Osagean, a thick sequence of fossiliferous limestone. Only near the top (Ste. Genevieve Formation) does the clastic content become significant, as an increasing amount of quartz sand indicates the beginning of instability that culminated in post-Mississippian–pre-Pennsylvanian uplift.

To the east, in the Michigan and Illinois basins, a sequence of deltaic siltstones and shales (Borden Siltstone: see Lineback, 1969) built up from the east toward the Mississippi River valley region. During early Meramecian time, this clastic material spilled westward over the Osagean carbonate bank that was forming west of the Illinois basin,

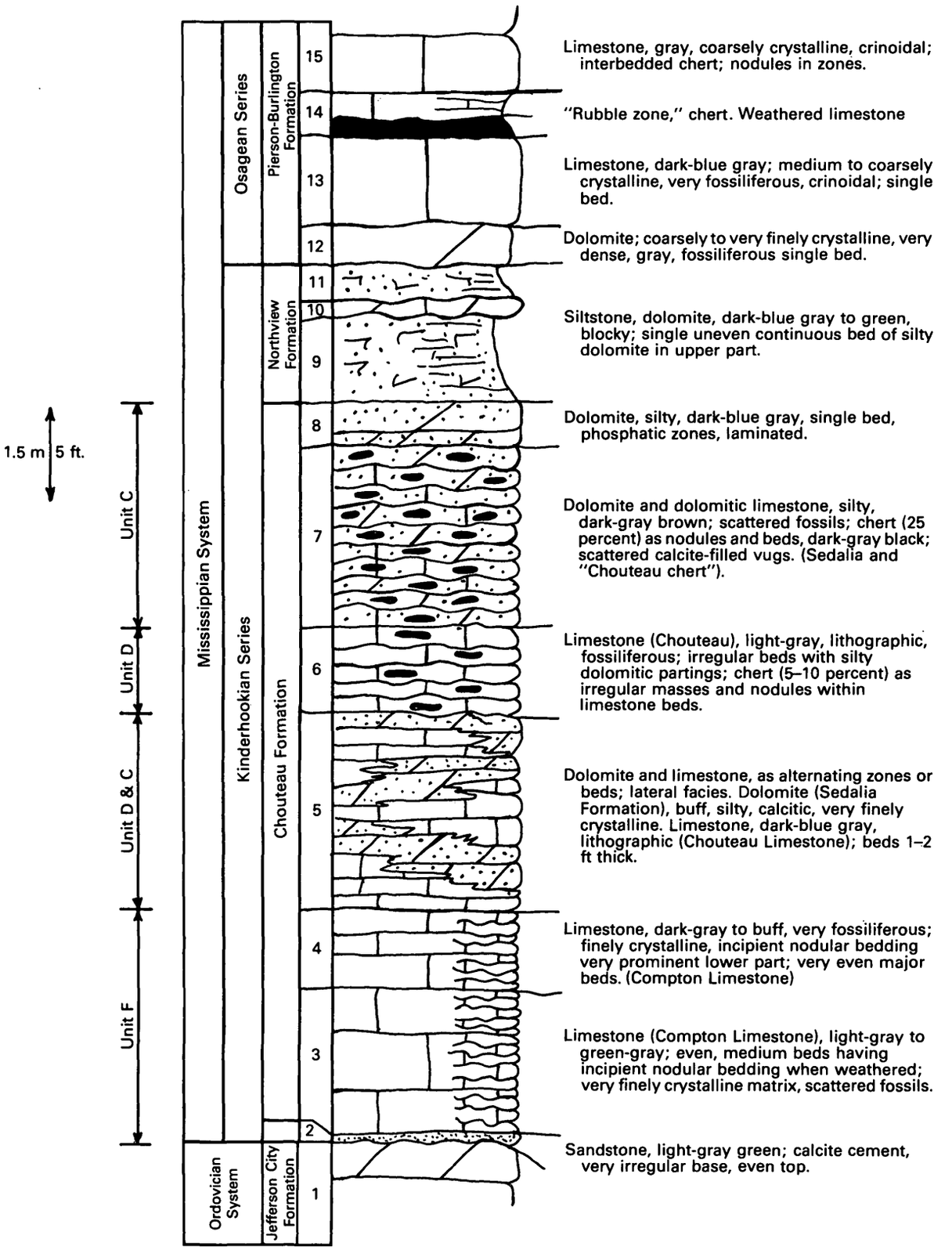


FIGURE 6.—Stratigraphic column of "Chouteau Group" section in the vicinity of Sedalia, Mo., within the type region of the Sedalia Formation (location at *A'* on fig. 8). Unit letters designate facies shown on figure 8.

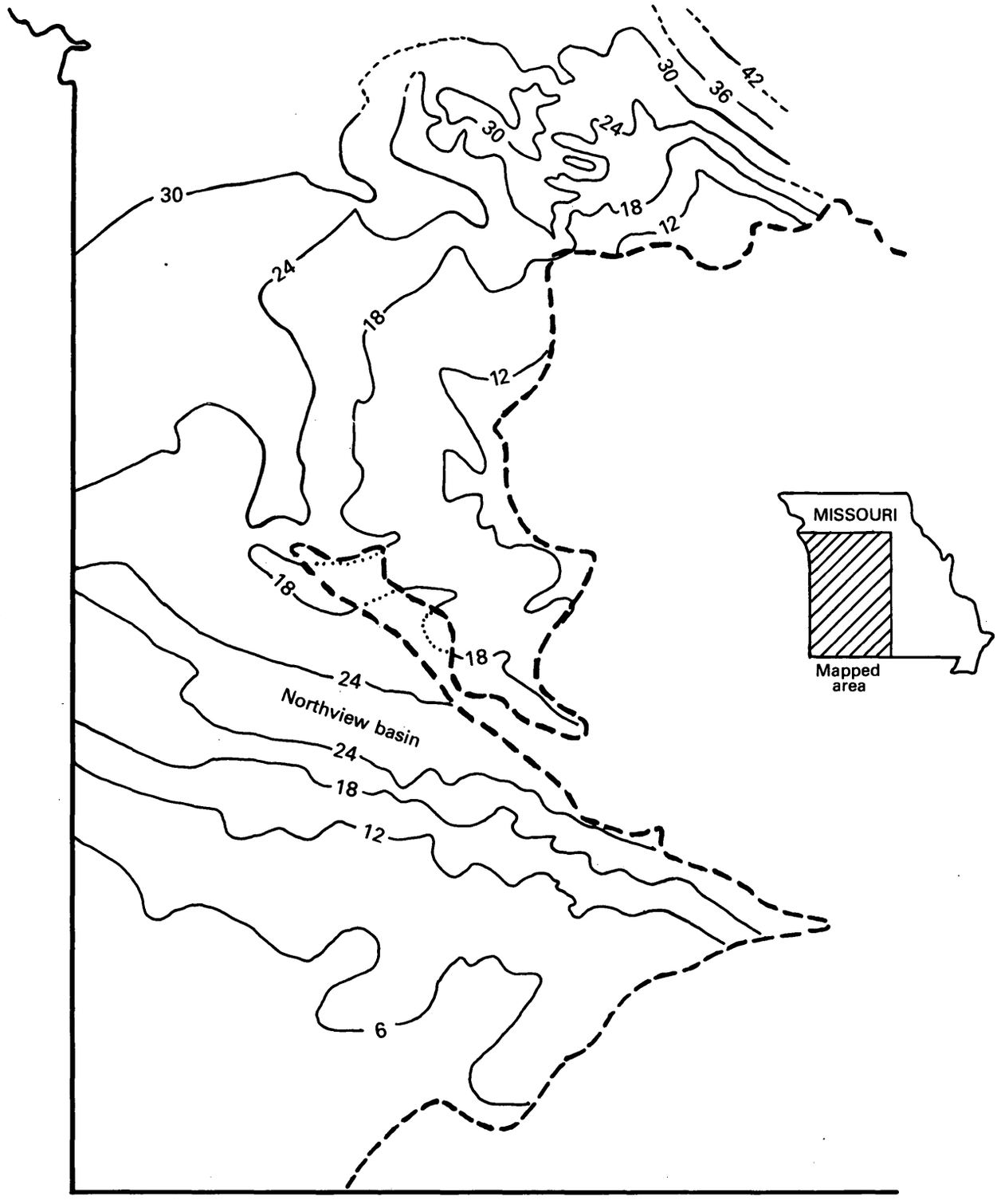


FIGURE 7.—Isopach map of the Chouteau Group, southwestern and western Missouri (modified from Beveridge and Clark, 1952). Isopachs in meters.

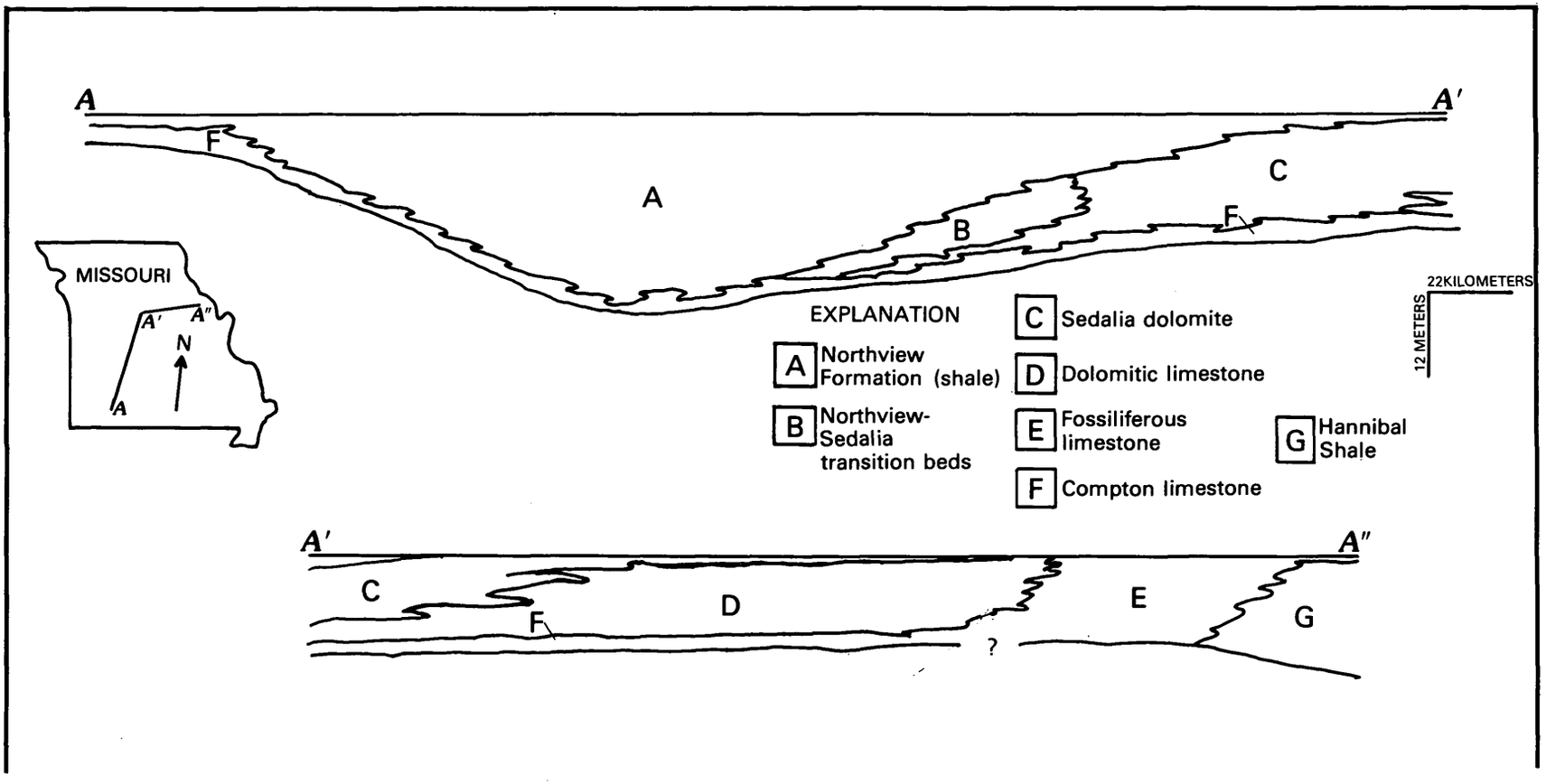


FIGURE 8.—Stratigraphic cross section of Kinderhookian strata from southwestern (*A*) to northeastern (*A''*) Missouri, illustrating carbonate facies of the Chouteau Group (modified from Frey, 1967).

stopping carbonate deposition by killing the predominantly echinoderm fauna responsible for a large part of the Osagean carbonate sediment and depositing shale and siltstone of the Warsaw Formation (a condition similar to that during deposition of the Hannibal Shale of Kinderhookian age). The Warsaw shales grade westward into calcareous shale and limestone, and finally in western Missouri, the sequence is again an unbroken one of fossiliferous limestone that shows little evidence of unconformity at the base of the Warsaw. The Keokuk-Warsaw contact is marked only by a thin (1–2 m) oolite (Short Creek Oolite Member of Keokuk Limestone).

The stable depositional conditions that produced a growing carbonate bank throughout Kinderhookian and Osagean time continued virtually unabated until upper Meramecian, when depositional environments changed, indicated by anhydrite beds and increased clastic rocks (St. Louis and Ste. Genevieve Formations) along with inconsistent limestone types of the St. Louis Limestone. Ste. Genevieve strata reflect more closely those of the overlying Chesterian Series and have in fact been recognized as such by Swann (1963).

CHESTERIAN SERIES

Worthen (1866) named the "Chester group" from a sequence of sandstones and limestones exposed in the bluffs of the Mississippi River valley in the vicinity of Chester, Randolph County, Ill. (south of St. Louis, Mo., fig. 1). These strata represent a shifting environment that produced an alternating sequence of 10 formations now recognized in southeastern Missouri (five sandstone and five limestone): Vienna Limestone, Tar Springs Sandstone, Glen Dean Limestone, Hardinsburg Formation, Golconda Formation, Cypress Formation, Paint Creek Formation, Yankeetown Sandstone, Renault Formation, and Aux Vases Sandstone. Conditions had changed considerably from the stable conditions of limestone deposition of the preceding series.

In addition, a Chesterian sequence is present in southwestern Missouri (Thompson, 1972) that has little depositional relationship to that in eastern Missouri; it is more closely related to Chesterian strata in Oklahoma and Texas. This limestone and shale sequence (Hindsville Limestone and Fayetteville Formation) appears to have been deposited in a depositional basin separate from that of the eastern sequence, as the difficulty of correlation by conodonts indicates (Thompson, 1972).

Outcrops of Chesterian rocks in southwestern Missouri are very restricted, preserved as downdropped fault blocks surrounded by Osagean strata. Obviously, Chesterian strata covered a much larger part of southwestern Missouri at one time, but the maximum extent is not known. Outcrops in eastern Missouri are restricted to the Mississippi River bluffs in northern Perry and southern Ste. Genevieve Counties.

SUMMARY OF MISSISSIPPIAN SYSTEM

Mississippian rocks in Missouri indicate depositional stability from earliest Kinderhookian into late Meramecian time. Thus, during two-thirds of Mississippian time, the region was covered by a warm shallow sea in which a broad carbonate shelf formed that extended throughout the western interior region (Missouri, Iowa, Kansas, northern Arkansas, and northeastern Oklahoma). Exceptions were the influxes of shale and silt into northeastern and east-central Missouri from the east that are represented by the basal Kinderhookian Hannibal Shale and the basal Meramecian Warsaw Formation. Both these units grade westward into limestone.

A northwest-trending trough of silty shale and dolomitic siltstone (Northview Formation) was rapidly deposited during late Kinderhookian time in part of southwestern Missouri, but the source of this material has not yet been identified. Deposition of the shale and siltstone did no more than create a pause in the limestone deposition in the region.

Limestones of the Mississippian System are composed largely of disaggregated echinoderms and other bioclastic debris. The percentage of echinoderm material varies, and other fossil groups are represented to various extents. Some limestone units are high in matrix material; others are very low, composed almost entirely of crinoid debris (Burlington Limestone).

The Mississippian carbonate shelf extended a short distance into Arkansas, where it abruptly terminated. In less than 8 km the composite Kinderhookian-lower Osagean section in northern Arkansas decreased from more than 25 m to less than 0.5 m (Thompson and Fellows, 1970). The southern end of the shelf facies grades within a short distance into a sediment-poor ("starved") limestone facies, where the rate of deposition was much slower than that of the shelf.

An uncommon situation exists in east-central and southeastern Missouri from the Meramec River valley just west of St. Louis southward. Osagean strata

(Fern Glen and Burlington) appear to be similar to those in western and southwestern Missouri (Pierson to Burlington sequence), but except for a very thin basal Mississippian sandstone (Bachelor Formation and possibly the Bushberg Sandstone), Kinderhookian carbonate rocks are missing; and no evidence is seen of prior deposition or erosion of these carbonate rocks. Perhaps Kinderhookian time in eastern and southeastern Missouri was a period of "still-stand."

Pre-Mississippian strata range from Early Ordovician (Canadian Series) to Late Devonian (Famennian Stage) in age. This surface reflects post-Devonian–pre-Mississippian erosion that left Upper Devonian strata in northern Missouri and scattered places in southwestern Missouri (Grassy Creek and Chattanooga shales) but removed all strata down to Lower Ordovician in western and southwestern Missouri.

The Kinderhookian-Osagean boundary is represented by a hiatus throughout all but possibly the extreme southwestern part of the State (Thompson and Fellows, 1970). This short period has been recognized by a fauna of late Kinderhookian conodonts absent from the Mississippi River valley sections. The base of the Osagean Series, as identified by conodonts (Thompson and Fellows, 1970; Thompson, 1975), is consistent and well represented throughout most of the State.

The Osagean-Meramecian boundary is transitional in all but the east-central part of Missouri, where the abrupt change from Keokuk limestone to Warsaw shale marks this boundary. In western Missouri, this boundary is identified as the top of a thin (1–3 m) oolitic limestone bed separating the Keokuk and Warsaw. Little, if any, time is lost across this "boundary."

The Meramecian-Chesterian boundary in eastern Missouri has traditionally been placed between the Ste. Genevieve Formation and the overlying Aux Vases Sandstone, identified on the basis of crinoids (Swann, 1963). However, lithologically, the basal part of the Ste. Genevieve, where the first clastic sediments appear, better reflects the conditions attributable to a series boundary. Conodonts do not indicate a faunal change between Ste. Genevieve and Chesterian strata but do indicate a distinct change between St. Louis and Ste. Genevieve rocks.

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

The Mississippian-Pennsylvanian boundary in Missouri is represented by a hiatus of variable but, in many places, considerable magnitude. Lower and (or) Middle Pennsylvanian strata rest on rocks ranging from Early Ordovician (Canadian) to Late Mississippian (Chesterian) in age. However, not all the inferred removal took place in post-Mississippian time; some took place in pre-Mississippian and also during Mississippian time. This hiatus contrasts sharply with the nearly transitional Mississippian-Pennsylvanian boundary within the second tier of counties south of the Missouri-Arkansas border in northwestern Arkansas (Washington to Independence Counties).

The youngest identified Mississippian rocks in southwestern Missouri constitute the middle Chesterian Fayetteville Formation (Thompson, 1972). No exposures of upper Chesterian strata (equivalent to Pitkin and Imo rocks in Arkansas, fig. 9) have been identified in southwestern Missouri. However, Thompson (1970) identified uncommon strata near an old coal pit in extreme southwestern Missouri as early Morrowan (Early Pennsylvanian) in age; the strata consist of marine sedimentary rocks that correlate, by conodonts, directly with the Prairie Grove Member of the Hale Formation in the type region of the Morrowan Series in Washington County, Ark. This correlation leads to the possibility that the transitional Mississippian-Pennsylvanian seas may have extended north into southwestern Missouri.

Current and unpublished studies by the author describe late Morrowan and Atokan strata in the west-central part of Missouri that are preserved within low regions of an undulating erosional surface on middle Mississippian (Meramecian and Osagean) limestones. Thus, considerable erosion took place before the appearance of Morrowan seas in this region. Because the Chesterian formations of southwestern Missouri rest on the Osagean Keokuk Limestone (the entire Meramecian and upper Osagean are missing), much of the pre-Pennsylvanian erosion might have been pre-Chesterian as well.

Late Morrowan and Atokan sediments were deposited in extreme western Missouri before initial deposition of the more widespread Desmoinesian sandstones. The total present extent of pre-Desmoinesian strata is quite limited. The overlying continental Desmoinesian sandstones overlapped the Atokan shales eastward over the Mississippian erosional surface, extending well beyond the known margin of Atokan deposition. Between the top of the Mississippian and basal Pennsylvanian sandstones is the "basal Pennsylvanian conglomerate,"

Pennsylvanian System	Atokan Series	Atokan Formation (Winslow Formation)	
	Morrowan Series	Bloyd Formation	Kessler Limestone Member Dye Shale Member Woolsey Member Brentwood Limestone Member
		Hale Formation	Prairie Grove Member Cane Hill Member
Mississippian System	Chesterian Series	Imo Formation Pitkin Formation Fayetteville Formation Batesville Sandstone Hindsville Limestone	

FIGURE 9.—Upper Mississippian (Chesterian Series) and Lower Pennsylvanian (Morrowan Series) formations of northwestern Arkansas.

composed of well-rounded boulders and pebbles of Mississippian chert within a quartz sand matrix (Graydon Formation).

Over much of the basal Pennsylvanian-outcrop region, the oldest Pennsylvanian sedimentary rocks are those of the Desmoinesian Cherokee Group (including the sandstone mentioned above). These sedimentary rocks are generally of a continental nature, a complex of distributary channel sandstones, interbedded shales and coals, and widespread sheet sandstones. In central and eastern Missouri, Pennsylvanian clay, shale, and sandstone were deposited on a karst surface of Lower Ordovician (Canadian) dolomites. These strata (Cheltenham Formation), previously considered Atokan in age (Searight and Howe, 1961), are now regarded as "unassigned" (Anderson and others, 1979). The lowest recognizable Pennsylvanian beds overlying these clay and shale beds are basal members of the Marmaton Group. Cheltenham strata are questionably correlated with Cherokee strata elsewhere.

PENNSYLVANIAN SYSTEM

Pennsylvanian strata of North America are not as easy to relate on a continent-wide basis as are those of the Mississippian because of the distinct differences in lithologic sequences between major depositional regions (such as the Pennsylvania coal basin, Illinois basin, and western interior coal basin of Kansas, Iowa, Oklahoma, Nebraska, and Missouri). Therefore, several separate classifications exist, each applicable to a particular region. As described by Moore and others (1944, chart 6) the "Mid-Continent Region" Pennsylvanian System consists of five series, originally identified as formations, bounded by major unconformities within the Pennsylvanian sequence. They are, in descending order: Virgilian Series (Moore, 1932), Missourian Series (Keyes, 1894), Desmoinesian Series (Keyes, 1894), Atokan Series (Taff and Adams, 1900; Lampasas Series, in Moore and others, 1944) and Morrowan Series (Adams and Ulrich, 1905). These unconformities often are marked by the presence of bodies of sandstone resting as sheets and (or) channels on an eroded surface of the previous series.

Pennsylvanian stratigraphic units in the midcontinent region (western-interior coal basin) are distinctive in their extreme thinness, despite great lateral persistence. The same formations—even members of formations—extend over Kansas, Nebraska, Iowa, and Missouri (and some into Oklahoma). A single shale bed 1 m thick can be identified from western Kansas to northern Missouri, and one of the coal beds (Crowebrug) has been correlated from Kansas to Pennsylvania (Hopkins and Simon, 1975, p. 187).

In this complex stratigraphic sequence, a great number of formations have been recognized—69 presently in Missouri, alone—composed of more than 100 formally recognized members. Because the Pennsylvanian depositional history was one of cyclic sequences (Weller, 1930; Moore, 1930, 1931), formations have been combined into groups by cyclic similarities. Originally proposed as formations, each of the nine formally named groups possesses peculiar and distinct attributes that distinguish it from others. The groups are bounded by unconformities of regional distribution. For clarity, and to best describe both physical and economic conditions, Pennsylvanian strata in Missouri will be detailed to the group level (fig. 10).

MORROWAN AND ATOKAN SERIES

Adams and Ulrich (1905) defined the "Morrow formation" from outcrops in Washington County, Ark. Although identified as the "Morrow series" by Moore (1932), Henbest (1962a,b) formally defined the Morrowan Series as presently recognized.

Taff and Adams (1900) named the "Atoka shale" from a thick sequence exposed in Atoka County,

FIGURE 10.—Stratigraphic framework for Pennsylvanian System in Missouri, to group level.

Okla. Unfortunately, this exposure is essentially unfossiliferous, and the inability to determine accurately the relationship between type Atokan strata and those of the type Morrowan in Arkansas has been the basis of a controversy over the validity of the Atokan Series as a time-stratigraphic (chronostratigraphic) unit (see Shaver and Smith, 1974). Moore and others (1944) defined this sequence as the Lampasas Series, from a section exposed in Texas. Dunn (1976) and Webster (1969) identified this interval as the Derryan Series, named by Thompson (1942) from a section in New Mexico. However, the relationship of Derryan strata to type Morrowan is also unclear because Thompson did not recognize Morrowan in his sections but identified all pre-Desmoinesian strata as "Derryan." Atokan Series is still used in the midcontinent region for lack of a more clearly defined series.

Distribution of Pennsylvanian strata older than Desmoinesian in Missouri is not well known; strata are generally discontinuous and in some areas are limited to remnants preserved in collapse or fault structures (fig. 11). Before 1970, no rocks of Morrowan age had been positively identified in Missouri. Sandstone capping outliers of Chesterian (Upper Mississippian) strata in extreme southwestern Missouri (formerly identified as the Hale Formation; Searight and Howe, 1961; Thompson, 1972) has recently been identified as Mississippian in age by E. Glick (Wedington Sandstone Member of the Fayetteville Formation (oral commun., 1975).) Thompson (1970) recovered a conodont fauna of definite Morrowan age from one isolated outcrop preserved as a block within a fault zone in southwestern Missouri; he correlated these rocks with the early Morrowan Prairie Grove Member of the Hale Formation in the type Morrowan region of northwestern Arkansas.

Beneath the shale of the Riverton Formation in west-central Missouri is a thin (1–3 m) calcium carbonate-cemented quartz sandstone (hereafter termed "calcareous sandstone") that lies directly on the eroded surface of Mississippian limestone. This sandstone was included within the Riverton by Searight (1959). However, it has yielded a conodont fauna that indicates a Morrowan age. Conodonts recovered from the shale of the overlying Riverton Formation indicate an Atokan age.

The Burgner Formation (Searight and Palmer, 1957), named from a core taken in a sink structure near Joplin, Mo., was dated by fusulinids (Thompson, 1953) as mid-Atokan in age. In the type Burgner Core, limestone of the limestone, shale, and coal sequence yielded a conodont fauna younger than that recovered from the calcareous sandstone

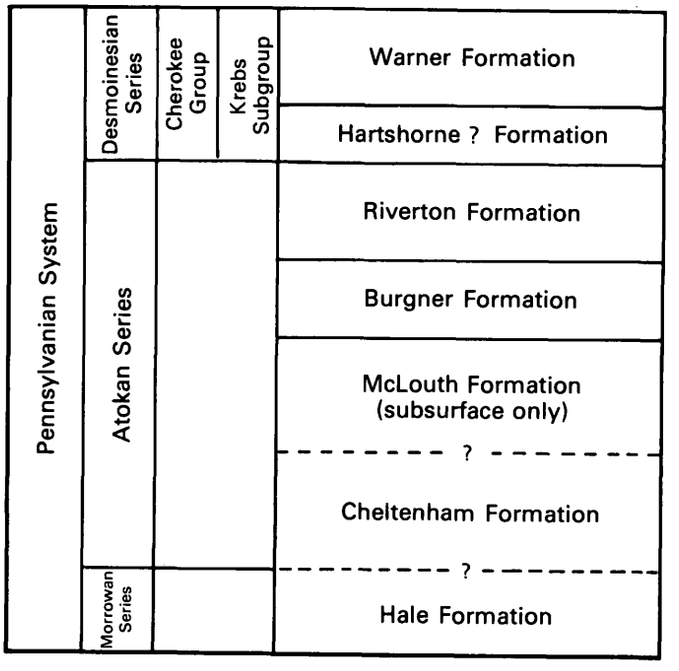


FIGURE 11.—Lower Pennsylvanian sequence in western Missouri, as presented by Searight and Howe (1961).

beneath the Riverton shales in west-central Missouri but definitely older than that recovered from the Riverton shales. Burgner strata are interpreted to lie approximately at the Morrowan-Atokan boundary and to be of very early Atokan age in at least the upper part. The Burgner, like the Riverton in the Joplin area, is found primarily within collapse or filled-sink structures in Mississippian limestones. The limestone of the Burgner Formation is definitely marine, as is the calcareous sandstone, and thus its presence indicates Morrowan to early Atokan seas in southwestern Missouri (Thompson, 1970) and into west-central Missouri.

The Riverton Formation (fig. 11), beneath the basal Krebs Subgroup of the Cherokee Group, has been preserved in several sink structures around Joplin. Riverton strata are also known north of Joplin in west-central Missouri beneath the basal formation of the Krebs Subgroup (Warner Formation). The pre-Pennsylvanian surface in west-central Missouri is broadly undulating. On the highest parts, the sandstone of the basal Krebs Warner Formation rests directly on Mississippian strata. The Riverton strata and underlying Morrowan calcareous sandstone are increasingly thick toward the lowest parts of the undulating surface. The calcareous sandstone is generally present only in the deepest parts, is more restricted than the overlying shale, and has been identified in only one small area (fig. 12). In the region of Joplin, beds of the Riverton Formation (coal, shale, and sandstone) have been distorted and dip steeply into circular collapse structures; this position indicates that the Riverton beds were let down into the structures after they were deposited. Much of the lead and zinc recovered from the Missouri part of the Tri-State mining district was obtained along the walls of these circular structures.

Searight and Howe (1961) regarded the Riverton as late Atokan in age (fig. 11). Conodonts recovered from the basal part of the Riverton at two localities (Thompson, unpub. data), one an open sink structure near Joplin, the other an outcrop in west-central Missouri, clearly indicate an Atokan age for the Riverton Shales; that is they are younger than the Burgner Formation. From this, the relationship of pre-Desmoinesian formations of western Missouri is shown in figure 13.

FIGURE 12.—Areas of known Morrowan and Atokan strata. ×, lower Morrowan strata; ○, Riverton and Burgner Formations near Joplin, Missouri, Atokan in age; □, Riverton Formation (Atokan) and underlying Morrowan calcareous sandstone.

DESMOINESIAN SERIES

The "Des Moines formation" was named by Keyes (1894, p. 82) to "represent the lower Coal Measures, or the marginal deposits of the Upper Carboniferous." The type locality is along the Des Moines River in central Iowa. Originally, the "Des Moines series" (Keyes, 1896) extended to the base of the present Kansas City Group and included the section now named the Pleasanton Group (lower Missourian Series). Moore (1932) restricted the "Des Moines series" to its present limits, which includes only the Cherokee and Marmaton Groups. The name was combined to "Desmoinesian" by Moore (1948).

Desmoinesian strata are divided into two named groups, the Cherokee and overlying Marmaton. They are quite distinct from each other, the Cherokee composed almost entirely of shale, clay, sandstone, and coal beds, the Marmaton, of alternating limestone and shale and of minor sandstone bodies associated with the thicker beds of shale.

Desmoinesian Series	Warner Formation
Atokan Series	Riverton Formation Burgner Formation "calcareous sandstone" "correlative of Prairie Grove Member of Hale Formation"
Morrowan Series	

FIGURE 13.—Proposed sequence of Lower Pennsylvanian formations in western and southwestern Missouri.

Cherokee Group.—Most of the minable coal beds in Missouri are found in the Cherokee Group. Haworth and Kirk (1894, p. 105) named the "Cherokee formation" for strata of the "lower division of the Lower Coal Measures" from exposures in Cherokee County, Kans. Depositional conditions were complex, most sedimentary rocks being sandstone (occurring as shallow channels (of a distributory nature) and broad sheets), siltstone, clay (underclay), overlying coal beds, and a few thin beds of limestone. Lower Cherokee strata contain thick coal-bearing shales between and contemporary with distributary-channel and widespread sheet sandstones. Sandstone is less abundant in upper Cherokee strata, where clay and shale are dominant.

Marmaton Group.—Marmaton strata are an alternating sequence of limestone and shale; several of the limestone beds are thick enough for quarrying. A coal bed (Summit coal) is present above the basal limestone but is minable only in a few restricted areas. Haworth (1898, p. 92) named the "upper division of the Lower Coal Measures" the "Marmaton formation" from strata exposed along the Marmaton River in eastern Kansas. Originally including Pleasanton strata in the upper part, Moore (1932) restricted the group to its present definition. Many early geologists called this sequence the "Henrietta formation," or "Henrietta group" (named by Keyes, 1898), but Greene and Searight (1949) formally abandoned this name in favor of Marmaton.

Marmaton strata are an alternation of two sedimentary cycles: a sequence of thin limestone-shale-limestone units, and a thick shale (in many places associated with channel sandstone bodies and coal beds). Four of each of these basic cycles constitute the Marmaton. The top of the group is marked by major channel sandstone of the basal Missourian Pleasanton Group.

MISSOURIAN SERIES

Keyes (1894, p. 82) named the "Missouri formation" to correspond to the "upper Coal Measures." The type locality is in the bluffs of the Missouri River valley in northwestern Missouri. Originally defined to include all Pennsylvanian strata above the Desmoinesian, Moore (1932) restricted the definition to include beds between two important unconformities, one at the base of the Pleasanton, the other (top) between the Pedee and overlying Douglas Groups.

The Missourian Series consists of four groups: the basal Pleasanton Group, which is an unconformable continental sandstone and shale sequence on the underlying marine Desmoinesian (Marmaton) strata, and the predominantly marine Kansas City, Lansing, and Pedee Groups.

Pleasanton Group.—The "Pleasanton shales" (Haworth and Bennett, 1896, p. 44) were named for a sequence of shale and sandstone cropping out in the vicinity of Pleasanton, Linn County, eastern Kansas. Although almost entirely a clastic unit, a conspicuous limestone (Exline in Missouri, Checkerboard in Kansas) about one-fourth to one-half meter thick, is persistent in the lower part of the group. One important aspect of Pleasanton strata is in the impressive channel sandstones exposed in west-central (Warrensburg Sandstone Member) and north-central (Moberly Sandstone Member) Missouri, representing remnants of a once-extensive drainage system in early Missourian time.

Kansas City Group.—The "Kansas City formation" (Hinds and Greene, 1915, p. 23) is a sequence of alternating beds of limestone and shale. Formations are defined on the basis of cycles of limestone-shale-limestone formations alternating with shale or shale-limestone-shale formations. In all, 17 formations have been named in the Kansas City Group, of which 5 are shale units not divided into members. Several limestone members are thick (3 m) and have been extensively quarried in the Kansas City region.

Complex cyclic sedimentation is represented in some of the Kansas City formations. Sequences of distinctive associations (Swope Formation) are repeated almost exactly in younger successions in the Virgilian Series (Shawnee Group).

Lansing and Pedee Groups.—The Lansing and Pedee Groups (originally part of the Kansas City Group) continue the limestone-shale-limestone sequence. The Pedee Group was removed by pre-Virgilian erosion in some places north of Kansas City; this removal left a Missourian-Virgilian unconformity. The "Lansing formation" was first identified by Hinds (1912, p. 7), and the Pedee was named by Moore (1932, p. 88); the type localities are near the town of Lansing, Leavenworth County, Kans., and along the "Pedee Branch in vicinity of Weston, Missouri," in Platte County (Moore, 1936, p. 137).

VIRGILIAN SERIES

Moore (1932) named the "Virgil series" for strata near the town of Virgil, Greenwood County,

Kans. Condra (1949, p. 11) located the type area as "on Verdigris River from west of Madison to Virgil and southeastward to central Wilson County." Virgilian strata are divided into three groups, the Douglas, Shawnee, and Wabaunsee. The formations of the last two are complex, and cyclic, some consisting of "megacyclothems," a certain repetitive cycle of cyclothems. Heckel (1968, 1975, 1977) and Heckel and Baeseman (1975) have described in detail the environmental sequences identified by specific rock types within these cyclic sequences.

Douglas Group.—Named for Douglas County, Kans., by Haworth (1898, p. 92, 93), the "Douglas formation" was proposed as a group by Moore (1932). The base of the group is marked by a channel sandstone (Tonganoxie Sandstone Member of Stranger Formation) in parts of northeastern Kansas and northwestern Missouri. The remaining Douglas strata are predominantly shale but contain a few thin limestone members.

Shawnee Group.—Haworth (1898, p. 93) named the "Shawnee formation" from strata exposed in Shawnee County, Kans. Moore (1932) redefined these strata as the Shawnee Group, composed of a sequence of "megacycles," each reflecting a complex cycle of sedimentation. Limestone beds predominate in this sequence, although some beds of thick shale are also present. Characteristic of these strata are certain units of thin shale that are laterally persistent over much of the midcontinent region.

Wabaunsee Group.—Named from strata in Wabaunsee County, Kans. (Prosser, 1895, p. 689), the "Wabaunsee formation" was redefined by Moore (1936) as the Wabaunsee Group. It is distinguished from the Shawnee Group by a larger relative percentage of shale and relatively more sand and sandstone in the shales. As stated by Moore (1936, p. 201), "A distinctive feature of the Wabaunsee group is the character of the cyclic sedimentary succession, which shows regularly alternating nonmarine and marine units in which a grouping of cyclothems in megacyclothems is not evident. This serves especially to set the Wabaunsee beds apart from those of the Shawnee group."

SUMMARY OF PENNSYLVANIAN SYSTEM

Whereas Mississippian strata represent a period of stable shallow marine deposition in the Missouri region, Pennsylvanian strata indicate a period of continuous change. Earliest Pennsylvanian sedimentary rocks (Morrowan Series) are known from one outcrop in southwestern Missouri, which may represent the extension of Morrowan seas of northwestern Arkansas into Missouri. Remnants of Atokan strata are primarily shales, which indicate less stable, more continental conditions. Strata of the lower Desmoinesian Cherokee Group are primarily sandstone and shale, which reflect a distributary, deltaic to coastal-plain environment; the fluctuating, very shallow swampy environment of the "Coal Measures" proper is best seen in the upper Cherokee Group.

Pennsylvanian strata of the upper Desmoinesian (Marmaton Group) and above, with the exception of the Pleasanton strata, generally consist of alternating limestone and shale. Conditions alternated from shallow marine to nonmarine continental. Marine phases consist of limestone and thin shale; these alternating with the continental phase, of thick shale, sandy shale, and (or) sandstone. Several coal beds formed during this continental phase are thick enough to be mined. However, most of the economically important coal beds are within the Cherokee Group.

Thus, in contrast with the stable conditions of Mississippian time, Pennsylvanian environments of deposition ranged from shallow open marine to complete regression to low-relief continental (deltaic and coastal plain).

MINERAL RESOURCES

Mineral production from Carboniferous strata in Missouri has consisted primarily of limestone, refractory clay, shale, lead, zinc, and coal. Few significant amounts of petroleum and natural gas have been recovered from these strata, although there is current interest in the "tar sands," or heavy oil in the lower Pennsylvanian sandstones of western Missouri.

MISSISSIPPIAN SYSTEM

Limestone is the single most important economic product derived from Mississippian strata in Missouri today. Both dimension and crushed and broken stone are produced from open-pit and drive-in mines. The limestone is used principally for construction aggregate, marble and dimension stone, agricultural limestone (aglime), riprap, filler, and the manufacture of cement and lime. Throughout the Mississippian outcrop region, quarries are common, and many are associated with past highway construction. Large permanent quarries exist where special products are produced, such as cement or dimen-

sion stone, and in urban areas, where the demand for construction aggregate is high. Several underground operations have been converted to warehouse storage. In the past, lead and zinc were recovered from Mississippian Formations in the Tri-State district of southwestern Missouri and the adjoining areas of Kansas and Oklahoma, but this activity has ceased in the last 10 years.

Lead and zinc were mined extensively in the Tri-State district (Missouri-Kansas-Oklahoma) from the late 19th century to the early 1970's, when low prices and decreasing quality or grade of ores forced closing of the mining and milling operations. Production of significant amounts had ceased in the early 1950's in Missouri. Peak production, in 1916, was valued at $41,681,000 and consisted of 155,527 tons of recoverable zinc and 30,827 tons of recoverable lead (Wharton and others, 1969).

KINDERHOOKIAN SERIES

Limestone of the Chouteau Group is quarried primarily for use as aggregates in bituminous surfacing, roadstone (base and surfacing), aglime, and riprap. It is generally dolomitic and (or) cherty and does not always meet the specifications for concrete aggregate. In western Missouri, the region of greatest thickness, Chouteau carbonate rocks were quarried adjacent to railroads, and several very large quarries were developed before 1950. Where less dolomitic, as in southwestern Missouri, Kinderhookian limestones are quarried with the overlying Osagean strata.

OSAGEAN SERIES

Osagean limestones are used extensively throughout their outcrop area as construction aggregate and aglime and for cement and lime manufacture. The Burlington Limestone is quarried in southwestern Missouri (Springfield) for lime manufacture and in northeastern Missouri (Hannibal) for the manufacture of cement. Several chert-free zones in Osagean formations are quite widespread, and those near construction projects are quarried. As stated, Osagean strata were the principal source beds for lead and zinc ores in the Tri-State district that included southwestern Missouri.

MERAMECIAN SERIES

Meramecian limestones, like those of the Osagean Series, are extensively quarried throughout their outcrop area for use as construction aggregates and in cement and lime manufacture. The Salem limestone is mined in southeastern Missouri (at Ste. Genevieve) for lime, and the St. Louis limestone is quarried in the St. Louis region for cement. The Mississippi Lime Co. at Ste. Genevieve is the largest lime plant in the United States. The Warsaw Formation is mined and quarried in southwestern Missouri (Carthage) for dimension stone, known commercially as "Carthage marble."

Lead and zinc in the Tri-State region have been recovered from Meramecian limestones. Several large solution structures (sinkholes) in Meramecian Warsaw limestone were filled with lower Pennsylvanian shales and sandstones. Galena and sphalerite were mined from the wall rock of these sink structures; many of the excavations are more than 200 feet in both depth and width.

CHESTERIAN SERIES

Chesterian strata, which have a very small outcrop area in the State, contain only a few limestone quarries in southwestern Missouri (Hindsville Limestone) and limestone and sandstone quarries along the Mississippi River in southeastern Missouri. The limestone and sandstone have been used primarily for riprap.

PENNSYLVANIAN SYSTEM

Pennsylvanian strata are commercially important sources of coal, limestone, shale, and refractory clay. Several thick beds of shale in central and western Missouri have been mined extensively for use in the manufacture of structural clay products (brick, tile, lightweight aggregate). Coal from the Cherokee Group continues to be used as fuel in Missouri's steam-powered electric-generating plants. Several beds of limestone in the Marmaton, Kansas City, and Shawnee Groups are of sufficient thickness to be sources of construction aggregates, aglime, and cement manufacture. East-central Missouri is one of the major refractory clay (fireclay) producing areas in the United States.

DESMOINESIAN SERIES

Cherokee Group.—Most minable coal beds in Missouri are within the Cherokee Group. Recent emphasis on replacing petroleum-based fuels has led to increased study of coal resources of Missouri. Evaluation of Missouri coal fields is currently underway by the Missouri Department of Natural Resources, Division of Geology and Land Survey, to refine reserve estimates.

The major refractory clay resources are pre-Marmaton but whether they are equivalent to

the Cherokee or are older (pre-Desmoinesian) is questionable.

Marmaton Group.—The principal resources of the Marmaton Group are limestone and coal. Several limestone beds, chiefly the Higginsville and Myrick Station, are quarried where they are of sufficient thickness. The principal coal beds that are mined locally are the Summit, Lexington, and Mulberry.

MISSOURIAN SERIES

Pleasanton Group.—Thick beds of shale in the Pleasanton Group in northwestern Missouri are a major source of raw material for the manufacture of structural clay products. The shale is quarried near Chillicothe for the manufacture of brick.

Kansas City Group.—The principal resource of Kansas City Group is limestone for construction aggregates and aglime. Several limestone members are quarried in the Kansas City region of northwestern Missouri (Bethany Falls, Winterset, Argentine). The Bethany Falls is quarried at Kansas City for cement manufacture. A large number of drive-in mines have been developed in the Bethany Falls limestone, and many of these have been converted to warehouse and office space.

Lansing and Pedee Groups.—A few limestone beds have been quarried in northwestern Missouri from Lansing (Spring Hill, Stoner) and Pedee (Iatan) strata, although the strata are primarily shale. Shale of the Weston Formation (Lansing Group) is quarried north of the Kansas City region for the manufacture of lightweight aggregate.

VIRGILIAN SERIES

Douglas and Shawnee Groups.—The Amazonia, Plattsmouth, and Ervine Creek limestones are the major source of construction aggregates and aglime in the extreme northwestern part of the State. The units are thin, and many quarries have been opened.

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The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States

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ON THE COVER

Swamp-forest landscape at time of coal formation: lepidodendrons (left), sigillarias (in the center), calamites, and cordaites (right), in addition to tree ferns and other ferns. Near the base of the largest *Lepidodendron* (left) is a large dragonfly (70-cm wingspread). (Reproduced from frontispiece in Kukuk, Paul (1938), "Geologie des Niederrheinisch-Westfälischen Steinkohlengebietes" by permission of Springer-Verlag, New York, Inc.)

The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States—

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GEOLOGICAL SURVEY

H. William Menard, *Director*

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FOREWORD

The year 1979 is not only the Centennial of the U.S. Geological Survey—it is also the year for the quadrennial meeting of the International Congress on Carboniferous Stratigraphy and Geology, which meets in the United States for its ninth session. This session is the first time that the major international congress, first organized in 1927, has met outside Europe. For this reason it is particularly appropriate that the Carboniferous Congress closely consider the Mississippian and Pennsylvanian Systems; American usage of these terms does not conform with the more traditional European usage of the term "Carboniferous."

In the spring of 1976, shortly after accepting the invitation to meet in the United States, the Permanent Committee for the Congress requested that a summary of American Carboniferous geology be prepared. The Geological Survey had already prepared Professional Paper 853, "Paleotectonic Investigations of the Pennsylvanian System in the United States," and was preparing Professional Paper 1010, "Paleotectonic Investigations of the Mississippian System in the United States." These major works emphasize geologic structures and draw heavily on subsurface data. The Permanent Committee also hoped for a report that would emphasize surface outcrops and provide more information on historical development, economic products, and other matters not considered in detail in Professional Papers 853 and 1010.

Because the U.S. Geological Survey did not possess all the information necessary to prepare such a work, the Chief Geologist turned to the Association of American State Geologists. An enthusiastic agreement was reached that those States in which Mississippian or Pennsylvanian rocks are exposed would provide the requested summaries; each State Geologist would be responsible for the preparation of the chapter on his State. In some States, the State Geologist himself became the sole author or wrote in conjunction with his colleagues; in others, the work was done by those in academic or commercial fields. A few State Geologists invited individuals within the U.S. Geological Survey to prepare the summaries for their States.

Although the authors followed guidelines closely, a diversity in outlook and approach may be found among these papers, for each has its own unique geographic view. In general, the papers conform to U.S. Geological Survey format. Most geologists have given measurements in metric units, following current practice; several authors, however, have used both metric and inch-pound measurements in indicating thickness of strata, isopach intervals, and similar data.

This series of contributions differs from typical U.S. Geological Survey stratigraphic studies in that these manuscripts have not been examined by the Geologic Names Committee of the Survey. This committee is charged with insuring consistent usage of formational and other stratigraphic names in U.S. Geological Survey publications. Because the names in these papers on the Carboniferous are those used by the State agencies, it would have been inappropriate for the Geologic Names Committee to take any action.

The Geological Survey has had a long tradition of warm cooperation with the State geological agencies. Cooperative projects are well known and mutually appreciated. The Carboniferous Congress has provided yet another opportunity for State and Federal scientific cooperation. This series of reports has incorporated much new geologic information and for many years will aid man's wise utilization of the resources of the Earth.

H. William Menard
Director, U.S. Geological Survey

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