STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 89

THE KANSAS ROCK COLUMN

By

RAYMOND C. MOORE, JOHN C. FRYE, J. M. JEWETT, WALLACE LEE,
AND HOWARD G. O'CONNOR

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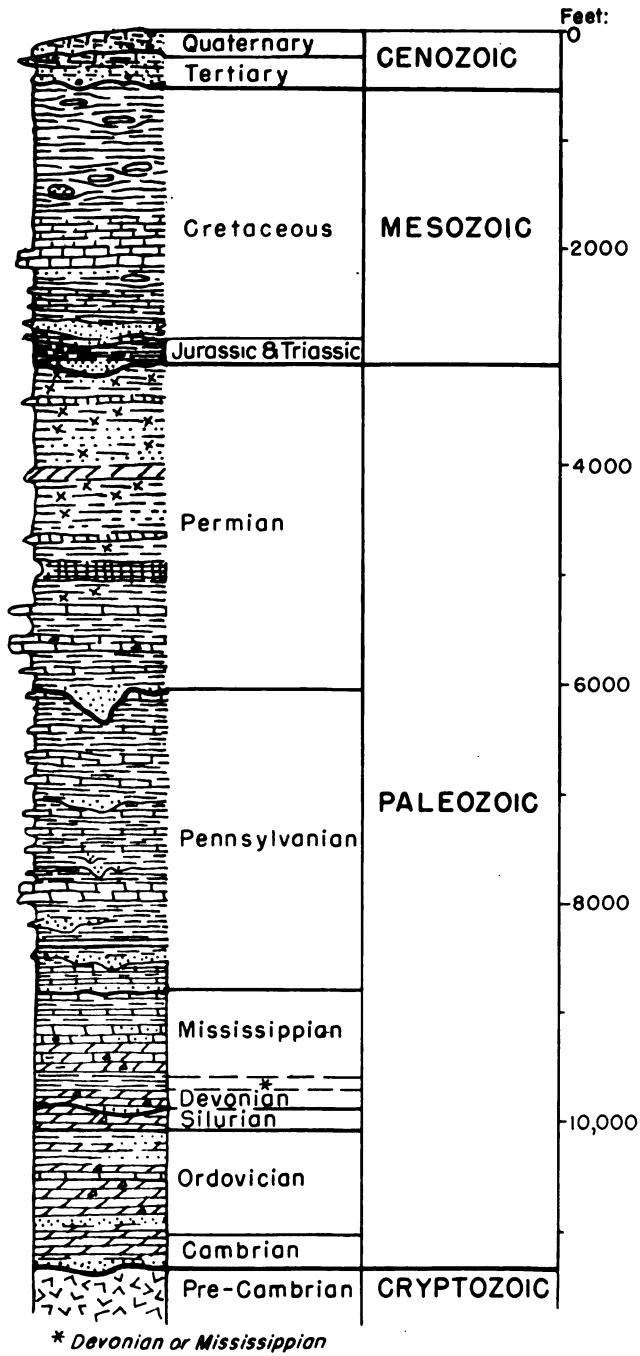


Fig. 1.—**Generalized column of Kansas rocks showing eras and systems.**

THE KANSAS ROCK COLUMN

By Raymond C. Moore, John C. Frye, John Mark Jewett, Wallace Lee, and Howard G. O'Connor

ABSTRACT

This paper summarizes knowledge of the sequence of rock strata in Kansas. A generalized composite section of rocks occurring above the Pre-Cambrian basement rocks is presented with classification and nomenclature used by the Kansas Geological Survey. This is accompanied by graphically represented selected measured sections and well logs for most parts of the rock column and summaries of areal distribution of major rock units.

INTRODUCTION

The State Geological Survey of Kansas has issued summaries from time to time indicating current classification and nomenclature of rock units in the State. These summaries have proved of value in unifying and clarifying stratigraphic usage in the State and have served as an easily accessible reference for those unfamiliar with Kansas stratigraphy. A tabular description of the rocks of Kansas was prepared in chart form by the State Geologist and distributed to those attending the annual meeting of the American Association of Petroleum Geologists in Wichita in March 1935. In October 1944, a more detailed description of the outcropping rocks of the State was issued as "Tabular Description of Outcropping Rocks in Kansas." The usefulness of these two earlier publications is demonstrated by the rapid exhaustion of available copies of each and the continuing requests for them that come to the Survey office.

The present contribution is similar to "Tabular Description of Outcropping Rocks in Kansas" in that it presents a generalized composite rock column for the State in graphic form supplemented by brief text. It differs from this earlier report, however, by treating subsurface as well as outcropping rocks, by giving specific measured sections or well logs which are judged to be typical of parts of the rock column, and by inclusion of pertinent summaries of areal distribution, structural relations, and cyclic sequences.

A conference of State Geological Surveys representing Iowa, Kansas, Missouri, Nebraska, and Oklahoma was held at Lawrence in May 1947. As a result of this conference classification of the Pennsylvanian rocks in the northern midcontinent area is now es-

sentially uniform on opposite sides of all state boundaries, except for divergence in classification in Oklahoma required by southward changes of facies (Moore, 1948, 1949). Although a comparable degree of uniformity has not as yet been possible in other systems, considerable progress toward uniform classification for the northern midcontinent has been made in recent years, particularly in the Cenozoic rocks.

Rocks of Kansas are of Cenozoic, Mesozoic, Paleozoic, and Cryptozoic (Pre-Cambrian) age. Exclusive of the Pre-Cambrian, which constitutes a more or less deeply buried basement complex, these rocks are assigned to 11 (possibly 12) geologic systems which embrace a time span of approximately 500 million years. They record the successive invasions of shallow seas that covered much or all of the State during many thousands of years. Some rock layers and unconsolidated deposits are of nonmarine origin, having been deposited by streams, the still water of lakes, air currents, or ice sheets. Such formations lack fossilized marine organisms, like those which are so abundant in many sea-laid strata of Kansas; they may contain remains of land plants, or traces of fresh-water life, or air-breathing animals. Also, there are numerous records of more or less widespread and prolonged erosion, when varying quantities of previously formed rocks were removed. These times of denudation indicate an emergent condition of the earth's surface in Kansas. They are defined by the local or regional absence of strata recognized elsewhere, and commonly also by irregularities along the contact of the sedimentary units which are separated by a hiatus in deposition. The hiatus is termed a disconformity if adjoining strata lie parallel, and it may be called a nonconformity if locally or regionally the rocks on opposite sides of the break show some divergence in structure. The term unconformity embraces both disconformity and nonconformity.

Except for revisions relating to Cenozoic deposits, the distribution of outcrops belonging to all main divisions and many subdivisions of the rock column of Kansas is adequately shown on the 1:500,000 scale geologic map of the State, on which 1 inch equals approximately 8 miles (Moore and Landes, 1937).

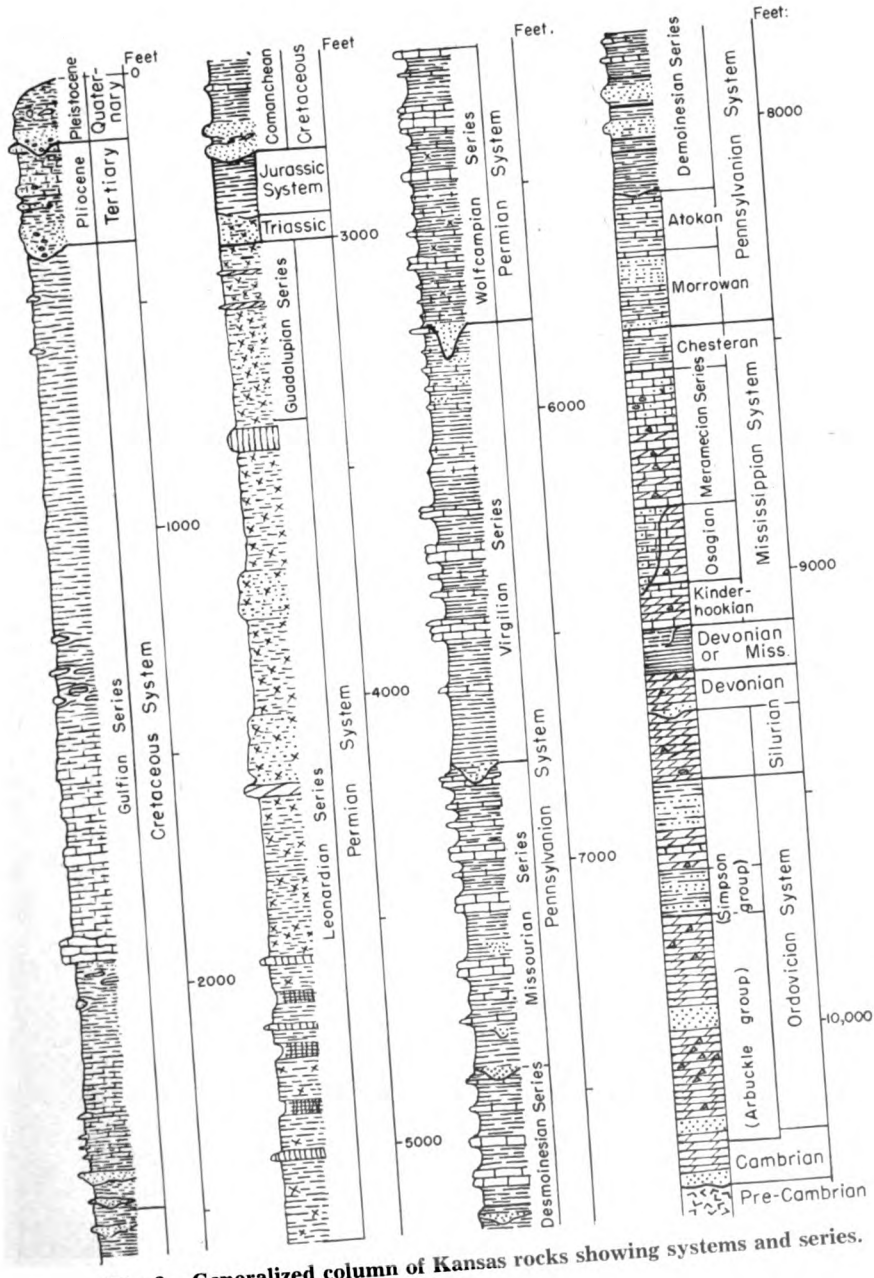


Fig. 2.—Generalized column of Kansas rocks showing systems and series.

CENOZOIC ROCKS

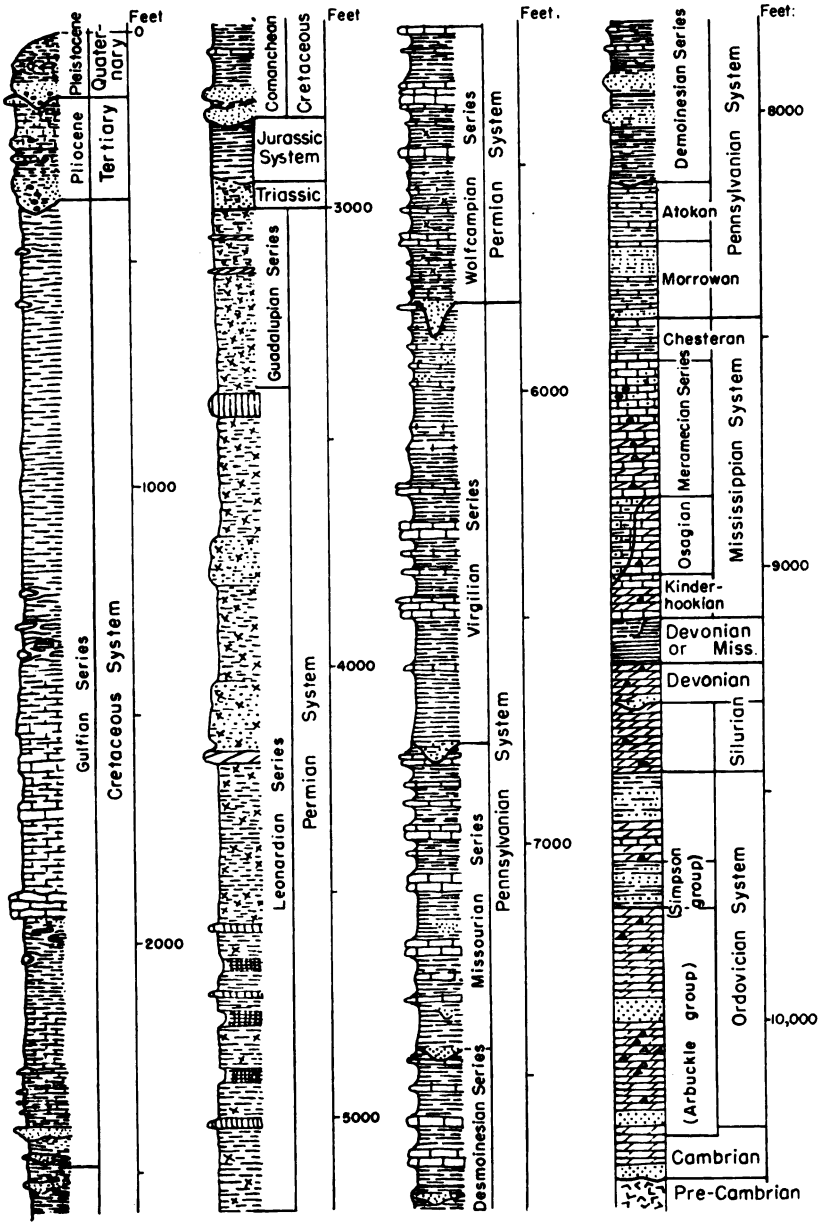
Formations belonging to the Cenozoic Era, last of first-rank geologic time divisions, are widespread in Kansas. They comprise Quaternary sediments, which include glacial deposits of northeastern Kansas and nonglacial deposits of Pleistocene time in all parts of the State, and Tertiary deposits, which cover most of western Kansas.

Distribution and structure.—Deposits of Cenozoic age occurring in Kansas constitute a discontinuous thin veneer which broadly conforms to the east-sloping land surface. Excepting the widespread Tertiary deposits of western Kansas, the Cenozoic sedimentary units are so patchy and irregular that they may hardly be said to exhibit regional structure.

QUATERNARY SYSTEM

Character and surface distribution.—Deposits of Quaternary age occur widely over Kansas. These are all nonmarine in origin and include glacial, fluvial, and eolian deposits. Glacial sediments occur only in northeastern Kansas, whereas stream-laid and windborne deposits occur generally in the western half of the State and along valleys in the eastern half. As much as 400 feet of Quaternary deposits has been penetrated in drilling, and maximum thickness of the several units aggregates nearly 1,000 feet. Massive eolian silts (loess) are the most widespread Quaternary deposits in Kansas and form the immediate surface materials over approximately one-half of the area of the State. Much of the fertile top soil of Kansas is made from Quaternary alluvium and loess.

Subsurface features.—The Quaternary System includes the youngest rocks of the State and is therefore the near-surface material. However, several features are revealed by the drill which are not apparent from surface observations. Chief among these are the abandoned filled valleys in areas where the surface topography is relatively flat; these include McPherson Valley and Wilson Valley of central Kansas, an extensive network of filled valleys in Rice County and under the Great Bend sand dune tract, and the glacially covered valley through Marshall, Nemaha, Jackson, and Atchison Counties in northeastern Kansas.



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Pleistocene Series

The distinctive sedimentary deposits formed in Pleistocene time, which comprises all of the Quaternary System, are glacial materials. Some glacial deposits, both those formed directly by ice work and those resulting from action of melt water derived from ice sheets, occur in Kansas, but they belong to the early and middle part of the Pleistocene Epoch. Outside the glaciated area of early Pleistocene time and throughout the State during the latter part of the Pleistocene Epoch, conditions resembled those of recent time.

RECENT STAGE (including some undifferentiated Wisconsinan deposits).—Sedimentary deposits formed since the time of disappearance of the last glacial ice sheet from North America are classed as belonging to the Recent Stage. They are chiefly stream-laid deposits in continental areas such as Kansas, but on borders of continents they include marine sediments. Inasmuch as the last ice sheet (Wisconsinan) did not reach Kansas and conditions that are typical of Recent time began in this region approximately in mid-Pleistocene time, the Wisconsinan-Recent boundary in Kansas is not clearly recognizable at many places.

Alluvium.—Gravel, sand, silt, and loam; gray to tan; underlies the valley flat of most stream valleys through the State. In western Kansas and along the through valleys of central and eastern Kansas the alluvium consists of sediments derived from the Rocky Mountain region mixed with local materials. In northeastern Kansas the alluvium is largely derived from glacial deposits; in southeastern Kansas it consists predominantly of chert gravel and sand and other material derived from the Paleozoic rocks of the region. Alluvium is generally thicker under major valleys and ranges in thickness from a few feet to more than 80 feet. Between Hutchinson and Wichita the alluvium of the Arkansas River Valley attains a known thickness of 275 feet.

Dune sand.—Eolian sand, well-sorted, predominantly quartz; gray to tan; mantles the surface of much of central and southwestern Kansas, especially in the Great Bend area, south of Arkansas River. The dune sand in many areas represents several cycles of dune development. The younger cycles are Recent in age and consist of loose sand, whereas the older cycles are Wisconsinan to Illinoian in age and in some places are red brown and are partly indurated. Maximum thickness, about 50 feet.

Terrace deposits.—Gravel, sand, silt, and clay; underlies low terrace surfaces in many valleys in all parts of the State. Recent to Wisconsinan in age. South of Kansas River Valley and east of the Flint Hills, terrace deposits are predominantly chert gravels. Thickness as much as 100 feet, commonly 30 feet.

WISCONSINAN, SANGAMONIAN, AND ILLINOIAN STAGES.—During Wisconsinan and Illinoian time continental glaciers advanced into states adjacent to Kansas but lacked by several hundred miles reaching the limits of Kansas. Eolian silt (loess) was deposited widely over the State, sand dune formation was active in the southwestern and south-central areas, and streams

built extensive fills in many places. Important changes in major drainage lines occurred during this time and the Sangamonian and Bradyan (mid-Wisconsinan) intervals were times of extensive soil formation.

Sanborn formation.—Massive silt, soil, sand, and gravel; widely distributed in northern and western Kansas. Sand and gravel are stream deposits, and widespread loess mantles extensive upland areas. Locally 200 feet thick, commonly 40 feet.

Bignell silt member.—Massive eolian silt; forms a discontinuous upland mantle in northwestern Kansas and along Missouri River Valley. Mankatoan and Caryan in age. Thickness 35 feet in Doniphan County, commonly 8 feet.

Peoria silt member.—Massive eolian silt, tan; widely distributed over the uplands of western, north-central, and extreme northeastern Kansas. Iowan and Tazewellian in age. The buried **Brady soil**, formed in pre-Bignell (Bradyan) time, occurs at the top of the Peoria silt. In some valley areas, unnamed water-laid sand and gravel occurs gradationally at the base of the silts. Exceeds 100 feet in thickness in Cheyenne and Doniphan Counties, commonly 30 feet.

Loveland silt member.—Massive silt and sandy silt, reddish-tan; in part eolian. Thick, prominent, buried **Sangamon soil**, formed in pre-Peoria (Sangamonian) time, occurs at the top of the Loveland silt. Illinoian and early Sangamonian in age. Thickness as much as 50 feet, commonly 20 feet.

Crete sand and gravel member.—Sand, gravel, and silt, in terrace position along some valleys; locally grades upward into Loveland silt member; in southeastern Kansas predominantly chert gravels. Illinoian in age. Commonly 50 feet thick.

YARMOUTHIAN AND KANSAN STAGES.—Deposition during Kansan time was largely influenced by Kansan glaciation. This ice sheet extended more than 100 miles into the State and glacial till occurs widely in the northeastern area. Some silt, sand, and gravel were deposited during the advance of this ice sheet, and during the time of its retreat they were deposited widely over the State as valley fillings. Some loess was deposited during late Kansan time but is now preserved at only a few places. In the area south of Kansas River Valley and east of the Flint Hills, Kansan deposits consist predominantly of chert gravels with some sand and silt, and occur as terraces along the major valleys. A fall of petrographically distinct volcanic ash occurred in latest Kansan time. During much of Yarmouthian time soil-forming processes were dominant.

Meade formation.—Gravel, sand, silt, clay, and volcanic ash. Derived from continental and mountain glacial outwash and locally. Occurs in terrace position along some valleys (particularly Smoky Hill), as filling in abandoned valleys (McPherson, Wilson, and others), as basin fillings, and above Kansas till. Thickness commonly 50 feet.

Sappa member.—Silt associated with some sand and clay. Contains **Pearlette volcanic ash bed**. Locally the buried **Yarmouth soil**, formed in pre-Sanborn (Yarmouthian) time, is preserved at top. Latest Kansan

and earliest Yarmouthian in age. Gradational downward into Grand Island member. Thickness commonly 30 feet.

Grand Island member.—Sand and gravel, arkosic, cross-bedded. Locally consists largely of locally derived rock types and in southeastern and east-central Kansas, chert gravels. Occurs as fillings of abandoned valleys in central and southwestern Kansas, as alluvial terraces in eastern and northern Kansas, and in erosional valleys in Kansas glacial till of the glaciated area. Late Kansan in age. Thickness commonly 25 feet.

Kansas glacial till.—Boulders, cobbles, gravel, sand, silt, and clay, unsorted; calcareous except in upper weathered zone; blue-gray to tan. In northeastern Kansas only. Maximum thickness more than 200 feet, commonly 40 feet.

Atchison formation.—Sand and silt, well-sorted, sand and gravel at base; commonly thinly laminated in upper part. Named from exposures in the vicinity of Atchison, Kansas. Not recognized beyond the limits of Kansan glaciation. Comprises pro-Kansan outwash of early Kansan age. Maximum thickness in Atchison County, 80 feet; commonly 40 feet.

AFTONIAN AND NEBRASKAN STAGES.—The Nebraskan glacier invaded only the extreme northeastern part of Kansas and deposits made by it are more restricted in distribution than are those of the Kansan. Some faulting occurred in southwestern Kansas and stream-laid deposits of this age occur at scattered localities in central and western Kansas. The Flint Hills constituted a major drainage divide entirely across the State and south of Kansas River Valley chert gravels cap intermediate to high terrace surfaces. During much of Aftonian time soil-forming processes were predominant.

Blanco formation.—Gravel, sand, silt, and clay; derived from continental and mountain outwash and locally. Occurs at a few places in terrace position along major valleys, in filled abandoned valleys (Rice County), and as basin and fault-trough fills. Thickness commonly 50 feet.

Fullerton member.—Silt, sand, and clay. Late Nebraskan or early Aftonian in age. Known from a few localities in central and southwestern Kansas. Thickness, 25 feet.

Holdrege member.—Sand and gravel, late Nebraskan in age. Probable equivalents in southeastern Kansas consist of chert gravels on high terrace levels. Maximum thickness, 200 feet; commonly 35 feet.

Nebraska glacial till.—Boulders, cobbles, gravel, sand, silt, and clay; unsorted; calcareous except in upper weathered zone; blue-gray to tan. **Afton soil** preserved in top at a few places. In northeastern Kansas only. Thickness commonly 30 feet.

David City formation.—Gravel and sand; deposited as pro-Nebraskan outwash. Early Nebraskan in age. Recognized only within the glacial border where overlain by Nebraska glacial till; in the southwest age equivalents are probably included within the Blanco formation; differentiated from late Tertiary (entirely chert) gravels by the presence of northeasterly derived pebbles typical of Nebraska till. Thickness, 10 feet.

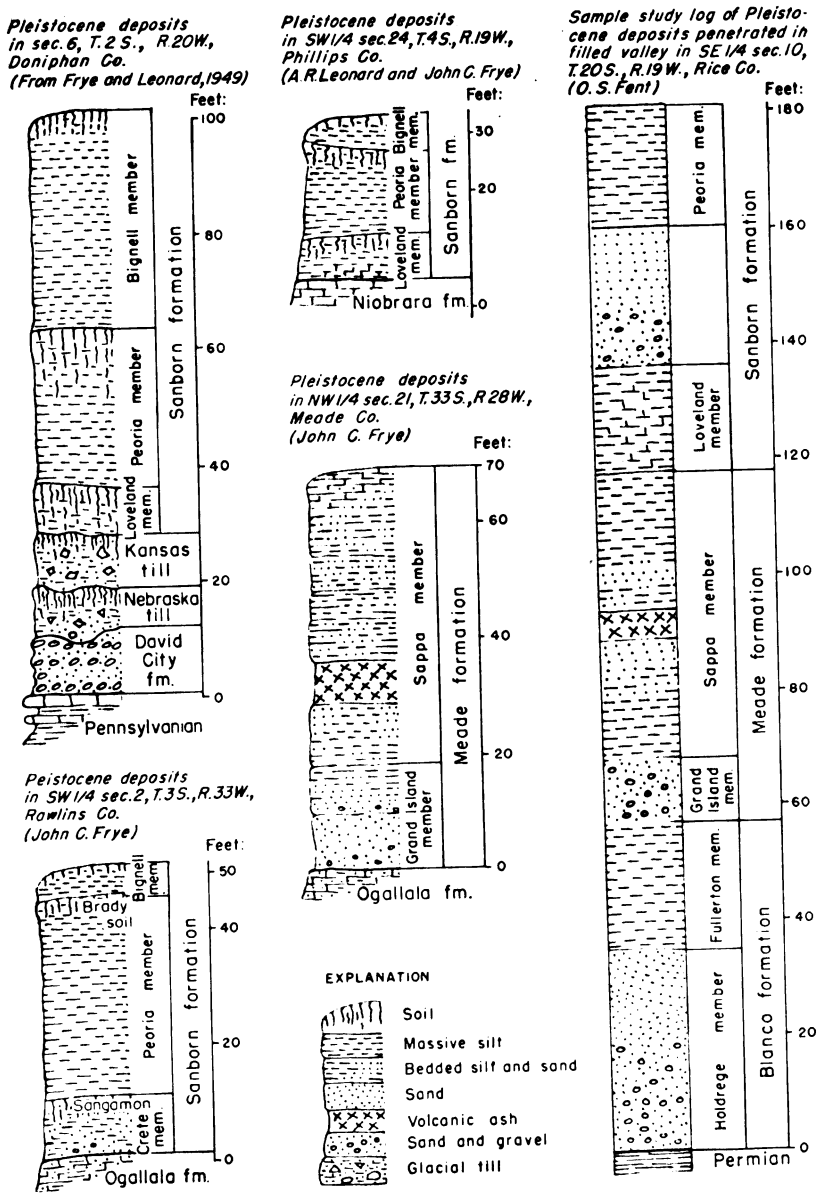

Fig. 6.—**Selected stratigraphic sections of Pleistocene deposits.**

A regional unconformity marks the base of the Quaternary deposits in Kansas. At all localities where non-eolian deposits have been observed in contact with Tertiary or older rocks, there is evidence of significant erosion prior to Quaternary deposition.

TERTIARY SYSTEM

Character and surface distribution.—Deposits of Tertiary age occur widely in central and western Kansas, and locally in eastern Kansas. The Tertiary rocks are all continental in origin and were deposited mostly by streams. The source area of most of the Kansas Tertiary was to the west, principally the area of igneous rocks in the Rocky Mountain region and the area of sedimentary rocks in eastern Colorado and western Kansas. The thickness of the Tertiary deposits ranges from a thin veneer to about 350 feet, but the maximum thickness has nowhere been observed at the surface. It is judged that the upper surface of Tertiary alluvium constituted a plain of low relief that merged westward with the erosion surface in the mountains and eastward with a subdued erosion surface in the Flint Hills area. The Flint Hills stood as a low but important drainage divide and were a minor source of sediments (mostly chert gravels) both to the west and east.

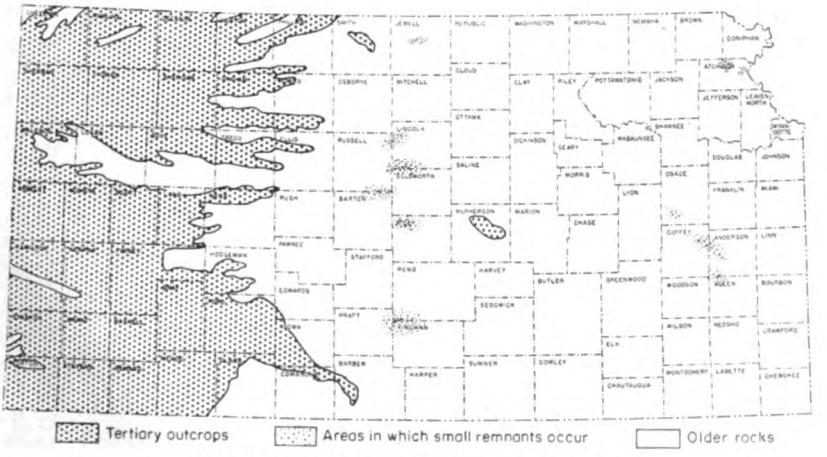

Fig. 7.—Distribution of Pliocene deposits.

Subsurface features.—The Tertiary deposits in western Kansas mantle an erosional topography of subdued relief. The beds progressively overlap on gentle valley sides, the early Pliocene sediments being restricted to relatively narrow strips whereas the late Pliocene sediments, except where removed by erosion, are widespread. A nonconformity exists within the Tertiary strata of Meade and Seward Counties.

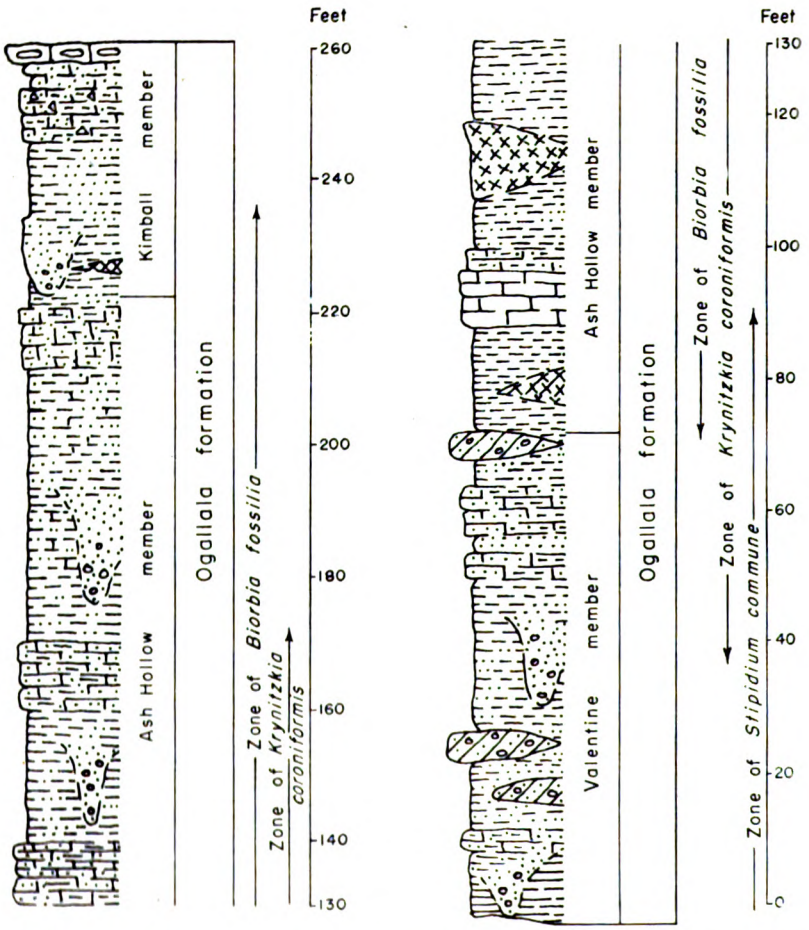

Fig. 8.—**Pliocene rocks in Kansas.** Refer to Figure 9 for explanation of lithologies.

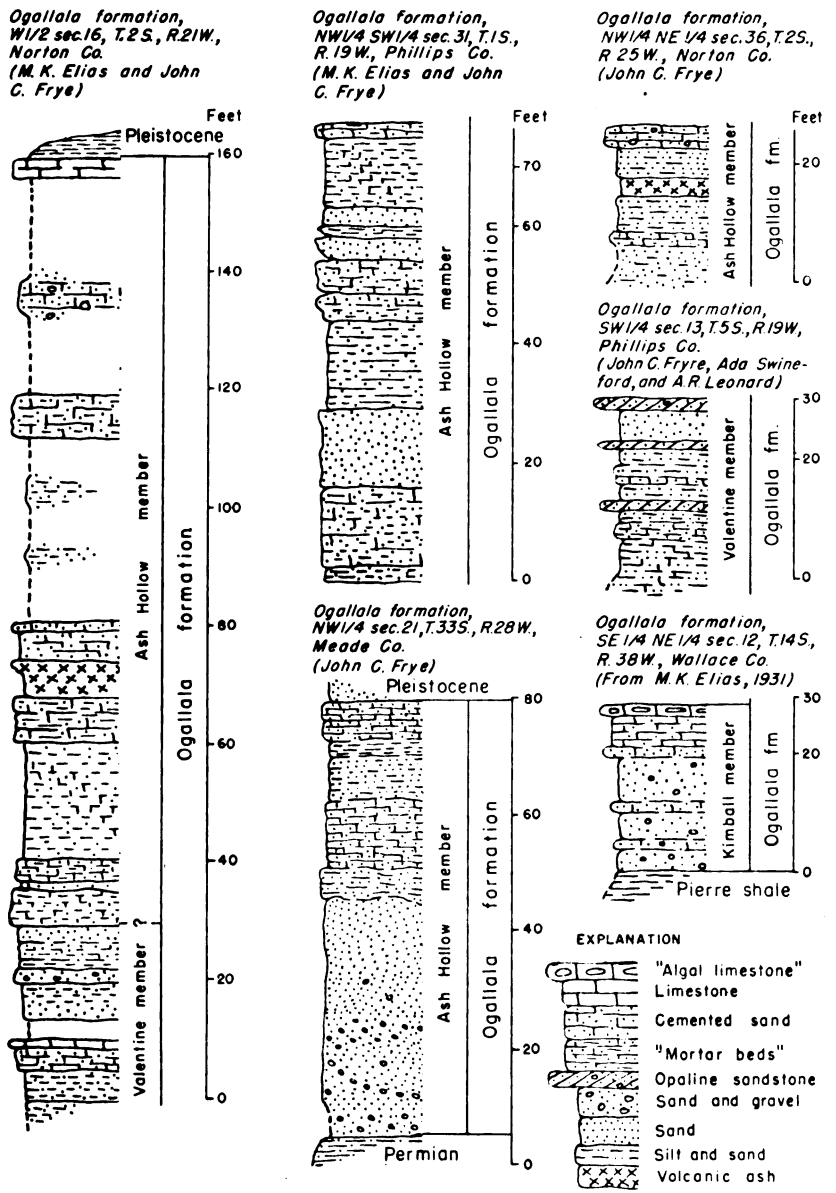

Fig. 9.—**Selected stratigraphic sections of Pliocene deposits.**

Pliocene Series

The Tertiary rocks of Kansas, so far as is known, are all included within the Pliocene Series.

Ogallala formation.—Arkosic gravel, sand, and silt, locally cemented with calcium carbonate; massive to cross-bedded; limestone, volcanic ash, opaline sandstone, and bentonitic clay; greenish-gray, pink, red, tan, and ash-gray. Distributed widely over the western one-third of Kansas and at a few places in the central part of the State. East of the Flint Hills, chert gravels in upland situations are of comparable age. Maximum thickness, 350 feet.

Kimball member.—Sand, gravel, silt, chert, and caliche; locally a hard limestone, called "Algal limestone," occurs at top, and coarse channel gravels, probably comparable to the Sidney gravels of Nebraska, at base. Exposed at scattered localities, principally in northwestern and north-central Kansas. Thickness commonly 35 feet.

Ash Hollow member.—Sand, gravel, and silt, in many zones loosely cemented forming "mortar beds"; soft fresh-water limestone, and volcanic ash; predominantly pink and gray. This middle Pliocene member is the most widely occurring unit of the Ogallala in Kansas. Maximum thickness, 200 feet.

Valentine member.—Gravel, sand, and silt, locally loosely cemented forming "mortar beds"; greenish-gray, pink, and gray; opaline sandstone, bentonitic clay, and soft fresh-water limestone. Early Pliocene and possibly late Miocene. Equivalent in age to **Laverne formation** in Meade and Seward Counties. Maximum thickness, 140 feet.

A major unconformity marks the base of the Tertiary rocks. They are known to rest on all subdivisions of the Comanchean Series (Cretaceous) and on Permian redbeds.

MESOZOIC ROCKS

Deposits of Mesozoic age, comprising part of the geologic section of Kansas, belong mostly to the Cretaceous System. These rocks cover many thousand square miles in the western part of the State. Older Mesozoic rocks, probably representing both the Jurassic and Triassic Systems, are identified in well borings but are absent or, in the case of Triassic, somewhat doubtfully recognized very locally in surface exposures.

Distribution and structure.—The outcrops of Mesozoic strata in Kansas are confined to the western two-thirds of the State. They extend much farther eastward along the northern border (Marshall County) than in the south (Barber County); in central Kansas exposures are found eastward as far as Dickinson and Marion Counties. Mesozoic rocks underlie thousands of square miles in western Kansas where Cenozoic formations cover the surface. In general, the Mesozoic strata are gently inclined toward the northwestern corner of Kansas, dipping westward, northwestward, or northward.

CRETACEOUS SYSTEM

Character and surface distribution.—Rocks of Cretaceous age crop out at the surface or underlie much of central and western Kansas. These rocks are mostly marine, but deposits of supposed continental origin are found in the Cheyenne sandstone and Dakota formation. Clayey and calcareous shale is the dominant constituent but fine-grained platy and chalky limestone comprises most of the Greenhorn and Niobrara, and sandstones occur in the Cheyenne, Kiowa, Dakota, Graneros, and Carlile. In general, these rocks dip very gently westward, but locally dips may occur in any direction. Small outcrops of dark-colored igneous rocks that penetrate Permian strata in Riley County are possibly Cretaceous in age. The thickness of the Cretaceous System in Kansas is about 2,750 feet.

Subsurface features.—In the subsurface the rocks assigned to the Gulfian Series display a remarkable degree of uniformity throughout the State; although some progressive changes in thickness occur, their essential characteristics remain the same. Rocks assigned to the Comanchean Series, however, display progressive overlap on the pre-Cretaceous rocks. The lowermost Cretaceous unit (Cheyenne sandstone) thickens from a featheredge to more than 300 feet in Russell and Ellis Counties.

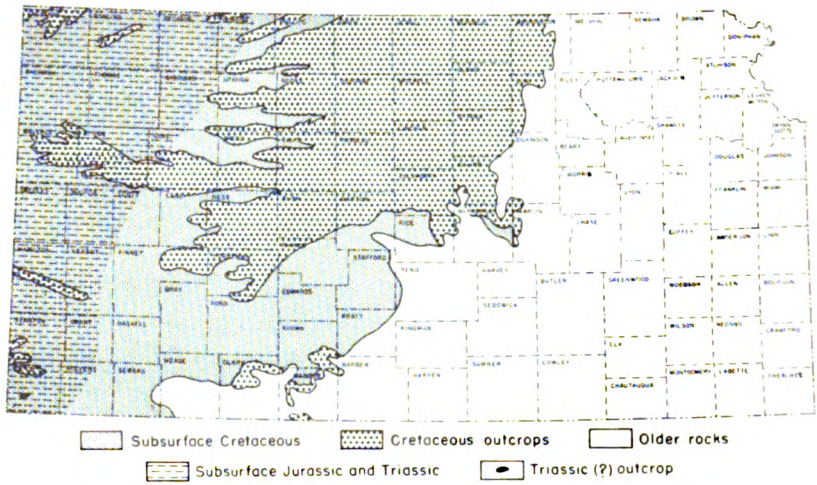

Fig. 10.—**Distribution of Triassic, Jurassic, and Cretaceous deposits.**

Gulfian Series

The upper part of the Cretaceous System is defined as the Gulfian Series. At the beginning of Gulfian time, continental and littoral deposits accumulated in Kansas, but these conditions rapidly gave way to marine conditions and the shales and limestones constituting the Colorado and Montana groups were deposited. Thickness about 2,500 feet.

MONTANA GROUP.—Dark-colored marine shales that crop out and underlie the surface of northwestern Kansas. Thickness 1,000 to 1,400 feet; average 1,235 feet.

Pierre shale.—Shale, thin-bedded, black to dark-gray, a few beds lighter in color, weathers to coffee-brown and gray; marine; contains concretions, selenite crystals, thin beds of bentonite, and locally chalky beds. Occurs in northwestern Kansas. Thickness ranges from 1,000 to 1,400 feet.

Beecher Island shale member.—Shale, gray. Irregular concretionary limestone near top, limonite concretions throughout, thin beds of bentonite and limestone concretions in lower part. Thickness, 100 feet.

UNNAMED SHALE MEMBER.—Shale, black to gray. Thickness ranges from 500 to 600 feet.

Salt Grass shale member.—Shale, clayey, gray; contains numerous thin bentonite beds, limestone concretions, and concretionary limonite zones distributed throughout. Thickness, 60 feet.

Lake Creek shale member.—Shale, thin-bedded, flaky, dark-gray and black; limestone concretions, zones of concretionary limonite, and locally gypsum are present. Thickness, 200 feet.

Weskan shale member.—Shale, clayey, gray. Bentonite beds more abundant in lower part, large limestone concretions and some limonite. Thickness, 170 feet.

Sharon Springs shale member.—Shale, flaky, black, somewhat bituminous, large septarian and ordinary limestone concretions abundant in upper part; a few beds of light-gray shale, locally thin chalk beds in lower part. Thickness, 155 feet.

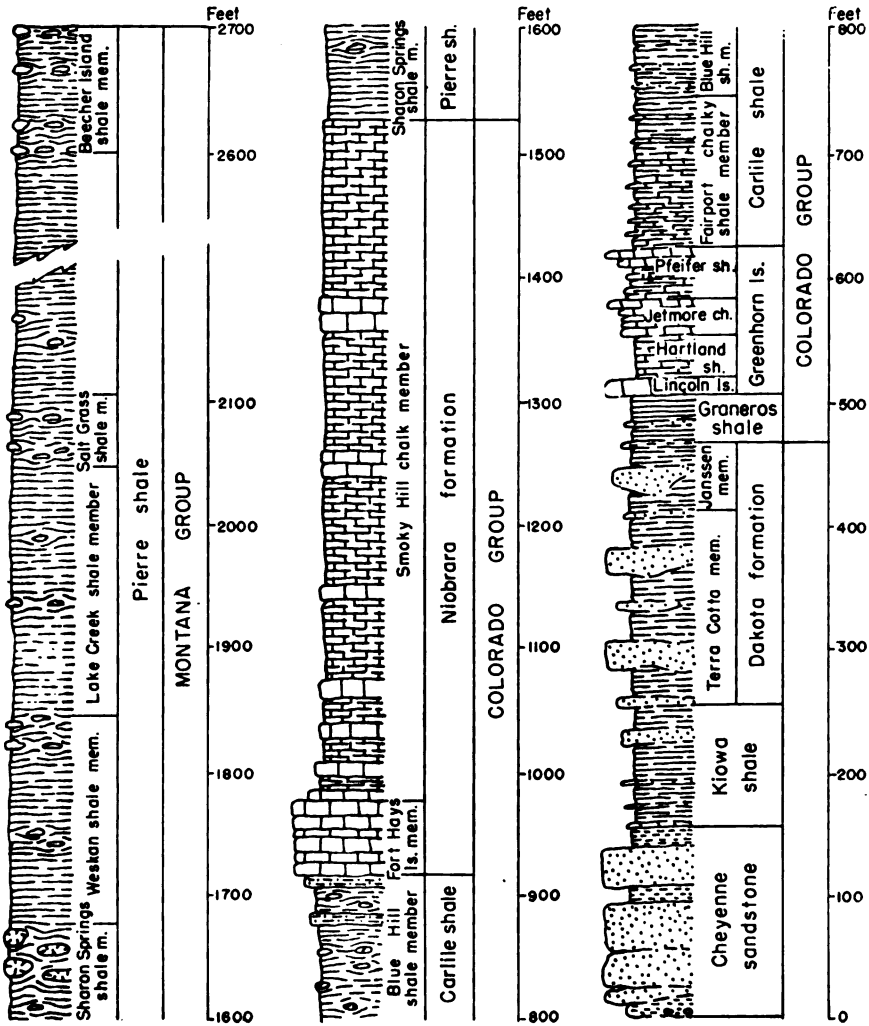

Fig. 11.—Cretaceous rocks in Kansas. Refer to Figure 12 for explanation of lithologies.

COLORADO GROUP.—Shales, calcareous and noncalcareous, that crop out and underlie the surface of north-central, northwestern, and west-central Kansas. Limestone beds occur interbedded with the calcareous shales. These rocks are all of marine origin. Thickness, about 1,050 feet.

Niobrara formation.—Calcareous shale and chalk, soft, interbedded, light-gray. Crops out in a belt trending generally northeast-southwest and extending from north-central to western Kansas. Thickness, 500 to 750 feet in Logan and Wallace Counties; average, 600 feet.

Smoky Hill chalk member.—Shale, chalky, interbedded, gray, weathers white, yellow, and orange; contains limonitic concretions, and locally massive chalk beds. Forms badland topography. Thickness, 450 feet to 700 feet in Logan County; average, 550 feet.

Fort Hays limestone member.—Chalk or chalky limestone, gray to cream-colored, massively bedded; thin beds of light to dark-gray chalky clay shale separate the massive chalky limestone beds. Extensively used for building stone. Thickness ranges from 45 feet in Smith County to 65 feet near the Colorado line.

Carlile shale.—Shale, chalky in lower part and containing thin chalk beds and bentonites near the base, black fissile shale and large septarian concretions in upper part, locally fine-grained sandstone at top; marine. Occurs in northwestern and western Kansas. Thickness, about 300 feet.

Blue Hill shale member.—Shale, clayey, gray-black to dark-gray, noncalcareous; abundant ordinary and septarian concretions and selenite crystals. Contains **Codell sandstone zone** in upper part; sandstone fine-grained and silty, maximum thickness 25 feet in Hamilton County; locally represented by silty shale and thin sand laminae in the shale. Thickness, 75 feet in Hamilton County to 200 feet in Russell County.

Fairport chalky shale member.—Shale, calcareous, and thin chalk beds, blue-gray to gray, weathers to light orange-tan; thin bentonite beds in base; chalky limestones more abundant near base. Thickness, 85 feet in Russell County to 147 feet in Hamilton County; average, 125 feet.

Greenhorn limestone.—Chalky limestone and calcareous shale, interbedded, thin-bedded, light-gray to dark-gray, weathers yellow-gray to light-gray; marine. Occurs in northwestern and western Kansas. Thickness, 65 feet in Jewell County, 95 feet in Ellis County, to 132 feet in Hamilton County; average, 100 feet.

Pfeifer shale member.—Chalky shale and chalky limestone in alternating layers. **Fencepost limestone bed** at top, blue-gray, weathers to light-tan. In Hamilton County the Pfeifer shale member and the underlying Jetmore chalk member are thicker than farther east. They cannot be distinguished and have been together designated the **Bridge Creek limestone member**, having a total thickness of 74 feet. Thickness of Pfeifer shale is typically 19 to 21 feet in Ellis and Russell Counties; average, 20 feet.

Jetmore chalk member.—Chalky shale and chalky limestone, interbedded, "Shell-rock limestone" bed at top, gray, weathers to light-gray. Thickness ranges from 20 feet (Russell and Ellis Counties) to 25 feet; average, 22 feet.

Hartland shale member.—Chalky shale, a few thin beds of chalky limestone and bentonite, gray. Thickness 23 feet in Kearny County to 35 feet in Ellis County; average, 30 feet.

Lincoln limestone member.—Chalky shale and chalky limestone, interbedded, light-gray; beds of dark-gray petroliferous hard crystalline limestone at base and top; shale contains thin beds of bentonitic clay. Member weathers to yellow-gray or yellow-tan. Thickness, 20 feet (Ellis County) to 35 feet; average, 28 feet.

Graneros shale.—Shale and clay shale, fissile, noncalcareous, blue-black, weathers to dark-gray and coffee-brown; largely or entirely marine but mostly unfossiliferous; locally contains sandstone beds and beds of "clay ironstone"; selenite crystals abundant. Rarely thin limestones in upper part. Thickens southward across western Kansas. Thickness ranges from 30 to 35 feet in Russell County to 65 feet near the Colorado line; average, 45 feet.

The rocks which comprise the Dakota formation, Kiowa shale, and Cheyenne sandstone formerly were classed as the Dakota group. The use of this grouping has been discontinued.

Dakota formation.—Clay, shale, siltstone, and sandstone, interbedded and lenticular; contains carbonaceous material, lignite, concretions of hematite and limonite, and locally quartzitic sandstone; white, gray, red, brown, and tan. Occurs in north-central and western Kansas. The **Cockrum sandstone** of southwestern Kansas is equivalent in age to part of the Dakota formation. Contains plant fossils and land vertebrates. Thickness, 100 to 300 feet.

Janssen clay member.—Clay, silt, and fissile shale, with lenticular sandstone, lignite, and lignitic clay common; gray to dark-gray, contains concretionary hematite and limonite and beds of "ironstone." Central and north-central Kansas. Thickness ranges from 30 to 80 feet.

Terra Cotta clay member.—Clay, shale, sandstone, and quartzitic sandstone, interbedded; red, gray, brown, and tan. Central and north-central Kansas. Sandstones are lenticular and weather brown, coarse-grained to fine-grained, abundant hematite and limonite concretions throughout. Quartzitic sandstone near top. Thickness 70 to 220 feet.

Comanchean Series

The lower part of the Cretaceous System is defined as the Comanchean Series. At the beginning of Comanchean time the Kansas area was being eroded and only upper Comanchean deposits occur in the State. The oldest Comanchean deposits in Kansas represent continental and littoral deposits laid down as the sea advanced northward. These nonmarine conditions rapidly gave way to marine conditions, and marine shales overlie the nonmarine and littoral de-

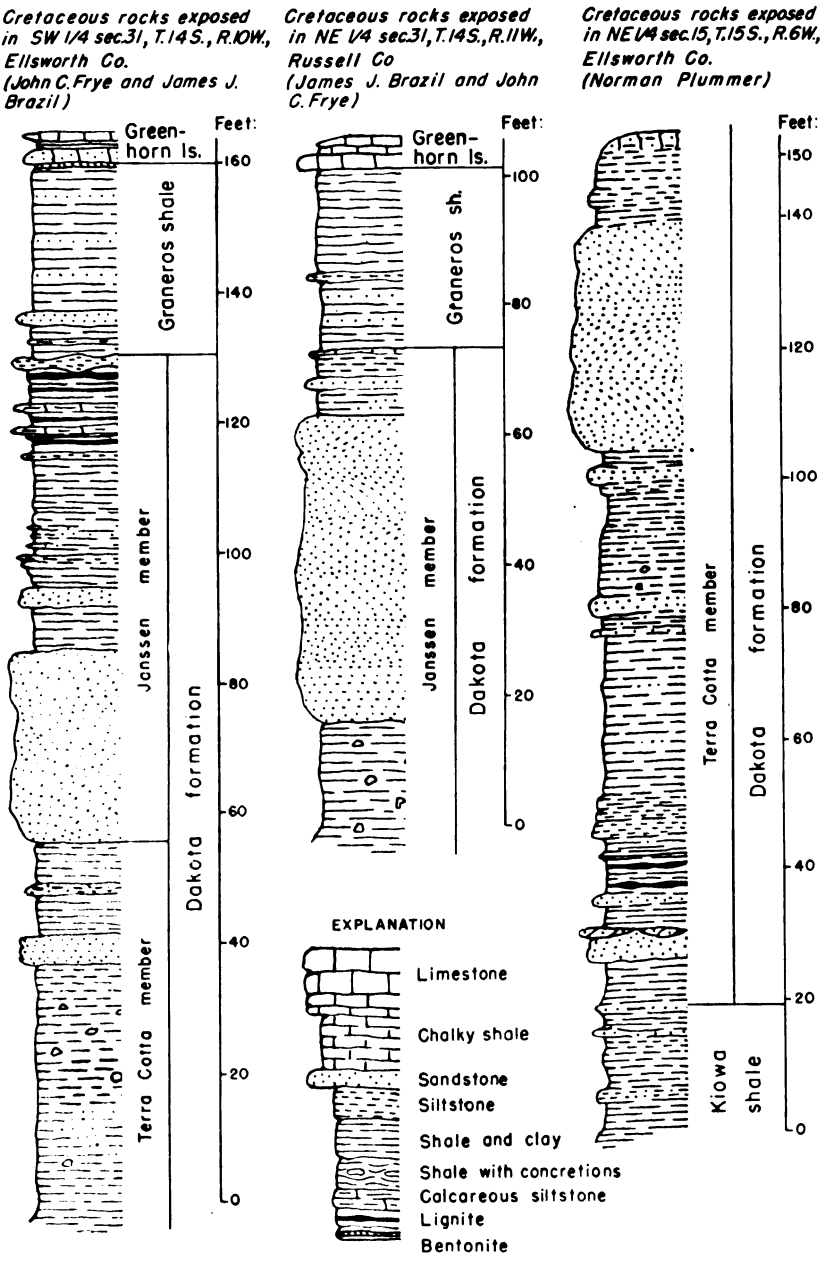

Fig. 12.—**Selected stratigraphic sections of the Dakota and Graneros formations.**

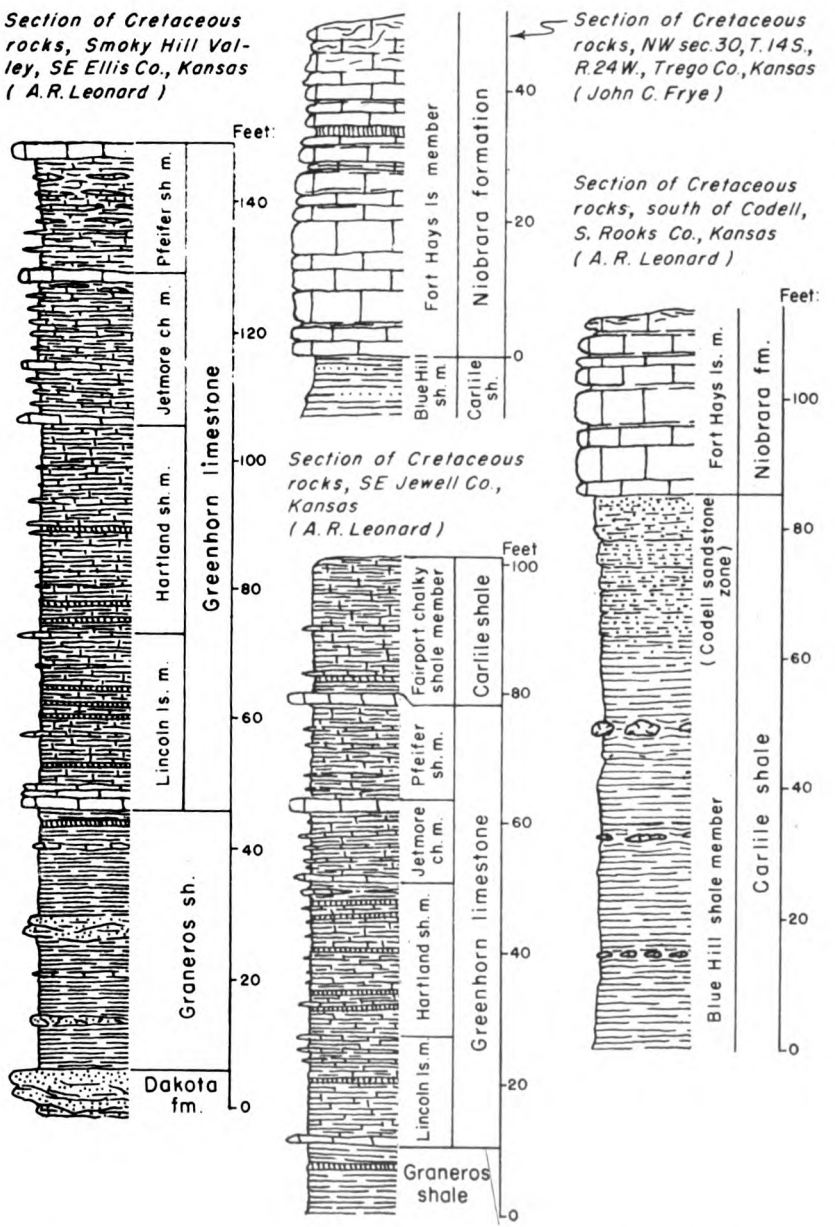

Fig. 13.—Selected stratigraphic sections of the Greenhorn, Carlile, and Niobrara formations. Refer to Figure 13 for explanation of lithologies.

posits. These rocks crop out in a belt extending diagonally north to south across central Kansas, and at a few places in southwestern Kansas. Thickness ranges from a featheredge to 400 feet; average, about 250 feet.

Kiowa shale.—Shale, fissile, light-gray, dark-gray, and black; contains thin limestone beds throughout, with the **Champion shell bed** at the base in the type area: Locally, lenticular sandstones occur at any position within the shale; beds of cone-in-cone; quartzitic sandstone; selenite crystals common. Abundant marine molluscan fauna in the thin limestones, shale, and sandstone. Thickens across central and western Kansas toward the south and southwest. Typical thickness, 60 to 150 feet.

Cheyenne sandstone.—Sandstone, white, buff, gray, tan, red, yellow, and purple, with white, light-gray, and buff dominant; and shale, light-gray to dark-gray. Sandstone, very fine-grained to coarse-grained, dominantly quartz, cross-bedded: shale, sandy and silty, cross-bedded, dark-gray, contains plant remains. Cobble zone at base, locally conglomeratic; locally a zone of redeposited red Permian sand at base. Thickens westward in the subsurface. Maximum thickness exposed, more than 75 feet; maximum thickness in the subsurface, 300 feet.

A major unconformity marks the base of the Cretaceous rocks. The Cretaceous rocks overlap northward on the pre-Cretaceous erosion surface, successively younger beds lying above the contact northward across the State, ranging from the Cheyenne sandstone in Comanche and Kiowa Counties to the Dakota formation in Washington County. Rocks underlying the unconformable contact range in age from the Herington limestone in Washington County to beds believed to be of Jurassic age in northwestern Kansas. A discontinuous zone of pebbles and cobbles occurs above the unconformity along the line of outcrop, the pebbles being included in Cheyenne sandstone, Kiowa shale, or Dakota formation as each constitutes the lowermost Cretaceous unit. The pebbles consist of igneous and metamorphic rocks and chert, with quartzite and chert predominating; they are well rounded and judged on the basis of lithology and contained fossils to have come from the northeast.

JURASSIC AND TRIASSIC SYSTEMS

Deposits judged to be of Jurassic and Triassic age occur in the subsurface throughout the western one-fifth of Kansas and crop out in a small area in southern Morton County. They consist primarily of varicolored shales and red sandstones and attain a maximum thickness of more than 325 feet. In the subsurface they pinch out eastward along an irregular line extending from Stevens County to Norton County and in general thicken toward the west. The Jurassic Morrison formation is judged to comprise most of this interval in northwestern Kansas, whereas Triassic sandstones tentatively assigned to the Dockum group are predominant in southwestern Kansas.

Morrison formation.—Shales correlated with the Morrison formation of the Jurassic System have been penetrated by drilling in northwestern Kansas. The shales are predominantly green in color and are characterized by pink jasperlike chert and pink gypsum. Where noted in wells, these shales range in thickness from 100 to 275 feet.

DOCKUM (?) GROUP.—Continental deposits of early Mesozoic age, identified as Triassic on the basis of vertebrate and plant remains, are widespread in western Texas and New Mexico. Certain outcrops in the panhandle of Oklahoma and southwestern Kansas, which possess similar lithology, are judged to be equivalent to the Triassic rocks farther south. Inasmuch as comparable Triassic rocks in Texas are called Dockum group, this name is tentatively employed in southwestern Kansas. Red siltstone, buff and white sandstone, and a small amount of gypsum are exposed in Morton County. Maximum exposed thickness is about 40 feet but in the subsurface of Morton and Stanton Counties the thickness may be greater.

IGNEOUS ROCKS

Outcrops of igneous rocks of undetermined age occur in Riley and Woodson Counties. In Riley County there are five known exposures of igneous rocks intruded into sediments of Permian age; in Woodson County granite and fine-grained igneous rocks seemingly are intruded into sediments of Pennsylvanian age.

GRANITE.—Coarse-grained granite crops out in Woodson County seemingly in a dike that is partly exposed along a line extending from near the Cen. sec. 13, T. 26 S., R. 16 E. eastward to a point slightly beyond the township line.

FINE-GRAINED MICACEOUS ROCKS.—In sec. 32, T. 26 S., R. 15 E., Woodson County, dark fine-grained micaceous rocks that crop out in a small area and occur in the shallow subsurface have been identified as igneous.

BASIC VOLCANIC ROCKS.—Five outcrops of basic volcanic rocks occur in Riley County. Location of three small outcrops are: sec. 22, T. 8 S., R. 5 E.; sec. 23, T. 8 S., R. 6 E.; and sec. 6, T. 9 S., R. 5 E. Recently two additional occurrences of similar rocks have been found in the northeastern part of the county a few miles north of Randolph.

METAMORPHIC ROCKS

In two localities in Woodson County rocks of Pennsylvanian age have become altered by contact metamorphism.

QUARTZITE.—In southwestern Woodson County in secs. 28, 29, 32, and 33, T. 26 S., R. 15 E., several feet of fine-grained quartzite derived from sandstone in the Douglas group crops out. This rock is associated with fine-grained micaceous rock that has been classed as igneous. Shales and thin limestones in the same area are intensely altered. In sec. 13 some alteration of sedimentary rocks that are associated with outcropping granite has been observed.

PALEOZOIC ROCKS

The outcropping consolidated rocks throughout most of eastern and central Kansas are all sedimentary strata of Late Paleozoic age. They include shale, sandstone, limestone, and conglomerate having widely varied characteristics, as well as coal beds, dolomite, and some other rock types. Paleozoic rocks underlie all of western Kansas. Locally exposed igneous rocks in Woodson and Riley Counties may be Paleozoic but they are probably much younger. The total thickness of exposed Paleozoic rocks in Kansas, derived by compiling average measurements of recognized subdivisions, may be given as approximately 6,000 feet.

Surface distribution and structure.—The eastern and south-central parts of Kansas contain extensive outcrops of Upper Paleozoic rocks, chiefly Permian and Pennsylvanian. This is a region of roughly parallel belts of plains which are developed on the outcrops of weak rocks and on the upper surface of some gently inclined hard formations. The plains are separated by hilly country which terminates eastward in a more or less prominent escarpment. The general trend of these escarpments is south-southwest across eastern Kansas. The Flint Hills, which are formed by Lower Permian strata, are an example.

At the outcrop, Paleozoic strata in Kansas show a very gentle west or west-northwest dip. It ranges mostly from 15 to 35 feet to the mile. Locally, there are dips in other directions or the layers may be quite hroizontal; nowhere are the strata steeply inclined. A noteworthy belt of distinct, although gentle, easterly dips may be traced across the State from the vicinity of Arkansas City in the south to the neighborhood of Seneca in the north; this defines the east limb of an anticlinal structure which overlies the buried Nemaha anticline. Drilling along this anticline in south-central Kansas has led to the discovery of important oil and gas fields. Faults having small displacement are observed in a few places, but nowhere in Kansas is faulting a very noticeable feature of the rock structure.

Subsurface distribution and structure.—In the subsurface, the Permian rocks underlie all of Kansas west of their outcrops in the central part of the State. Except for a few square miles in the southeastern corner of Kansas where Mississippian formations are exposed, Pennsylvanian rocks blanket the State. The lower parts of

the Pennsylvanian sequence locally are missing on account of overlap of deposits on pre-Pennsylvanian topographic features, and the upper parts in eastern Kansas have been removed by erosion. Like the outcrops, the Pennsylvanian and Permian rocks in the subsurface generally dip northwestward, but the formations flatten in western Kansas and at the Colorado line they dip eastward.

Mississippian rocks were also originally coextensive with the State, but they were eroded from the Central Kansas uplift and the northern end of the Nemaha anticline before Pennsylvanian deposition began in Kansas. Devonian and Silurian rocks (Hunton) and Upper Ordovician rocks were originally more widely distributed in the State than now, but like the Mississippian, their limits have been greatly restricted by pre-Pennsylvanian and earlier periods of erosion and they are now confined to northeastern Kansas. Rocks of Middle Ordovician age, representing the Viola limestone and the Simpson formation of Oklahoma, still blanket the State except on higher parts of the Central Kansas uplift, on the northern end of the Nemaha anticline, and on the Chautauqua arch. Some formations of the Arbuckle group (Lower Ordovician and Upper Cambrian) were originally deposited throughout Kansas, but they have been removed from parts of the Central Kansas uplift and the northern end of the Nemaha anticline. Owing to structural and erosional events during the deposition of the Arbuckle sequence, the Arbuckle formations are very irregularly distributed.

All the pre-Pennsylvanian formations participated in the structural movements that deformed the Pennsylvanian and younger rocks. The pre-Pennsylvanian and especially the pre-Mississippian rocks, however, had already sustained structural deformations at variance with the later movements which have resulted in some areas of marked discordance between the regional structure at the surface and in the subsurface.

PERMIAN SYSTEM

Character and surface distribution.—Rocks of Permian age which occur in Kansas include evenly stratified predominantly marine deposits in the lower part of the section and irregularly bedded, mainly nonmarine deposits in the upper part. Light ash-gray to cream-colored limestone beds, many of which are distinguished by abundance of flinty chert, form persistent benches or escarpments, among which the so-called Flint Hills are most prominent. The Flint Hills extend across Kansas from Nemaha County on the Nebraska border to western Chautauqua County adjoining the Oklahoma boundary. The escarpments are east-facing because the gentle regional dip of the Permian strata is westward. Between the limestone formations and members of the Lower Permian are gray, green, and red shale units, in part containing marine fossils and in part representing nonmarine sedimentation. Sandstone is virtually absent in this part of the section.

Middle and upper parts of the Permain succession consist mainly of shale and sandstone, many of them red in color. Thick deposits of salt which occur do not crop out, because the Kansas climate is not arid enough to allow such soluble rock to be exposed at the surface. Gypsum beds, some of minable thickness, may be seen, however, and a few thin but persistent dolomites occur in the redbeds part of the Permian section.

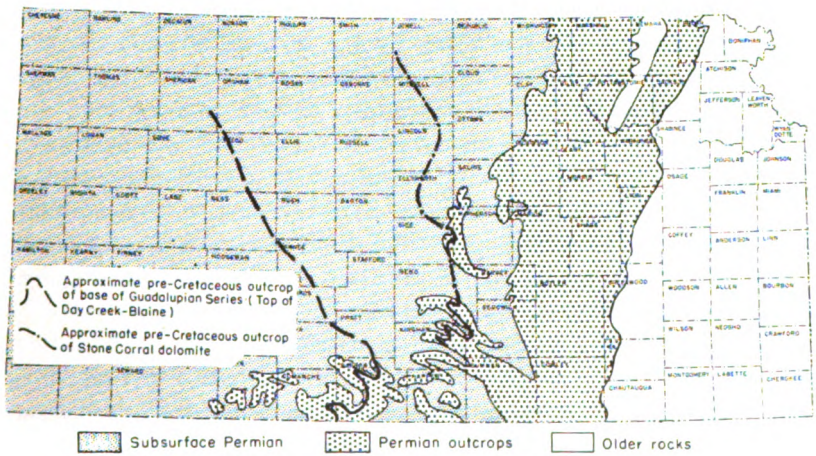

Fig. 14.—Distribution of Permian rocks in Kansas.

The outcrops of Permian rocks in Kansas form a belt extending from Washington, Marshall, Nemaha, and Brown Counties on the northern boundary to Meade, Clark, Comanche, Barber, Harper, Sumner, and Cowley Counties on the Kansas-Oklahoma line (Fig. 14). The total outcrop thickness is about 3,000 feet.

Subsurface distribution and character.—Permian rocks underlie all of Kansas west of the outcrop belt. They are covered unconformably by Triassic (?) rocks locally near the southwestern corner of the State, by Jurassic in the subsurface of some northwestern counties, and elsewhere by Cretaceous, Tertiary, and Quaternary formations. Maximum thickness is attained in the Hugoton basin. The Lower Permian section is somewhat thinner, but not greatly below average, above the Central Kansas uplift.

The structure of buried Permian rocks in Kansas is broadly synclinal, except where formations of the system overlie the Nemaha buried ridge. The axis of the broad syncline trends slightly west of northward across the western third of the State and it plunges gently northward (Fig. 46). The prevailing dip of Permian strata is westward or northwestward from the outcrop belt to the trough of the Hugoton embayment in Meade and Seward Counties and the synclinal axis trending northward to Decatur County. Eastward dips are found in westernmost Kansas.

Upper Permian rocks (Guadalupian Series) comprise red shale (Taloga) at the top, dolomite (Day Creek) which grades westward into anhydrite and gypsum, and red siltstone and sandstone (Whitehorse) at the base. The series is 460 feet thick in Morton County (Taloga, 160 feet; Day Creek, 20 feet; Whitehorse, 280 feet). It thins northward to only 19 feet of red silty sandstone and shale (Whitehorse) in Wallace County.

The middle part of subsurface Permian deposits in Kansas (Leonardian Series) consists predominantly of red shale and sandstone grading downward into gray shale. Gypsum occurs at the top, a persistent dolomite near the middle, and thick salt near the base. Leonardian strata attain a thickness of about 2,000 feet in southwestern Kansas. So far as known, the Leonardian rocks are conformable with overlying and underlying Permian strata.

Upper Leonardian (Nippewalla) rocks include red shale (Dog Creek), gypsum (Blaine), and alternating red shale and sandstone; this division thickens southward from about 400 feet in Wallace, Logan, and Gove Counties to more than 800 feet in Stevens and

Meade Counties. The Dog Creek-Blaine part of the succession increases westward from 50 feet in eastern sections to 200 feet at the Colorado border.

Lower Leonardian (Sumner) rocks comprise dolomite (Stone Corral), red shale (Ninnescah), and predominantly gray shale (Wellington) associated with salt deposits. This division thickens southeastward from 500 feet in Wallace County to 1,200 feet in Ford County. The Stone Corral dolomite, which extends westward (with increased gypsum content) beyond the Colorado line, ranges in thickness from 30 to 100 feet. Ninnescah beds, which range from 60 feet in Rooks County to 450 feet in Pratt County, contain discontinuous thin beds of gypsum, limestone, and dolomite, and salt lentils up to 50 feet thick in western Kansas. Wellington deposits include gray gypsiferous shale (100 to 230 feet) at the top, a salt lentil (350 feet thick in central Kansas), and gray shale and gypsum (70 to 150 feet) at the base. Red shale (25 to 50 feet) near the top of the Wellington is traceable westward to Trego and Edwards Counties. The upper Wellington includes much gypsum and several thin limestones in western Kansas. Maximum thickness (about 700 feet) of Wellington rocks is attained where salt deposits are thickest, in the Reno-Russell and Comanche-Clark County areas.

Lower Permian (Wolfcampian Series) rocks of the subsurface compromise fossiliferous limestones alternating with shales. Nearly all the principal limestone units and many lesser ones are traced down dip to the western border of Kansas. The intervening shale formations become thinner westward. Southward thickening of shale is less pronounced than in the Pennsylvanian, and in Kansas there is less transition of limestone into clastic beds.

Upper Wolfcampian (Chase) rocks range in thickness from 200 feet in Wallace County to 460 feet in Meade County. Limestones (except Wreford) grade westward into dolomite or dolomitic limestone. Cherty zones (Winfield, Florence, Wreford) are very persistent in the subsurface. Middle Wolfcampian (Council Grove) strata consists mainly of thin limestones separated by shales which are less red and variegated than in the outcrops. Most easily recognized in the subsurface is the Cottonwood-to-Neva sequence. In central and western Kansas, the Neva is generally oölitic. The Foraker limestone contains abundant fusulines, but on account of its shaly character it is not clearly defined in sample or electric logs.

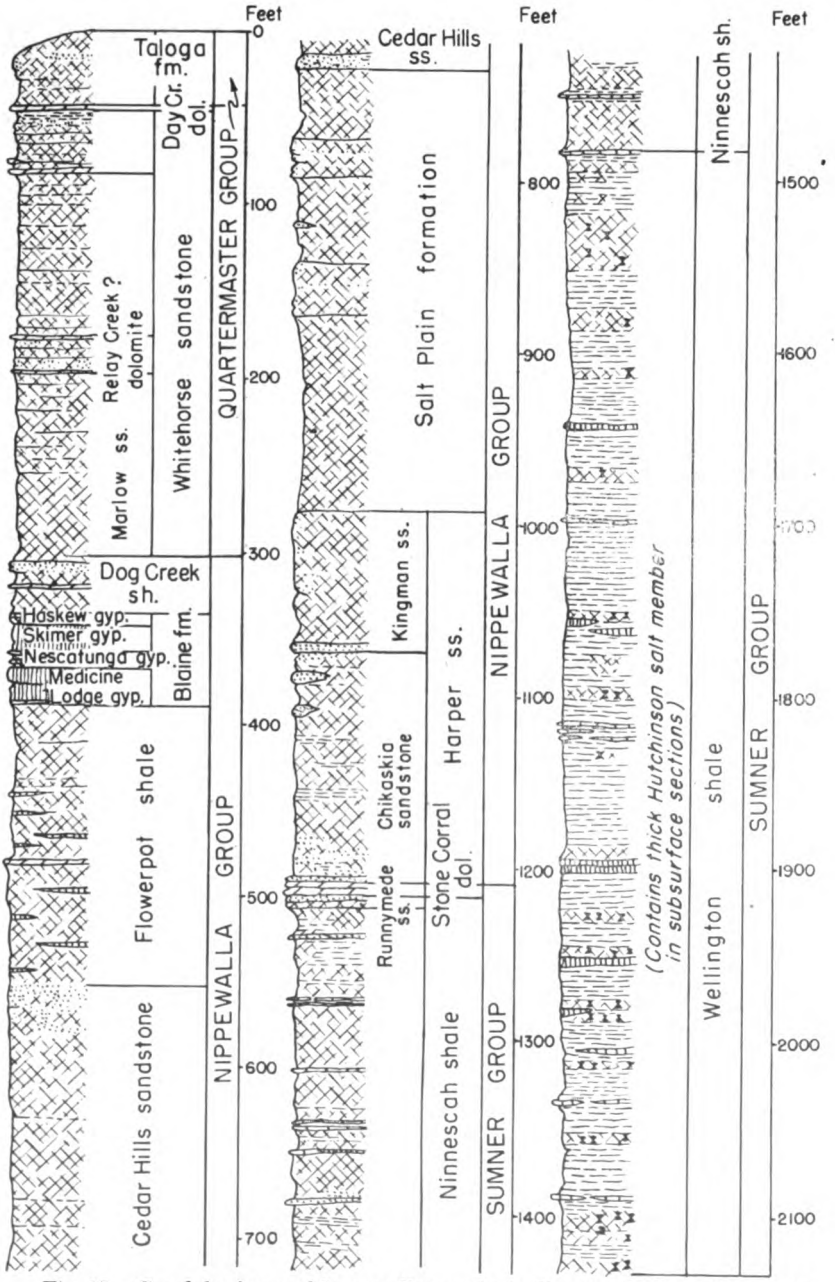

Fig. 15.—**Guadalupian and Leonardian rocks in Kansas.** Refer to Figure 17 for explanation of lithologies.

Thickness of Council Grove rocks ranges from 300 feet on the Central Kansas uplift and in Wallace County to 500 feet in parts of the Hugoton embayment.

Lower Wolfcampian (Admire) beds lack identifying characteristics in the subsurface. Thin limestones are recognized in samples and electric logs, but their correlation with the outcrops is uncertain. Basal Admire beds (Towle shale, Indian Cave sandstone) can rarely be determined in the subsurface because of their similarity to upper Pennsylvanian rocks. Consequently, the contact of Permian and Pennsylvanian rocks is obscure.

Guadalupian Series

This division of the Permian System, which is defined from fossiliferous marine rocks in western Texas and in southeastern New Mexico, crops out in southern Kansas. In this region, it comprises unfossiliferous deposits that seem to have been laid partly on land by sluggish streams and action of winds and partly in shallow basins occupied by strongly saline waters. Bedding is mostly irregular. Reddish color, which signifies abundance of ferric oxide, prevails. Thickness of outcropping rocks belonging to this series in Kansas is about 290 feet. The subsurface thickness averages about 460 feet in southwestern Kansas.

QUARTERMASTER GROUP.—Permian beds above the Day Creek dolomite have been classified as belonging in the Quartermaster group. They seem to be equivalent to the lower part of the Quartermaster formation of western Oklahoma and the panhandle region of Texas. The maximum outcrop thickness of these rocks in Kansas is about 45 feet.

Taloga formation.—Redbeds of silty shale, siltstone, and very fine feldspathic sandstone, called "Big Basin" in some reports, belong to the Taloga formation. The lower 25 feet is chiefly silty shale. Outcrops are in western Clark and eastern Meade Counties. The strata are seemingly equivalent, all or in part, to the Quartermaster formation in Oklahoma. Thickness, maximum about 45 feet.

Beds below the Taloga formation and above the Dog Creek shale are not assigned to a group.

Day Creek dolomite.—Fine-grained dense dolomite cropping out in western Clark County. It is seemingly absent between the northern part of T. 33 S., R. 24 W. and a point in Oklahoma near the center of T. 25 N., R. 25 W. (Indian meridian). Thickness in Kansas is about 2 feet.

Whitehorse sandstone.—Redbeds of feldspathic sandstone, siltstone, and shale and a minor amount of dolomite. Cross bedding is common and the formation is characterized by "sand balls," which are water-worn small "sand crystals" consisting of sand pseudomorphs after calcite, and by crystals of barite, anhydrite, calcite, and gypsum. The outcrops are in southeastern Meade, Clark, and southwestern Kiowa Counties. Thickness is about 270 feet.

UPPER SHALE MEMBER.—Redbeds of silty shale, siltstone and a minor amount of very fine sandstone, with a zone of dolomitic beds in the basal part and a zone of gray-green sandy shale in the upper part, mostly brick-red or maroon. Thickness is about 38 feet.

EVEN-BEDDED MEMBER.—Sandstone, very fine, and shaly siltstone, mostly even-bedded but locally cross-bedded in the upper part; containing "sand balls" and "sand crystals"; maroon. Thickness is about 100 feet.

Relay Creek (?) dolomite and sandstone member.—Two beds of dolomite separated by red and white fine sandstone. The dolomite beds range in thickness from a few inches to about 1 foot. Locally the dolomite beds are altered to anhydrite or gypsum. Individual layers in the sandstone are identified with difficulty; locally the rock is cross-bedded. Thickness is about 22 feet.

Marlow sandstone member.—Redbeds of sandstone, fine-grained, locally shaly or silty, cross-bedded. "Sand balls" locally prominent. Thickness about 110 feet.

Leonardian Series

This major division of the Permian, named from strata in the Glass Mountains region of western Texas, is judged to be represented in Kansas by about 1,900 feet of rocks that are chiefly unfossiliferous clastics (sandstone, shale) and evaporites (anhydrite, gypsum, salt). Red silty shale, siltstone, and sandstone predominate in the upper part. Gray silty shale is the most common rock type in the lower part, although red and other bright colors are present.

NIPPEWALLA GROUP.—The upper part of strata assigned to the Leonardian Series is most widely exposed in south-central Kansas west of Arkansas River. This group consists mostly of redbeds that form a plain. In Barber County and adjacent area the topography of the Nippewalla outcrop area locally has considerable relief and is "badland" in type. Gypsum beds make prominent escarpments. The total thickness of the group is approximately 930 feet.

Dog Creek shale.—Maroon silty shale, siltstone, very fine feldspathic sandstone, thin layers of dolomite, dolomitic sandstone, and gypsum. The top generally is marked by about 3 feet of maroon shale, but locally a gypsum bed about 1 foot thick and having red stripes occurs at the top. The most persistent part is a bed of white and red very fine sandstone, about 6 feet thick, that locally is capped by dolomitic sandstone, which occurs next below the upper maroon shale portion. The outcrops are in southern Kiowa, eastern Comanche, and western Barber Counties. In Kiowa County the formation is overlapped by Cretaceous sandstone (Cheyenne). Reported thickness ranges from 14 to 53 feet.

Blaine formation.—Gypsum beds separated by dolomite and red shale. The formation is divided into four members. Outcrops are in Clark, Comanche, Barber, and Pratt Counties. Thickness is about 50 feet.

Haskew gypsum member.—One foot or less of gypsum underlain by about 5 feet of red shale. The gypsum bed has been removed by solu-

tion at many places. The thickness of the gypsum and underlying shale beds is about 6 feet.

Shimer gypsum member.—A thick bed of gypsum overlying a bed of dolomite that ranges in thickness from about 6 inches to 1½ feet. Excessive solution and erosion of the gypsum bed have greatly reduced its thickness in many places. Measured sections believed to show the original thickness range from 14 to 24 feet.

Nescatunga gypsum member.—A bed of gypsum with overlying and underlying red shale. The gypsum bed varies in thickness within short distances and is known to range from about 2 to 8 feet. Locally as much as 8 feet of red shale separates the gypsum from the next higher and lower gypsum beds.

Medicine Lodge gypsum member.—The thickest bed of gypsum in Kansas. Ordinarily there is a bed of oölitic dolomite at the base which ranges from 6 inches to 1 foot in thickness. Exposures are in Barber, Clark, and Comanche Counties. This gypsum bed forms a conspicuous rim rock at the top of steep slopes of the Flowerpot shale. The maximum thickness is 30 feet or more; average 20 feet.

Flowerpot shale.—Shale, silty, red, soft, gypsiferous. A thin lenticular bed of dolomite has been observed in the middle part, and the formation is cut by intersecting veins of satin spar gypsum. Thin fine sandstones occur near top. Outcrops are in Barber, southeastern Kiowa, and Comanche Counties. Commonly stands in steep slopes, eroded into innumerable gullies, and strewn with clear, white pink, and red satin spar and clear crystals of selenite. Measured thicknesses range from 170 to 190 feet.

Cedar Hills sandstone.—Feldspathic sandstone, siltstone, and silty shale, chiefly red, containing beds of white sandstone in the upper and lower parts; the upper one contains "snow balls" of white gypsum. Shaly siltstone separates the more resistant and more massive coarse siltstone and very fine sandstones. The upper part below the "snow ball"-bearing sandstone commonly is eroded into a badland plateau. The more massive sandstones are generally weathered into rounded hills and the shaly portions are weathered into canyon-dissected slopes. Outcrops are in Barber and Harper Counties. Thickness is about 180 feet.

Salt Plain formation.—Chiefly red, flaky, silty shale and some siltstone. There are two prominent coarse siltstone beds, the upper, about 25 feet thick, occurring about 42 feet below the top of the formation and the lower **Crisfield,** about 29 feet thick, occurring about 115 feet below the top of the formation. The coarse siltstones are partly cross-bedded. Outcrops are in southeastern Barber, Harper, and southern Kingman Counties where the formation has weathered into a nearly featureless plain. In Kingman County the formation is overlapped by Cenozoic deposits. The thickness is reported to be 265 feet.

Harper sandstone.—Chiefly red siltstone and very fine sandstone divided into two members. The outcrops are in Harper, Kingman, Reno, and Rice Counties. Northward the formation is overlapped by Cenozoic rocks. Thickness is about 220 feet.

Kingman sandstone member.—Red siltstone and sandstone and a few beds of red shale and white sandstone. A prominent bed of white sandstone, 3 feet thick, occurs at the base. Thickness is about 80 feet.

Chikaskia member.—Siltstone, sandstone, and shale, mostly red but some gray; fissile, fine-grained, ripple-marked, and locally cross-bedded sandstone in lower part. Some white sandstone and dolomite lenses and concretions occur in the upper part. Along the outcrop in Kansas the formation thins northward; the thickness ranges from about 100 to 160 feet.

SUMNER GROUP.—This division comprises about 1,000 feet of strata at the outcrop, chiefly silty shale. Thick beds of salt occur in the subsurface. Gray shale predominates but there are also beds of red and green shale and deposits of dolomite, limestone, gypsum, and anhydrite.

Stone Corral dolomite.—Dolomite, anhydrite, and gypsum. The anhydrite and gypsum portions are lost in exposed sections and the remaining dolomite ledge is cellular or contains numerous calcite-filled or gypsum filled vugs. The color is chiefly gray but locally there are red and pink streaks. At some exposures the formation is chiefly red shale, bounded above and below by thin dolomite beds. Ripple marks on dolomite slabs are more or less characteristic. The outcrop belt is interrupted in eastern Rice, western McPherson, and other counties to the south by eastward overlap of Cenozoic deposits. This is one of the most readily recognized "key beds" in the Kansas redbed section. It is reported to produce well-marked reflections in seismograph surveys. Maximum measured thickness at the outcrop is about 6 feet.

Ninnescah shale.—Predominantly silty shale, mostly red, but containing some gray shale, impure limestone, and calcareous siltstone. The **Runnymede sandstone,** 7 to 8 feet thick, very fine sandstone and siltstone, forms the upper part of the formation. Weathered surfaces show bright green copper carbonate. Seven other distinctive beds of calcareous siltstone and calcareous shale can be traced for long distances. *Cyzicus* ("*Estheria*") shells are rather common. Some of the beds show ripple marks. Rosette-shaped calcareous concretions occur in the middle part. Weathering and erosion in this part have produced the "Red Jaw" country in Reno County. The formation thins northward. In the subsurface near the Nebraska line it is about 50 feet thick. The maximum outcrop thickness is about 450 feet; average thickness at outcrop, about 300 feet.

Wellington formation.—Chiefly silty shale, with a few hundred feet of salt in the middle part in the subsurface. Outcrops contain several more or less lenticular beds of gypsum and fine-grained limestone. The **Milan limestone member,** consisting of 1 foot of greenish-gray shaly limestone that on the outcrop is characterized by bright-green copper carbonate, occurs at the top and thus marks the top of the Wellington formation in a comparatively large area. Elsewhere change in color from gray to red may be regarded as the upper boundary, which may be at different horizons in different places. The upper 300 feet of the Wellington is largely gray shale with thin interbedded deposits of calcareous material. The **Hutchinson salt**

member occurs in the middle part but is not exposed. Individual beds of salt attaining thicknesses of more than 17 feet are mined at Hutchinson, Lyons, and Kanopolis. The fossil insect-bearing **Carlton limestone member** occurs a short distance below the Hutchinson salt. Bright-red and green shale is conspicuous in the lower part, which contains more or less discontinuous beds of impure limestone and gypsum. A bed of impure dolomitic limestone, not definitely known to be of widespread occurrence, has been named the **Hollenberg limestone.** In general, outcrops of the Wellington formation are poor and discontinuous. Total thickness of the formation is about 700 feet.

Wolfcampian Series

This division, formerly called the Big Blue Series, contains the older Permian rocks of Kansas. Shales and limestones predominate, subdivisions being remarkably persistent. The thicker shales are bright colored. The outcrop thickness in Kansas is about 785 feet.

CHASE GROUP.—The topmost group of Wolfcampian beds is made up of about 335 feet of prominent escarpment-making limestones and shales. The shale units are characterized by shades of reds and greens. Chert or flint-bearing limestones are important in this division, which largely comprises the rocks in which the Flint Hills are developed.

Nolans limestone.—This formation consists of upper and lower limestone members separated by shale in northern and central Kansas. In southern Kansas member boundaries are not clearly defined. Thickness ranges from about 22 to 35 feet.

Herington limestone member.—Limestone and dolomite, yellowish-tan, soft and dense, more dolomitic in southern and central Kansas than in the northern part of the State. Outcrops are characterized by siliceous and calcareous geodes and concretions and cauliflowerlike masses of drusy flint weathered from the matrix. Fossil mollusks are locally abundant. Thickness ranges from about 7 to 10 feet in the northern part and is about 30 feet in the southern part of Kansas.

Paddock shale member.—Shale, gray; in northern Kansas contains stringers and vein fillings of calcite; in southern Kansas buff, contains dolomite in the lower part. Fossil pelecypods are locally abundant in northern and central outcrops. Thickness ranges from about 7 to 13 feet.

Krider limestone member.—Commonly two beds of limestone separated by a bed of shale, each about 1 foot thick. In southern Kansas the separating shale is somewhat thicker. The color commonly is yellowish-brown. Characteristic thickness is about 4 feet.

Odell shale.—Shale, chiefly red and green with some gray and yellow. Thicknesses range from about 20 to 40 feet.

Winfield limestone.—A thick upper limestone locally cherty underlain by about 10 feet of fossiliferous gray shale, which is underlain in turn by

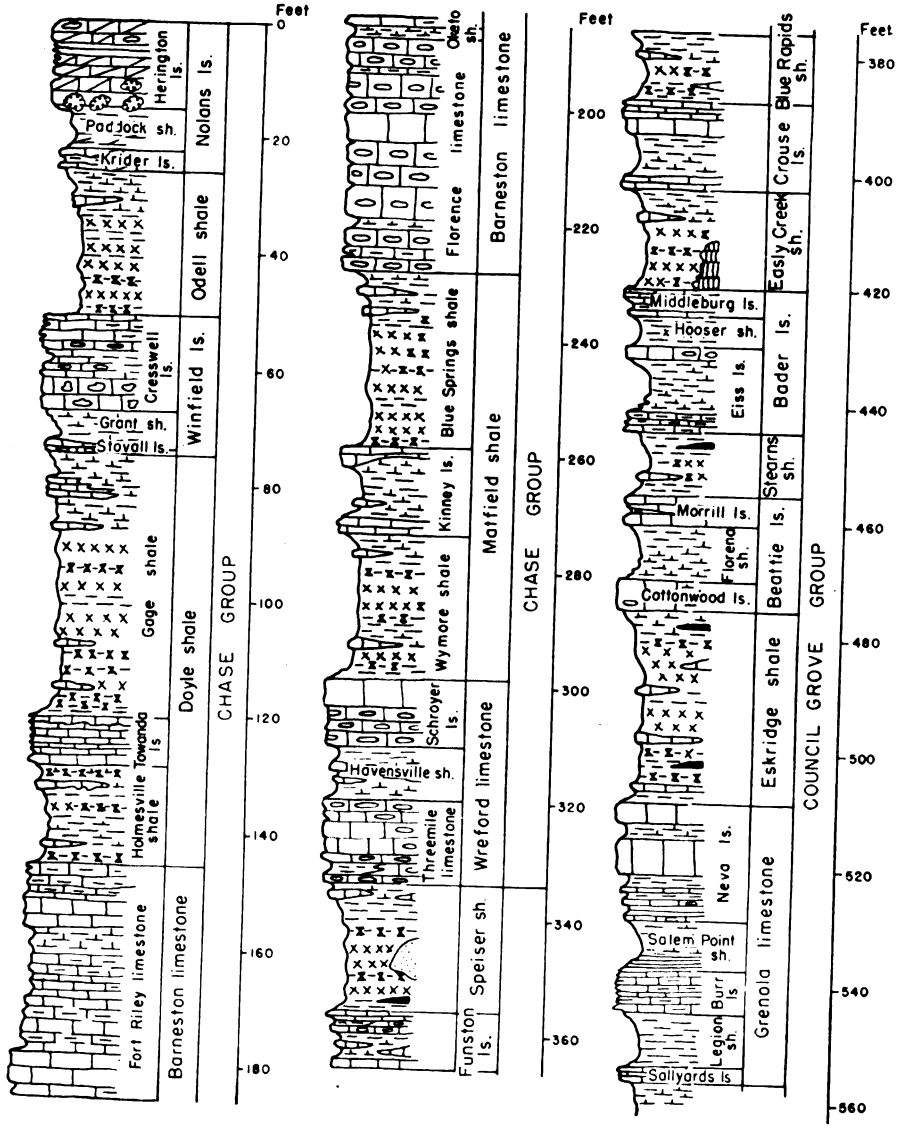

Fig. 16.—**Upper Wolfcampian rocks in Kansas.** Refer to Figure 17 for explanation of lithologies.

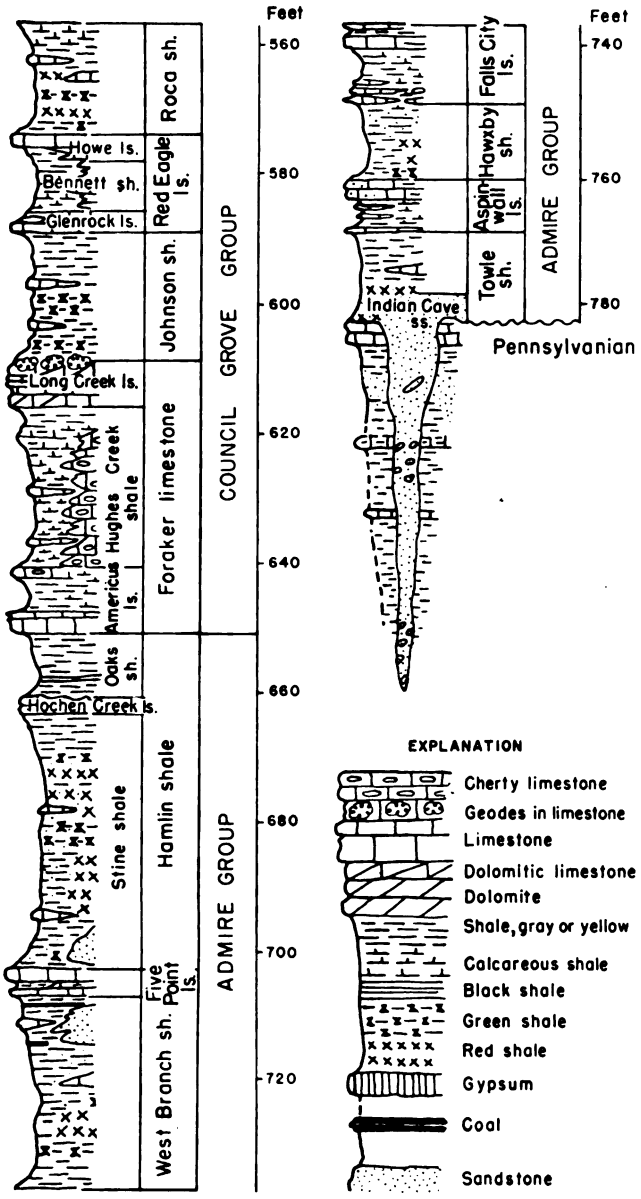

Fig. 17.—**Lower Wolfcampian rocks in Kansas.**

a thin bed of limestone locally cherty. Individual members are not definitely identified in southern Kansas. The combined thickness is about 25 feet.

Cresswell limestone member.—This member consists of limestone and locally shale in the upper and middle parts and of massive fossiliferous limestone in the lower part. The upper part, which has been called "Luta limestone," is thinner bedded and more shaly. The shaly middle part commonly contains calcareous concretions, geodes, and locally chert. Echinoid spines and other fossils are plentiful in the lower massive limestone. Throughtout a considerable distance the lower massive ledge is almost constantly 3 feet thick. Total thickness of the member is commonly about 17 feet.

Grant shale member.—Shale, gray, calcareous and fossiliferous. A distinct unit except in southern Kansas, where it probably has been included in the lower part of the Cresswell limestone. Thickness in northern part is about 10 to 12 feet; in central about 6 feet.

Stovall limestone member.—Limestone, gray, dense, with an abundance of steel-gray flint where thin in northern Kansas. It becomes thicker and noncherty in central and southern parts. Fossils are rare. The thickness is commonly about 1 foot.

Doyle shale.—Two shale members and a separating limestone member. The thickness is about 70 feet.

Gage shale member.—Mostly clayey shale, but calcareous fossiliferous shale and a minor amount of limestone occur in the upper part. The lower and middle parts are chiefly varicolored noncalcareous shale consisting of red, green, purple, and chocolate-colored zones interbedded with gray and yellow layers. The characteristic thickness is approximately 45 feet.

Towanda limestone member.—Limestone, light bluish-gray to yellow, slabby and platy in middle and lower parts, brecciated in upper. Fossils are generally rare. About 15 feet has been measured in Geary County but the common thickness ranges from about 5 to 10 feet.

Holmesville shale member.—Shale, unfossiliferous, upper part characteristically green, with gray, yellow, and red; contains impure limestone and "box work." The thickness ranges from about 7 to 30 feet.

Barneston limestone.—This formation comprises two limestone members separated by a thin shale member. The upper limestone makes an extensive dip slope and crops out as a steep escarpment that extends from north to south across Kansas. The western part of the Flint Hills is capped chiefly by the Barneston limestone. The thickness of the formation ranges from about 80 to 90 feet.

Fort Riley limestone member.—Limestone, light-gray and tan, massive and thin-bedded, and a minor amount of gray shale. In the basal part there are thin, more or less shaly beds that are overlain by a massive "rim rock," which is a conspicuous outcrop maker. Thin shaly beds and locally clay shale deposits occur in the middle part. The upper strata

are rather massive but less so than the "rim rock." Fossil algae are conspicuous in "rim rock." Thickness ranges from about 30 to 45 feet.

Oketo shale member.—Shale, gray, calcareous. Generally absent in southern Kansas and locally absent elsewhere. The thickness, according to measured sections, ranges from a featheredge to possibly 8 feet, but where present this shale parting between flinty limestone below and nonflinty limestone above is generally less than 5 feet.

Florence limestone member.—Limestone, an abundance of flint, and a minor amount of shale. The limestone is commonly lighter in color than the included nodules and layers of gray flint. Shale partings are rather common locally. Fossils are somewhat sparse. In most places along the outcrop the thickness is between 35 and 45 feet.

Matfield shale.—Two units of varicolored shale separated by a limestone member. The thickness ranges from about 50 to 80 feet.

Blue Springs shale member.—Shale, chiefly red and gray, and a relatively minor amount of limestone except in southern Kansas where several limestone beds occur in the upper part of the member. Farther north the member is less calcareous and limestone is absent. Fossils occur in thin limestones and in gray shale beds in the southern part of the outcrop area. Thickness about 30 feet.

Kinney limestone member.—Limestone and shale; generally an upper and lower gray fossiliferous limestone separated by gray fossiliferous shale. The thickness ranges from about 1 to 24 feet.

Wymore shale member.—Shale, chiefly gray and yellow but including red, green, and purple bands. Locally most of the unit is composed of bright-colored clay shale. Limestone beds and fossiliferous shale beds are included in the lower part in the southern part of the State. Thickness is about 25 feet.

Wreford limestone.—Two limestones and a shale member. The limestone members are characterized by an abundance of flint in some of the beds. The thickness ranges from about 30 to 40 feet.

Schroyer limestone member.—Limestone, light-gray to nearly white, mostly flint-bearing, but commonly containing a nonflinty bed (about 3 feet thick) in the upper part. The thickness ranges from about 8 to 20 feet.

Havensville shale member.—Shale, gray and calcareous, and thin limestone beds. This unit cannot be easily identified in parts of southern Kansas where the Wreford limestone comprises a more or less continuous limestone section. Thickness ranges from about 6 to 18 feet.

Threemile limestone member.—Limestone, light-gray to nearly white flinty in part, but containing massive and more resistant nonflinty beds in middle and lower parts. Thickness ranges from about 7 to 22 feet or more.

COUNCIL GROVE GROUP.—This division of the Permian rocks comprises about 310 to 330 feet of limestone and shale. In general, these rocks include less massive and thinner limestone units than occur in the overlying group.

Speiser shale.—Shale and limestone. The upper part consists of gray fossiliferous shale underlain by a fairly persistent limestone bed, which is commonly less than 1 foot thick and occurs about 3 feet below the Threemile limestone. The remainder of the formation consists of beds of varicolored shale, red shale being predominant. The thickness of the formation is about 18 feet in northern and central Kansas and about 35 feet in the southern part of the State where a lenticular bed of sandstone occurs in the middle part.

Funston limestone.—Light-gray to bluish-gray limestone separated by gray to yellow shale that commonly is abundantly fossiliferous. In southern and central Kansas bluish to nearly black shale occurs in the lower part, and locally the limestone beds contain flint. The thickness of the Funston ranges from about 5 to 26 feet.

Blue Rapids shale.—Shale, gray, green and red; containing local limestones and locally a coal bed in Geary County. The thickness ranges from about 15 to 30 feet.

Crouse limestone.—Limestone and shale. The formation comprises an upper and lower limestone separated by a few feet of fossiliferous shale. The upper part displays platy structure and weathers tan to brown. The limestone beds locally are flinty. Thickness ranges from about 10 to 18 feet or more.

Easly Creek shale.—Shale, red, green, and gray, partly calcareous and containing local limestone beds. The upper part is light-colored and calcareous; the lower part is largely red shale. In Marshall County a commercially worked bed of gypsum, approximately 8 feet thick, occurs in the basal part. Thickness is approximately 15 to 20 feet.

Bader limestone.—Two limestones and a shale member. The thickness range is between approximately 15 and 30 feet.

Middleburg limestone member.—Limestone and shale. Upper part of upper limestone platy; middle zone olive to dark-gray shale, lower part of which is fossiliferous; lower limestone slabby to massive. Thickness ranges from about 3 to 8 feet.

Hooser shale member.—Shale, gray, green, and red. Thickness ranges from about 3 to 8 feet or more.

Eiss limestone member.—Limestone and shale. Two beds of limestone separated by shale are remarkably persistent across Kansas. The upper limestone bed, 2 to 3 feet thick, is siliceous and locally contains some flint. The middle part (2 to 11 feet locally) consists of gray fossiliferous shale. The lower limestone, 1½ to 6 feet thick, is shaly, thin-bedded, and fossiliferous. Thickness ranges from about 7 to 18 feet.

Stearns shale.—This shale contains a minor amount of impure limestone. The color is mostly gray to olive but red shale occurs in the middle and lower parts; locally contains a thin coal bed in Lyon and Morris Counties. Thickness ranges from about 7 feet in southern Kansas to about 20 feet in the northern part of the State.

Beattie limestone.—Two limestones and a shale member. Thickness ranges from about 15 to 25 feet.

Morrill limestone member.—This unit consists of brown to gray impure cellular limestone that generally contains one or more thin shale partings. In southern Kansas the Morrill thickens, mainly as a result of algal accumulations in the upper part. Thickness ranges from about 2 to about 8 feet.

Florena shale member.—A highly fossiliferous gray shale containing thin limestone beds in southern Kansas. The brachiopod *Chonetes granulifer* is abundant in this shale throughout its line of outcrop. In southern Kansas the variety of fossils is greater than in the north; the fauna contains numerous species of pelecypods and brachiopods and well-preserved specimens of a small trilobite are locally common. The thickness ranges from about 3 to 18 feet.

Cottonwood limestone member.—Limestone, massive, light-buff, weathering nearly white, containing abundant slender fusulines in the upper part. In southern Kansas it is thin-bedded and shaly. Throughout parts of its line of outcrop it is marked by a fringe of shrubs along the grass-covered Flint Hills slopes. Except for thinning toward the south, the thickness of the Cottonwood limestone is remarkably constant, amounting to about 6 feet.

Eskridge shale.—Shale and a minor amount of limestone and locally thin coal beds. Red and green shale are predominant in most exposures. Ostracodes, mollusks, and algae occur in impure limestones. Coal occurs in the upper part in Brown County. In central Kansas a seemingly persistent limestone ranging up to about 2 feet in thickness, overlain locally by coaly material and underlain more persistently by green shale; occurs a few feet from the base. The thickness ranges from about 20 to 40 feet.

Grenola limestone.—Redefined in accordance with usage of the Nebraska Geological Survey to include strata between the base of the Sallyards limestone and the top of the Neva limestone. The thickness ranges from about 38 to 48 feet.

Neva limestone member.—Four or five limestones separated by shales. The topmost limestone is algal or molluscan and ranges from a few inches to nearly 6 feet in thickness. It is separated from the main ledge by fossiliferous shale ranging in thickness from about 1 to 6 feet. The main ledge is gray brecciated fossiliferous limestone that weathers pitted and cellular. It ranges in thickness from slightly less than 2 to about 8 feet and locally contains shale breaks. The main ledge is underlain by a persistent shale about 0.5 to 3.5 feet thick, commonly containing fusulines in the upper part and locally black in the lower part. The lower part of the member consists of 2 or 3 limestones separated by thin shales. In southern Kansas these lower limestones are thicker and locally chert-bearing. The upper of these limestones, commonly with fusulines, bears a crust of small brachiopods on its upper surface. The lowermost shale commonly is black. The basal limestone commonly is algal or molluscan. The thickness of these lower beds ranges from about 3 to 10 feet. Thickness of the Neva member ranges from about 16 to 24 feet.

Salem Point shale member.—Shale, gray, lower part dark to black, calcareous, without fossils or very sparingly fossiliferous. Thickness ranges from 6 to 10 feet.

Burr limestone member.—Limestone, gray, and shale, gray to olive and dark-gray to black in northern Kansas. Ostracodes occur in upper layers and mollusks and other fossils are rather abundant in the lower beds. Thickness ranges from about 8 to 15 feet.

Legion shale member.—Shale, mostly gray but locally zones of black; in central Kansas upper part commonly fossiliferous. Thickness ranges from about 4 to 12 feet.

Sallyards limestone member.—Limestone, shaly to massive with thin shale breaks. Persistent molluscan fauna, and locally other fossils. Thickness ranges from about 0.5 to 3.5 feet.

Roca shale.—Defined to exclude Legion shale and Sallyards limestone. Shale and limestone; gray, red, and green shale and thin impure limestones. Thickness ranges from about 15 to 20 feet.

Red Eagle limestone.—Two limestones and a shale member. In southern Kansas the Red Eagle limestone is a single ledge about 20 feet thick, but the two limestone members that are differentiated in central and northern Kansas can be identified also in southern Kansas. The thickness ranges from about 6 to 20 feet.

Howe limestone member.—Limestone, variable in lithology and thickness. Foraminiferal in central Kansas. Thickness ranges from less than 1 foot to a maximum of about 15 feet.

Bennett shale member.—Shale and locally some impure limestone. The shale is characteristically dark gray to black in lower part and light gray in the upper part. At some exposures, fossil brachiopods are abundant in black shale. The Bennett grades into limestone southward from Elk County. Thickness ranges from about 2.5 to 15 feet.

Glenrock limestone member.—Limestone, gray and brown, impure in the northern part of the outcrop area, purer limestone in the central and southern part. Fusulines are characteristic. Thickness in the northern part of the State ranges from about 1 to 2 feet but in central Kansas it is thicker, being as much as 19 feet.

Johnson shale.—Shale, gray and green; contains thin beds of argillaceous limestone. Dark carbonaceous material occurs in the upper part. The lower and middle parts are locally somewhat sandy. The thickness ranges from about 14 to about 25 feet.

Foraker limestone.—Two limestones and a shale member. The thickness is about 50 feet.

Long Creek limestone member.—Alternating beds of yellow limestone or dolomite and shale, or thin-bedded limestone; celestite and colorless to pink or red quartz, in the upper part characteristic. In southern Kansas light-gray limestone, more or less massive in the upper and lower parts, sparsely fossiliferous. Thickness ranges from about 4.5 to possibly 17 feet.

Hughes Creek shale member.—In northern and central Kansas this part of the Foraker comprises light-gray to nearly black shale and thin limestone beds containing a profusion of fusulines and abundant brachiopods. In southern Kansas the member is a nearly continuous limestone section, massive in the lower part and containing much light-blue flint. Fusulines are plentiful in the flint and limestone. Thickness ranges from about 20 to 40 feet.

Americus limestone member.—Commonly two limestone beds separated by shale, the upper bed containing flint nodules in southern Kansas. The limestone commonly is bluish-gray and the shale is gray to nearly black. Fusulines and brachiopods are plentiful. The upper limestone ranges from about 1 to 5 feet in thickness. It is shaly in part. Northward from Wabaunsee County it is represented by shaly limestone or calcareous shale, and strata between the Long Creek limestone and the basal limestone bed of the Americus are included in the Hughes Creek shale. The shale between the two main limestone units, where identifiable, ranges from about 3 to 13 feet in thickness. The lower limestone, commonly with a shale break, ranges from about 2 to 4 feet in thickness. Rhombic blocks of limestone mark the outcrop of the lower bed across the State.

ADMIRE GROUP.—This division chiefly consists of clastic deposits but contains thin limestones and some coal. Shale predominates. The thickness, except in places where the Indian Cave sandstone is present, is about 130 feet. The maximum thickness of the Indian Cave sandstone is reported to be 250 feet in Pottawatomie County.

Hamlin shale.—Two shales and a limestone member. Thickness about 50 feet.

Oaks shale member.—Shale, mostly gray, locally nearly black in part. Crystals of pink celestite occur as vein fillings in Brown County. Thickness ranges from a featheredge in Wabaunsee County to a maximum of about 20 feet in northern Kansas, and from about 2 to 12 feet in central and southern Kansas.

Houchen Creek limestone member.—Limestone, upper gray, commonly consisting largely of lobate algal deposits, massive; lower part porous, silty, impure, yellow-brown. Thickness ranges from about 1 to 4 feet.

Stine shale member.—Shale, red, green, and gray, small amount of sandstone, and thin limestone beds. Thickness ranges from 30 feet or less to about 50 feet.

Five Point limestone.—One or more limestones, massive to slabby, fossiliferous; locally upper part a thin coquina. Thickness is about 1 to 8 feet.

West Branch shale.—Shale, gray, green, and red, upper part sandy in central and southern Kansas; contains up to 5 or more feet of sandstone in upper part locally. One or more coal beds occur rather persistently in the upper and middle parts. Limestone lenses occur in the West Branch shale in northern Kansas; lower boundary not definitely determined in south-

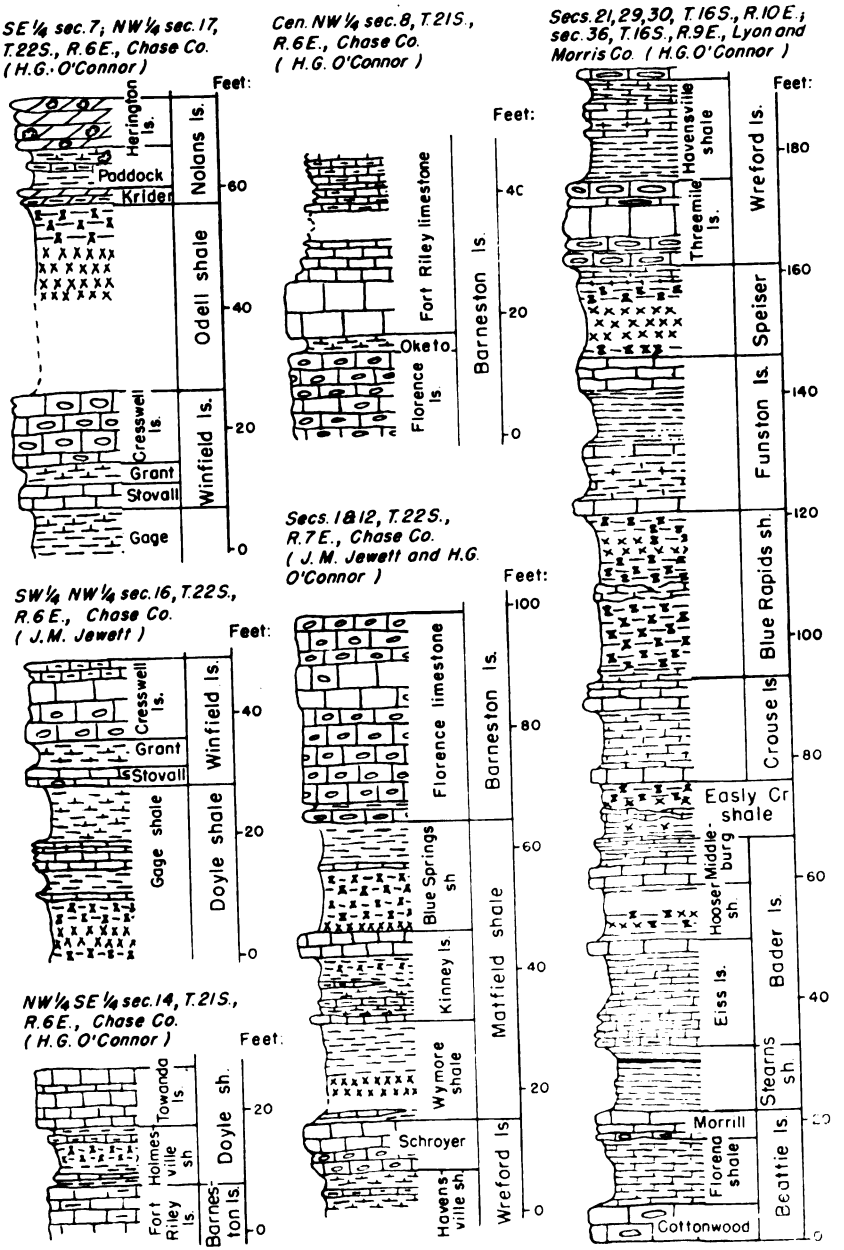

Fig. 18.—**Selected stratigraphic sections of Chase and Council Grove rocks.** Refer to Figure 17 for explanation of lithologies.

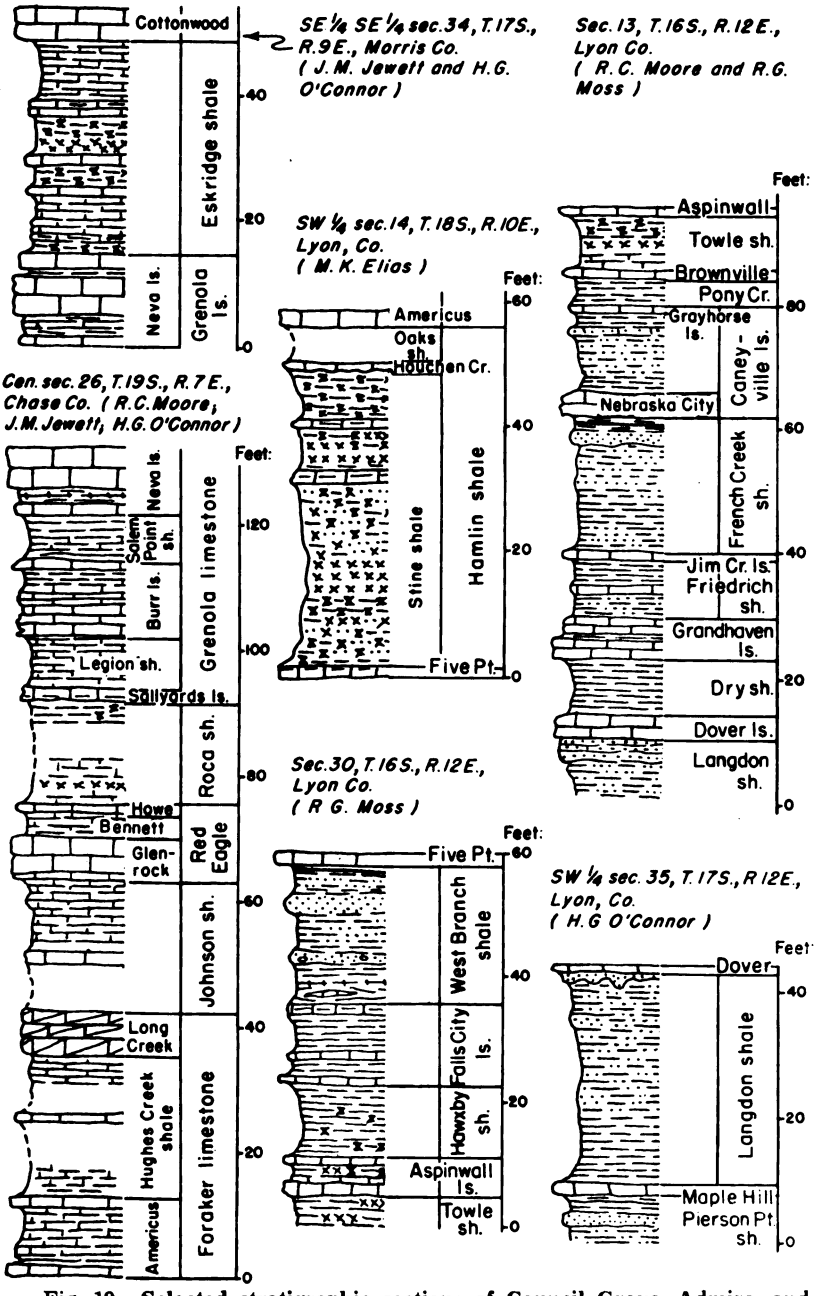

Fig. 19.—Selected stratigraphic sections of Council Grove, Admire, and Wabaunsee rocks. Refer to Figure 17 for explanation of lithologies.

ern part of the State. Thickness ranges from about 20 feet to about 40 feet in the northern part of the State.

Falls City limestone.—In central and northern Kansas upper and lower limestone beds separated by gray shale. Upper boundary undetermined in parts of southern Kansas. Limestone beds are argillaceous and commonly are molluscan with some bryozoans and brachiopods. Cone-in-cone zones are characteristic of upper beds in central Kansas. Lower beds, locally, are thin impure limestones or zones of limestone nodules. The thickness where determined ranges from about 9 to 15 feet.

Hawxby shale.—Shale, gray to yellow, and especially in lower part, green and red. Upper part calcareous and locally sandy. Thickness ranges from about 6 to 15 feet.

Aspinwall limestone.—One limestone bed or several separated by calcareous shale. Thickens southward with calcareous shale becoming dominant in lower and middle parts. Commonly sparsely fossiliferous with mollusks and productid brachiopods predominant. Thickness ranges from about 1 to 15 feet.

Towle shale.—Clayey and silty shale, siltstone, sandstone, and locally thin limestone; gray, red, and green clay, locally sandy. The Indian Cave sandstone occurs in the lower part filling channels cut into Pennsylvanian rocks. Thickness of the Towle shale where the Indian Cave is absent ranges from about 2 to 17 feet.

> **Indian Cave sandstone member.**—Sandstone, siltstone, and locally conglomerate in part; occurs as local channel fillings that grade upward into the basal part of the unnamed upper member of the Towle shale. Reported maximum thickness, about 250 feet.

This seemingly important, although obscure, unconfirmity is marked mainly by large channel sand fillings that occur at intervals from Nebraska into Oklahoma. Massive sandstone, well exposed in the Indian Cave type locality in Nebraska, in eastern Wabaunsee County, in southeastern Cowley County, and elsewhere has been identified as Indian Cave. Erosion channels below the Indian Cave sandstone bring deposits classified as lowermost Wolfcampian into contact with rocks ranging downward from the Brownville limestone, or possibly slightly younger beds, to the Auburn shale. This evidence of widespread erosion, accompanied by rather noteworthy change in the lithologic characters of limestones, and paleontologic change, which is accentuated by the disappearance of old species and the appearance of some new genera and species, warrant the placement of the Wolfcampian-Virgilian boundary at this position.

PENNSYLVANIAN SYSTEM

Character and surface distribution.—This division of Late Paleozoic rocks is widely represented throughout the world, being distinguished by importance of its coal deposits and by characters of its large assemblage of marine invertebrates and varied land plants. It is one of the most important among outcropping strata of Kansas, both on account of the economic value of its contained materials and the prominent status of its rock succession as a standard of reference in studies of equivalent-aged deposits in other parts of the continent. The Pennsylvanian rocks comprise the upper part of a large division that has long been known as the Carboniferous System. The term Carboniferous is almost universally used by geologists outside of North America and has been employed by the State Geological Survey of Kansas in designating outcrops shown on the large geological map of the State (1937) and described in numerous reports. Pennsylvanian rocks have been classified in these publications as a subsystem. Here, we recognize the validity of considerations that have led a great majority of American geologists to treat the Pennsylvanian as an independent geologic system. The aggregate thickness of exposed formations belonging to this system in Kansas is about 3,100 feet. Outcrops occur throughout the eastern one-fourth of the State.

Subsurface distribution and structure.—The well cuttings from Pennsylvanian rocks do not reveal weathering characteristics, paleontologic content (except Foraminifera), or cyclical attributes of the sediments, which aid in distinguishing the formations in the outcrops. Sample logs generally show a monotonous succession of limestones, some of which are cherty and oölitic. Chert is a persistent characteristic of some beds, but chert occurs locally in nearly every limestone. Oölites and algal remains are recognizably persistent only locally.

In most subsurface areas, the top and bottom of conspicuously calcareous groups can be determined approximately in sample logs and accurately in electric logs. The extraordinarily close approach to parallelism of the limestones above the Cherokee and their slow convergence toward the west and toward local anticlinal features permits identification in electric logs of formations and members occurring between datum horizons. Toward the south, limestone beds disappear.

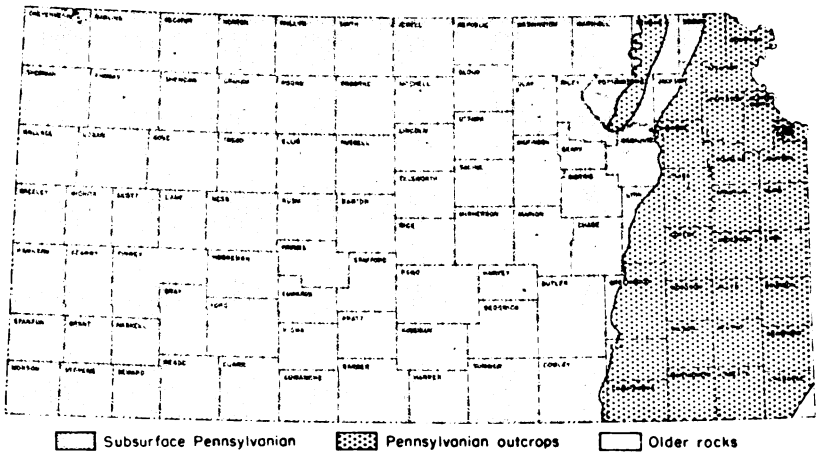

Fig. 20.—Distribution of Pennsylvanian rocks.

All series and group divisions of the Pennsylvanian succession (except Pedee) have been traced westward in the subsurface to the Colorado line, although some units wedge out or become indistinguishable. Northward thinning of shale formations and members, as seen in outcrops, has its counterpart in westward thinning of shales in the subsurface. Some limestones also become thinner and wedge out westward, but they are much more persistent than the shales. In western Kansas, the Pennsylvanian System consists mainly of limestones separated by shale beds, most of which are so thin that they can be recognized only in the electric logs. As along outcrops, most shales in the subsurface thicken southward toward the Oklahoma border, and many limestones wedge out or grade into shale or sandstone in this direction.

The principal datum horizons in the subsurface Pennsylvanian succession are the top and base of the Shawnee group, top of the Lansing group, base of the Kansas City group, and (in many areas) base of the Marmaton group. The Oread is well identified in electric logs by the distinctive pattern of the Heebner and Snyderville shales, separated by thin Leavenworth limestone.

Although thickness of the Pennsylvanian Series and its constituent groups increases southeastward, the regularity is modified by local structural features developed by differential movements during Pennsylvanian time. Before earliest Pennsylvanian sedi-

mentation in eastern Kansas, the beveled surface of Mississippian and older rocks was deformed by revival of the Nemaha anticline, Central Kansas uplift, and various minor structures. Downward movement of this surface east of the Nemaha anticline allowed accumulation of 700 to 1,000 feet of Desmoinesian rocks (Marmaton and Cherokee) in the Forest City basin. A maximum of only 400 feet of Desmoinesian rocks accumulated in the deepest part of the Salina basin. The crest of the Nemaha anticline was only thinly covered by Desmoinesian rocks. At the Burns dome in Butler County, only the Marmaton was deposited on the crest of the rising Nemaha anticline. Near the Nebraska line, the crest was not covered by sediments until early Kansas City time. Varying thicknesses of Desmoinesian rocks cover the crest of the Nemaha at other less elevated points. In general, greater thicknesses of Desmoinesian rocks overlie the crest of the Nemaha anticline toward the south.

Parts of the Central Kansas uplift were not covered by Pennsylvanian sediments until Kansas City time. The differential character of the structural movement in this region is revealed by gradual thinning of all Pennsylvanian groups above the Desmoinesian over crests of both major and minor anticlines. Most of the Pennsylvanian groups thicken in the contemporaneously subsiding Hugoton basin. In southwestern Kansas, the thickness of the Desmoinesian (about 640 feet in Meade County) is exceeded only in the Forest City and Cherokee basins.

Rocks of Atokan and Morrowan age were deposited in the Hugoton basin before Pennsylvanian deposition began in eastern Kansas. In Meade County, the Atokan is about 400 feet thick and the Morrowan about 135 feet thick but in Morton County there is more than 400 feet of Morrowan rocks. Both Atokan and Morrowan in Kansas are confined to the Hugoton basin, where they thin northward.

Virgilian Series

The Virgilian Series comprises the youngest Pennsylvanian rocks of the midcontinent region. They are separated from rocks above and below by unconformities. In Kansas this series is divided into three groups on the basis of general differences in lithology and the nature of cyclic deposits. The thickness is commonly about 1,200 feet.

WABAUNSEE GROUP.—The uppermost major division of Virgilian strata includes beds below the unconformity that separates Permian and Pennsyl-

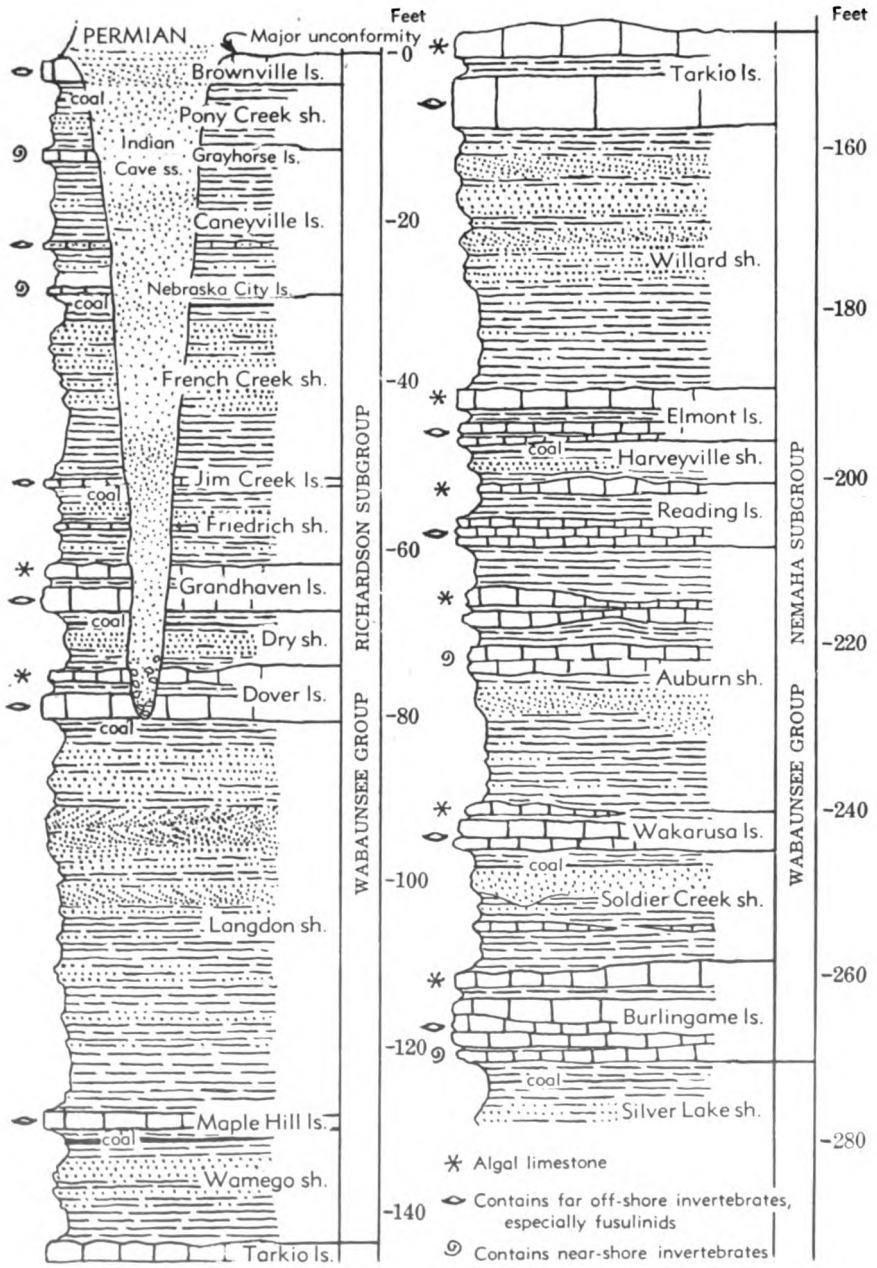

Fig. 21.—**Virgilian (upper Wabaunsee) rocks in Kansas.** Read Pierson Point shale for Wamego shale.

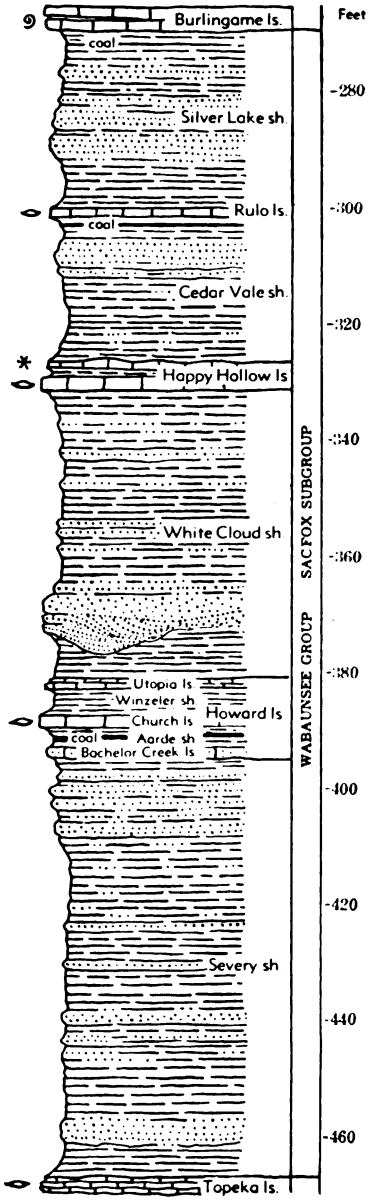

Fig. 22.—Virgilian (lower Wabaunsee) rocks in Kansas. Refer to Figure 21 for explanation of fossil symbols.

vanian rocks and above the top of the Topeka limestone. Where the Indian Cave sandstone is absent the top of the Pennsylvanian is drawn at the top of the Brownville limestone. Limestones in this group are uniformly thin but persistent. Sandstone is plentiful, but shale is the chief rock. The thickness of the Wabaunsee group is about 500 feet, excepting in places where the overlying unconformity cuts out the upper beds.

RICHARDSON SUBGROUP.—Strata from the top of the Brownville limestone to the top of the Tarkio limestone are included in the Richardson subgroup. This division can be distinguished in northern Kansas. The thickness commonly is about 140 feet.

Brownville limestone.—Bluish-gray limestone that weathers yellowish or brown, occurring in one bed or in two beds separated by a thin layer of shale. Varying texture from impure sandy-appearing rock to fairly pure dense limestone. Characteristic fossils include large fusulines, brachiopods *Meekopora* and *Chonetes granulifer*, crinoid fragments, and bryozoans. The thickness ranges from about 2 to 8 feet.

Pony Creek shale.—Bluish-gray shale chiefly, some red clay shale or sandy shale locally. Commonly sandstone or siltstone occurs near the middle part, locally this type of deposit fills channels cut downward into beds as low as the Friedrich shale or lower. A thin coal bed occurs in the upper middle part in southern Kansas. Brachiopods and bryozoans more or less common in upper layers. Thickness ranges from about 5 to 50 feet or more.

Caneyville limestone.—Three limestones and separating shales in the southern part of the outcrop area; two limestones and a shale elsewhere. Thickness ranges from about 12 to 25 feet.

Grayhorse limestone member.—Gray, medium- to coarse-grained limestone, fragmental or coquinoid, ferruginous, broken surfaces showing curved cleavage surfaces of iron- or magnesium-bearing carbonate crystals. Large specimens of *Myalina* are rather common. Thickness ranges from about 0.5 to 6 feet.

SHALE ranging in thickness from about 10 to 23 feet; contains locally in southern Kansas about 1 foot of fusuline-bearing limestone.

Nebraska City limestone member.—Gray, impure, soft limestone; contains bryozoans, brachiopods, algae, and sparse mollusks. Thickness ranges from about 1 foot to 5 feet.

French Creek shale.—Bluish-gray to yellowish-brown clayey and sandy shale commonly containing light-brown or tan sandstone and one or more coal beds in the upper part. Thickness ranges from about 20 to 45 feet.

Jim Creek limestone.—A persistent bluish-gray, fine-grained, hard limestone, containing in many places slender fusulines and, more locally, a large variety of other marine fossils. The thickness ranges from a few inches to about 2 feet.

Friedrich shale.—Bluish-gray shale that weathers yellowish and brown. Sandstone is more or less common and in southern Kansas thin coal and limestone beds are included. Locally sandstone-filled channels cut downward 30 feet or more into lower beds. Contains pelecypods, sparse bryozoans, and brachiopods. Thickness ranges from about 5 to 40 feet or more.

Grandhaven limestone.—Commonly two limestones separated by a few feet of shale, less commonly a single bed. The upper limestone is light-gray and weathers almost white, oölitic or algal deposits forming a prominent part of the rock. In exposures along Cottonwood River, this member is cross-bedded and carries abundant brachiopods and bryozoans and some mollusks. Large fusulines are present at some outcrops. The formation is traced from Shawnee County southward to Oklahoma and may be recognized north of Kansas River. The thickness ranges from about 2 to 10 feet.

Dry shale.—Gray, locally red and green, generally clayey, but locally somewhat sandy shale containing a thin coal bed in southern Kansas. Marine fossils are abundant locally in the upper part. The thickness ranges from about 3 to 20 feet.

Dover limestone.—In northern Kansas commonly a single bed of limestone and in central Kansas a single bed of limestone or calcareous sandstone. Southward from Greenwood County a fine-grained blue-gray limestone with a mixed fauna of mollusks and brachiopods occurs below the more persistent and characteristic fusuline- and algal-bearing part. The thickness in northern Kansas ranges from about 1 to 5 feet; in southern counties, where shale comprises most of the formation, the thickness is as much as 24 feet.

Langdon shale.—Bluish-gray clayey to sandy shale, containing the persistent thin **Nyman coal** and locally platy to massive sandstone in the upper part. Marine invertebrates are abundant at places in northern Kansas below the upper sandy facies. Not differentiated from the Pierson Point shale south of Cottonwood River. Thickness ranges from about 5 to 50 feet.

Maple Hill limestone.—Gray, medium-hard limestone, weathering reddish-brown; generally bearing crinoid remains, bryozoans, brachiopods, and sparse mollusks. Fusulines are more or less common. The Maple Hill limestone is not definitely recognized south of Emporia but is believed to be represented in southern Kansas by thinner-bedded limestone. Thickness about 1 to 4 feet.

Pierson Point shale.—Bluish-gray clay shale and yellowish-brown micaceous sandy shale, locally containing a zone of mixed fauna; nearly black shale locally in the upper part. Between Kansas and Cottonwood Rivers a more or less persistent coal bed occurs in the upper-middle part. A mixed marine fauna. The formation is not differentiated from the Willard shale south of Lyon County. The term "Wamego shale" was introduced a few years ago by the Nebraska Geological Survey to replace Pierson Point, then thought to be unsuited for these beds. Recently, however, the Nebraska Survey has found that the older name is appropriate. The thickness ranges from about 4 to 25 feet.

NEMAHA SUBGROUP.—Strata from the top of the Tarkio limestone to the base of the Burlingame limestone comprise the Nemaha subgroup. This division is distinguished in northern Kansas. The thickness commonly is about 160 feet.

Tarkio limestone.—This formation, consisting of gray limestone that weathers deep yellowish brown, is one of the most easily recognized units in the Wabaunsee group. It is characterized by the brown color of weath-

ered outcrops and the abundance of large fusulines. Locally algal remains occur in the upper part. The formation is present from a point in northern Lyon County northward across the State, and seemingly occurs at some places in southern Kansas. The thickness ranges from a featheredge to about 10 feet.

Willard shale.—Dark bluish-gray and brown shale, and sandstone. Sandstone is prominent in many places in northern Kansas but thin or absent farther south. Inasmuch as the Maple Hill and Tarkio limestones are not recognized in southern Kansas, the shale and sandstone section containing one or more local coal beds extending from the base of the Willard to the top of the Langdon shale is designated as the **Willard-Langdon shale;** its thickness ranges from about 10 to 55 feet. The thickness of the Willard in northern Kansas ranges from about 30 to 65 feet, the maximum being near Kansas River.

Elmont limestone.—Dark-blue massive limestone containing fusulines and brachiopods; weathers bluish-gray and displays closely spaced vertical joints. Locally a coquinoid or conglomeratic limestone occurs above the persistent fusulinid bed and is separated from it by a few inches to several feet of shale. Other exposures show a conglomerate of limestone pebbles associated with one or more brachiopod and molluscan beds below the fusulinid bed. Thickness ranges from about 1 to 15 feet

Harveyville shale.—Bluish and greenish-brown clayey shale, locally sandy shale and thin platy sandstone. In places a coal bed occurs above the sandstone and marine invertebrate fossils are found above the coal horizon. The formation is continuous across Kansas, having a thickness range from less than 1 to 25 feet.

Reading limestone.—The most persistent part consists of dark-blue, dense, hard limestone showing vertical jointing, and weathering light bluish gray mottled with light brown or yellow. The formation comprises one to four beds of limestone and blue-gray shale beds locally with a coal bed in southern Kansas between the limestone layers. Fusulines are characteristic of the persistent dense blue limestone. Locally an upper algal phase is present as a single distinct limestone above the more persistent part, and a brachiopod- and pelecypod-bearing limestone may be present below the persistent bed. Thickness of the formation is about 1.5 to 15 feet.

Auburn shale.—A somewhat complex and variable unit composed chiefly of shale, containing minor amounts of sandstone and limestone, part of which is chalky. Near Kansas River there are lenses of cross-bedded limestone and conglomerate and coquinoid masses of molluscan and algal remains as much as several feet thick. Dark shale containing numerous ostracodes and pelecypods occurs locally. There are two or more local coal beds. The thickness of the formation in Kansas ranges from about 20 to 70 feet.

Wakarusa limestone.—Dark bluish hard limestone that becomes brown when weathered. Locally, an algal-molluscan or fine-grained sandy limestone occurs in the upper part and a mollusk- or brachiopod-bearing limestone may be present below the more persistent part. Shale separates the limestones where more than one is present. Fusulines, massive bryozoans,

large brachiopods (*Dictyoclostus*), algal remains, and other fossils are characteristic of the persistent ledge. The thickness of the formation ranges from about 2 to 18 feet.

Soldier Creek shale.—Bluish-gray clayey to sandy shale; locally a thin coal bed in the upper part. Marine invertebrates occur in the upper part in places. Thickness ranges from less than 1 to about 25 feet.

Burlingame limestone.—Limestone, brown, fine-grained, hard, thick-bedded, appearing mottled and brecciated in some exposures. Shale commonly separates the limestone beds. Fusulines are fairly common in the more persistent part, and algal remains are conspicuous near the top. Spongelike algal deposits, composed of *Somphospongia*, are numerous in a few exposures in northern Kansas. The thickness of the formation ranges from about 2 to 16 feet.

SACFOX SUBGROUP.—Strata from the base of the Burlingame limestone to the top of the Topeka limestone are included in the Sacfox subgroup. The thickness commonly is about 200 feet.

Silver Lake shale.—Gray and yellow clay shale, variably associated with platy impure limestone, sandy shale, or sandstone. Sandstone-filled channels occasionally cut downward into beds as low as the Cedar Vale shale or lower. One or more coal beds occur in the upper part. Marine invertebrates and land plant fossils are present locally. The thickness ranges from about 4 to 45 feet or more.

Rulo limestone.—Bluish-gray limestone that locally is mottled with light brown when weathered. Locally a molluscan phase occurs in the lower part and a thin algal zone in the upper part. Brachiopods and bryozoans are more or less common in the more persistent part. The thickness ranges from less than 1 to about 4 feet.

Cedar Vale shale.—Bluish to yellowish-brown clayey and sandy shale and sandstone with a persistent coal bed (**Elmo**) near the top and locally other coal beds. Marine invertebrate fossils occur above the coal. The thickness ranges from about 16 to 60 feet.

Happy Hollow limestone.—Generally a single, very persistent massive bed of pinkish-brown limestone characterized by large fusulines and less plentiful other fossils. In some places there is an upper oölitic or algal bed in contact with the more persistent part or separated from it by a thin shale bed, and locally a dark bluish-gray limestone occurs a few feet below the fusuline-bearing bed. In some areas the fusuline bed is seemingly absent and the formation is represented only by algal and molluscan beds. Thickness ranges from about 1 to 8 feet or more.

White Cloud shale.—Bluish-gray to yellowish-brown clayey and sandy shale. Locally sandstone and conglomerate fill channels cut downward into beds as low as the Howard limestone or lower. Sparse marine and land plant fossils are present. The thickness ranges from about 30 to 80 feet.

Howard limestone.—Three limestone members and two shale members, of which the middle limestone is the most persistent. The thickness of the formation ranges from about 8 to 40 feet.

Utopia limestone member.—Gray to brown limestone and sandy limestone resembling a coquina in many outcrops. Fossils include algal

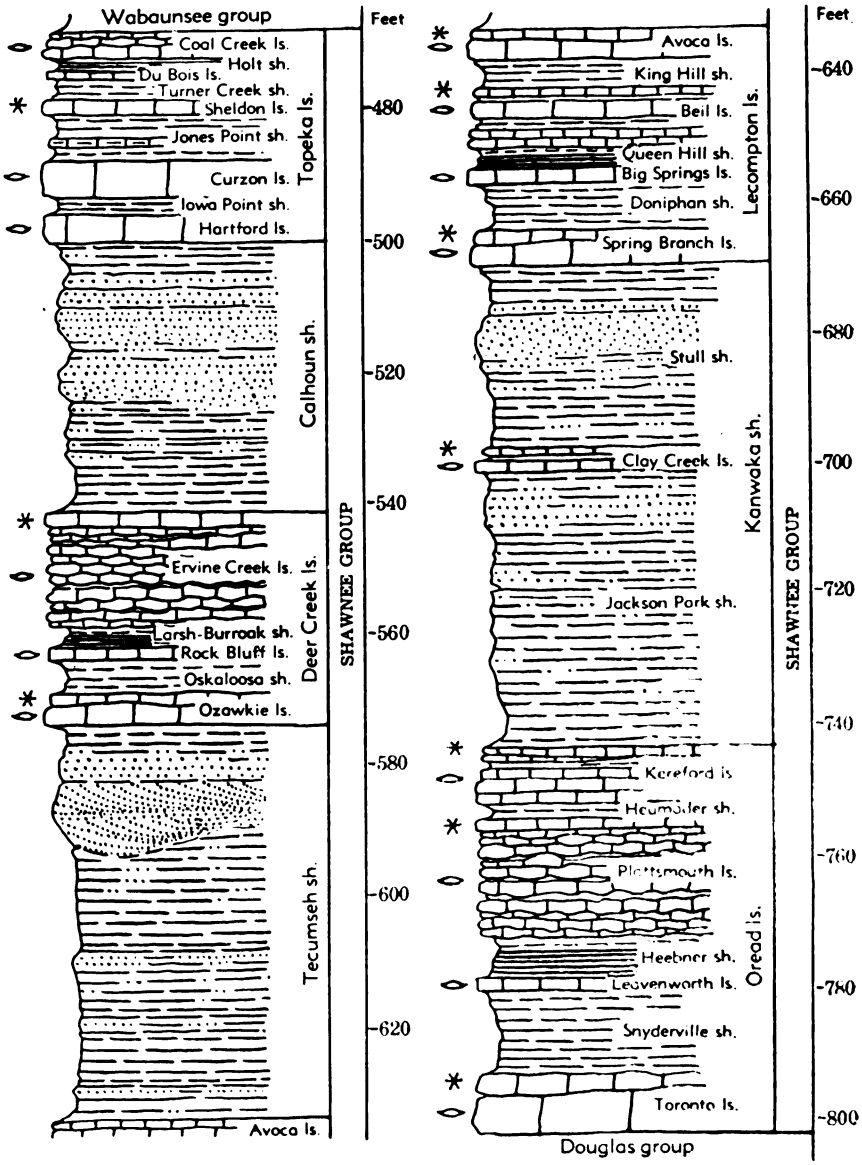

Fig. 23.—**Virgilian (Shawnee) rocks in Kansas.** Refer to Figure 21 for explanation of fossil symbols.

remains, fusulines, bryozoans, brachiopods, and mollusks. The thickness ranges commonly from less than 1 foot to a maximum of about 16 feet. Consists of two or more limestones and an ostracode-bearing shale in parts of the State.

Winzeler shale member.—Bluish-gray to yellowish-gray clay shale. Marine fossils occur in the lower part. Thickness is about 1 to 12 feet.

Church limestone member.—Commonly one massive bed of blue to bluish-gray limestone that weathers to a deep rich brown. Crinoid remains, productid brachiopods, and "cryptozoan" algae are more or less characteristic. A thin zone at the top contains abundant bryozoans, and fusulines occur sparingly in the upper part in southern Kansas. The thickness ranges from about 1.5 to 6 feet.

Aarde shale member.—Bluish-gray to yellowish-gray clayey and sandy shale containing a very persistent coal bed (**Nodaway**), ranging from about 1 inch to 2 feet in thickness, and persistent black fissile shale. A hard dense vertical-jointed limestone, 3 inches to 1 foot or more thick, occurs next below the black fissile shale in many outcrops. Thickness ranges from about 2 to 15 feet.

Bachelor Creek limestone member.—Commonly sparsely fossiliferous, bluish-gray, impure, sandy limestone which is present from Osage County southward. Locally two beds separated by shale. Thickness is as much as 8 feet.

Severy shale.—Yellowish-brown and bluish-gray clay shale and a minor amount of platy to massive sandstone. Sparse marine fossils occur in the uppermost part and in shales below some thin limestone beds which occur in southern Kansas. A disconformity in the lower part of the Severy is indicated by various outcrops in northern Kansas. Locally, as in southern Shawnee County, sandstone fills channels cut well into the Topeka limestone. Where the Bachelor Creek limestone is absent the base of the Nodaway coal is regarded as the top of the Severy shale. The thickness is commonly 70 to 80 feet.

SHAWNEE GROUP.—The Shawnee group comprises four limestone formations and three shale formations. Thick limestones and a distinctive type of cyclic sedimentation are characteristics that distinguish these rocks from those of neighboring groups. The average thickness is about 325 feet.

Topeka limestone.—Limestones and shales having a wide range of lithology. Locally between Kansas River and Greenwood County the upper part is cut out by a disconformity in the Severy shale. In southern Kansas all members are not positively identified. In Oklahoma, the upper part of the Pawhuska formation is correlated with the Topeka limestone. The thickness of the Topeka ranges from a nearly constant measurement of 33 feet in northern Kansas to 55 feet near the Oklahoma boundary.

Coal Creek limestone member.—Light bluish-gray limestone and nodular shale or dark-blue more massive limestone that weathers light bluish gray or brown. The member is not positively identified south of Kansas River, but the "red limestone" in southern Kansas is probably its equivalent. Fusulines are locally abundant and at many places nu-

merous other well-preserved invertebrate fossils are found. The thickness of the Coal Creek limestone ranges from 2 to 5 feet.

Holt shale member.—Bluish-gray shale in the upper part and black shale in the lower part. This member is not recognized with certainty south of Topeka because the limestone beds above and below it seem to disappear, at least for many miles, and because the distinctive black slaty beds do not persist southward. Shale beneath the uppermost Topeka limestone in southern Kansas probably represents the Holt member, however. Corneous brachiopods and conodonts occur in the black shale. The thickness ranges from 1.5 to 3 feet.

Du Bois limestone member.—One or more dark-blue or greenish-blue fine-grained, somewhat earthy limestone beds with prominent vertical jointing. Not definitely recognized south of Topeka. Mollusks and brachiopods are common. The thickness commonly ranges from about 0.5 to 2 feet.

Turner Creek shale member.—Bluish or greenish-gray clayey and calcareous shale, bearing few invertebrate fossils. The thickness ranges from 1 to 5 feet in northern Kansas; shale in southern Kansas that is correlated with the Turner Creek measures 12 to 15 feet.

Sheldon limestone member.—A massive light-gray to nearly white, very fine-grained, dense limestone that commonly contains numerous small algal growths of the type known as *Osagia*. The rock weathers light yellowish gray and makes smooth rounded surfaces at the outcrop. The member is a persistent layer that is identified northward from Kansas River but seemingly is absent to the south as far as Greenwood County; in southern Kansas there is an algal limestone at the Sheldon horizon. Thickness ranges from 0.7 to 2 feet .

Jones Point shale member.—Clayey, calcareous, and silty gray shale, locally containing nodular or platy limestone beds. The member contains fairly numerous brachiopods and mollusks at some outcrops but is poor in fossils at many exposures. The thickness in northern Kansas ranges from 1 to 10 feet, but beds in Elk and Chautauqua Counties that are correlated with the Jones Point shale are 10 to 15 feet.

Curzon limestone member.—This is a persistent prominent subdivision of the Topeka formation that is readily and positively identifiable throughout northern Kansas. It consists of two or more beds of massive bluish-gray, brown-weathering limestone that is mostly hard and resistant, forming a well-marked escarpment. Nodules of chert are common. Fusulines occur sparingly to very abundantly in the lower and middle parts of the member, together with some brachiopods and other invertebrates; bryozoans and echinoid remains are common in upper layers. The thickness ranges from 5 to 12 feet.

Iowa Point shale member.—Yellowish-gray to bluish-gray, clayey to calcareous shale that locally contains sandstone layers and a thin coal bed. This shale is typically developed and thickest in northern Kansas near the Nebraska boundary; in sections near Topeka it is only 2 feet thick, and farther south it disappears, as indicated by fusuline-bearing lower layers of the Curzon resting directly on the algal upper part of the Hartford limestone. Thickness, a featheredge to 14 feet.

Hartford limestone member.—Massive, light bluish-gray limestone that weathers brownish. This member commonly bears numerous fusulines except in the upper part, which contains numerous *Osagia* and is of algal origin. The lower beds are characterized by presence of the chambered sponge, *Amblysiphonella*. The upper algal limestone is highly variable in thickness, ranging from almost nothing to 12 feet. The thickness ranges from about 3 to 13 feet.

Calhoun shale.—Clayey and sandy shale, a minor amount of limestone, and one or more coal beds. In northern Kansas, a thin coal bed and much sandstone, a part of which fills channels, occur near the top of the formation. Dark-gray, silty, fossiliferous shale comprises the lower part, and plant remains occur in the sandy part. In southern Kansas, the shale progressively diminishes in thickness until near the Oklahoma boundary it is locally absent. In northern Kansas, near the Nebraska line, the Calhoun is only 10 feet thick. Maximum thickness of this shale, about 45 feet, is developed near Kansas River.

Deer Creek limestone.—A persistent, escarpment-making formation comprising three limestone members and two shale members. Lithologic characters are fairly constant. The thickness ranges from about 20 to a local abnormal maximum in Osage County of 80 feet.

Ervine Creek limestone member.—Mainly composed of light-gray to nearly white or bluish-gray fine-grained limestone characterized by thin, wavy bedding that locally contains chert nodules. It bears a large assemblage of invertebrate fossils, including fusulines, corals, echinoid and crinoid fragments, bryozoans, brachiopods, and mollusks. Shale partings contain ostracodes and small foraminifers. The thickness ranges from about 5 to 32 feet. Above the wavy-bedded limestone is a less persistent limestone, generally massive, that is variable in lithology. Locally it is oölitic; elsewhere it is coquinoid, nodular, very fine-grained, or sandy; the alga called *Osagia* is common. This limestone, which ranges from a featheredge to about 6 feet, is generally separated from the underlying limestone by 1 to 2 feet of yellowish clayey to sandy shale but the shale is absent in many places.

Larsh-Burroak shale member.—Gray or yellow clayey shale in the upper part and black, more or less fissile shale in the lower part. Fossils are rare in the upper part but conodonts occur in the black portion. Thickness ranges from about 2.5 to 7 feet.

Rock Bluff limestone member.—Massive, vertical-jointed bed of dark-blue limestone that develops a bluish-gray or creamy surface film on weathering. Fusulines are common; a few brachiopods and other marine invertebrates are present. The thickness ranges from about 1 to 3 feet.

Oskaloosa shale member.—Bluish or yellowish-gray shale in northern Kansas and sandy micaceous shale containing a red zone and some nodular limestone in the southern part of the State. The thickness ranges from an observed minimum of 3 feet to a maximum of about 50 feet locally in Osage County.

Ozawkie limestone member.—Brownish-gray, brown-weathering, massive limestone. Fossils are somewhat sparse, but fusulines and other marine fossils are abundant in some outcrops. Commonly the thickness is about 5 feet but ranges from about 1 to 20 feet.

Tecumseh shale.—Chiefly clayey and sandy shale, locally having a more or less discontinuous limestone (**Ost**) in the upper part. This limestone is not persistent enough to call for subdivision of the formation as in Nebraska. Sandstone is locally present not far below the Deer Creek limestone. The thickness of the Tecumseh ranges from an observed minimum of 12 feet in southern Kansas to a maximum of about 65 feet near Kansas River.

Lecompton limestone.—Four limestone members and three shale members, all of which can be traced across Kansas, make up this formation. The thickness ranges from about 30 to 50 feet.

Avoca limestone member.—Dark bluish-gray somewhat earthy limestone occurring in one or more beds. Large fusulines are the most common fossils. In southern Kansas a "cryptozoan"-bearing limestone is a characteristic element of the member. Algal-molluscan limestone beds occur at the top of the Avoca in some outcrops. The thickness ranges from about 1 to 20 feet.

King Hill shale member.—Bluish-green to reddish-gray shale, calcareous in northern Kansas. Brachiopods occur in the upper part. The thickness range is from about 4 to 20 feet.

Beil limestone member.—Alternating beds of hard bluish-gray limestone, weathering yellowish, and calcareous shale, or light-gray, nearly white, wavy-bedded limestone in southern Kansas. Algal limestone resembling an oölite comprises the upper part in northern Kansas. Corals and fusulines are abundant and characteristic. The thickness ranges from about 4 to 15 feet.

Queen Hill shale member.—Bluish-gray or yellow shale in the upper part; hard black fissile shale, bearing conodonts, in the lower part. The thickness ranges from about 3 to 6 feet.

Big Springs limestone member.—Dark bluish-gray dense limestone, commonly occurring as a single bed with prominent vertical jointing. Locally two or three limestone beds separated by shale. Weathering produces a yellowish-brown film. Fusulines are abundant. The thickness ranges from about 1 to 5 feet.

Doniphan shale member.—Shale, sandstone, and thin limestone beds. Thicker and contains some red shale and prominent sandstone beds in southern Kansas. Fusulines are plentiful in the basal part at some exposures. Thickness ranges from about 5 to 34 feet.

Spring Branch limestone member.—Gray, somewhat sandy limestone that weathers deep brown and occurs in massive slightly uneven beds. Fusulines are abundant in most outcrops. In northern Kansas the thickness is commonly 5 feet; in southern Kansas this member locally is very sandy impure limestone about 4 feet thick.

Kanwaka shale.—In northern Kansas, divisible into two shale members and a limestone member. In southern Kansas, much of the interval between the Lecompton and Oread formations is occupied by sandstone, sandy shale, and red shale, collectively called **Elgin sandstone.** Thickness ranges from about 40 to 145 feet.

Stull shale member.—Yellowish-brown sandy shale, locally one or more coal beds. Sandstone containing somewhat plentiful land plant fossils and partly filling channels occurs in the upper part in northern Kansas and much or all of the Elgin sandstone in the southern part of the State may belong in this division. The Stull shale is identified definitely in Kansas northward from the central part of the State and tentatively in parts of southern Kansas. The thickness ranges from about 25 to at least 45 feet.

Clay Creek limestone member.—Dark-blue to bluish-gray limestone, commonly massive and dense; vertical jointing is characteristic. Fusulines are locally abundant and other fossils are fairly plentiful. Locally oölitic, algal, and crinoidal deposits occur above the more persistent part. The Clay Creek limestone is persistent in northern Kansas at least as far southward as Osage County and is tentatively identified in Greenwood and Elk Counties as a zone of fossiliferous and calcareous sandy shale. The thickness may be as much as 5 feet.

Jackson Park shale member.—Bluish-gray and yellowish-brown sandy shale and sandstone. Land plant fossils are more or less abundant. Locally in Douglas County, a thin coal bed and clam-bearing sandy layers occur in the upper part. This and higher subdivisions of the Kanwaka here named are not so definitely differentiated in southern Kansas. The observed thickness ranges from 16 to 52 feet.

Oread limestone.—The basal formation of the Shawnee group comprises four limestone members and three shale members, the outcrop of which is marked by a prominent escarpment across the State from Doniphan County, in the north, to Chautauqua County, in the south. The average thickness in northern and central Kansas is 52 feet; in southern Kansas the thickness increases to about 100 feet owing mainly to expansion of the interval between the lower two limestone members.

Kereford limestone member.—This member is variable in lithology, commonly more or less oölitic or fine-grained and flaggy. In northern Kansas, upper slabby cross-bedded layers, containing algal and locally land plant remains, overlie more massive rock that contains fusulines and other marine invertebrates. At some outcrops the member consists of a single bed of dark bluish-gray dense limestone; elsewhere, especially in Osage County, it is made up of dense bluish flaggy limestone partly interbedded with shale. The Kereford is not recognized in southern Kansas. Thickness ranges from a featheredge to more than 40 feet.

Heumader shale member.—Commonly dark-gray shale, locally bluish or greenish, clayey to silty, and in southern Kansas sandy. Well-preserved mollusks and other fossils occur commonly. Thickness in northern Kansas ranges from 2 to 5 feet.

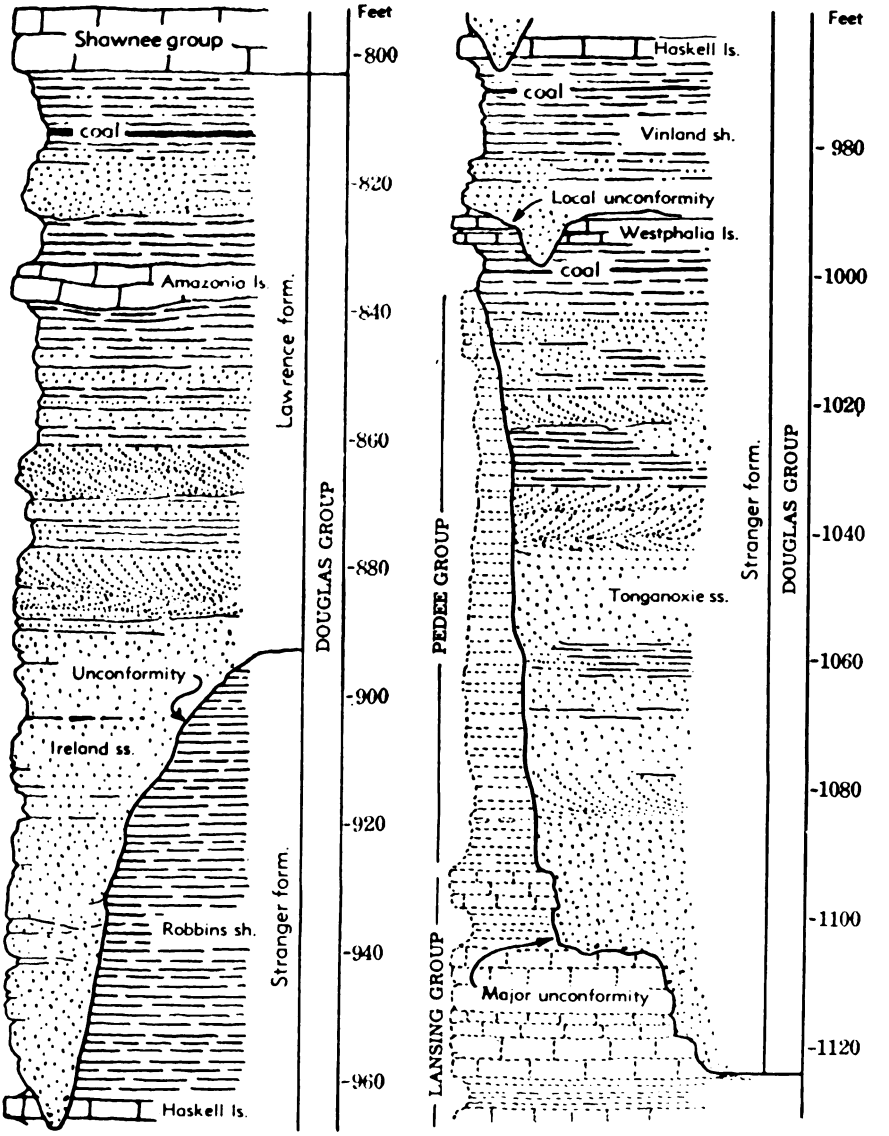

Fig. 24.—Virgilian (Douglas) rocks in Kansas.

Plattsmouth limestone member.—The Plattsmouth is the main limestone member of the Oread formation. Commonly it is light bluish-gray, light-weathering, dense limestone that occurs in wavy beds. Flint is more or less abundant in the northern part of the outcrop. Fossils include fusulines, corals, bryozoans, brachiopods, sparse mollusks, and other invertebrates. Algal remains occur locally at the top. The thickness ranges from 2 feet in southern Greenwood County to 23 feet in Atchison County; in southern Kansas the member is commonly 15 to 20 feet thick.

Heebner shale member.—In many outcrops this member consists of four distinct shale units which are, in descending order: calcareous clay shale, dark bluish-gray shale, black platy shale, and a thin bed of gray or yellow clay shale. The black platy shale is almost everywhere the thickest part, but is commonly less than 3 feet. Small brachiopods occur in the upper part, conodonts are found in the black shale, and locally there are numerous gastropods in the thin film of clay at the base of the member. The thickness of the Heebner shale across Kansas is very constant, ranging from 5 to 7 feet. It is also a widely distributed marker in the subsurface, which is identified in radioactivity logs by its very strong gamma ray emanations.

Leavenworth limestone member.—A dark bluish-gray, dense, massive limestone occurring in a single bed having prominent vertical joints. Fusulines and brachiopods are the most common fossils. Almost everywhere across Kansas the thickness is more than 1 and less than 2 feet.

Snyderville shale member.—Gray and bluish-gray clay and in part red shale. In northern Kansas, it is largely a structureless underclay-like deposit; in southern Kansas, it is partly red and sandy and locally contains sandstone and impure nodular limestone. Marine fossils especially *Chonetes* occur in the uppermost part; in southern Kansas other zones are also fossiliferous. The thickness in the northern part of the State averages about 12 feet, but it increases to about 75 feet in southern Kansas.

Toronto limestone member.—Brownish-gray massive limestone that weathers deep brown. Locally flinty or algal limestone occurs in the upper part. The Toronto is typically developed from Woodson County northward but is thinner and sandy or locally absent in southern Kansas. The member is absent also in part of southern Douglas County, where a limestone conglomerate occupies its approximate stratigraphic position. Fusulines, corals, and small brachiopods are the most common fossils. The thickness of the Toronto in northern Kansas ranges from 8 to 12 feet; in southern Kansas it is generally less than 4 feet.

DOUGLAS GROUP.—The Douglas group underlies the Shawnee group conformably, except possibly in southern Douglas County. It comprises chiefly clastic rocks, shale, and sandstone. Limestone, coal, and conglomerates are quantitatively of minor importance. The thickness is approximately 250 feet.

Lawrence shale.—Blue-gray and yellowish shale, tan-colored sandstone, and a minor amount of coal, limestone, and conglomerate comprise

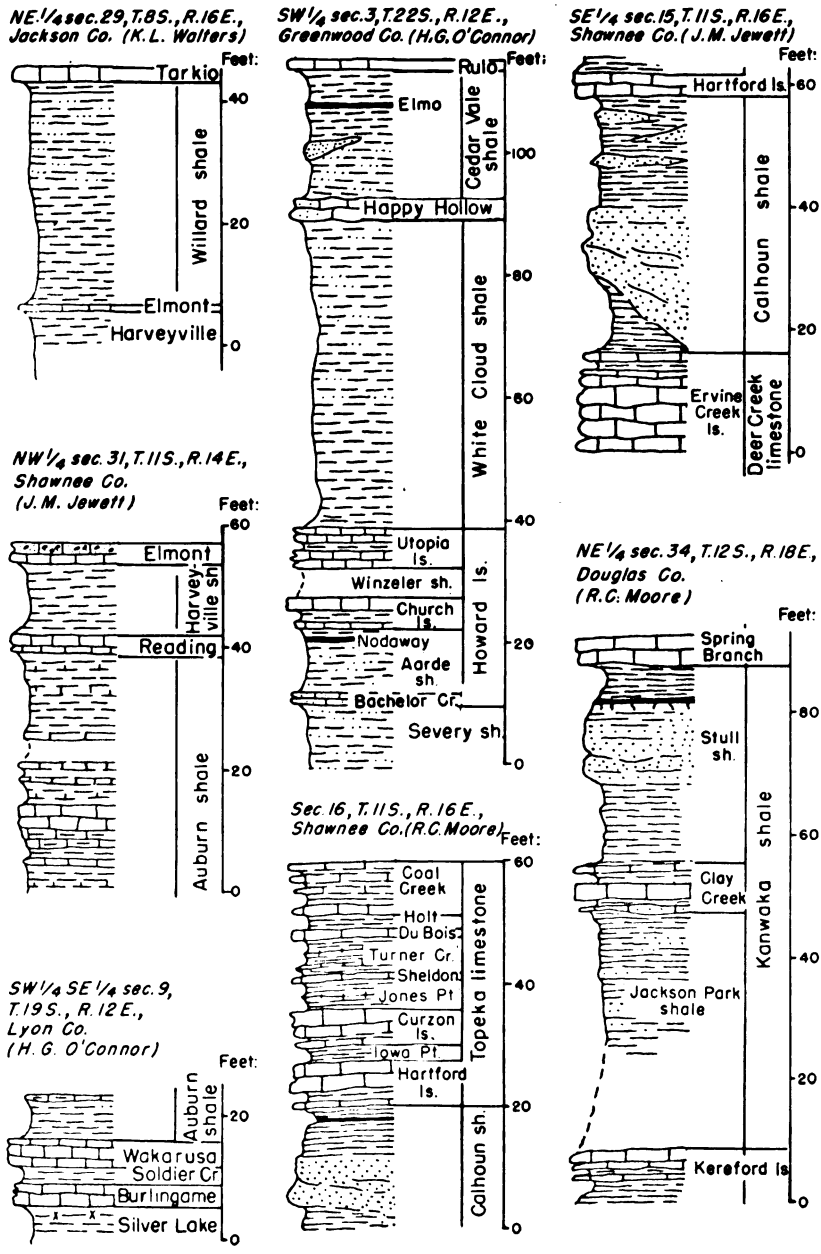

Fig. 25.—Selected stratigraphic sections of Wabaunsee and Shawnee rocks.

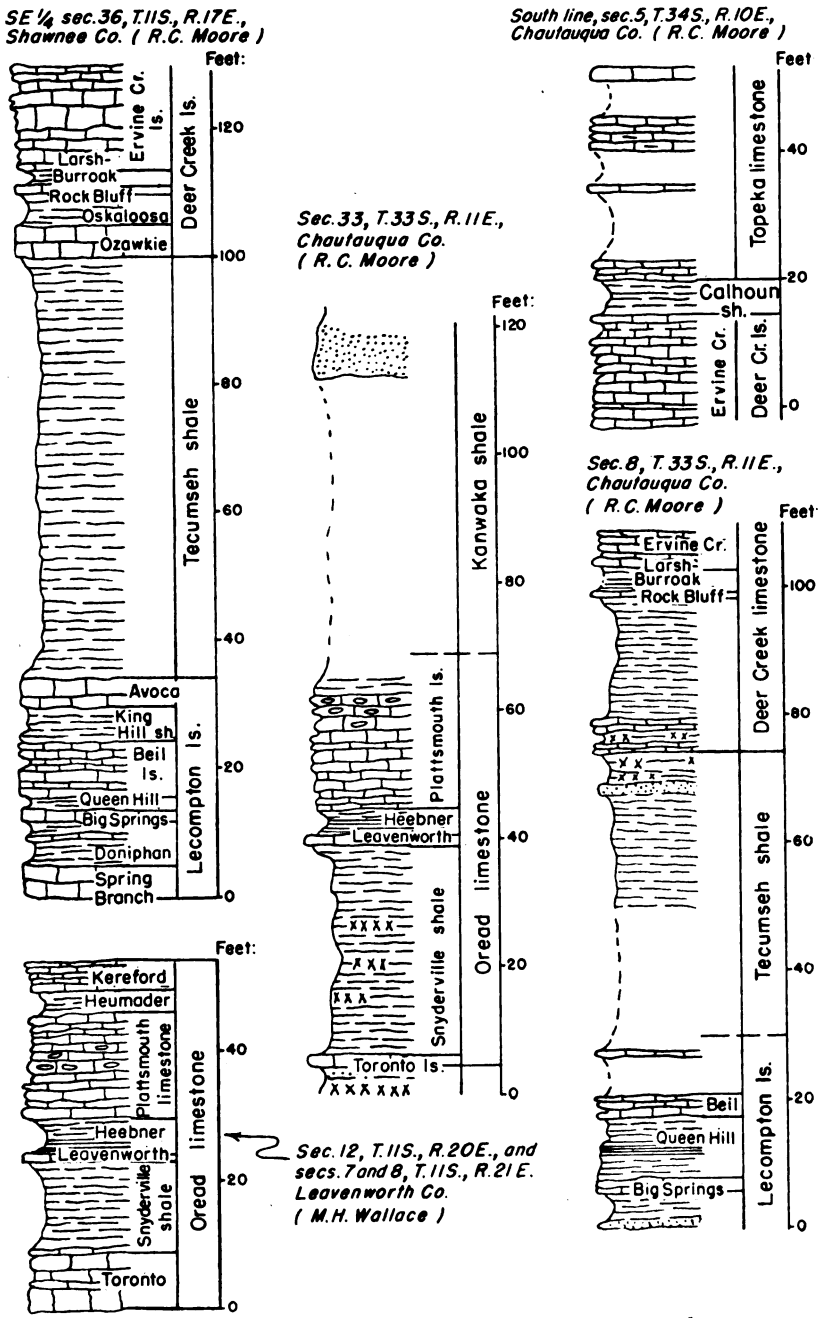

Fig. 26.—Selected stratigraphic sections of Shawnee rocks.

the Lawrence shale. The formation extends from the base of the Toronto limestone to the disconformity below the Ireland sandstone or, in places where the disconformity is undeterminable, to the top of the Haskell limestone. Except for members known as the Amazonia limestone and Ireland sandstone, which are somewhat impersistent, the Lawrence shale is not subdivided. The thickness ranges from about 40 to 175 feet.

Amazonia limestone member.—This is typically a light-gray, dense, hard limestone occurring about 25 or 30 feet below the top of the Lawrence shale. Locally it is partly coquinoid or brecciated in appearance. Outcrops are found in Doniphan, Atchison, Franklin, Coffey, and Woodson Counties and possibly farther south. In Franklin County and vicinity, the Amazonia occurs a few feet below the **Williamsburg coal,** which is mined at several places. Sponges are locally common in the member (Atchison County) and fusulines occur in limestone that may be Amazonia in southern Kansas. Fossils are not abundant generally. Thickness ranges from a featheredge to about 13 feet. In the southern outcrop area it averages about 1.5 feet.

Ireland sandstone member.—Light-buff or tan thin-bedded and massive sandstone, in part cross-bedded. Where thickest, the sandstone lies above a disconformity, which is identified in many places but seemingly is not continuous. In some places, especially where the Ireland cuts out the Haskell limestone and still lower beds, a limestone conglomerate is found at the base of the sandstone. The upper boundary is somewhat indefinite, because much sandy shale and thin-bedded sandstone occur in the upper part of the Lawrence shale. Local coal beds are associated with these sandy sediments. In Woodson County, the top of the Ireland sandstone is only a few feet below the Amazonia limestone. The thickness of the Ireland sandstone ranges from a featheredge to 100 feet or more.

Stranger formation.—Light-tan to yellowish-gray sandstone and shale and a minor amount of limestone, coal, and conglomerate. Thickness ranges from 40 to 220 feet.

Robbins shale member.—Gray and yellowish-gray marine shale, locally cut out and overlapped by the Ireland sandstone in Franklin County and the southern part of Douglas County. This member is essentially restricted to areas southward from Woodson County. Phosphatic concretions occur in a zone at the base in the northern part of the outcrop area. Thickness ranges from a featheredge to 110 feet.

Haskell limestone member.—Bluish-gray fine-grained limestone, locally having oölitic layers at the top and base. Pelecypods and gastropods occur in the oölitic facies. The main part bears algal remains, fusulines, and brachiopods. In parts of Douglas and Franklin Counties, the Haskell limestone is cut out and overlapped by Ireland sandstone. The thickness ranges from a featheredge to about 10 feet.

Vinland shale member.—Gray, clayey, calcareous, and sandy shale and locally some sandstone underlying the Haskell is named the Vinland shale. Locally in Woodson County, a dark-green layer occurs in the middle part. North of Anderson and Coffey Counties, where the

Westphalia limestone is absent, the top of the Upper Sibley coal is regarded as marking the base of the Vinland shale. A disconformity beneath a sandstone at the base of the Vinland cuts out the Westphalia limestone locally in Coffey County. The thickness of the Vinland shale member ranges from about 9 to 50 feet.

Westphalia limestone member.—A limestone characterized by abundant fusulines; not definitely recognized north of T. 19 S., but fairly persistent in southern Kansas. A limestone slightly above the Upper Sibley coal in Douglas and Leavenworth Counties probably represents this limestone. The thickness of the member ranges from a featheredge to about 5 feet.

Tonganoxie sandstone member.—Massive cross-bedded sandstone and sandy shale, containing several discontinuous coal beds, form the lower part of the Stranger formation in most places. The **Upper** and **Lower Sibley coals**, in the northern part of the outcrop area, are the most important coal beds of the unit. The top of the Tonganoxie member is rather indefinite, but in general the base of the Westphalia limestone or the top of the Upper Sibley coal bed is defined as the boundary. Locally, limestone conglomerate occurs at the base. Like the Ireland sandstone, the Tonganoxie is more massive and is thicker in southern Kansas, where the two sandstones form the Chautauqua Hills escarpment. The thickness ranges from a featheredge to 90 feet.

A disconformity below the Tonganoxie sandstone brings deposits classified as lowermost Virgilian into contact with rocks ranging downward from the Iatan limestone, or perhaps a little higher, at least to the lower part of the Stanton limestone. Paleontological evidence indicating a significant hiatus in sedimentation and evidence of widespread, though not great, erosion support placement of the Missourian-Virgilian boundary in this position. The disconformity is obscure in the northern midcontinent area but it corresponds to the prominent nonconformity in southern Oklahoma that records erosion of mountains formed by the Arbuckle orogeny.

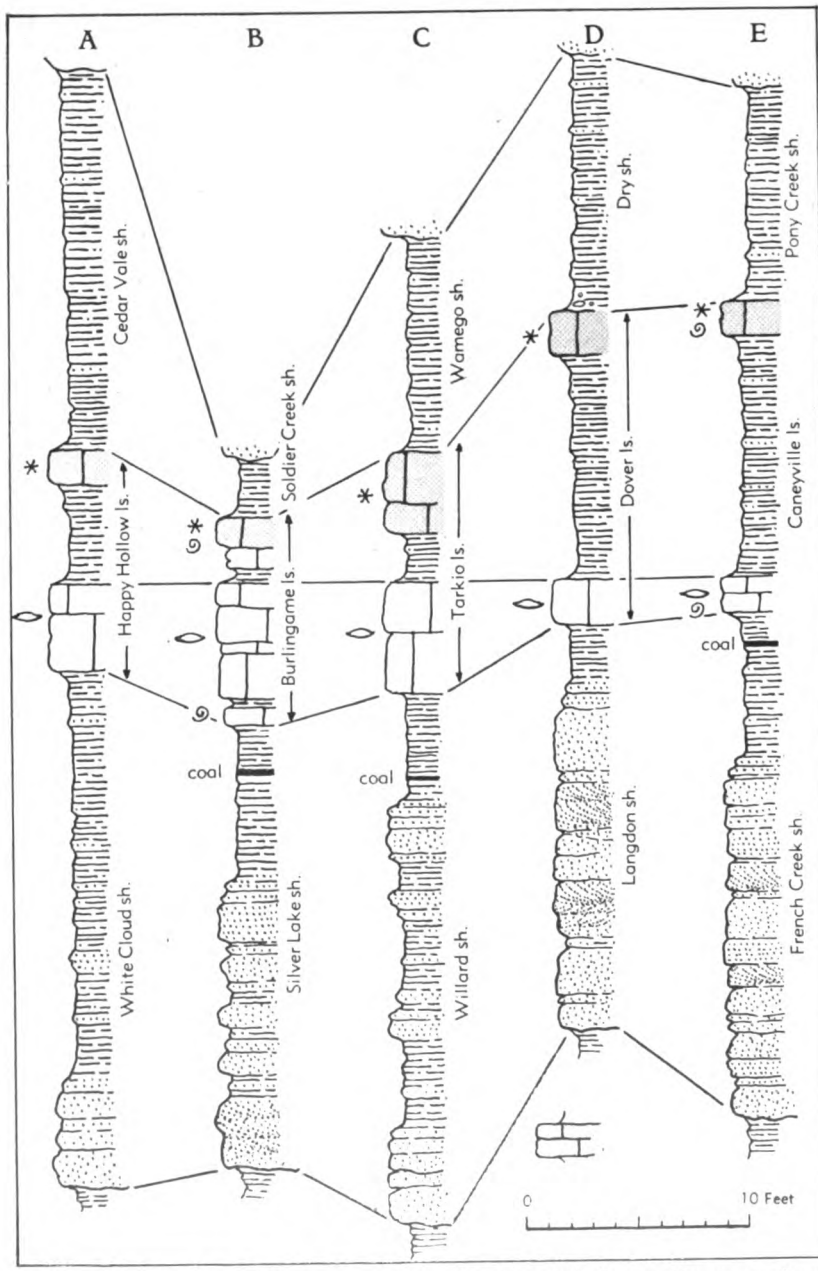

Fig. 27.—**Sections of Wabaunsee beds showing cyclothems.** Corresponding phases of the cyclothems are correlated. The stratigraphic position of the cyclothems is indicated in the general section at right in Figure 28. Algal-molluscan limesone beds are shaded. Refer to Figure 21 for explanation of fossil symbols.

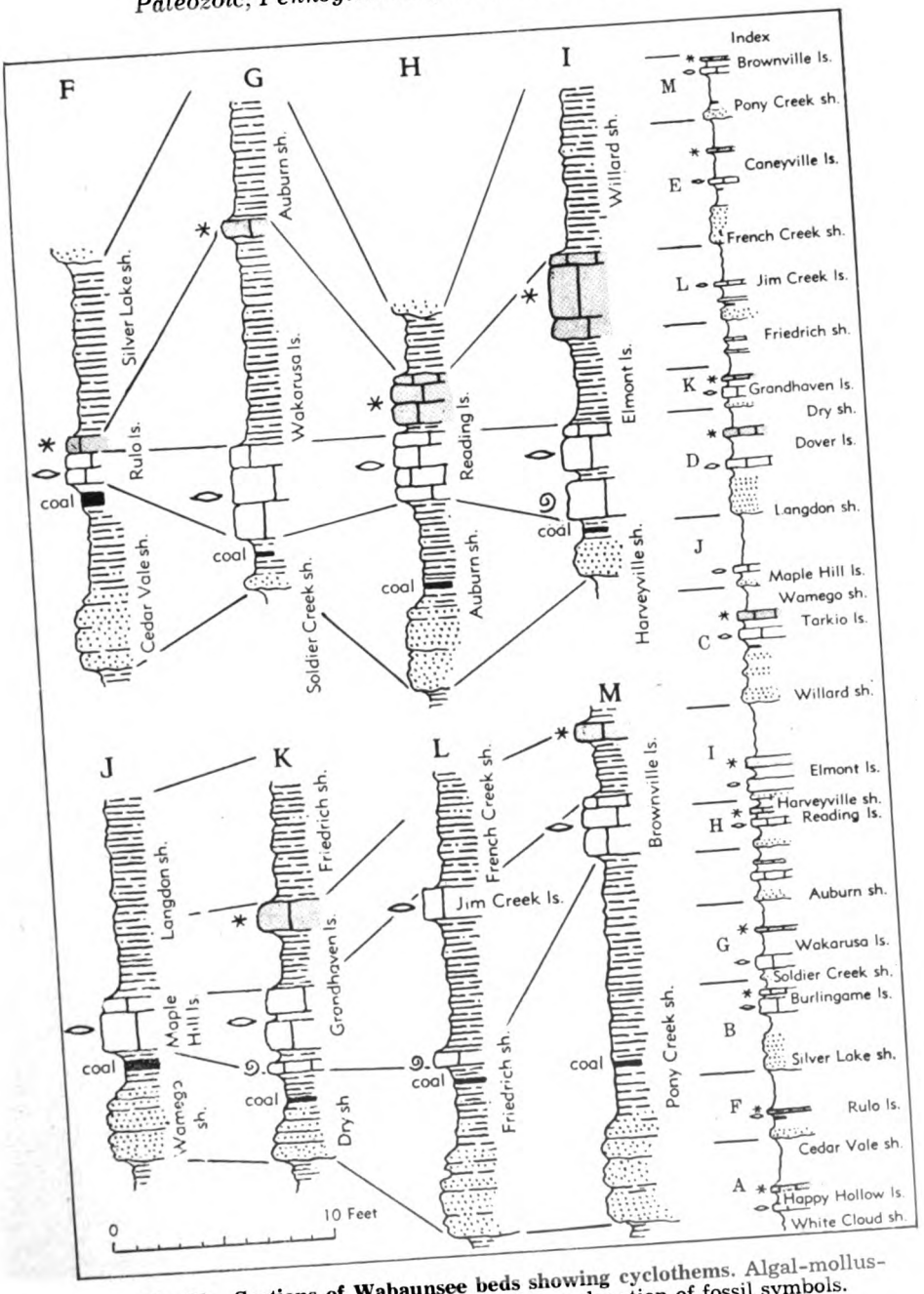

Fig. 28.—Sections of Wabaunsee beds showing cyclothems. Algal-mollusican beds are shaded. Refer to Figure 21 for explanation of fossil symbols.

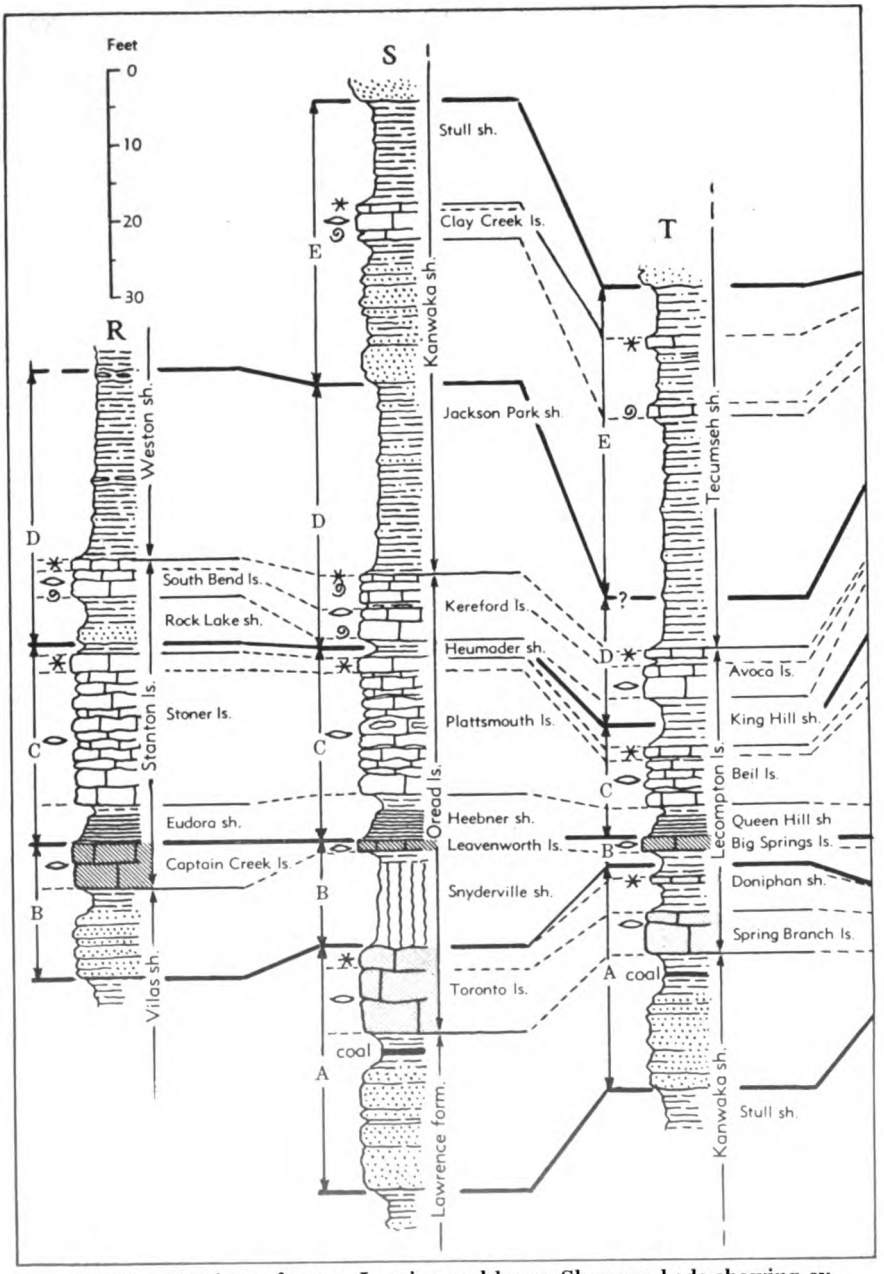

Fig. 29.—Sections of upper Lansing and lower Shawnee beds showing cyclothems and megacyclothems. The cyclothems are indicated by the letters A-E. Megacyclothems include the entire sequence of beds in any one of the three plotted sections, R, S, T. Stratigraphic position of the sequences is indicated on the general section at right in Figure 30. Refer to Figure 21 for explanation of fossil symbols.

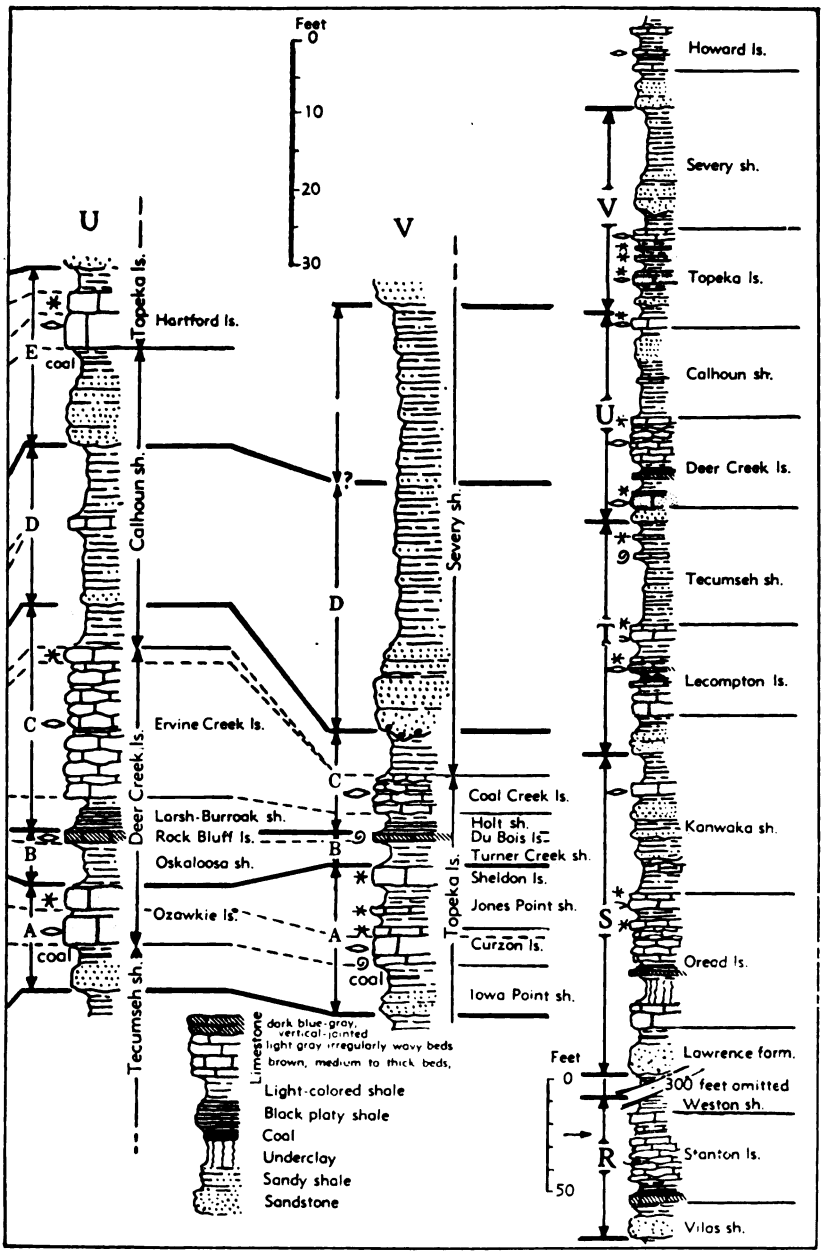

Fig. 30.—Sections of upper Shawnee beds showing cyclothems and megacyclothems. These units are differentiated as explained in description of Figure 29. Refer to Figure 21 for explanation of fossil symbols.

Missourian Series

Upper Pennsylvanian rocks of Kansas, classed as belonging to the Missourian Series, lie between two regional disconformities that form boundaries between this division and adjoining strata. The Missourian deposits are essentially distinguished by paleontologic characters and to some extent by peculiarities of cyclic sedimentation. The outcrop area of this series in Kansas is a 20- to 40-mile wide belt, marked by fairly strong east-facing escarpments, extending from Doniphan County in the northeast to Montgomery County in the south. The thickness is about 700 feet.

PEDEE GROUP.—This topmost division of the Missourian rocks includes the Weston shale below, the Iatan limestone above, and possibly a few feet of sandy and clayey shale above the Iatan limestone. These beds, occurring between the Stanton limestone and the disconformity that defines the top of the Missourian Series, are classified as a separate group, because the conformably underlying Lansing group is a compact unit consisting mainly of limestone. Average thickness is 90 feet.

Iatan limestone.—Light bluish-gray or nearly white limestone. The texture is very fine and dense, but there are numerous thin, irregular plates of clear calcite. Fossil remains are not abundant, but fusulines, brachiopods, bryozoans, crinoid fragments, and small corals are somewhat common locally; algal remains are abundant in the upper part at many places. The formation is extensive in northeastern Kansas but is cut out by the post-Missourian disconformity near Leavenworth and southward at least to the vicinity of southern Douglas County. The thickness ranges from about 4 to 22 feet.

Weston shale.—Dark bluish to bluish-gray clay shale, generally unfossiliferous but containing thin fossiliferous limestone beds locally. There are some beds of shaly and even-bedded sandstone toward the south. In many places the formation is characterized by flattish, elliptical concretions of ironstone. At many places the post-Missourian disconformity has cut out most or all the Weston shale. The thickness ranges from a feather-edge to 200 feet.

LANSING GROUP.—This part of the Missourian includes a rather compact assemblage of two limestones and a thin shale formation. It makes an escarpment that is traced readily across Kansas. The group is recognizable in the subsurface of the eastern and central parts of the State, but in western Kansas it is clearly separable from underlying Kansas City beds. The thickness averages about 85 feet.

Stanton limestone.—Three limestone and two shale members. In northeastern Kansas the formation is rather uniform in character and thickness, but in east-central and southern Kansas there are great local variations. Near the Oklahoma-Kansas boundary, the Stanton is difficult to trace. The thickness of the formation ranges from about 10 to 90 feet. The characteristic thickness is about 42 feet.

South Bend limestone member.—The topmost division of the Stanton is composed of dark-gray fine-grained limestone. The lower part is

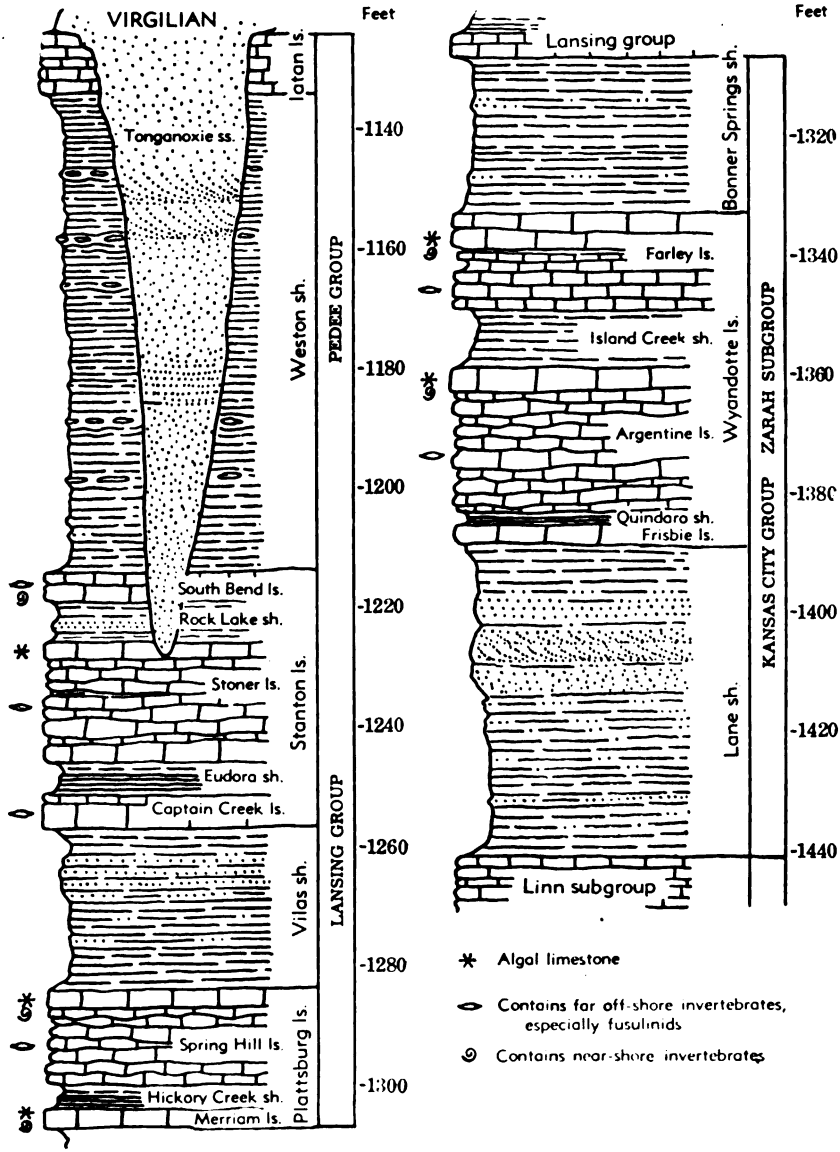

Fig. 31.—Missourian (Pedee, Lansing, and Kansas City) rocks in Kansas.

sandy and locally contains some sandy shale. Fusulines and the brachiopod *Meekella* are the most common fossils. The thickness is rather constantly about 5 feet.

Rock Lake shale member.—Chiefly sandy shale and soft buff sandstone, and commonly a thin layer of greenish or gray clay shale in the lower part. In Anderson County the Rock Lake member locally contains an assemblage of well-preserved land plants, including *Walchia*, mixed with remains of amphibians, fishes, a scorpion, and marine invertebrates. The sandstone is generally even-bedded or massive, and contains marine fossils, mostly mollusks. Locally a disconformity at base. The thickness ranges from about 1 to 15 feet.

Stoner limestone member.—Light bluish-gray to nearly white, mostly thin wavy-bedded limestone having thin shale partings between the layers. The rock is fine-grained, but locally there is much crystalline calcite. It is generally sparingly fossiliferous, but to the north it contains abundant *Triticites*. This limestone makes a rather prominent escarpment in Kansas. It ranges in thickness from 11 to 40 feet.

Eudora shale member.—Dark-gray and black fissile shale in the lower part and greenish-gray to bluish-gray clay shale in the upper part. Abundantly fossiliferous in northern Kansas but barren of megascopic fossils in northeastern Kansas. Thickness is locally 1 or 2 feet in some northern exposures and as much as 50 feet in part of Montgomery County.

Captain Creek limestone member.—Dark to bluish-gray, granular or dense, brittle limestone. It is massive or even-bedded and in most places shows vertical joints. The upper few inches in some exposures is a brecciated silicified mottled pink and gray bed. The brachiopod *Enteletes pugnoides* is abundant and the fusuline *Triticites neglectus* occurs commonly on bedding planes. Characteristic thicknesses along Kansas River range from 4.5 to 5.5 feet. Locally in Miami County it is a little more than 10 feet thick, and near Independence, in Montgomery County, limestone 55 feet thick has been assigned to this member.

Vilas shale.—Gray to buff clayey and sandy shale, sparsely fossiliferous. Locally along Kansas River, hard gray ripple-marked sandstone occurs in the upper part and farther south a considerable thickness of reddish-brown soft sandstone is found in some exposures. The thickness in the Kansas River Valley and northward is about 15 feet, but to the south the thickness locally increases to 90 feet.

Plattsburg limestone.—Two limestone members separated by a shale member. The upper limestone is the most prominent, except locally as in eastern Franklin County. The thickness of the formation ranges from a a featheredge to more than 100 feet at a few places in southern Kansas. The formation disappears near the Oklahoma line, but seemingly reappears farther south and is represented in the upper part of the Ochelata group. Average thickness of the Plattsburg limestone in Kansas is about 23 feet.

Spring Hill limestone member.—Bluish-gray, fine-grained, brittle, thin-bedded limestone in the lower part and light-gray algal (oölitic) or granular limestone in the upper part. Characteristic fossils include algal remains, several species of sponges, echinoid spines, and the brachiopods *Marginifera, Enteletes,* a robust *Composita, Neospirifer,* and *Isogramma.* The thickness ranges from 8 to 50 feet or more but commonly is about 15 feet.

Hickory Creek shale member.—Gray, green, and black shale. Where thin (0.5 to 2 feet), this member contains a black carbonaceous zone, and where thick (to 15 feet), it is mostly gray or yellowish in color and is clayey. Fossils are rare or lacking in this shale. The thickness in many places is less than 1 foot but about 5 feet is more common.

Merriam limestone member.—Commonly the lower part of this member is drab or light-gray limestone and the upper part is bluish-gray fine-grained limestone. Locally, because of accumulation of algal and granular limestone in the uppermost part, the Merriam is thicker than the overlying Spring Hill limestone. Numerous productids and a few other brachiopods are characteristic. Several species of nautiloid cephalopods are found in Franklin County where the member contains much algal (oölitic) limestone. The thickness ranges from less than 1 foot to about 10 feet (eastern Franklin County).

KANSAS CITY GROUP.—As now defined, the Kansas City group includes strata from the base of the Hertha limestone to the base of the Plattsburg limestone. Three subgroups are recognized. The Kansas City group is about 350 feet thick in the latitude of Iola and about 325 feet thick in the Kansas City area.

ZARAH SUBGROUP.—The upper part of the Kansas City group, comprising approximately one-third of the section, is designated as the Zarah subgroup. It includes beds between the top of the Iola formation and base of the Plattsburg formation. Near Kansas City, this interval is mainly characterized by prominent limestone members of the Wyandotte formation, occurring between the relatively thin Lane shale and Bonner Springs shale, which comprise the lower and upper parts of the subgroup, respectively. The thickness of subdivisions varies greatly from place to place. Average thickness of the subgroup in Kansas is about 100 feet.

Bonner Springs shale.—This formation consists of gray to buff shale, sandy shale, and sandstone. The upper part of the shale consists of olive-green clay shale containing a maroon band near the top in the northern part of the outcrop area. Soft, nodular, cavernous limestone commonly overlies the maroon shale. Sandstone is rather prevalent in the lower part of the Bonner Springs shale, and in some exposures it occupies definite channels cut in clay shale. Southward from southeastern Franklin County where the underlying Wyandotte limestone disappears, the Bonner Springs shale rests directly on Lane shale, and beds between the Iola and Plattsburg limestones are designated as **Lane-Bonner Springs shale.** The thickness of the Lane-Bonner Springs ranges from 55 to 170 feet. Locally along Kansas River, the Bonner Springs shale is absent; the maximum observed thickness is 60 feet in T. 17 S., R. 20 E.

Wyandotte limestone.—Three limestone and two shale members. The lower two limestones and their separating shale are are more constant in lithologic character and thickness, but the entire formation, which is prominent in northeastern Kansas and especially along Kansas River, disappears a short distance southwest of Lane in southeastern Franklin County. It reappears as thin limestone and sandstone beds a few miles north of Garnett in Anderson County, but can be identified for only a few miles. The thickness ranges from a featheredge to 75 feet.

Farley limestone member.—This member comprises an extremely variable assemblage of limestone and shale beds that is recognized only north of T. 14 S. Many types of limestone are represented, but oölitic-appearing algal limestone, limestone breccia or conglomerate, and dense mottled pinkish-gray limestone are characteristic. A thin bed of dark greenish-gray sandy shale containing a molluscan fauna occurs rather persistently in the middle part. Cross bedding is common, both in algal limestone and in breccia. The algal and oölitic facies commonly occur in massive beds; the breccias and conglomerates are slabby. Wavy and thin-bedded, mottled, dense limestone, chiefly in the lower part, is somewhat similar to the main body of the underlying Argentine limestone. The Farley limestone is abundantly fossiliferous, mollusks predominating. The relative quantitative importance of limestone and shale in this member varies from place to place. Thickness ranges from a featheredge to about 35 feet.

Island Creek shale member.—A gray, yellow, and bluish clay shale of highly variable thickness. Locally in Wyandotte County, several feet of sandstone, seemingly a channel filling, occupies this position. The thickness ranges from a featheredge to about 40 feet.

Argentine limestone member.—This is a prominent escarpment-making light bluish-gray limestone, much of which weathers creamy white. Wavy bedding is common; clay partings are numerous in some outcrops. Marine fossils are plentiful. The thickness ranges from a featheredge to 35 feet.

Quindaro shale member.—Black fissile yellowish-gray calcareous shale or soft shaly limestone, 1 to 4 feet thick

Frisbie limestone member.—Bluish-gray to dark-blue massive limestone, locally bearing numerous marine fossils. The thickness commonly ranges from 1 to 3 feet.

Lane shale.—Dark bluish-gray clay shale, commonly containing rather abundant marine fossils; gray and yellowish-brown unfossiliferous sandy shale, and thin-bedded sandstone. The thickness ranges from about 15 to 105 feet. Southward from the point where the Wyandotte limestone pinches out, the Lane and Bonner Springs shales merge. The thickness of the combined units (Lane-Bonner Springs shale) ranges from about 55 feet to 170 feet locally in Allen County. Average thickness of the Lane shale is about 50 feet.

LINN SUBGROUP.—Named from prominent outcrops in western Linn County, the middle division of the Kansas City group is designated Linn subgroup. It comprises strata from the top of the Iola formation to the top of the

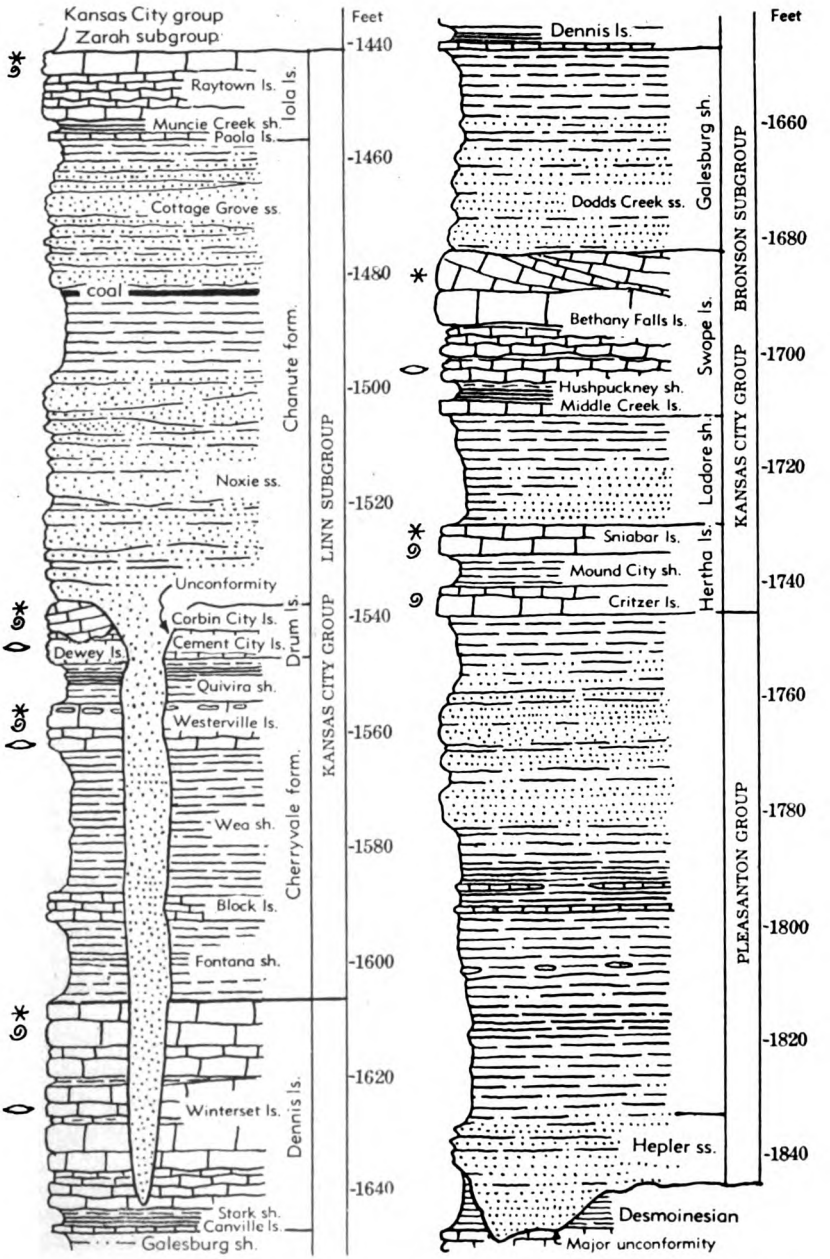

Fig. 32.—Missourian (Kansas City and Pleasanton) rocks in Kansas. Refer to Figure 31 for explanation of fossil symbols.

Dennis limestone. These deposits are well defined in all parts of the outcrop area except locally in parts of southern Kansas where a disconformity at or near the base of the Chanute shale brings upper Zarah deposits in contact with beds as low as the basal part of the Dennis formation. The subgroup is characterized by relative prominence of shales, persistent limestones, and locally much sandstone. The average thickness is about 110 feet.

Iola limestone.—Two limestone members and a shale member. The upper limestone is the most conspicuous part of the formation. The thickness ranges from a featheredge along the Kansas-Oklahoma line and locally elsewhere in southern Kansas to about 30 feet in Allen County. In northeastern Kansas the thickness commonly is about 7.5 feet.

Raytown limestone member.—Light-gray wavy-bedded limestone throughout much of the outcrop area; dark-gray to buff more massively bedded limestone in the Kansas River Valley, where abundant light-colored large fossil shells give the rock a mottled appearance. Deposits of algal and crinoidal material ranging in thickness from a mere crust, as in the Kansas City area, to several feet in Allen County, occur commonly in the upper part of the member. The thickness in the Kansas City area is about 5 feet, in Miami County 6 feet, and in the vicinity of Iola 28 feet. It thins southward from Allen County and is absent locally in southern Kansas, but reappears in northern Oklahoma where it is named the Avant limestone.

Muncie Creek shale member.—Black fissile shale overlain by gray or buff shale containing abundant phosphatic nodules. The thickness commonly ranges from about 1 to 3 feet.

Paola limestone member.—Dark bluish-gray, massive-bedded, brittle, vertical-jointed limestone that weathers bluish-gray. "Worm borings," which are irregular subcylindrical bodies that differ slightly in color and texture from surrounding rock matrix, are more or less characteristic. The thickness ranges from a featheredge to about 2 feet.

Chanute shale.—Yellowish-brown sandy shale and dark-gray to greenish shale, sandstone, and one coal bed. The sandy shale and sandstone occur chiefly in the upper part, above the coal bed. Members have been differentiated in southern Kansas but are not distinguished north of Allen County. The thickness of the Chanute shale ranges from 12 feet near Kansas City to 165 feet in southern Kansas.

Cottage Grove sandstone member.—Yellowish-brown or tan thin-bedded to massive sandstone makes up the upper one-third to one-half of the Chanute shale in southeastern Kansas, but this sandstone occurs only locally in northeastern Kansas. Thickness ranges from a featheredge to 60 feet.

UNNAMED CLAY SHALE, locally calcareous and nodular or sandy, occurs in the lower middle part of the Chanute shale. The persistent **Thayer coal,** or a thin bed of underclay, is commonly found at the top of this shale, next below the Cottage Grove sandstone. The Thayer coal ranges in thickness from less than an inch to 2.5 feet. The unnamed shale is

10 to 75 feet thick, the maximum being observed in places where the Noxie sandstone is absent.

Noxie sandstone member.—Sandstone at the base of the Chanute shale, commonly filling channels that extend as low as the Stark shale or perhaps lower, is known as the Noxie sandstone member. Locally a limestone conglomerate occurs at the base. This member of the Chanute is recognized only in south-central and southern Kansas where the thickness locally reaches 100 feet.

The disconformity at the base of the Noxie sandstone is recognized at many places in southern Kansas, especially from T. 28 S. southward.

Drum limestone.—Two limestone members locally separated by a thin shale. The thickness ranges from a featheredge to about 60 feet. Throughout most of the outcrop area, however, the formation is less than 10 feet thick.

Corbin City limestone member.—Chiefly light-gray oölitic cross-bedded limestone that is highly fossiliferous. This member is best developed in the vicinity of Independence, where it is 50 feet or more thick. It is represented by a few feet of limestone conglomerate in southern Kansas near Coffeyville and by 1 foot or less of chiefly algal limestone in the Kansas City area. Fossils are abundant in the thick oölitic facies. A few inches of shale that lies between these two limestones at some exposures is included with the Corbin City member. In southern Kansas, the Corbin City limestone rests disconformably on the Dewey limestone. In the vicinity of Cherryvale in Montgomery County the oölitic limestone of the upper member fills hollows nearly 5 feet deep in the lower limestone.

Dewey limestone member.—Bluish-gray limestone, mottled with brown on weathering, commonly fine-grained or dense, and more or less massive, comprises the Dewey limestone. Marine fossils are generally abundant. A horn coral, identified as *Caninia torquia,* is characteristic of the upper part of this limestone in northeastern Kansas. The thickness ranges from about 2 to 10 feet.

Cherryvale shale.—The Cherryvale shale comprises beds between the base of the Drum limestone and the top of the Dennis limestone, uppermost formation in the Bronson subgroup. At its type locality near Cherryvale, Montgomery County, this section consists almost entirely of bluish-gray clayey to silty shale, or in near-by exposures there are numerous beds of dense blue-gray limestone in the upper part; still farther south in the vicinity of Coffeyville similar limestone beds occur in the lower part. None of the members of the formation, with probable exception of the Block limestone and underlying Fontana shale, are differentiated in southern Kansas. Farther north, the formation is divided into members: Quivira shale, Westerville limestone, Wea shale, Block limestone, and Fontana shale. The thickness of the formation is commonly about 60 feet.

Quivira shale member.—This unit consists chiefly of olive-green clay shale having generally about 1 foot of black or maroon shale in the basal or middle part. Small brachiopods occur in the black facies,

The thickness ranges from 3 to 11 feet. The Quivira shale is differentiated only in northeastern Kansas, from Miami County northward.

Westerville limestone member.—A persistent unit northward from Miami County, but variable in lithology. Cross-bedded oölite is characteristic in the Kansas City area; accordingly, this limestone has been designated frequently as the "Kansas City oölite." Flint or chert, which is light pink and hence differs from other Pennsylvanian cherts, comprises 50 percent or more of the rock in some outcrops. The thickness ranges from less than a foot to 16 feet.

Wea shale member.—Chiefly olive-green clay shale containing a persistent thin zone of maroon silty shale in the upper part. For about 50 miles south of the place in Miami County where the Westerville limestone pinches out, strata between the Block and Drum limestones are termed **Wea-Quivira shale.** This combined unit is 30 to 85 feet thick. The thickness of the Wea, where it can be differentiated, ranges from about 15 to 35 feet.

Block limestone member.—Bluish-gray fine-grained, hard limestone. The rock is commonly massive and displays vertical jointing, but locally it is thin-bedded. In the Kansas City area, the unit is represented by thin blue limestone beds separated by shale. Fusulines are generally common, and locally *Marginifera wabashensis* is abundant. The Block limestone has not been identified definitely south of Linn County, but seemingly is well developed in Montgomery County. Observed thickness ranges from about 3 to 8 feet.

Fontana shale member.—Greenish-gray to buff shale bearing scattered calcareous nodules is defined under the name Fontana northward from Linn County. In southern Kansas, where the Block limestone is tentatively identified, the underlying shale is probably equivalent to the Fontana member. The Fontana shale ranges in thickness from about 5 to 25 feet.

BRONSON SUBGROUP.—A lower division of the Kansas City group, called Bronson subgroup, comprises strata from the top of the Dennis limestone to the base of the Hertha formation. Except in southern Kansas, where the Galesburg and Ladore shales are thick and limestones are thin or lacking, the subgroup is characterized by dominance of limestones which form a prominent escarpment. Total thickness of the Bronson beds ranges from about 85 feet in the Kansas City area to about 175 feet in southern Kansas.

Dennis limestone.—The uppermost formation of the Bronson subgroup contains two limestone members and a shale member. The capping limestone forms a long dip slope that terminates eastward at the prominent Bronson escarpment. In Oklahoma, this formation is known as the Hogshooter limestone. The thickness of the Dennis ranges from 2 feet in parts of Neosho County, where it is largely removed by pre-Chanute erosion, to 60 feet in northeastern Labette County.

Winterset limestone member.—Light bluish-gray and light-gray limestone characterized by abundant flint. In the Kansas River area, the flint is almost black, but elsewhere it is light gray. Along much of the outcrop belt, cross-bedded oölite occurs in the upper part of

the Winterset and there is much light-gray thin-bedded limestone having a brecciated appearance. Black platy shale containing land plant remains occurs in the middle part of the member in northern outcrops and calcareous gray shale occupies the same position in southern Kansas. Marine invertebrates are more or less abundant in various zones; in places there are well-preserved molluscan faunas. Locally in Neosho County, the Winterset limestone and possibly lower beds are cut out by the disconformity at the base of the Chanute shale. The thickness ranges from a featheredge to about 50 feet.

Stark shale member.—Chiefly black shale but containing some gray and yellow shale in the upper part. The member is recognized only locally in Montgomery County and neighboring parts of Oklahoma but becomes persistent northward from northwestern Labette County. The normal thickness is about 3 feet.

Canville limestone member.—Medium dark-gray dense to granular limestone, commonly massive but locally platy or slabby. This limestone is persistent from northwestern Labette County to Linn County. It is represented in parts of Montgomery County by about 1 foot of dark bluish-gray vertical-jointed limestone, and it reappears locally in Oklahoma. Thickness ranges from a featheredge to about 2 feet .

Galesburg shale.—Gray and yellow marine shale, sandy nonmarine shale, sandstone, and a little coal. Probably some of the sandy shale and sandstone is marine. In the Kansas River Valley, the unit is about 3 feet thick and comprises calcareous nodular shale that is clearly distinguished by its light color and other lithologic features from the overlying black Stark shale. The thickness increases rather abruptly southward from Bourbon County and much sandstone is present in Neosho, Labette, and Montgomery Counties. Plant fossils are fairly common in the sandy facies. Southward from the point where the Swope limestone disappears, a few miles north of the Oklahoma line, the Galesburg is not separable as a unit and it forms the upper part of the **Coffeyville formation.** The thickness of the Galesburg shale ranges from 3 to 75 feet .

Dodds Creek sandstone member.—Massive to thin-bedded sandstone, seemingly of deltaic origin, which occurs in the Galesburg shale in southern Kansas, is named the Dodds Creek sandstone member. The thickness of this subdivision is as much as 40 feet.

Swope limestone.—Two limestone members and a shale member. The upper limestone is the most persistent, but it is not recognized southward from eastern Montgomery County (northern part of T. 34 S.). The thickness ranges from a featheredge to about 35 feet.

Bethany Falls limestone member.—Light-gray, dense, thin-bedded limestone overlain by mottled gray, massive, algal limestone or by nearly white oölitic limestone that is commonly cross-bedded. Fossils are more or less common in the lower thin-bedded part. The thickness of the thin-bedded division ranges from 1 to 20 feet and that of the massive division from 7 to 15 feet. The total thickness ranges from about 12 to 30 feet.

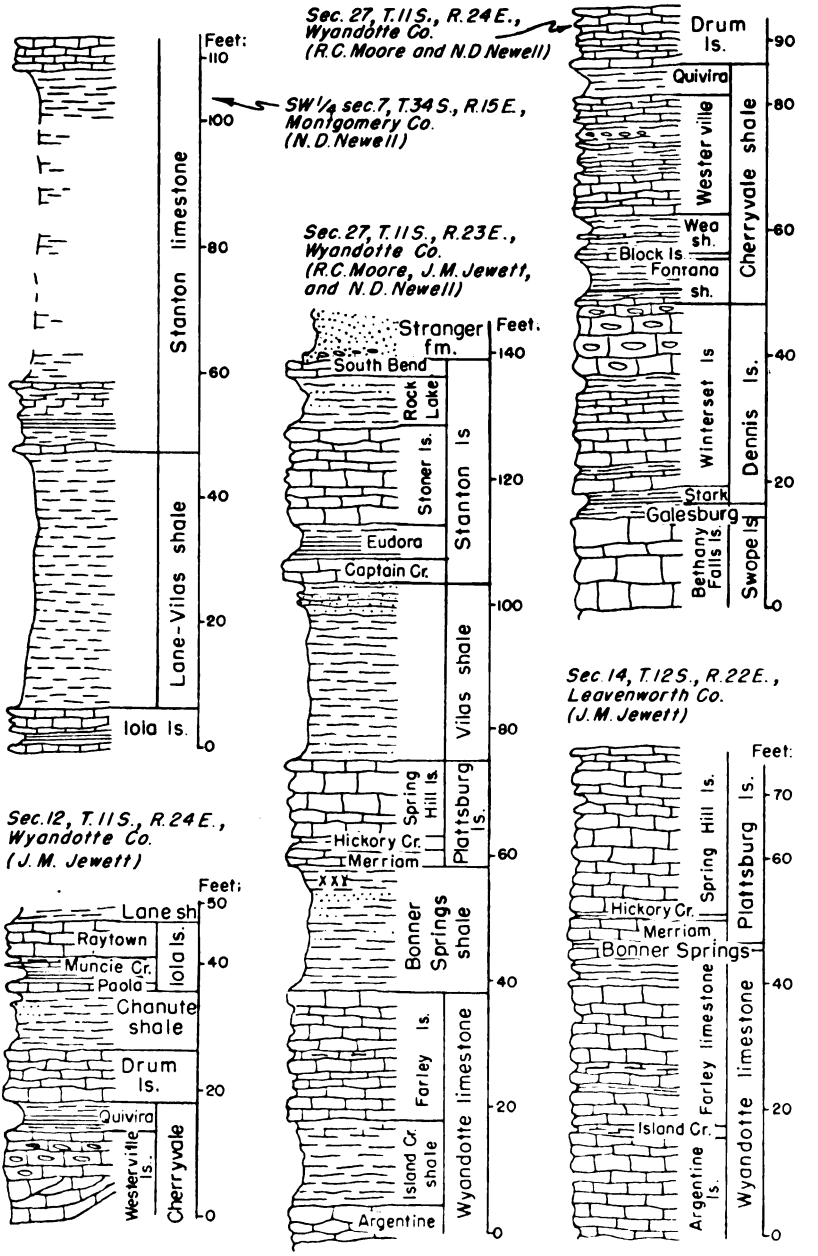

Fig 33.—Selected stratigraphic sections of Lansing and Kansas City rocks.

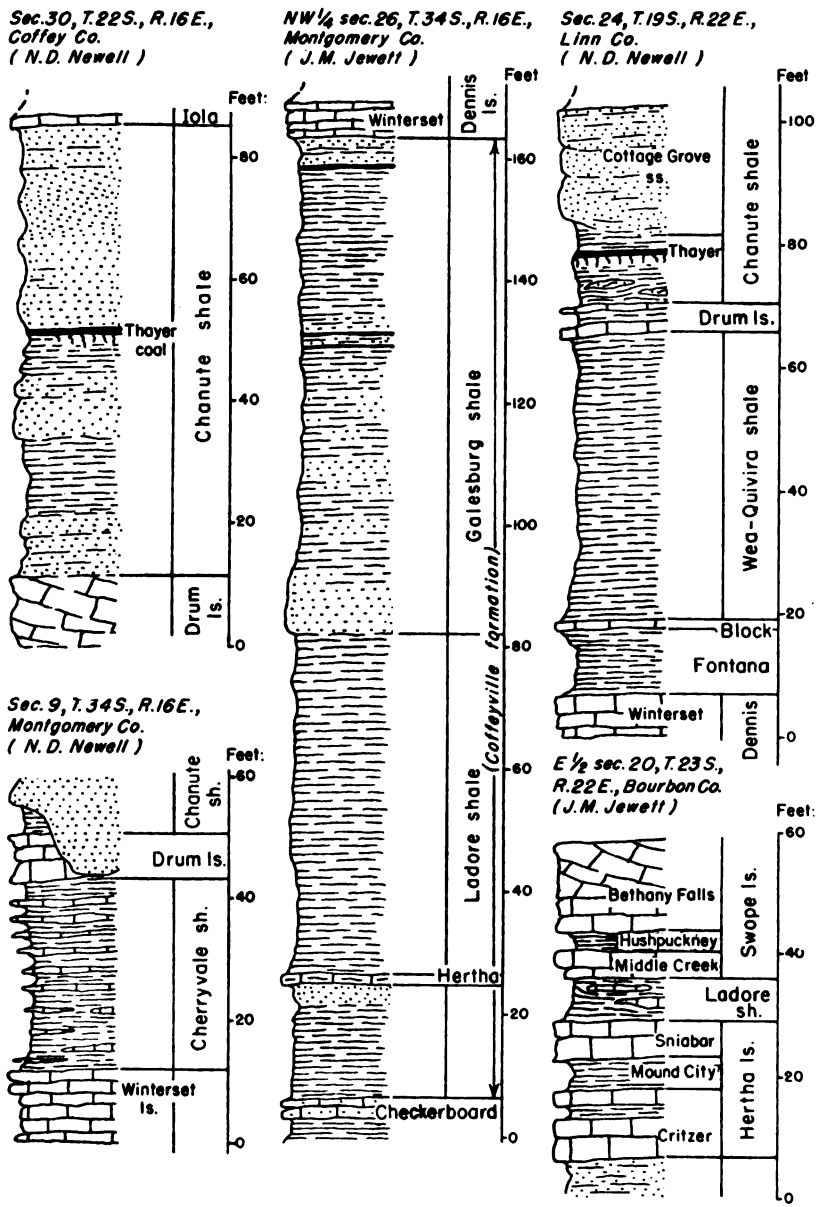

Fig. 34.—Selected stratigraphic sections of Lansing, Kansas City, and Pleasanton rocks. Refer to Figure 30 for explanation of lithologies.

Hushpuckney shale member.—Bluish-gray clay shale in the upper part, black fissile shale in the lower part. This unit and the underlying Middle Creek limestone are persistent northward from Neosho County. The thickness ranges from a featheredge to about 6 feet.

Middle Creek limestone member.—Dark bluish-gray limestone, commonly dense and brittle, vertical-jointed. The maximum observed thickness is in southern Linn County where it is about 8 feet; the common thickness is about 2 feet.

Ladore shale.—Gray and brownish-yellow shale, sandstone, and some coal. Like the Galesburg shale, the formation thickens southward. The Ladore is a thin marine shale in the Kansas City area and east-central Kansas, but it expands into a sandy deltaic deposit in southern Kansas. In Montgomery and southern Labette Counties, it is not easily separated from the overlying Galesburg shale and the two form the upper more sandy part of the Coffeyville formation. Thin coal beds are present in Labette county, and plant fossils are plentiful there. The thickness ranges from 2 to 50 feet.

Hertha limestone.—Two limestone members and a shale member. The two limestones are persistent and distinct throughout much of the Kansas outcrop area, especially in Miami, Linn, and northern Bourbon Counties. In southern outcrops, the shale member is thin or absent. The formation is easily recognized northward from T. 33 S., Labette County, and can be identified in a thin zone as far southward as Coffeyville. The thickness ranges from a featheredge to about 30 feet.

Sniabar limestone member.—Gray and brown limestone, ranging from more or less massive to thin-bedded. Marine fossils are moderately common and locally the coral "*Aulopora*" is abundant. The thickness ranges from a featheredge to about 10 feet.

Mound City shale member.—Gray and yellow clayey to calcareous shale, containing a persistent 2-inch bed of crinoidal limestone in Linn and Bourbon Counties. Marine fossils are locally plentiful. The thickness ranges from a featheredge to about 14 feet.

Critzer limestone member.—Massive, brownish-gray, granular, partly algal limestone, and thin wavy-bedded gray limestone. In a part of the outcrop area this member is the most conspicuous part of the Hertha limestone, commonly forming a rimrock cliff along the Hertha escarpment. Much of the rock weathers deep brown. Bellerophontid gastropods are characteristic of the massive facies; brachiopods and corals are plentiful locally in the thin-bedded facies. The thickness ranges from a featheredge to about 11 feet.

PLEASANTON GROUP.—Rocks lying between the base of the Hertha limestone and the disconformity that separates Missourian from Desmoinesian beds are mainly clastic sediments that mostly represent mechanically weathered detritus derived from land and deposited in shallow seas which advanced over Kansas after a time of more or less prolonged emergence. Gray, yellow, and dark-gray to black clay shale predominates, but there is much sandstone and some limestone and coal. The thickness ranges from about 70 feet to 130 feet.

SANDSTONE AND INTERBEDDED BLACK SHALE AND FLAGGY LIMESTONE—In Linn and Miami Counties the upper part of this division is partly occupied by massive sandstone (**Knobtown**) which is locally as much as 25 feet thick. In southern Linn and northern Bourbon Counties, thin beds of dense blue limestone alternating with thin beds of nearly black shale occupy the same position and attain a thickness of 45 feet. These deposits are absent for a short distance farther south, but black shale occurs in this position in Neosho and Labette Counties. Near the point in Labette County where the Hertha limestone becomes very thin about 40 feet of black shale forms the top of the Pleasanton section. Average thickness of this division is about 30 feet.

LIGHT-COLORED SHALE.—Gray to yellowish shale that locally contains a few thin limestone beds comprises most of the middle and lower parts of the Pleasanton. This facies commonly extends downward to the Hepler sandstone. Fine-grained sandstone or siltstone forms the middle part of the Pleasanton in some places. In southern Bourbon and northern Labette Counties, light-colored shale extends to the base of the Hertha limestone. The thickness of this shale unit ranges from about 20 to 100 feet.

Checkerboard limestone.—Gray limestone, locally a coquina of gastropods or crinoid fragments; where more fully developed this formation comprises two thin limestones separated by dark shale. The Checkerboard limestone is an important marker in the Pennsylvanian strata of eastern Oklahoma and is recognized in southern Kansas as far north as T. 31 S. The thickness ranges from a featheredge to about 6 feet.

Hepler sandstone.—Brown and gray sandstone named Hepler is a remarkably persistent sheetlike deposit overlying the regional disconformity at the base of the Missourian Series. A calcareous facies of the Hepler sandstone is seen locally in southern Kansas, but the unit and unconformable relationships cannot be identified in the subsurface a short distance west of the outcrops. The thickness ranges from about 2 to 20 feet.

The disconformity below the Hepler sandstone brings deposits classified as lowermost Missourian into contact with rocks ranging from the Memorial shale downward to the upper part of the Bandera shale. Paleontological evidence and indication of widespread interruption in sedimentation, accompanied by some erosion, support placement of the Desmoinesian-Missourian boundary at this position.

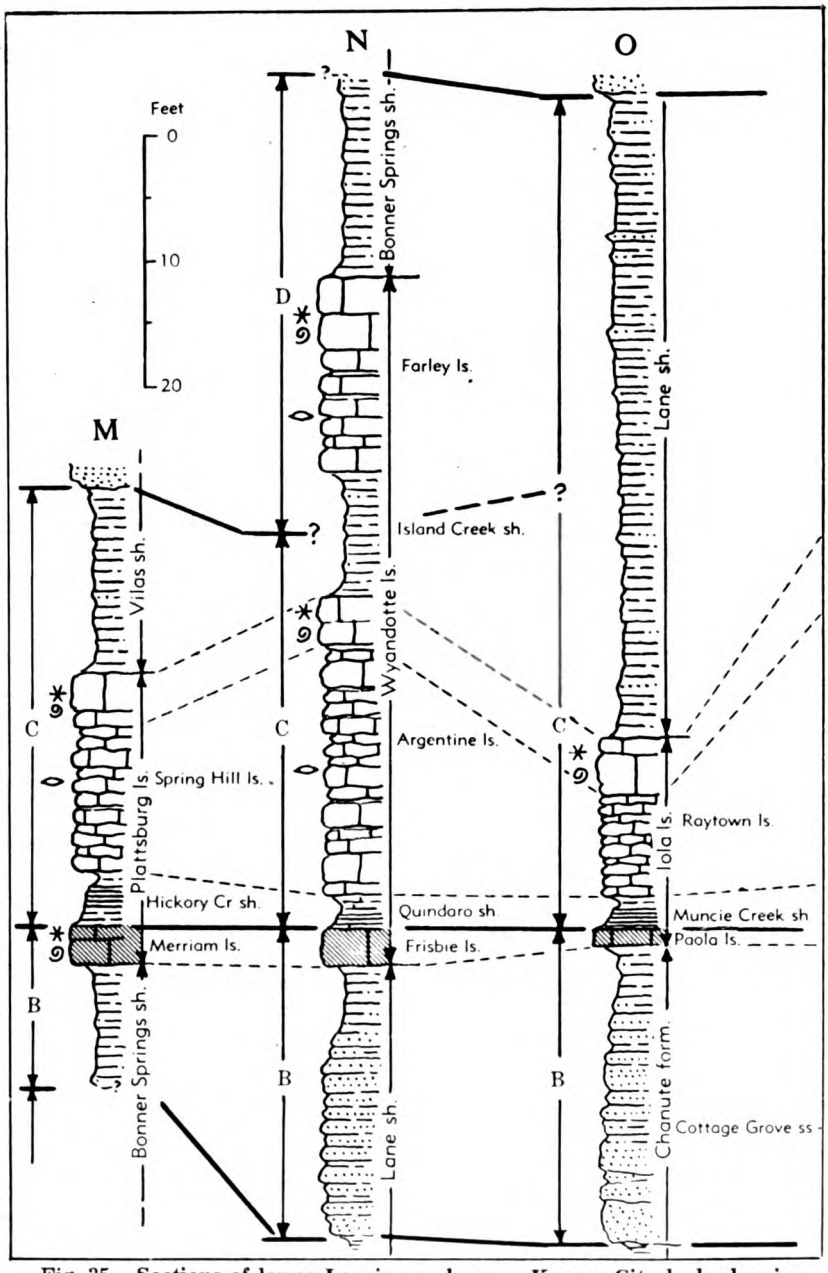

Fig. 35.—Sections of lower Lansing and upper Kansas City beds showing cyclothems grouped in megacyclothems. The individual cyclothems are indicated by the letters B, C, and D. Megacyclothems comprise the entire sequence of beds in any one of the three plotted sections, M, N, O. Stratigraphic position of the sequences is shown on the index section in Figure 36. Read Pierson Point shale for Wamego shale.

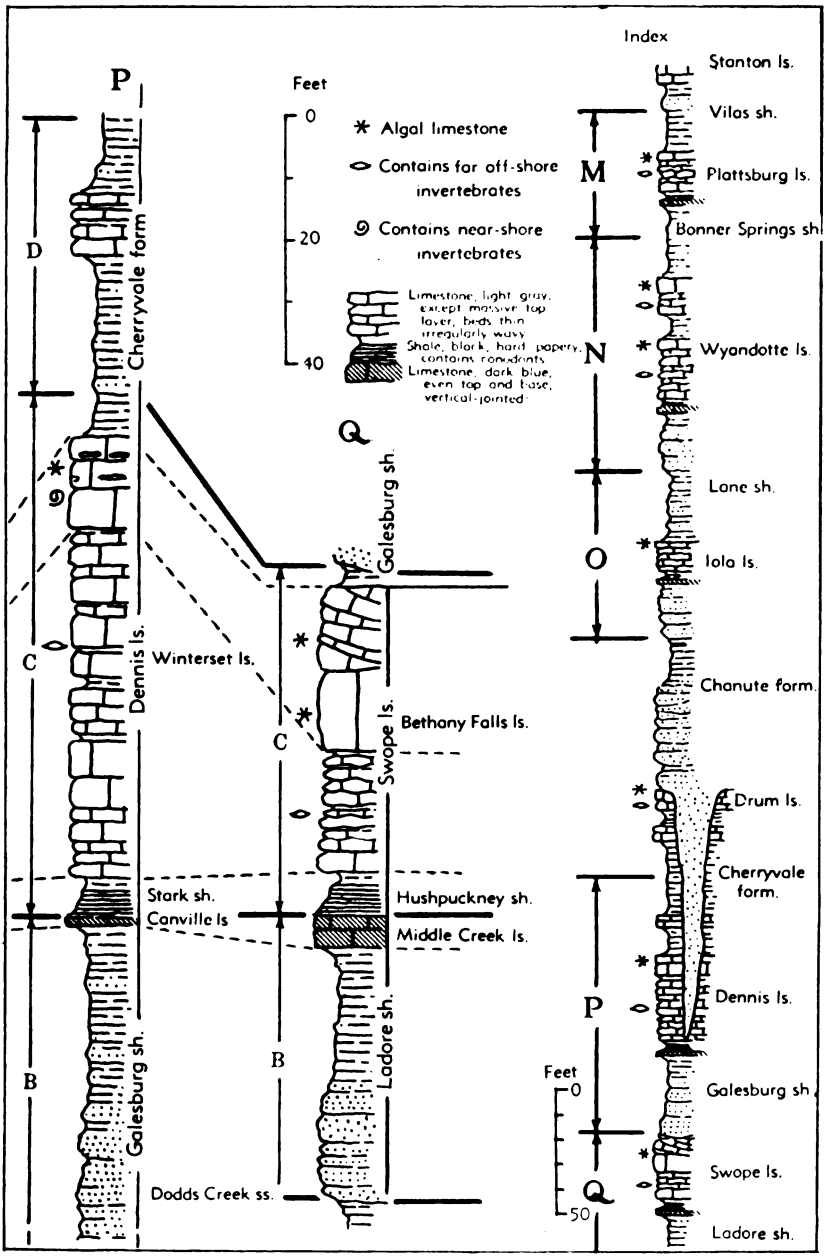

Fig. 36.—Sections of lower Kansas City beds showing cyclothems and megacyclothems. These units are differentiated as explained in description of **Figure 35.**

Desmoinesian Series

The lowermost major division of the Pennsylvanian rocks at outcrops in Kansas is named the Desmoinesian Series. Named from exposures in central Iowa, it comprises the upper part of the Middle Pennsylvanian. The series occupies the stratigraphic interval between important regional disconformities. The Desmoinesian deposits are set off from the overlying Missourian rocks by pronounced paleontologic and lithologic differences.

MARMATON GROUP.—The upper part of the Desmoinesian beds in Kansas, approximately 250 feet thick, is assigned to the Marmaton group. These strata are more calcareous and more dominantly marine than those of the underlying Cherokee shale.

Memorial shale.—Gray and yellowish clay shale, generally unfossiliferous. In Labette County it comprises dark-gray shale that bears marine fossils and contains two or more coal beds. The unit locally is absent owing to pre-Missourian erosion. The maximum known thickness is 30 feet.

Lenapah limestone.—Two limestone members separated by a shale member. The formation is locally reduced in thickness or absent as a result of pre-Missourian erosion. The lower two members are absent in some places, owing to nondeposition. The Lenapah is well marked in southeastern Kansas but inconspicuous in east-central Kansas. Thickness ranges from 1 to 18 feet.

Idenbro limestone member.—Chiefly light-gray crystalline and pseudobrecciated limestone; in Linn and Bourbon Counties represented by brownish-gray to dark-gray limestone containing limonitic inclusions, mostly crystalline, but dense and earthy locally. This member forms low escarpments and broad dip slopes in the southern part of the outcrop area. The Idenbro limestone possibly is equivalent to rock called the Sni Mills limestone in Missouri. Characteristic thickness in the northern part is 1 to 2 feet; in the southern part it is 6 to 9 feet.

Perry Farm shale member.—Light- to dark-gray clay shale containing nodules of limestone; grades laterally into nodular limestone south of the Kansas-Oklahoma line. The shale is abundantly fossiliferous locally, brachiopods occurring in the upper part and a molluscan fauna in the middle and lower parts. The member is locally absent in the northern part of the outcrop area. The thickness ranges from a featheredge to about 20 feet.

Norfleet limestone member.—Dark brownish-gray massive to bluish-gray slabby limestone. The Norfleet resembles local facies of the Idenbro limestone in some northern outcrops. South of the Kansas-Oklahoma line, this member grades into massive dense limestone that is continuous with overlying nodular limestone facies of the Perry Farm shale, but distinction of the two members is clear. The thickness ranges from a few inches to about 3 feet.

Nowata shale.—Gray to yellow clay shale, sandy shale, and sandstone; marine and nonmarine. The formation is locally absent in Linn County and in the subsurface of Miami County, owing to pre-Missourian erosion. Measured thickness in Kansas, 3 to 30 feet.

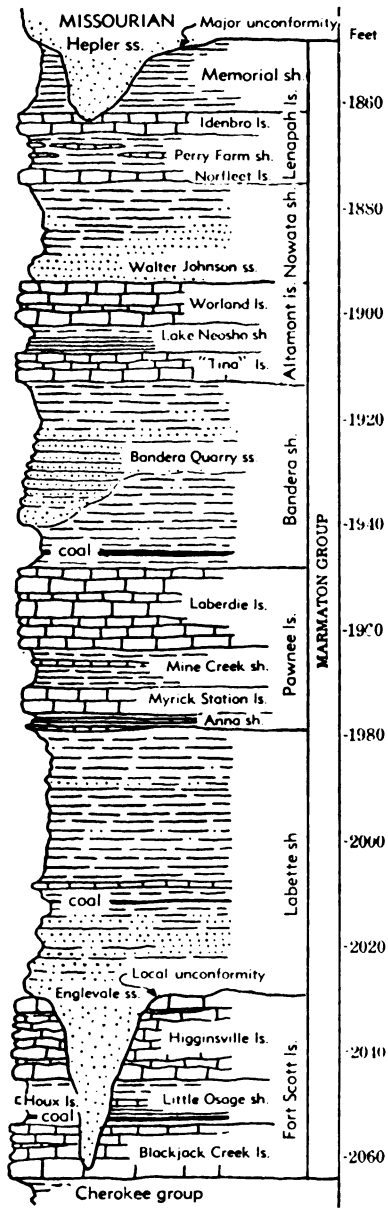

Fig. 37.—Desmoinesian (Marmaton) rocks in Kansas. Read Amoret for **"Tina."**

Walter Johnson sandstone member.—Thin-bedded to massive sandstone in the lower and middle Nowata shale, observed in parts of southern Kansas, has been named the Walter Johnson sandstone. It is equivalent to the "Wayside sand" of the subsurface. Outcrop thicknesses are commonly 4 to 10 feet.

Altamont limestone.—Two limestone members separated by a shale member. The lower limestone is most prominent in the southern part of the outcrop area, and the upper limestone is most prominent in northern outcrops. The formation is locally absent in the subsurface of Miami County owing to pre-Missourian erosion. The thickness is about 6 to 25 feet.

Worland limestone member.—Light-gray limestone, dense, semilithographic in upper part, remainder mostly crystalline, pseudobrecciated and wavy-bedded. Marine fossils characteristically are few but there are prominent brachiopods and fusulines, the latter locally abundant. Thickness commonly about 8 feet.

Lake Neosho shale member.—Light- and dark-gray and nearly black shale; generally black in middle part, locally all dark; containing abundant phosphatic concretions. The thickness ranges from about 2 to 8 feet.

Amoret limestone member.—Light-gray, massive, coralline (*Chaetetes*) and dense limestone, associated with two shale beds in the southern part of the outcrop area. The limestone is darker, more granular and locally cross-bedded in the northern part. The thickness is 1 foot or less to 2 feet in the northern part, about 10 feet in the southern part.

Bandera shale.—Mainly nonmarine gray, yellow, and maroon clay shale, mostly blocky, well-bedded; massive to thin-bedded sandstone; and the **Mulberry coal** bed near the base. Maroon bands occur in the upper part. The formation contains limonitic concretions and veins and locally septarian limestone concretions. Plant fossils are found in the sandy facies, generally in the lower part. The Mulberry coal is a persistent bed in the lower part of the Bandera north of Crawford County. Shale below the coal is is light to dark gray and carbonaceous. Locally, a thin dark-gray limestone lies closely above the Mulberry coal. The thickness ranges from about 20 to 50 feet.

Bandera Quarry sandstone member.—Gray and brown sandstone, generally thin-bedded, locally "flagstones," lenticular. The thickness ranges from a featheredge to 30 feet or more.

Pawnee limestone.—The upper main part of the Pawnee formation comprises two persistent limestone members separated by a shale member; the lower part consists of shale and a thin nonpersistent basal limestone. Thickness ranges from about 15 to 60 feet.

Laberdie limestone member.—Light-gray crystalline, and coralline (*Chaetetes*) limestone in thin wavy to massive beds that form extensive dip slopes and cap prominent escarpments. Fusulines and other marine fossils are locally plentiful. Field studies in Missouri not yet published, are reported to indicate equivalence of the Laberdie limestone to the

unit called Coal City limestone in northern Missouri and Iowa. The thickness is about 10 to 20 feet.

Mine Creek shale member.—Light- and dark-gray to black shale, flaky, platy and fissile, containing one or more thin limestone beds in the middle part locally. Generally brachiopods are abundant, corals fewer. This member is reduced to very slight thickness or is absent in the southern part of the outcrop area. The thickness ranges from a featheredge to 15 feet.

Myrick Station limestone member.—Dark-gray, brown, and light-gray limestone. The lower part, comprising about 2 feet of massive dark-gray brown-weathering limestone, is most persistent, and this is overlain locally by lighter-colored coralline (*Chaetetes*) limestone. The thickness ranges from 2 to about 8.5 feet.

Anna shale member.—Black, platy, locally fissile shale, containing a few inches of gray shale near the top in some places; small smooth phosphatic concretions are common. A thin bed or lenses of dark, slabby, crystalline, locally crinoidal limestone occur in the basal part. Thickness commonly ranges from 2 to 5 feet.

Labette shale.—Gray and yellow clay shale, sandy shale, sandstone, and thin coal and limestone beds; a rather persistent black shale and a bed of coal occur in the basal part. Black shale occurs locally in the upper part. Some sections show several thin limestone and coal beds. A persistent limestone, 1 to 2 feet thick, occurs in the middle lower part. Thickness ranges from about 30 to 100 feet.

Englevale sandstone member.—This is one of several bodies of sandstone, collectively referred to as **Warrensburg sandstone,** lying in the middle and lower parts of the Labette shale. This is the "Peru sand" of the subsurface. Average thickness, about 30 feet.

Fort Scott limestone.—Comprises two limestones and an intervening shale member, the latter containing a persistent coal and a limestone bed in the northern part of the outcrop area. Characteristic thickness is about 33 feet.

Higginsville limestone member.—Chiefly light-gray thin-bedded to massive limestone characterized by the scattered occurrence of unusually large crinoid stems, irregular distribution of minute, medium, and large fusulines, and colonies of *Chaetetes* that generally are isolated but locally form the entire upper part. Characteristic thickness is about 15 feet.

Little Osage shale member.—Black platy shale containing small smooth phosphatic concretions, and gray clayey calcareous shale, coal, and limestone. Upper part generally light gray and calcareous, lower part commonly black and platy. The **Houx limestone** is a persistent thin bed of granular limestone that occurs a few inches to 2 or more feet below the Higginsville limestone. The **Summit coal,** which is persistent from northern Crawford County northeastward into Missouri, occurs in the upper middle part of the Little Osage shale. Thickness of the member ranges from about 4 to 12 feet.

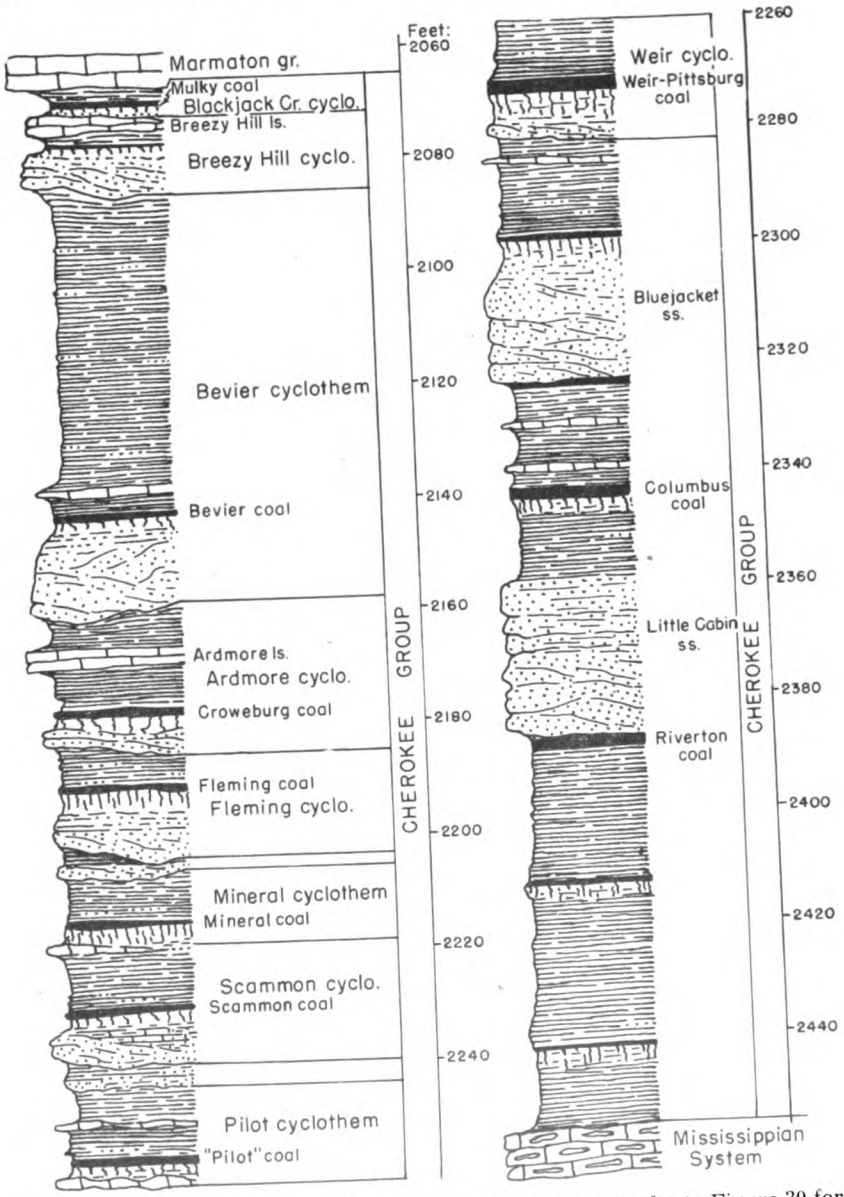

Fig. 38.—Desmoinesian (Cherokee) rocks in Kansas. Refer to Figure 30 for explanation of lithologies.

Blackjack Creek limestone member.—Brownish-gray, granular, and massive to light-gray, crystalline, pseudobrecciated, thinner bedded, and locally *Chaetetes*-bearing. The lower part, the only persistent part of the member, is approximately 2 feet thick and consists of brownish-gray brown-weathering "cement rock." Thickness ranges from about 4 to 17.5 feet.

CHEROKEE GROUP.—Pennsylvanian rocks below the Fort Scott limestone in Kansas, which consist mainly of clastic rocks with light- and dark-colored shale predominating, are now classified as a group. There is much sandstone and sandy shale, and the most important coal beds of the State are in the Cherokee. The amount of limestone is small. The group is not readily divisible into mappable units, and until work now in progress is completed, the rocks are described on the basis of cyclic deposition. Parts thus differentiated are not treated as formations but are called cyclothems (deposits of a cycle). Some differences from previous publications are introduced in this report on the basis of studies by W. B. Howe, of the Kansas Geological Survey. The thickness at the outcrop ranges from about 400 to 550 feet.

Blackjack Creek cyclothem.—Sandy shale, underclay, coal (**Mulky** bed), black shale, and limestone (Blackjack Creek limestone) belonging in the lower part of the Fort Scott limestone comprise a widely distributed cyclic sequence which may be termed the Blackjack Creek cyclothem. Average thickness is about 15 feet.

Breezy Hill cyclothem.—In the northeastern part of the outcrop area, the Breezy Hill cyclothem consists of a thin impure limestone of irregular thickness (**Breezy Hill limestone**) and a thin-bedded fine-grained sandstone ("Squirrel" of the subsurface). To the southwest, in Labette County, Kansas, and Craig County, Oklahoma, an underclay, coal, and calcareous shale sequence separates the Breezy Hill limestone and "Squirrel" sandstone. Thickness ranges from 10 to 15 feet.

Bevier cyclothem.—Beds assigned to this cyclothem include strata below the "Squirrel" sandstone and above the Ardmore limestone in the northern and eastern parts of the outcrop area in Kansas. In the southwestern part, the unconformity at the base of this cycle occurs 12 to 15 feet above the Ardmore limestone. Where fully developed, this cycle includes: a basal sandstone, underclay, coal (**Bevier**), dark impure limestone, and an upper gray shale, the latter ranging in thickness from 40 to 80 feet. Thickness of the entire cyclothem ranges from 45 to 85 feet. The "Stice" coal of some reports is the same as the Bevier coal of Crawford and Cherokee Counties, Kansas.

Ardmore cyclothem.—The **Ardmore limestone** and **Croweburg coal** (Broken Arrow of Oklahoma) are persistent units in the Ardmore cyclothem. Where fully developed, this cyclothem includes, in ascending order: "fresh-water" limestone or sandstone, underclay, coal (Croweburg), gray shale, black slaty shale, massive limestone (Ardmore), and gray shale, calcareous in the basal part. Thickness ranges from 20 to 35 feet. Further work may establish assignment of the Ardmore limestone with associated black shale and the Croweburg coal to separate cyclothems. In such event,

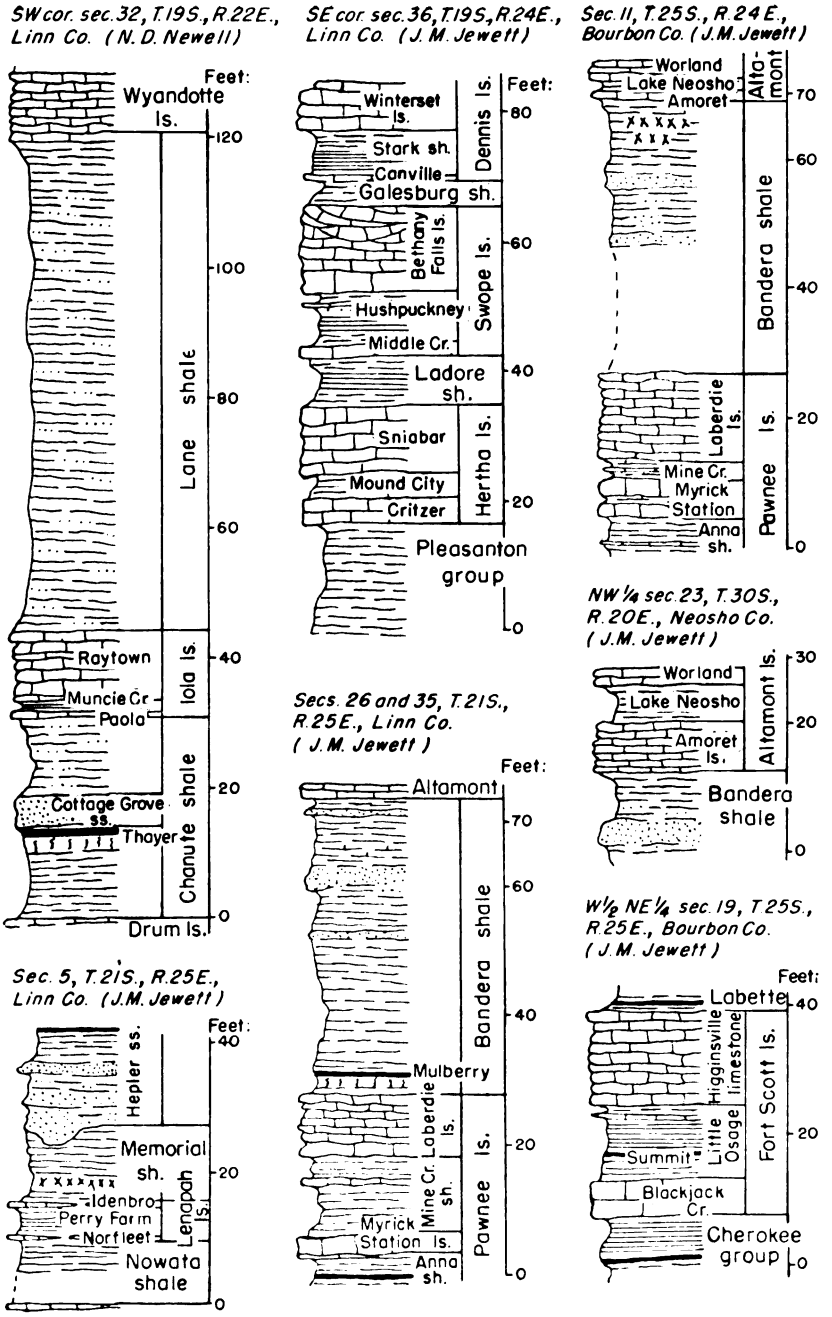

Fig. 39.—**Selected stratigraphic sections of Kansas City, Pleasanton, and Marmaton rocks.** Refer to Figure 30 for explanation of lithologies.

the Croweburg coal, overlying gray shale, and underlying underclay and sandstone or fresh-water limestone may constitute a distinct cyclic unit.

Fleming cyclothem.—Strata included in this cyclothem include, in ascending order: sandstone, underclay, coal (Fleming), dark-gray to black shale, calcareous in lower part. The **Fleming coal** is characterized by its irregular thickness. Thickness of this cyclothem ranges from 15 to 20 feet.

UNNAMED CYCLOTHEM.—Field work now in progress indicates the local existence of a cyclothem in this position. At present it is recognized only in western Cherokee County, where a nearly fully developed cycle exists.

Mineral cyclothem.—This cyclic unit consists of underclay, coal (**Mineral**), black shale, and gray shale. The black shale is calcareous, and abundantly fossiliferous, especially where thin beds of black limestone occur in the shale. The thickness of the cyclothem is about 12 feet.

Scammon cyclothem.—This cyclothem is rarely exposed, because the **Scammon coal** is not now minable, and present strip-mining operations rarely intercept it. It includes in ascending order: sandstone or impure limestone, underclay, coal (Scammon), black shale, commonly calcareous and fossiliferous, and gray shale. Thickness ranges from 20 to 30 feet.

UNNAMED CYCLOTHEM—Field investigations of the Kansas and Missouri Geological Surveys indicate the presence of a cyclothem between the Scammon and Pilot cyclic units. Only partial development of this cyclothem is known to exist in Kansas, however.

Pilot cyclothem.—Strata of this cyclothem include, in ascending order: "fresh-water" limestone, underclay, coal (**Pilot**), black shale, dark pyritic limestone, and dark-gray shale. Thickness of this cyclothem ranges from 15 to 20 feet.

Weir cyclothem.—This unit includes the most important coal deposit of Kansas. It contains an unusually thick underclay and a basal sandstone. Over much of the outcrop area, the coal (**Weir-Pittsburg**) is characterized by a parting in the lower part. Thickness of the coal averages about 3 feet, and the total thickness of the cyclothem is about 30 feet.

Lower Cherokee cyclothems.—Present knowledge of lower Cherokee strata does not allow reliable division of them into cyclic units. Only broad features may be noted. The thickness of deposits between the Weir Pittsburg coal and Mississippian limestones ranges from 200 to 250 feet in Cherokee and Crawford Counties. The basal part of the Cherokee group at outcrops in southeastern Kansas is commonly black shale. Several persistent coals occur in this part of the section, including, in descending order, **Knifeton, Rowe (Columbus)**, and **Riverton.** Two important sandstones, **Bluejacket** and **Little Cabin,** also occur in this section. The Little Cabin sandstone is correlated with the Warner sandstone of Oklahoma. In some reports, five cyclothems have been named and described as occurring in the Cherokee section below the Weir cyclothem, but these are not now judged to be established reliably. Nevertheless, sequences of sandstone, underclay, coal, black shale, and gray shale in the lower part of the Cherokee are similar to the cyclical arrangement of higher beds of the group.

Atokan Series

Rocks ranging in thickness from a featheredge to about 500 feet and encountered at a depth of about 4,500 feet in southwestern Kansas are assigned to the Atokan Series. These rocks comprise chiefly limestone and shaly limestone. The Atokan deposits are separated from overlying Desmoinesian rocks and from underlying Morrowan deposits by unconformities.

Morrowan Series

In Kansas rocks of Morrowan age are known only in the southwestern part of the State, at a depth of about 5,500 feet. These rocks, in part classified as the **Kearny formation,** comprise shale, limestone, and sandstone. The maximum thickness in Kansas is about 350 feet.

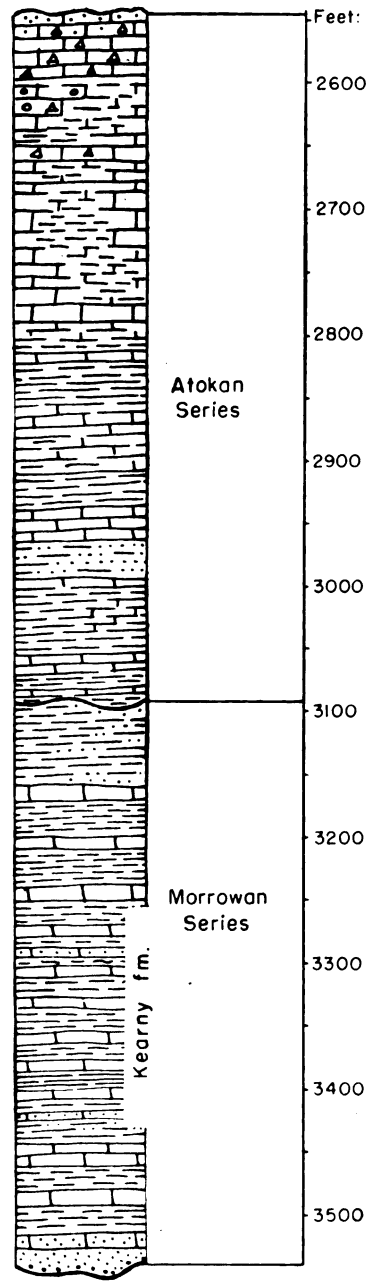

Fig. 40.—**Atokan and Morrowan rocks in Kansas.**

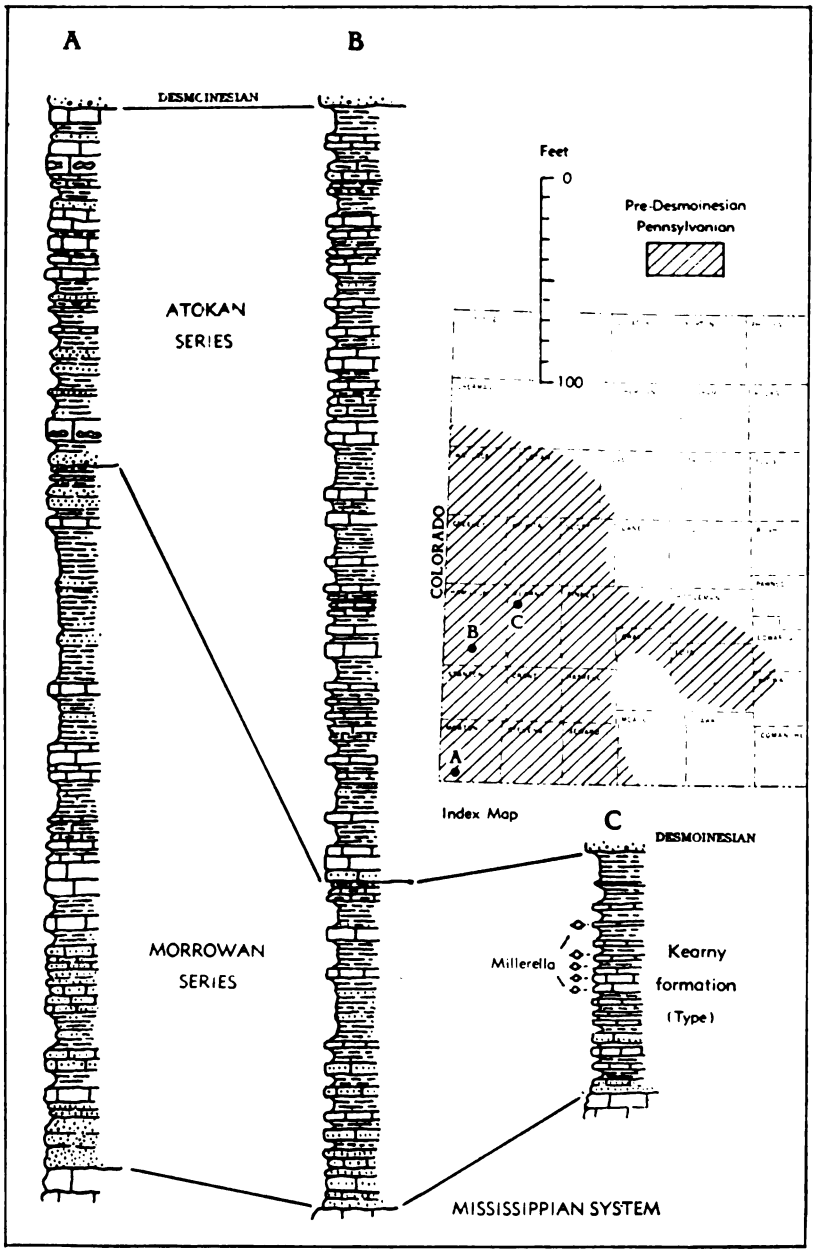

Fig. 41.—Sections of Morrowan and Atokan rocks encountered in wells in southwestern Kansas. These strata are not exposed anywhere within the borders of Kansas but are represented by outcrops in Oklahoma.

PRE-PENNSYLVANIAN ROCKS*

Except for a small area of Mississippian rocks in the southern part of the State, the pre-Pennsylvanian rocks which crop out in the neighboring areas are known in Kansas only from cuttings, cores, and various kinds of records of drilled wells, supplemented by geophysical information. The present distribution of these rocks in the subsurface of Kansas is closely related to the pre-Pennsylvanian structural movements of the State and to subsequent periods of erosional beveling that stripped some of the formations from large areas where they occurred originally.

Regional relations.—The pre-Pennsylvanian rocks of Kansas range in age from Pre-Cambrian to Mississippian. Their distribution, thickness, structural, and stratigraphic relations, and in considerable degree, their lithologic characters are reflections of earth movements which affected the Kansas region in Paleozoic geologic history. The location and relationships of principal movements are shown diagrammatically in Figures 43 to 46.

Cambrian and Ordovician Arbuckle rocks were removed from the crest of the pre-St. Peter Southeast Nebraska arch, before deposition of the St. Peter sandstone (Ordovician) and they were in part removed from marginal areas, especially along the crest of the contemporaneous arch extending southward across Kansas. On the Chautauqua arch, the Arbuckle rocks were reduced in thickness and all formations older than the Chattanooga shale (?Devonian) were removed from its crest during periods of uplift and erosion that preceded the deposition of the Devonian rocks and again before the deposition of the Chattanooga shale. Middle and Late Ordovician, Silurian, and Devonian rocks were beveled on the northern flank of the Chautauqua arch in Kansas and on its southern flank in northeastern Oklahoma. The Chattanooga shale was deposited across this beveled surface and rests unconformably on rocks from Arbuckle to Devonian. Downwarping of the North Kansas basin, which occurred contemporaneously with the rise of the Chautauqua arch, preserved greater thicknesses of Devonian, Silurian, and Late and Middle Ordovician rocks in that area than are known in other parts of Kansas.

* The classification and nomenclature of the pre-Pennsylvanian rocks described in this report by Wallace Lee, although adopted by the State Geological Survey of Kansas, differ somewhat from usage in formal reports of the U. S. Geological Survey.

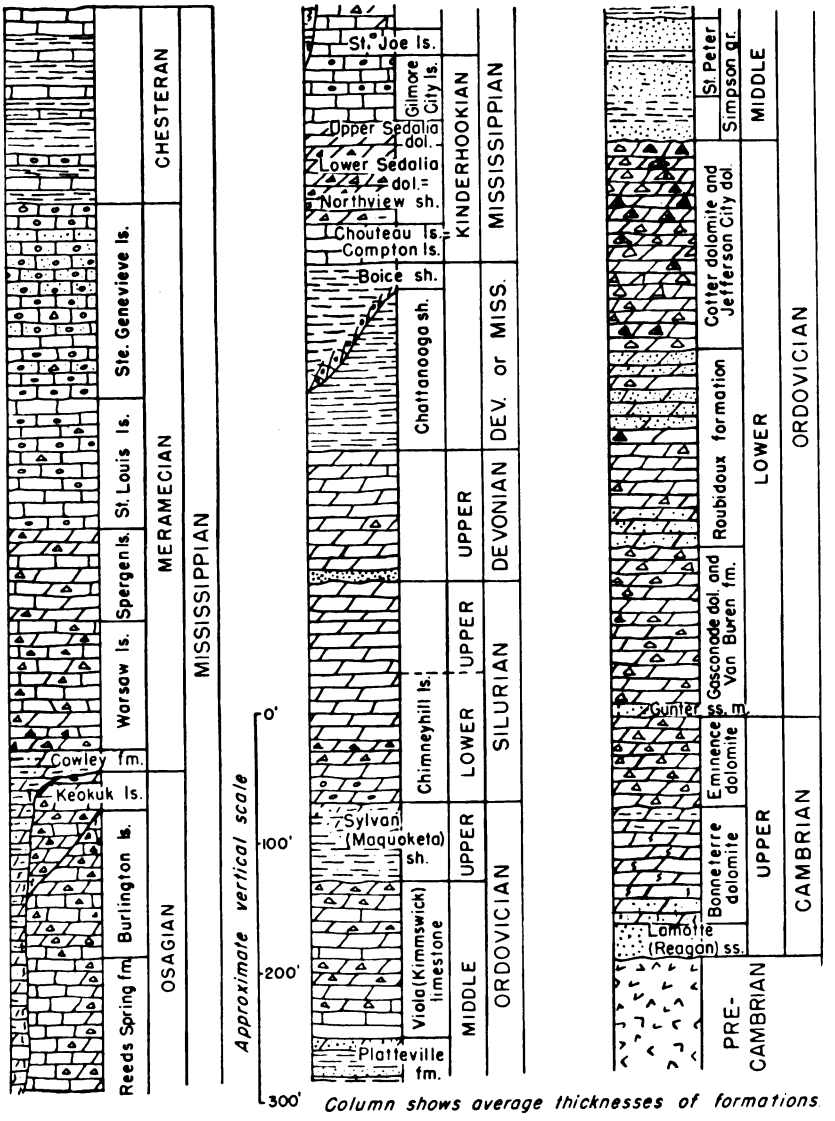

Fig. 42.—**Pre-Pennsylvanian Paleozoic rocks in Kansas.** The complete sequence is present nowhere in Kansas.

On the Central Kansas uplift, some formations were removed after the initial movements that occurred before Mississippian time. Greatly renewed activity of this structural feature occurred after Mississippian time and erosion of the uplifted area removed the whole sequence of Mississippian rocks and some additional older rocks from its crest before the beginning of Pennsylvanian deposition.

The Nemaha anticline, which was raised contemporaneously with the Central Kansas uplift, was also beveled with the removal of progressively greater thicknesses of rock toward the north and toward the south. In southern Kansas only the upper formations of the Mississippian were lost, but near the Nebraska line the whole sequence of pre-Pennsylvanian sedimentary rocks was eroded from the crest. Secondary anticlines, like the Voshell and Abilene anticlines and others, were similarly affected by post-Mississippian erosion but in minor degree.

On the other hand, in contemporaneously downwarped areas that became the Hugoton embayment, the Salina basin, and the Forest City basin (but not the Cherokee basin) greater thicknesses of pre-Pennsylvanian rocks were preserved below the level of erosion than in other areas.

Mississippian System

Mississippian rocks are found at the surface in Kansas only in a small area of less than two townships in Cherokee County, in the extreme southeastern corner of the State. In the subsurface, Mississippian rocks are present throughout the State except on the crest of the Central Kansas uplift and northern end and northwestern flank of the Nemaha anticline, from which Mississippian formations were stripped during uplift and erosion that preceded the deposition of Pennsylvanian rocks. The Mississippian rocks have a maximum thickness in the Hugoton embayment of southwestern Kansas where drilling has revealed more than 1,600 feet.

CHESTERAN SERIES.—Important unconformities separate the Chesteran Series from Pennsylvanian rocks above and Meramecian beds below. White semigranular limestones of Batesville age, which crop out in northeastern Oklahoma above Keokuk limestone, extend into southeastern Kansas, where they have maximum thickness of less than 20 feet. In the subsurface of southwestern Kansas, Chesteran rocks are confined to deeper parts of the Hugoton embayment in Morton, Seward, Meade, Clark, and adjacent counties

to the north, occurring at depths of 5,100 to 5,900 feet below the surface. They consist of granular and semigranular limestones, alternating irregularly with yellow, black, gray, and brown shale and marl. Thickness increases southward from a featheredge at the north, the total being 350 feet near the State line. Fossils from cores examined by M. K. Elias are correlated with upper, middle, and lower parts of the Illinois Chesteran sequence.

MERAMECIAN SERIES.—In southern Kansas, the Meramecian Series lies disconformably on deeply eroded Osagian rocks, but in northeastern Kansas this disconformity is obscure. The upper formations consist almost entirely of limestone, but lower formations contain interbedded dolomite or are mainly silty dolomite and dolomitic siltstone containing variably large quantities of chert. Meramecian rocks probably extended originally throughout Kansas but were eroded from most of the State before Pennsylvanian deposits were formed.

Ste. Genevieve limestone.—Disconformable beneath Chesteran but seemingly conformable on St. Louis limestone, the Ste. Genevieve underlies a small part of northeastern Kansas in the deeper part of the Forest City basin, but is widespread in the Hugoton embayment of southwestern Kansas. It consists mainly of silty and sandy white limestone interbedded with fine-textured oölitic limestone. The thickness is about 30 feet in Doniphan and Atchison Counties, and 215 feet in the Hugoton embayment, where the formation maintains fairly constant thickness except as beveled by pre-Pennsylvanian erosion on the flanks of uplifted areas.

St. Louis limestone.—Conformable with Meramecian rocks above and below, the St. Louis consists typically of noncherty lithographic and sublithographic limestone but also includes semigranular and oölitic limestone containing traces of translucent chert. Although restricted to basin areas, it is more widely distributed than the Ste. Genevieve but is absent in the Salina basin. Maximum thickness in the Forest City basin is about 50 feet and in the Hugoton embayment about 200 feet.

Spergen limestone.—In northeastern Kansas the Spergen limestone consists mainly of noncherty or sparsely cherty sugary to silty dolomite interstratified with noncherty granular limestone, which in some places constitutes the greater part of the formation. The microfossiliferous chert resembles that in the conformably underlying Warsaw. The foraminifer *Endothyra baileyi* is commonly present in the granular limestones. In southwestern Kansas, the Spergen consists mainly of semigranular and granular limestone although it is in part dolomitic. Thickness of the Spergen is about 50 feet in the deepest part of the Salina basin, where it underlies Pennsylvanian rocks, and in the Forest City basin, where it underlies the St. Louis limestone. In the Hugoton embayment, it is about 100 feet thick.

Warsaw limestone.—Composed mainly of semigranular limestone interlaminated with sugary dolomite, the Warsaw includes relatively large amounts of distinctive microfossiliferous chert. Insoluble residues of some dolomite beds are spongy masses of spicules. In southern Kansas, the Warsaw grades downward into the Cowley formation without break, but elsewhere it is obscurely unconformable on rocks of Keokuk or Burlington

age. The formation is widespread in central parts of the Salina and Forest City basins and in the Hugoton embayment. It is 30 to 40 feet thick in the Forest City and Salina basins and 300 to 350 feet in the central part of the Hugoton embayment.

Cowley formation.—Silty dolomite, dolomitic siltstone, and variably large amounts of dark microfossiliferous chert characterize the Cowley formation. Color of the beds ranges locally from gray to black. In southeastern Kansas, grains of glauconite are thinly disseminated throughout, but especially conspicuous in the basal 20 to 30 feet. In southwestern Kansas, chert is less abundant and glauconite is inconspicuous or absent in the basal beds. The formation was deposited in a basin eroded in older Mississippian rocks. Locally in southeastern Kansas, pre-Cowley valleys were cut through Chattanooga shale into upper Arbuckle beds. The upland north of the basin was only slightly dissected. When the basin became filled by silty Cowley sediments, the sea spread widely across the upland area and sedimentation represented by the subsurface Warsaw prevailed. In Kansas, the Cowley formation is restricted to an east-west belt 15 to 75 miles wide north of the Oklahoma border. Where the Cowley cuts out Chattanooga shale and rests on Arbuckle dolomite, it has a thickness of more than 300 feet.

OSAGIAN SERIES.—Formations of the Osagian Series consist of varied sequences of dolomite and limestone distinguished from one another mainly by characters of included cherts. The older Osagian formations are restricted to southern Kansas and are overlapped northward by younger formations. Basal Osagian rocks are separated from the underlying Kinderhookian by a low angular unconformity.

Keokuk limestone and **Burlington limestone.**—Although lithologically distinct in some subsurface areas and divided by an important disconformity, the Keokuk and Burlington formations are not clearly separable in others. In southeastern Kansas, where the Burlington is absent, Keokuk beds are characterized by white tripolitic chert, siliceous limestone, and dolomite. Toward the north, limestone and dolomite of probable Burlington age, containing dense opaque white chert and varying amounts of quartz, underlie the Keokuk. Upper Keokuk rocks closely resemble some Burlington beds and where such deposits form a single sequence, they are not readily distinguishable. Near Wichita, where the Burlington consists of white semigranular limestone, it is differentiated from underlying limestone of Fern Glen age only by traces of quartz in the insoluble residues. The Keokuk and Burlington are not distinctly differentiated in southwestern Kansas although tripolitic silica occurs in some wells. The Keokuk and Burlington sequence of rocks is widely distributed in Kansas and formerly covered most, if not all, of the State. Pre-Pennsylvanian erosion beveled these strata, removing them from the Central Kansas uplift, the northern part of the Nemaha anticline, and country north of the Salina basin. In most areas, the Burlington seems to grade downward without break into Fern Glen deposits but at margins of basins, and especially toward the north in eastern Kansas, Burlington-Keokuk beds overlap onto pre-Osagian rocks. The combined thickness of the Keokuk and Burlington, where

not trenched by pre-Cowley erosion, ranges from 170 feet or more in the south to about 100 feet in the north.

Reeds Spring formation and St. Joe limestone.—Two formations of Fern Glen age are recognized at outcrops in southwestern Missouri and in the subsurface near the outcrops; the Reeds Spring formation above and the St. Joe limestone below. The Reeds Spring consists of buff and gray sugary dolomite with abundant dark to brown semitranslucent chalcedonic chert and parti-colored semiopaque chert. These rocks grade westward into gray interlaminated dolomite and limestone with gray and blue-gray chalcedonic semitranslucent chert and semiopaque chert. In southeastern Kansas, white semigranular and coarsely granular noncherty limestone beneath the Reeds Spring is classed as St. Joe limestone. In the Wichita area, St. Joe, Reeds Spring, and Burlington rocks are all semigranular almost pure limestone, the Reeds Spring division being identified by the presence of small amounts of chalcedonic chert in the insoluble residues. Rocks of Fern Glen age overlap on pre-Mississippian formations on the southeastern and southern flank of the contemporaneously rising Central Kansas uplift. In this area, reddish and greenish argillaceous limestone, mostly noncherty, and some calcareous red shale represent upper parts of the Fern Glen deposits, whereas the lower (St. Joe) part is dark gray and argillaceous. Farther westward, the lower beds include lithographic limestones. Rocks of Fern Glen age occur only in the southern part of the State. Both east and west of the Nemaha anticline and on the south flank of the Central Kansas uplift, the noncherty St. Joe limestone is overlapped toward the north by Reeds Spring, and this in turn by Burlington and by Keokuk. The upper part of the Fern Glen rocks (Reeds Spring), where overlain by Burlington in southern Kansas, has a maximum thickness of about 150 feet. It wedges out northward in Ottawa County on the west side of the Nemaha anticline and in Jackson County on the east side. The St. Joe limestone has maximum thickness of about 45 feet in southeastern Kansas, but farther west it is mostly less than 20 feet thick. The correlation of the St. Joe with beds in southwestern Kansas is uncertain.

KINDERHOOKIAN SERIES.—A low angular unconformity separates the Kinderhookian Series from overlying Osagian rocks. All Kinderhookian formations thicken northward toward a basin in central Iowa, whereas the Osagian formations thicken southward.

Gilmore City limestone.—Uppermost of the Kinderhookian deposits in Kansas is the Gilmore City limestone, which consists of noncherty, soft chalky limestone enclosing granules of broken calcareous fossils. In some zones, the granules are coated with algal crusts. Other zones are characterized by oölites, including some of irregular shape and black color. In western Kansas, the formation contains some chert. The Gilmore City limestone of Kansas occurs northeast and southwest of the Central Kansas uplift, lying disconformably on Sedalia dolomite. It thickens northwestward from a featheredge in Leavenworth County to 76 feet in Cloud County and westward from a featheredge in Finney County to 120 feet in Scott County, becoming thinner again farther northwest.

Sedalia dolomite.—The upper part of the Sedalia dolomite consists of noncherty or sparsely cherty buff to gray dolomite, which extends from outcrops in Missouri westward to the northeastern flank of the Central Kansas uplift. It conformably overlies lower Sedalia east of the Nemaha anticline, but overlaps upon the Chattanooga shale to the west. In Kansas, the upper member has a maximum thickness of 30 feet near Kansas City but is rarely more than 10 feet thick west of the Nemaha anticline, where it occurs in local outliers beneath Gilmore City limestone or Fern Glen rocks, as in McPherson and adjoining counties. The chert of the lower member is generally ash gray and characterized by somewhat unique stippled markings. Southward, it thins and wedges out near the Oklahoma border. In southeastern Kansas lower Sedalia dolomite is equal to **Northview shale.**

Compton limestone.—The Compton limestone of Chouteau age is the lowest limestone formation of the Kinderhookian Series. It closely resembles the St. Joe limestone in southeastern Kansas but is slightly greenish-gray and less granular. Like the lower member of the Sedalia, it lies entirely east of the Nemaha anticline. The Compton ranges in thickness from a featheredge east of the Nemaha anticline and at the Oklahoma border in southeastern Kansas to about 45 feet near Kansas City.

Mississippian or Devonian System

The shale sequence between Mississippian and Devonian limestones in northeastern Kansas is divided into two formations; Boice shale above and Chattanooga shale below. They are separated by a marked disconformity with topographic relief locally of as much as 110 feet. It is probable, although not proved, that the Boice shale is of Mississippian age and the Chattanooga shale (often miscalled "Kinderhook" shale) is of Devonian age.

Boice shale.—Dark or light greenish-gray spore-bearing silty or dolomitic shale and basal beds of red shale or ferruginous oölite of variable thickness comprise the Boice shale. These strata conformably underlie Compton limestone or occur disconformably beneath upper Sedalia. They lie disconformably on deeply eroded Chattanooga. The Boice shale is confined to northeastern Kansas but extends somewhat west of the Nemaha anticline. Its maximum known thickness is 110 feet near the Nebraska border in Brown County.

Chattanooga shale.—The Chattanooga shale is silty, pyritiferous, and in some places partly dolomitic. Spores are thinly disseminated throughout but most common in basal beds. The shale is black in southern Kansas but northward it grades into gray shale. The **Misener sandstone member** at the base of the shale is a distinct unit in some places but in most of eastern Kansas it is represented only by disseminated rounded sand grains. The Chattanooga shale is separated from underlying rocks by a low angular unconformity. From north to south, the Chattanooga overlaps on beveled older rocks ranging in age from Devonian to Middle Ordovician.

It is present in most of eastern and central Kansas, but absent at the northern end of the Nemaha anticline, in the area northwest and northeast of the Salina basin, on the Central Kansas uplift, and southwest of the uplift. It extends in a continuous sheet westward along the Oklahoma border to Clark County in the south and Osborne County in the north. Its thickness ranges from a featheredge in Osborne, Clark, and intermediate counties to more than 250 feet in northeastern Kansas near the Nebraska border. Abnormal thicknesses of Chattanooga shale occur in McPherson County and areas to the east where the formation was deposited in valleys eroded in the older rocks.

Devonian System

Limestones and dolomites of Devonian age commonly are included with Silurian rocks in a subsurface unit called "**Hunton limestone.**" The Devonian rocks of east-central Kansas consist of relatively pure lithographic and sublithographic limestones that grade northwestward into dolomite in the North Kansas basin. In some places, particularly just east of the Nemaha anticline, the Devonian is very coarsely crystalline and porous. A cherty zone commonly occurs 30 to 100 feet above the base. Basal Devonian beds, consisting of sandy dolomite or limestone, are distinguished readily from the nonsandy Silurian. An unconformity which occurs at the base of the Devonian section is one of the most important in the geologic sequence of Kansas, for it represents local pre-Devonian erosion of Silurian and older rocks hundreds of feet thick. In eastern Kansas, the Devonian successively overlaps Silurian, Sylvan, Viola, and upper Arbuckle rocks from north to south. Devonian limestones which once crossed the Chautauqua arch into Oklahoma were destroyed by pre-Chattanooga erosion. Devonian rocks now are confined to eastern Kansas where they occur flanking the Central Kansas uplift and Chautauqua arch. They are absent in the Hugoton embayment. In northeastern Kansas the maximum known thickness of the Devonian limestones and dolomites (215 feet) occurs in Nemaha County.

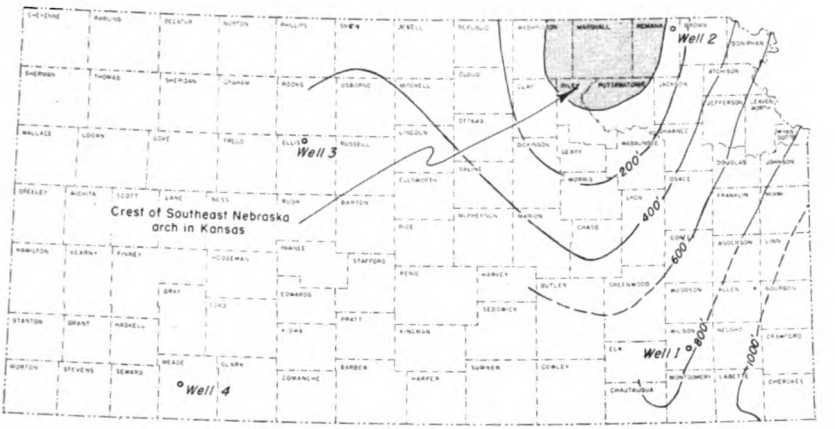

Fig. 43.—Pre-Simpson (pre-St. Peter) structural features in Kansas. Shown in eastern Kansas by the thickness of the earlier Paleozoic formations beveled by the Simpson (St. Peter). Lower Ordovician and Upper Cambrian rocks absent on crest of the Southeast Nebraska arch; its southern extension shown by 200-foot thickness contours. In southeastern Kansas the pre-Simpson thickness of the Arbuckle dolomites was later reduced by pre-Chattanooga erosion.

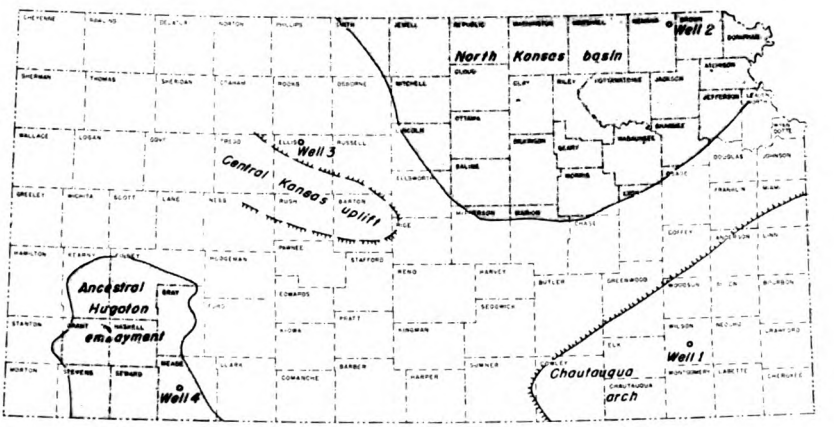

Fig. 44.—Structural features developed in Kansas between Simpson time and Mississippian time. North Kansas basin outlined by the 400-foot thickness contour (base of Simpson to base of Mississippian rocks). Early movement of Central Kansas uplift outlined by assumed pre-Mississippian border of Viola limestone. Central area of ancestral Hugoton embayment shown by 150-foot Viola limestone thickness contour. Chautauqua arch outlined by pre-Chattanooga outcrop of base of Simpson.

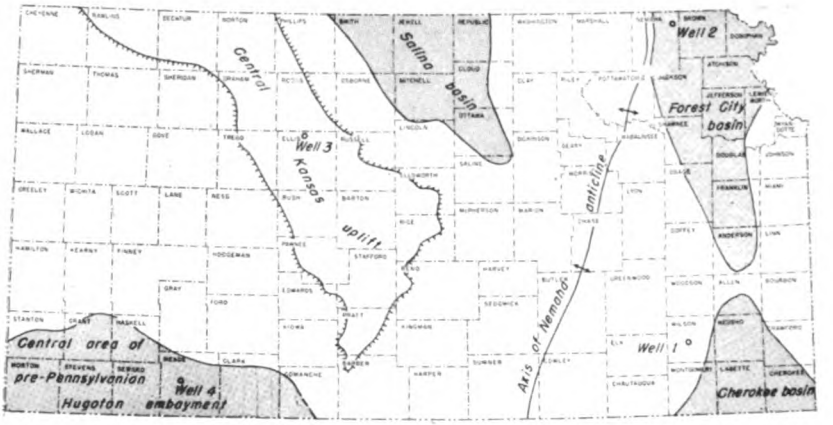

Fig. 45.—Post-Mississippian - pre-Mesozoic structural features in Kansas. Central Kansas uplift outlined by margin of Mississippian rocks; Forest City and Cherokee basins by the generalized 750-foot thickness contour of Desmoinesian rocks; and central Salina basin by 300-foot thickness contour of Desmoinesian rocks. Nemaha anticline is shown by the trend of its axis. Central part of pre-Pennsylvanian Hugoton basin shown by approximate margin of Chesteran rocks.

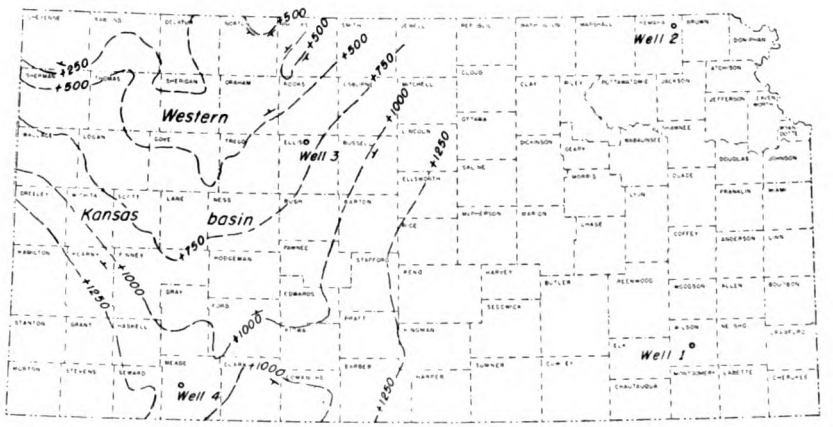

Fig. 46.—**Post-Permian structural features in Kansas.** Western Kansas basin, evolved from Hugoton embayment, shown by generalized 250-foot structure contours on the Stone Corral. This basin is now the result of post-Dakota movements that tilted the Hugoton embayment northward toward a large basin in western Nebraska.

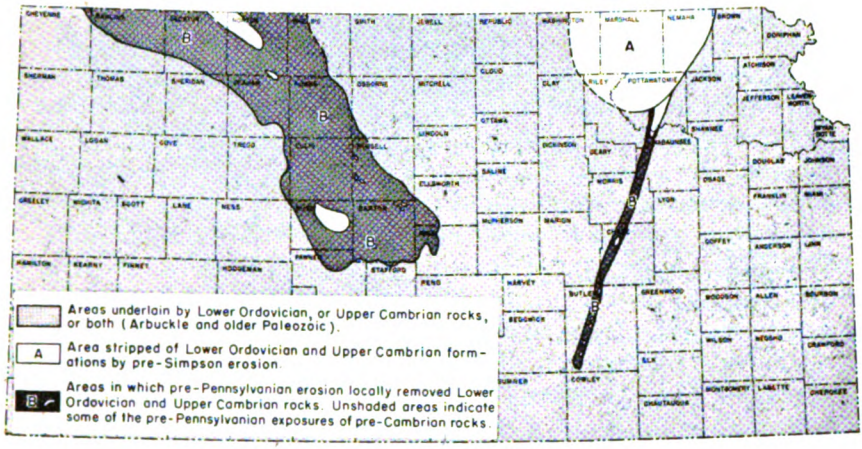

Fig. 47.—Distribution of pre-Simpson rocks in Kansas. Lower Ordovician or Upper Cambrian rocks or both underlie all of Kansas except in areas where removed by erosion. Some areas of pre-Simpson Pre-Cambrian outcrop are not shown.

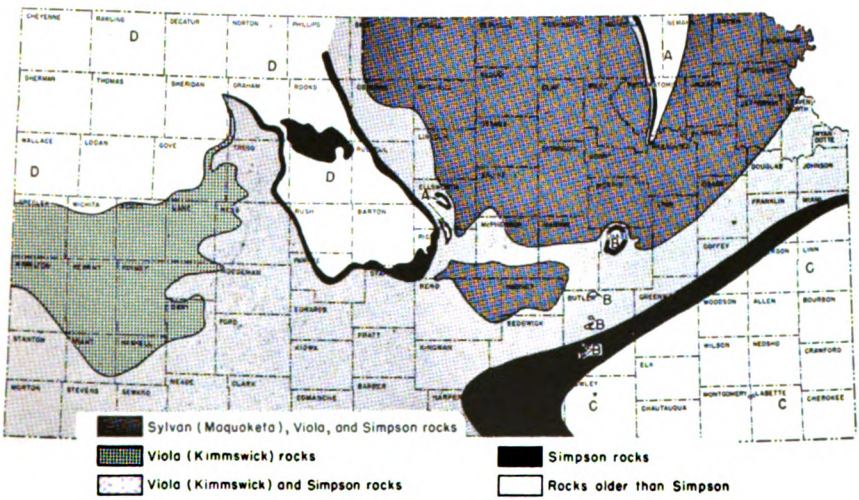

Fig. 48.—. Distribution of Simpson, Viola, and Sylvan (Maquoketa) rocks in Kansas. Separation of Sylvan areas in McPherson and Marion Cos. reveals a pre-Chattanooga valley. Nemaha anticline, **A**, pre-Pennsylvanian erosion removed pre-Pennsylvanian rocks from crest and beveled Pre-Cambrian to Devonian rocks on both flanks. Southern Nemaha anticline, **B**, pre-Pennsylvanian erosion exposed Pre-Cambrian rocks on local domes and beveled younger rocks (not shown) on their flanks. Chautauqua arch, **C**, pre-Chattanooga erosion removed upper part of Arbuckle group. Central Kansas uplift, **D**, pre-Pennsylvanian beveling exposed Lower Ordovician and Upper Cambrian rocks. Pre-Cambrian rocks exposed locally on anticlines; Simpson inliers preserved in synclines.

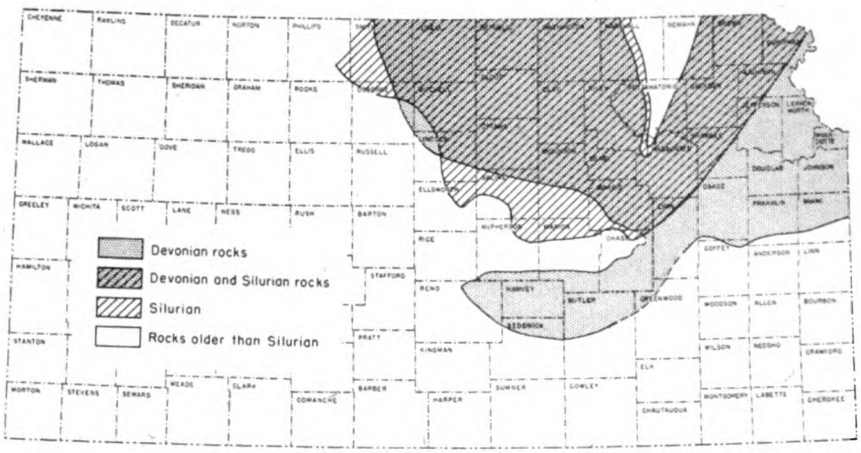

Fig. 49.—Distribution of "Hunton" (Devonian and Silurian) rocks in Kansas. Devonian unconformably overlaps older rocks from Arbuckle to Silurian. Re-entrant in McPherson and Marion Counties outlines pre-Chattanooga valley. Distribution of Devonian and older rocks on crest of Nemaha anticline (Morris and Wabaunsee Cos.) not yet revealed.

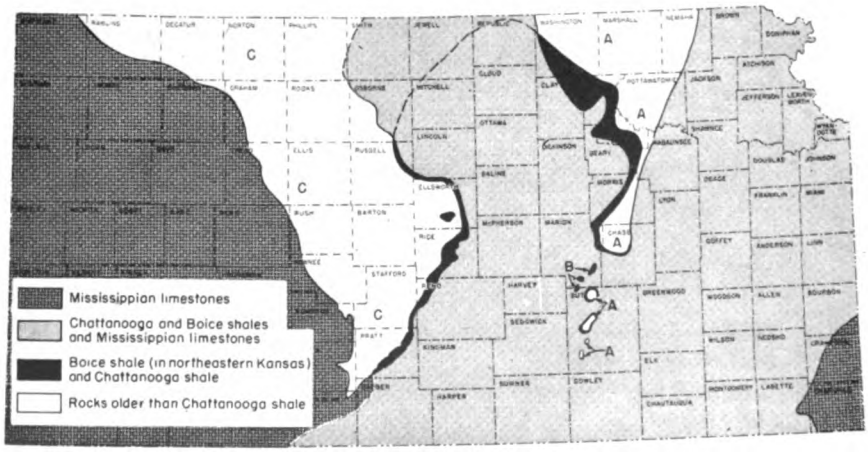

Fig. 50.—Distribution of Chattanooga and Mississippian rocks in Kansas. In parts of Barber and Comanche Counties and southeastern and north-central Kansas, Mississippian limestones overlap margin of the shale. Chattanooga unconformably overlaps rocks from Arbuckle to Devonian. On Nemaha anticline, **A**, pre-Pennsylvanian erosion removed Mississippian and locally older rocks. On local domes on west flank Nemaha anticline, **B**, only Mississippian was eroded. On Central Kansas uplift, **C**, pre-Pennsylvanian erosion removed the Mississippian limestones. Outliers of Chattanooga shale occur in Ellsworth County and elsewhere.

Silurian System

Lack of sand grains mainly distinguishes the Silurian rocks of Kansas from the Devonian. Dolomite predominates but on the margin of the North Kansas basin some limestone is interbedded. The lower part of the Silurian, of probable Chimneyhill age, includes dolomitic oölite at the base, overlain by beds containing opaque white chert and slightly silty dolomite with sparsely distributed siliceous foraminifers. Higher strata are mostly white coarse dolomite. The Silurian rests disconformably on Sylvan (Maquoketa) shale, but without marked relief. In Kansas, the Silurian is restricted to the ancient North Kansas basin northeast of the Central Kansas uplift and north of the Chautauqua arch. Maximum thickness of the system in Kansas is 435 feet in Nemaha County.

Ordovician System

Late Ordovician rocks are represented in Kansas by the Sylvan (Maquoketa) shale. Middle Ordovician deposits include the Viola (Kimmswick) limestone and dolomite and Platteville formation (the latter being equivalent to the upper part of the Simpson group of Oklahoma). Early Ordovician rocks include the St. Peter sandstone and slightly older rocks of Simpson age, and formations referred to the "Arbuckle group."

Sylvan (Maquoketa) shale.—The characteristic Sylvan shale of northeastern Kansas consists of greenish-gray silty dolomitic shale or cherty silty dolomite. In southern Kansas, the Sylvan becomes more argillaceous and less cherty and dolomitic. An obscure low angular unconformity between the Sylvan shale and the underlying Viola is revealed by the overlap, toward the southwest, of the Sylvan upon progressively older zones of the Viola. Like the overlying Silurian and Devonian rocks the Sylvan is now restricted principally to the area that once formed the North Kansas basin. It was originally continuous with areas of Sylvan shale in Oklahoma, but connection across the Chautauqua arch was broken by pre-Devonian and pre-Chattanooga beveling. The Sylvan is not recognized in southwestern Kansas. In eastern Kansas, where it occurs beneath the Silurian rocks, the Sylvan ranges from 155 feet in the north to less than 40 feet in the south.

Viola limestone.—The Viola limestone of Kansas, which represents only part of the Viola of Oklahoma, consists of dolomite and limestone containing some cherty beds characterized by black flecks and spicular and tubelike fragments of microorganisms. In deep parts of the North Kansas basin, the carbonate rocks of the Viola are almost entirely dolomite, but toward margins of the basin earthy and granular limestone appears, es-

pecially at the base. An unconformity between Viola and Platteville rocks in Kansas is revealed by northward thickening of the Platteville formation. The Viola occurs throughout the State except on the Central Kansas uplift, Chautauqua arch, and northern end of the Nemaha anticline. In the Hugoton embayment it is overlain by Mississippian limestone. In eastern Kansas the Viola is 310 feet thick (Washington County), and it thins southward to 20 feet in Harvey County. In southwestern Kansas it thickens from a beveled edge on the flanks of the Central Kansas uplift to more than 200 feet in the deepest part of the Hugoton embayment at the State line.

Simpson group.—The Simpson rocks of Kansas include the Platteville formation, of Middle Ordovician age, and the St. Peter sandstone and slightly older rocks of Early Ordovician age.

Platteville formation.—Upper beds of the Platteville formation in Kansas consist of dolomite, limestone, sandstone, and green shale in varied succession, and at the basal part is a persistent dolomite. Some sand generally occurs in the basal dolomite and disseminated in the shales and dolomites of the upper part. In Kansas, the formation is restricted to the North Kansas basin. The Platteville is obscurely unconformable on the St. Peter sandstone in northeastern Kansas, where formations whose thickness aggregates about 900 feet at southeastern Missouri outcrops are missing. Maximum known thickness of the formation in Kansas is 100 feet in Brown County, from which it wedges out southward on the flanks of the Chautauqua arch and the Central Kansas uplift.

St. Peter sandstone and **lower Simpson beds.**—The St. Peter sandstone and underlying green shale and sandstone, which occur near the Oklahoma border, are part of the Simpson group. A shaly zone in the middle part of the St. Peter in northeastern Kansas becomes more prominent southward, and westward near the Oklahoma border upper St. Peter sandstone is underlain by light-green and dark-green clay shale, sandy clay, and sandstone. In the Hugoton embayment, the Simpson is represented by sandy dolomite, white dolomitic sandstone, and blue-green to gray plastic shale. The sandstones are glauconitic. Rocks of Simpson age were formerly present throughout eastern and central Kansas, but pre-Devonian and pre-Chattanooga erosion removed them from the Chautauqua arch, and pre-Pennsylvanian and pre-Mississippian erosion removed them from considerable areas on the Central Kansas uplift and northern end of the Nemaha anticline. A low angular unconformity separates the St. Peter and associated Simpson beds from underlying rocks. The St. Peter overlies Pre-Cambrian and Upper Cambrian rocks on the Nebraska arch in northeastern Kansas and in outward directions overlaps on progressively younger Lower Ordovician rocks. The thickness of the St. Peter sandstone averages about 50 feet in northeastern Kansas. The St. Peter and associated Simpson rocks increase in thickness to 190 feet near the Oklahoma line. In the Hugoton embayment the Simpson is about 90 feet thick and thins to the north and west.

Arbuckle group.—The Arbuckle group consists of Early Ordovician and Late Cambrian deposits, its subdivisions in Kansas being units that crop out in Mis-

souri: Cotter and Jefferson City dolomites, Roubidoux formation, Gasconade dolomite, Van Buren formation, and Eminence dolomite. The Eminence is Cambrian and the others Ordovician.

Cotter and Jefferson City dolomites.—Because dolomitic rocks representing the Cotter and Jefferson City dolomites of outcrops are not distinctly separable on lithologic criteria, they are classed together in the subsurface. They consist mainly of coarsely granular cherty dolomite. The upper part of the sequence includes much oölitic chert which becomes white and decreases in volume toward the base where white tripolitic chert becomes abundant. These rocks unconformably underlie various formations, such as St. Peter sandstone on the flank of the Southeast Nebraska arch, Chattanooga shale on the Chautauqua arch, and Pennsylvanian rocks on parts of the Central Kansas uplift and Nemaha anticline. The Jefferson City dolomite probably is conformable on Roubidoux formation. The Cotter-Jefferson City sequence ranges in thickness from a featheredge in northern Kansas to more than 650 feet in Cowley County.

Roubidoux formation.—In Kansas, this formation consists mainly of sandy dolomite; fine-grained sand with some secondary enlargement is irregularly distributed throughout. Deposition of the Roubidoux seems to have been preceded by warping and erosion of older rocks. Thickness of the formation generally ranges from 150 to 200 feet.

Gasconade dolomite and **Van Buren formation.**—Deposits in Kansas which correspond to the Gasconade and Van Buren formations at outcrops in Missouri are not clearly separable in the subsurface. They consist mainly of very cherty coarse granular dolomite. The chert in the upper part, which is dense and gray to dark bluish, grades downward to white dense and quartzose chert. Like the Roubidoux, the **Gunter sandstone member** at the base of the Van Buren formation is a sandy dolomite in Kansas. The Van Buren formation is unconformable on Eminence beds and probably also Bonneterre, Lamotte, and Pre-Cambrian. The Proctor dolomite of Missouri is not recognized in the Kansas section. Gasconade-Van Buren rocks are reported in the subsurface in a belt along the Missouri state line. Their thickness ranges from a beveled edge to more than 200 feet in southeastern Kansas.

Cambrian System

Three Late Cambrian formations of Missouri are encountered in the subsurface of Kansas. The youngest of these (Eminence dolomite) is included in the Arbuckle group. Underlying rocks include the Bonneterre dolomite, equivalent to Honey Creek limestone in Oklahoma, and Lamotte sandstone, equivalent to Reagan sandstone in Oklahoma.

Eminence dolomite.—Very cherty buff to white very coarsely crystalline dolomite is included in the Eminence dolomite. Vitreous semitranslucent chert contains cavities incrusted by fine crystalline quartz. The

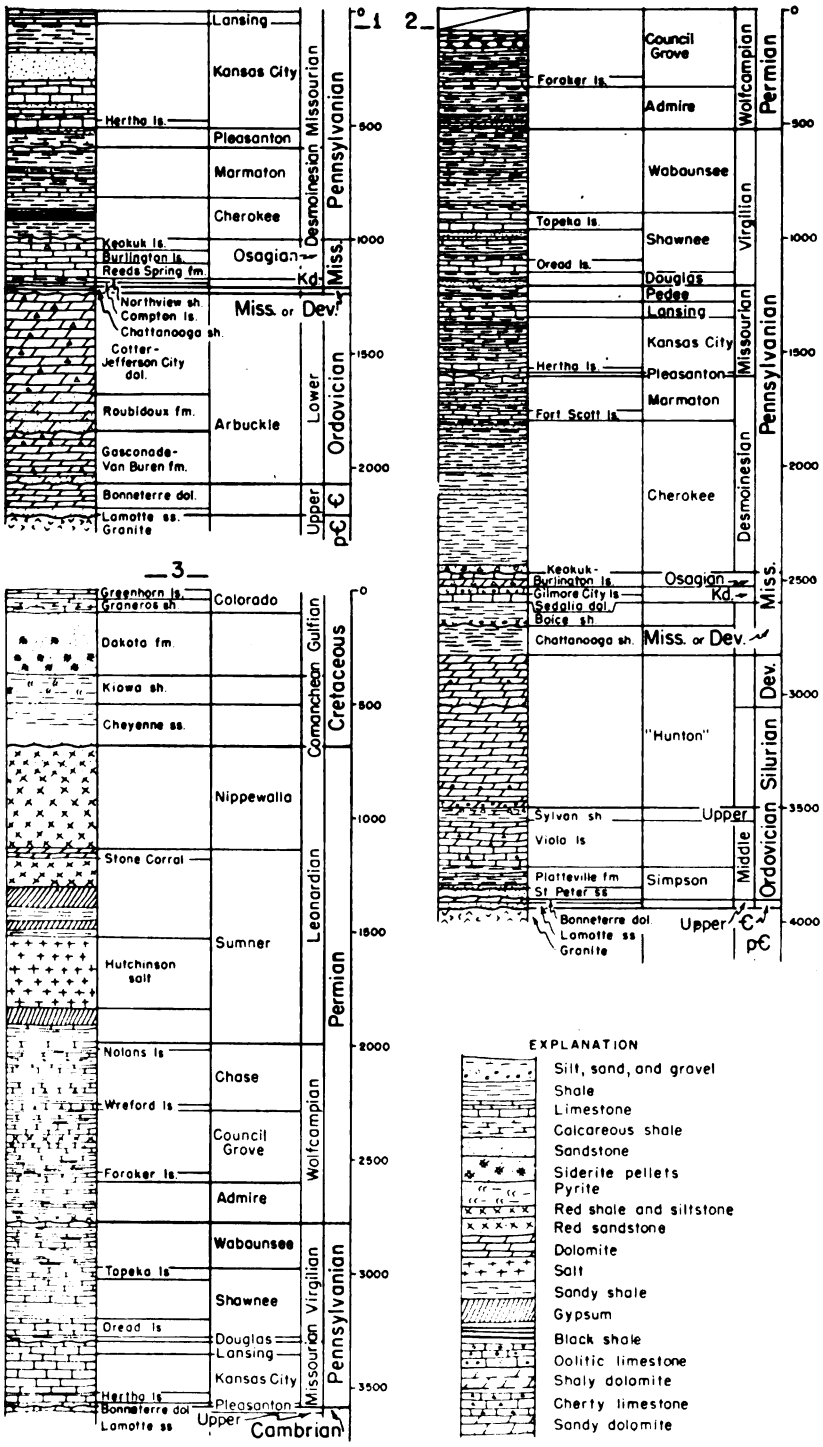

Fig. 51.—**Selected sample study logs.**

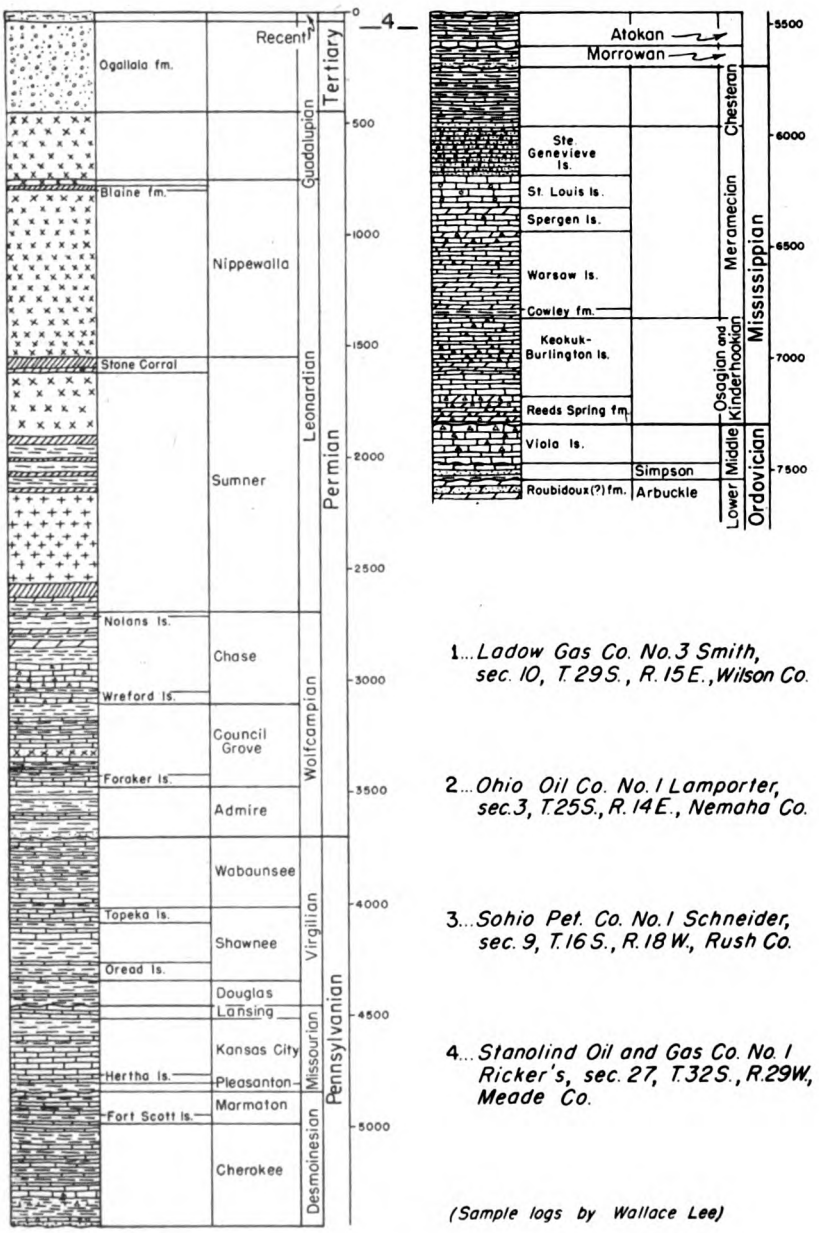

Fig. 52.—**Selected sample study logs.**

chert commonly is mixed so intimately with the dolomite that insoluble residues consist largely of chert with lacelike interconnecting molds of dolomite crystals. A low angular unconformity separates the Eminence from Bonneterre. Occurrence of Eminence deposits in eastern Kansas is confined mostly to a belt three counties wide bordering Missouri, but it is recognized also in western Kansas. The formation thickens eastward from a beveled edge to more than 150 feet at the Missouri line. Thicknesses of 40 to 87 feet are reported in west-central Kansas.

Bonneterre dolomite.—The Bonneterre is a conspicuously glauconitic, noncherty dolomite which is dark gray to brown and finely crystalline in eastern Kansas and buff to white and coarsely crystalline in western Kansas. It includes sandy and silty dolomites, and dolomitic shale locally near the top. The Bonneterre is distributed throughout Kansas except on parts of uplifts such as the Southeast Nebraska arch, Central Kansas uplift, and Nemaha anticline. The Bonneterre grades downward into the Lamotte sandstone with which it is conformable. The thickness ranges from a beveled edge at margins of some uplifts to 150 feet in basin areas where it underlies the Eminence in eastern and western Kansas and locally in McPherson County.

Lamotte sandstone.—The sand grains composing the Lamotte are ill sorted, rounded to angular, and coarse to fine. Arkosic material occurs in the lower part adjacent to Pre-Cambrian rocks. The Lamotte sandstone was deposited unconformably on a complex of Pre-Cambrian rocks which formed an uneven surface of very low relief. The formation is widespread in Kansas beneath the Bonneterre but locally Bonneterre overlaps on the Pre-Cambrian surface. Thicknesses of 80 to 130 feet have been reported in southeastern Kansas but the average thickness is about 20 feet.

PRE- CAMBRIAN ROCKS

Rocks of Pre-Cambrian age underlie all of Kansas. They include granite, porphyry, gneiss, schist, quartzite, slate, and marble, according to reports of deep wells. Granite or gneiss probably is most widespread.

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