Stratigraphy and Structure of Middle and Upper Ordovician Rocks in the Sedgwick Basin and Adjacent Areas, South-Central Kansas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 702

Prepared in cooperation with the State Geological Survey of Kansas

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By W. L. Adkison

ABSTRACT

The Middle and Upper Ordovician rocks of Sedgwick basin, south-central Kansas, have yielded large amounts of oil and some gas. These rocks are assigned to three units: the Simpson Group, Viola Limestone, and Sylvan Shale (from oldest to youngest).

The Simpson Group, as much as 254 feet thick, unconformably overlies the Arbuckle Group and consists of sandstone, shale, dolomite, and limestone. The group thins regionally toward the northwest. The percentage of sandstone increases southeastward, and the percentage of carbonate rocks is generally greatest in the northern and westernmost parts of the area. Areas where the Simpson is thin in much of the western part may indicate pre-Simpson topographic highs that trend mostly northeast and north.

The Viola Limestone, possibly as much as 239 feet thick, consists of limestone, dolomite, and chert. In much of the western part of the area, the formation includes residual chert and at a few places clastic rocks that may be cavern fillings. Karst topography at the top of the Viola is tentatively interpreted from the thickness map. Evidently the formation was exposed to subaerial erosion and underground drainage, and parts of it were dissolved. Erosion removed part of the Viola in the central part of the area, and cut through into the Simpson at one place, before the Sylvan Shale was deposited.

The Sylvan Shale consists of shale and dolomite and unconformably overlies the Viola. It is found mainly in the northern part of the area, where it is as much as 142 feet thick. The Sylvan is also present in the southwestern part of the area adjacent to the Oklahoma State line.

In the eastern part of the study area Devonian carbonates overlap southward across Silurian carbonates, the Sylvan Shale, Viola Limestone, and possibly onto the Simpson Group. The Chattanooga Shale, Devonian and Mississippian in age, unconformably overlies the Ordovician rocks in most of the area. In the western part, a variable clastic sequence of Early Mississippian (Kinderhook) age overlies Ordovician beds. Rocks of Middle and Late Pennsylvanian age unconformably overlie the Ordovician rocks at places along the Nemaha and Pratt anticlines and on much of the Central Kansas uplift.

Early Ordovician (pre-Simpson) movements probably tilted the area toward the south. A structural hinge line may have extended westward through the southern part of the area and separated a large relatively flat platform area to the north from a more rapidly subsiding basin area in Oklahoma. Precambrian rocks were locally exposed by erosion in the northern part of the area, but detailed structural relations are unknown.

Folding after Early Ordovician time and before Mississippian time formed the North Kansas basin, Chautauqua arch, and the ancestral Central Kansas uplift. The northern part of the map area lies high on the southwestern flank of the North Kansas basin, and the southeastern part includes the western part of the Chautauqua arch. Broad uplift of the arch occurred in Silurian and Late Devonian times, although minor movements probably began as early as Middle Ordovician (late Simpson) time and recurred in Late Ordovician (post-Viola pre-Sylvan) time. Structural movements in the western part of the area during Late Devonian time probably formed a broad low arch that plunged gently southward and possibly merged northward with the ancestral Central Kansas uplift.

The major structural features in the area were formed largely at the end of Mississippian or in the early part of Pennsylvanian time. The Sedgwick basin is a broad relatively shallow southward-plunging northeast embayment of the Anadarko basin of Oklahoma. It is limited on the east by the Nemaha anticline and on the west by the Central Kansas uplift and Pratt anticline. The northern limit is obscurely defined by thinning of Mississippian rocks. Several anticlines in the basin are generally subparallel to the Nemaha anticline and plunge southward. Post-Mississippian structural features are primarily folds, but faults are locally significant, especially along the larger anticlines.

Hundreds of oil and gas fields have been discovered in the area, and many of these are productive from Middle and Upper Ordovician rocks. Anticlines probably provided the traps for oil in most fields that produce from the Middle and Upper Ordovician rocks; stratigraphic traps in these rocks are less well known.

INTRODUCTION

This report describes the stratigraphy, lithologic composition, and general structure of the Middle and Upper Ordovician subsurface rocks of the Sedgwick basin and adjacent areas in south-central Kansas (fig. 1). The area includes about 15,000 square miles in parts of 22 counties. The city of Wichita lies in the east-central part of the area.

The Sedgwick basin is a south-plunging northeast embayment of the Anadarko basin of Oklahoma. The basin and adjacent positive features were formed by structural movements, mainly in Early Pennsylvanian time. The basin is limited on the east by the Nemaha anticline and on the west by the

Central Kansas uplift and the Pratt anticline (fig. 1). The border of the Sedgwick basin with the Salina basin to the north is rather poorly defined.

The Middle and Upper Ordovician rocks are assigned, from oldest to youngest, to the Simpson Group, Viola Limestone, and Sylvan Shale. The underlying Arbuckle Group (Upper Cambrian and Lower Ordovician) was not studied for this report.

Ordovician rocks have yielded large amounts of oil and gas in Kansas for many years, and this report is intended to aid in the continuing search for new oil and gas fields.

ACKNOWLEDGMENTS

Much of the work for this report was done in Lawrence, Kans., during the years 1958–66 under a cooperative agreement with the State Geological Survey of Kansas. The report was completed with informal cooperation by the State Survey after the writer left Kansas.

The study of Ordovician rocks in the map area was facilitated by the large collection of samples, logs, and other data in the files of the State Geological Survey of Kansas. Geologists of the State Survey who aided this study include Edwin D. Goebel, Paul L. Hilpman, Mrs. Margaret O. Oros, and Douglas L. Beene. Several other members of the State Survey aided in many ways.

The petroleum industry in Kansas and the Kansas Geological Society deserve much credit for their cooperative effort in collecting a vast amount of subsurface data about wells drilled in the State. Their sustained effort for many years has facilitated the publication of many reports on the subsurface geology of Kansas.

The writer wishes to thank James D. Davies,

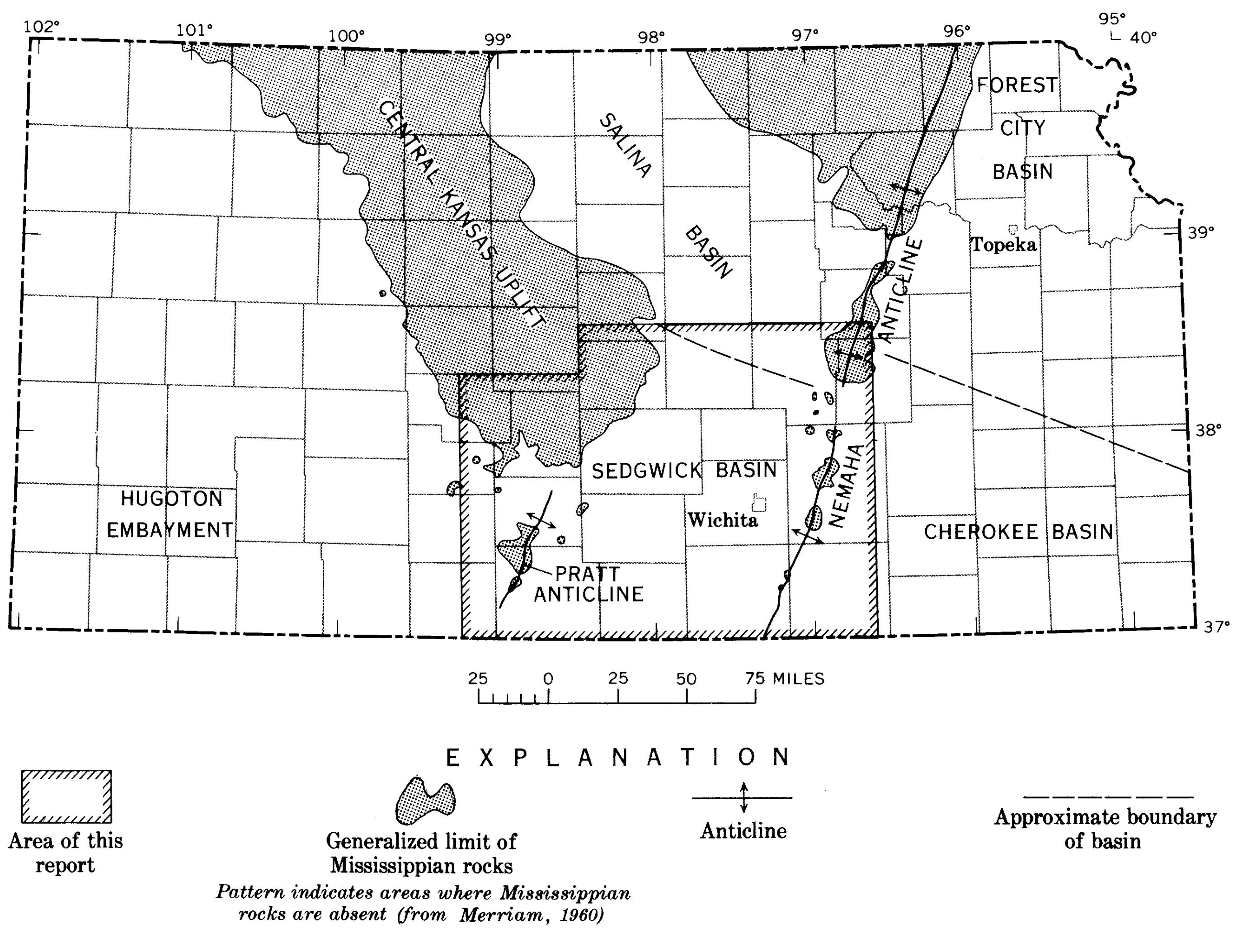

FIGURE 1.—Map of Kansas showing the area of this report in relation to major structural features formed mainly in Late Mississippian and Early Pennsylvanian time.

Kansas Sample Log Service, Wichita, for permission to use his sample logs for wells in the project area. The late Wendell S. Johns, while a graduate student at the University of Kansas, allowed the writer to copy many of his sample logs, some of which were made by W. J. Magathan.

Facilities of the University of Kansas Computation Center were used to process the large amount of data and to print work maps. The computer programming was done by Charles O. Morgan and Jesse McNellis, both of the U.S. Geological Survey. Ronald B. Martin, while a graduate student at the University of Kansas, assisted in the compilation of data and of oil- and gas-field maps. Lee Swartling also assisted on the project.

METHODS OF INVESTIGATION

Study of the Ordovician rocks is based largely on interpretive sample logs which were prepared by several geologists over a considerable span of time. Logs by Kansas Sample Log Service that were available in the files of the Kansas Geological Survey before March 15, 1968, provide most of the basic framework for the study. The interpretive sample logs are supplemented by selected electrical and radioactivity logs, some percentage sample logs, and some drillers' logs and well-completion reports. Because the study is primarily regional, thousands of wells, especially in the many oil and gas fields, were not considered. The inclusion of additional well data would doubtless bring out many local details of structure, lithologic composition, and areal distribution of the rock units. However, many local field studies are available in the literature, and several are cited in this report.

Most of the interpretive sample logs are for wells drilled with rotary tools. Accurate determination of the thickness and sequence of beds is generally difficult when one examines rotary-drilled samples alone because they include a high percentage of caved or recirculated cuttings. Electrical, radioactivity, and drilling-time logs are a useful supplement to indicate accurately the depths of lithologic changes and to suggest lithologic composition. Many interpretive sample logs used in this study were prepared from concurrent study of the samples and electrical or radioactivity logs, but perhaps as many as two-thirds of the total number of interpretive sample logs seemingly were prepared from sample study alone. Interpretations of rotary-drilled samples by different geologists are likely to differ somewhat, and complete agreement regarding details cannot be expected.

In an attempt to attain greater uniformity among the interpretive sample logs, the writer compared each log prepared from samples alone with the electrical or radioactivity log for that well (if one was available). The depths of lithologic contacts and the lithology shown on the sample log were then modified as necessary to agree with those indicated or suggested by the electrical or radioactivity log. For some logs this modification resulted in pronounced changes in relative amounts of different rock types from those shown on the original log. This is to be expected because the quality of the well samples, as noted on the sample logs, ranged from good to very poor or even worthless. The sample logs prepared from samples alone, of wells for which electrical or radioactivity logs were unavailable, were compared with electrical or radioactivity logs of nearby wells if possible but generally were not modified. Some sample logs had intervals of missing or worthless samples, and for these, stratigraphic contacts were determined from electrical or radioactivity logs, drillers logs, or completion reports.

The relatively few percentage sample logs were used only for stratigraphic, thickness, and structural control because of the difficulty in determining the total thicknesses of different rock types in a stratigraphic unit.

The electrical and radioactivity logs used in this study were selected partly to provide stratigraphic, thickness, and structural control in areas of sparse sample-log control. In general, an effort was made to have at least one log (sample, electrical, or radioactivity) from or near each oil or gas field with production from Middle or Upper Ordovician rocks. Stratigraphic contacts on the electrical and radioactivity logs were determined with the aid of completion reports and by comparison with similar logs of nearby wells for which sample logs were available. Some contacts were very obscure because of locally complex stratigraphy or poor logs.

Information from completion reports and a few drillers' logs provided additional control in some parts of the report area, chiefly the eastern half. The accuracy of the stratigraphic contacts in these reports is generally unknown, for some operators probably use different criteria for determining contacts. This factor is discussed in more detail in later parts of the report.

Stratigraphic correlation of pre-Pennsylvanian rocks in central Kansas has long been based primarily on lithologic similarities and stratigraphic position. Significant improvements have been made in mechanical logging since World War II; accordingly, correlations based on electrical or radioactive properties of the rocks are more reliable. Despite this improvement, the identification and delineation of some Ordovician units in certain areas is generally best where well samples are used.

STRATIGRAPHY

The subsurface stratigraphy of the central Kansas oil fields has been well established through decades of work by many geologists who have examined samples from thousands of wells and outcrops. During the 1920's and 1930's correlations of lower Paleozoic rocks, based mainly on lithology and stratigraphic position, were extended into Kansas from Oklahoma, Missouri, and Iowa. As early as 1921, Ordovician rocks were traced northward from Oklahoma into east-central Kansas by Aurin, Clark, and Trager (1921). Several years later the presence of Ordovician rocks in central Kansas was further established by paleontologic studies (Udden, 1926; Twenhofel, 1927; Edson, 1929). Some of the early geologists were understandably reluctant to apply stratigraphic terminology of the Upper Mississippi Valley, the Ozark region of Missouri, or the Arbuckle Mountains of Oklahoma to the subsurface rocks in central Kansas. Several new names were proposed for subsurface stratigraphic units, mainly during the 1920's, but their use gradually diminished in favor of outcrop terminology from the areas outside Kansas. In this report, nomenclature of the Arbuckle Mountains of Oklahoma is used for the Ordovician rocks, and the generally accepted correlations with the stratigraphic column in Missouri are briefly mentioned. The stratigraphic nomenclature used in this report is shown in table 1.

TABLE 1.—*Stratigraphic nomenclature used in this report*

System	*Series*	*Rock unit*
Pennsylvanian	Middle	Rocks of Des Moines age.
		Unconformity.
Mississippian	Upper	Rocks of Chester age.
		Unconformity.
		Rocks of Meramec age.
	Lower	Rocks of Osage age.
		Rocks of Kinderhook age.
		Unconformity.
Mississippian and Devonian		Chattanooga Shale.
		Unconformity.
Devonian		Hunton Group (upper part).
		Unconformity.
Silurian		Hunton Group (lower part).
Ordovician	Upper	Sylvan Shale.
		Unconformity.
	Upper and Middle	Viola Limestone.
	Middle	Simpson Group.
		Unconformity.
Ordovician and Cambrian		Arbuckle Group.
Cambrian	Upper	Bonneterre Dolomite.
		Reagan Sandstone.
		Unconformity.
Precambrian		Rocks of Precambrian age.

PRE-MIDDLE ORDOVICIAN ROCKS

Rocks of Precambrian, Late Cambrian, and Early Ordovician ages occur beneath the Simpson Group of Middle Ordovician age in the report area (fig. 1, table 1). The pre-Simpson rocks were not studied but are briefly described in order to provide background for the description of the Middle and Upper Ordovician rocks.

Precambrian rocks were exposed by erosion in Early Ordovician (pre-Simpson) time at a few places in the northern part of the area. Quartzite or quartz gneiss underlies the Simpson Group in the Natural Gas and Oil 1 Enlow well in sec. 9, T. 24 S., R. 16 W. This relation is shown on plate 1 (well 2, cross section *E–F*). At the location of the Enlow well, Sheats (1956, p. 34, 35) tentatively interpreted a hill of Precambrian rocks. According to a later report (Cole and others, 1961, p. 136, 137), Precambrian rocks underlie the Simpson Group in a well in sec. 2, T. 24 S., R. 16 W., in a well in sec. 30, T. 23 S., R. 15 W., and in one or possibly two wells in sec. 32, T. 23 S., R. 15 W. Lee (1956, pl. 1, panel 1) postulated that there was a large hill of Precambrian rocks in T. 24 S., R. 16 W., and another smaller hill centering in the northeastern part of T. 21 S., R. 15 W. In sec. 1 of this township, Precambrian rocks are overlain in different wells by Arbuckle, Simpson, and Pennsylvanian rocks (Cole and others, 1961, p. 134).

In Marion County, Precambrian quartzite underlies the Simpson Group in the Anderson-Prichard 1 Jost well, sec. 22, T. 19 S., R. 2 E. (well 21, cross section *C–D*, (pl. 1). In sec. 28 of the same township, Precambrian rocks also occur beneath the Simpson, as indicated by the electrical log and completion report for the Anderson-Prichard 1 "D" Scully well. The Jost and Scully wells may be located above a buried hill of Precambrian rocks similar to those in northeastern Barton County which were studied in detail by Walters (1946, p. 660–710). He noted that buried Precambrian hills "are of fairly common occurrence and widespread distribution in the Mid-Continent."

Rocks of Late Cambrian and Early Ordovician age underlie the Simpson Group in the remainder of the mapped area. These rocks include, from oldest to youngest, the Reagan Sandstone, Bonneterre Dolomite, and Arbuckle Group (see table 1). Many petroleum geologists consider the Bonneterre as part of the Arbuckle because both are predominantly dolomite. The thickness of rocks between the Precambrian and the Simpson Group exceeds 1,100 feet in southwestern Harper County and decreases northward and eastward (Kelly and Merriam, 1964, fig. 3). Relatively few wells in the mapped area have been drilled more than a few tens of feet into the Arbuckle Group.

A major unconformity separates the Arbuckle and older rocks from the Simpson Group. The surface of unconformity probably had some local topographic relief, but in this study the location and size of ancient topographic features could not be determined with reasonable certainty. In the western part of the area, thickness variations of the Simpson Group, described later in this report, suggest that erosion in Early Ordovician time may have cut several shallow valleys into the carbonates of the Arbuckle Group. The trend of these possible valleys is mostly toward the south and southwest and is in agreement with Dapples' (1955, fig. 9) interpretation of southward- to southwestward-flowing currents in central and eastern Kansas in Simpson time. Local topographic relief at the beginning of Simpson deposition was probably less than 50 feet in most of the western part of the area.

The erosional surface of the Arbuckle Group may have included sinkholes and other solution features at the beginning of Simpson deposition, but such features were not identified with certainty during this study. Sinkholes in the Arbuckle Group filled with rocks of the Simpson Group have been tentatively identified in eastern Kansas (Lee and others, 1946, sheet 1; Lee and Merriam, 1954, pl. 2; Merriam and Atkinson, 1956), and similar sinkholes may be present in the Sedgwick basin.

MIDDLE AND UPPER ORDOVICIAN ROCKS

The Middle and Upper Ordovician rocks include the Simpson Group, Viola Limestone, and Sylvan Shale, in order of decreasing age. Correlation of these rocks in selected wells in the Sedgwick basin is shown by a series of four interlocking cross sections, (pl. 1). The rocks are overlain by rock units as old as Silurian and as young as Pennsylvanian. Rocks that directly overlie the Middle and Upper Ordovician rocks are shown in figure 2.

SIMPSON GROUP

The Simpson Group, of Middle Ordovician age, unconformably overlies the Arbuckle Group and attains a maximum thickness of 254 feet in southwestern Harper County near the Oklahoma State line. The Simpson Group in Kansas is equivalent to part of the Simpson Group in the type area in southern Oklahoma. Many writers have discussed the subsurface stratigraphy of the Simpson in Oklahoma and the correlation of these rocks northward into Kansas. A symposium on the Simpson (Tulsa Geological Society, 1965) includes a bibliography on the Simpson Group and equivalent rocks in Kansas, Oklahoma, and Texas (Cramer, 1965, p. 251–264). This symposium also includes a regional stratigraphic study of the Simpson in Oklahoma (Statler, 1965, p. 162–211) and a broad study of these rocks in the central Midcontinent (Ireland, 1965, p. 74–89). A regional analysis of the Simpson in Oklahoma was published by Schramm (1964, p. 1164–1195).

Since the 1920's the lower part of the Simpson Group in east-central Kansas has generally been correlated with the St. Peter Sandstone of Missouri. Leatherock (1945) correlated the lower part of the Simpson in north-central Kansas with the St. Peter Sandstone of Missouri and the upper part of the group with the overlying Platteville Formation of northwest Missouri and adjacent areas. This subdivision of the Simpson was used by Lee, Leatherock, and Botinelly (1948, p. 33–37) and Lee (1956, p. 31–34) in reports on the Salina basin area of north-central Kansas. The Simpson Group is not subdivided in this report mainly because detailed correlations within the group are complicated by facies changes in many parts of the mapped area. The thickness and distribution of the Simpson Group are shown on plate 2, and some variations in lithology are shown by the cross sections on plate 1.

The Simpson Group probably once covered the entire mapped area, but post-Ordovician erosion has removed it at several places. The Simpson is missing over most of the broad Chautauqua arch in southeastern Kansas (fig. 3) and northeastern Oklahoma. This arch, formed mainly in Silurian and Late Devonian times, plunges gently westward into the study area. In western Cowley County, a few erosional remnants of the lower Simpson strata are tentatively mapped as outliers near the pinchout of the group (pl. 2). The identification of these as remnants of the Simpson is rather questionable at some places because they also resemble sandstone (Misener sand of informal usage) at the base of the Chattanooga Shale of Devonian and Mississippian age. The Simpson is absent from structurally high parts of the Nemaha anticline in the eastern part of the area and from the Central Kansas uplift in the northwestern part as a result of Late Mississippian or Early Pennsylvanian uplift and erosion.

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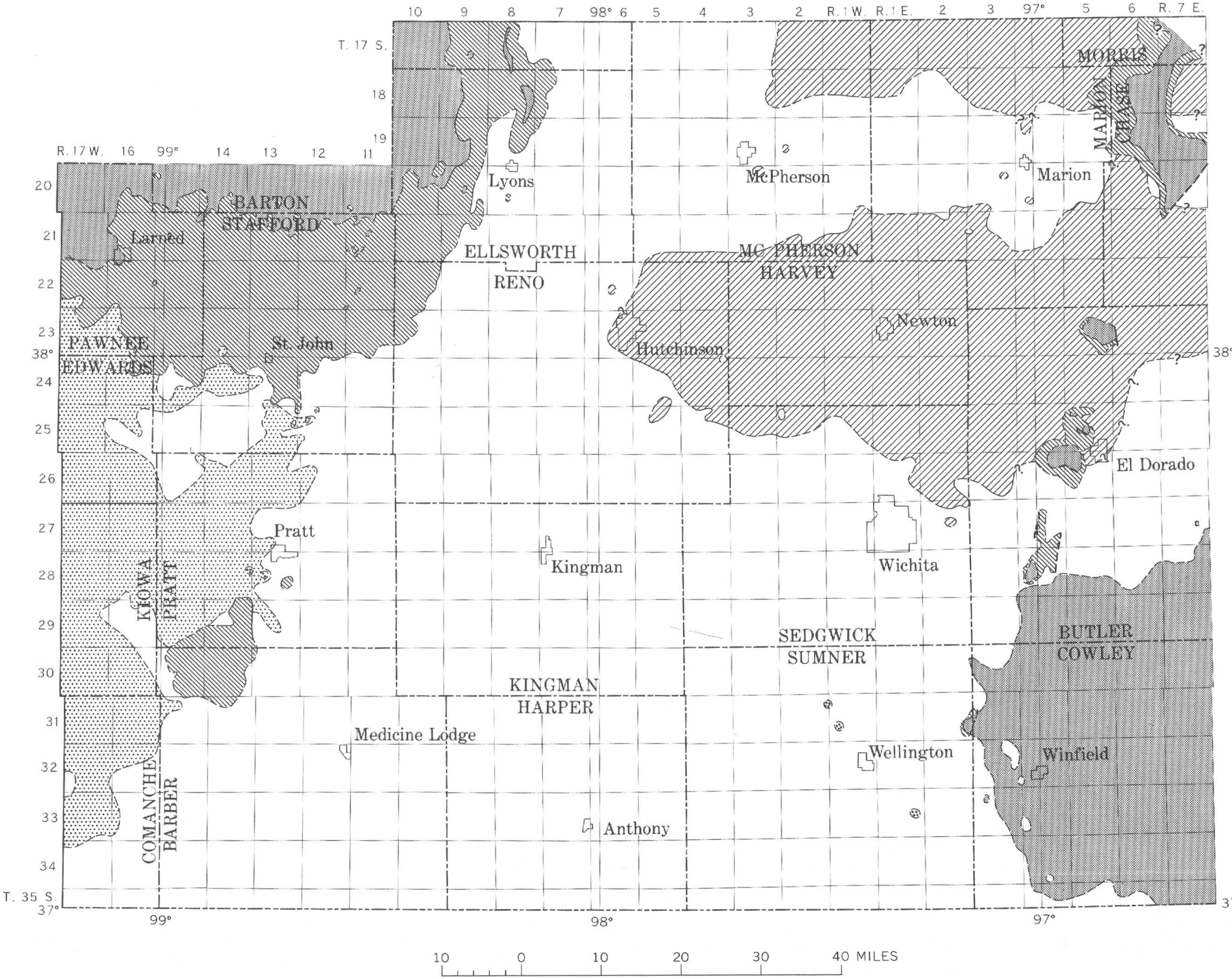


R. 17 W.
R. 1 W.
R. 1 E.
R. 7 E.
T. 17 S.
T. 35 S.
99°
98°
97°
38°
37°
Lyons
McPherson
Marion
Larned
BARTON
STAFFORD
ELLSWORTH
RENO
MC PHERSON
HARVEY
MORRIS
MARION
CHASE
PAWNEE
EDWARDS
St. John
Hutchinson
Newton
El Dorado
Pratt
Kingman
Wichita
KIOWA
PRATT
SEDGWICK
SUMNER
BUTLER
COWLEY
KINGMAN
HARPER
Medicine Lodge
Wellington
Winfield
COMANCHE
BARBER
Anthony
10 0 10 20 30 40 MILES

EXPLANATION

Rocks of Pennsylvanian age

Hunton Group of Silurian and Devonian age

Carbonate rocks of Mississippian age

Area where Middle and Upper Ordovician rocks are absent

Sandy shale, sandstone, and conglomerate of Early Mississippian (Kinderhook) age

Contact

Dashed or queried where approximately located

Chattanooga Shale of Devonian and Mississippian age

May include shale of Kinderhook age in western part of area

Fault

Dashed where approximately located

FIGURE 2.—Geologic units that directly overlie Middle and Upper Ordovician rocks in the Sedgwick basin and adjacent areas, south-central Kansas.

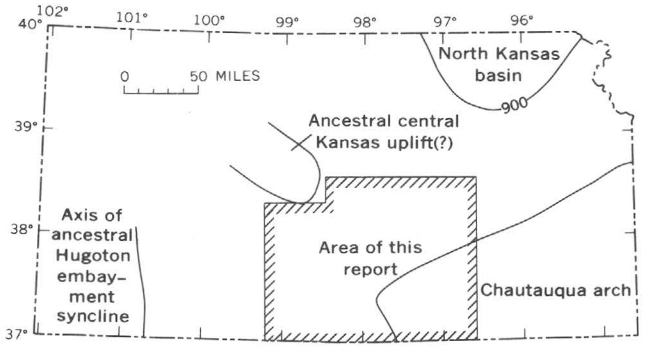


FIGURE 3.—Major structural features formed in central and eastern Kansas from Early Ordovician (Upper Arbuckle) through Late Devonian (lower Chattanooga) time. The Chautauqua arch is outlined by the pinchout of the Viola Limestone, and the North Kansas basin is outlined by the contour line of 900-foot rock thickness between the Arbuckle Group and rocks of Kinderhook age. (After Lee, 1956, fig. 2*B*).

LITHOLOGY

The Simpson Group consists of sandstone, shale, dolomite, and limestone. The ratios of the rock types of the group vary greatly from place to place in the area. Coarse-grained siltstone probably has been logged as sandstone by the geologists whose sample logs are used in this report.

In well samples the base of the Simpson is generally distinct and easily recognized by a downward change from sandstone or shale to dolomite. The top of the Simpson is marked by sandy carbonates, sandstone, or shale. Some operators, geologists, and drillers probably include any carbonate rock at the top of the Simpson with the overlying Viola Limestone and place the top of the Simpson at the first sandstone or green shale below the Viola. For example, in a report on the El Dorado oil field of Butler County, Biederman (1966, p. 42, 43) apparently placed the upper contact of the Simpson at the top of a sandstone and included the overlying partly sandy dolomite in the Viola Limestone.

Sandstone in the Simpson is mostly white to light gray and very quartzose. The grain size ranges from very fine to coarse, but the fine and medium sizes dominate. The sand grains are subangular to highly rounded and frosted, and quartz overgrowths are locally abundant. The cementing material varies greatly in amount and consists mainly of dolomite, silica, and calcite. Some sandstone is so loosely cemented that it is largely reduced to individual grains by drilling. Accessory particles of glauconite, black phosphatic(?) grains, and shale fragments are fairly numerous in sandstone in the lower and middle parts of the group. At some places the basal sandstone contains reworked fragments of dolomite and chert from the underlying Arbuckle Group. For example, the lower 43 feet of the Simpson in the Marathon Oil 1 F. Zeller well, sec. 17, T. 35 S., R. 8 W., consists mainly of light-gray fine- to coarse-grained sandstone in which granules and pebbles of very finely crystalline dolomite are embedded. Hiestand (1933, fig. 3) indicated that to the north the basal bed was an "erratic, conglomeratic zone" in the Voshell oil field of McPherson County. Sandstone in the upper part of the Simpson locally contains gray to yellowish-brown sandy chert.

Sandstone is more common in the upper or middle parts of the Simpson than in the lower part, although the lower part is chiefly sandstone at some places in the area (pl. 1). Many sandstone beds are no more than a few feet thick, and most beds are probably less than 20 feet thick.

The shale is greenish gray to dark greenish gray or dark gray, clayey, and generally well indurated. It has a somewhat waxy luster. Many beds include "floating" rounded sand grains and thin lenses and stringers of sandstone.

The dolomite and limestone are gray and brown, finely to medium crystalline, and locally cherty. The carbonates are sandy or silty for the most part, and in places these rocks probably grade laterally into dolomitic or limy sandstone.

Sandy carbonate beds, where present, are generally found in the upper part of the group, although sandy dolomite beds are logged in the middle part of the group in some wells (pl. 1). Some of these beds in the middle part might be erroneously logged from caved or recirculated samples. In many wells the top of the Simpson is marked by a bed of sandy limestone or dolomite.

The percentages of sandstone and carbonate rock in the Simpson are shown in figures 4 and 5 for areas where post-Viola erosion has not decreased the original thickness of the group. To prepare the sandstone-percentage map (fig. 4), only interpretive sample logs of wells that penetrated the entire group were used, and some of these were deleted because of missing-sample intervals or apparently serious inaccuracies in sample interpretation. The carbonate-percentage map (fig. 5) includes data from many wells in which drilling stopped in the Simpson because the carbonate rocks are generally found at or near the top of the group. For wells that did not reach the base of the Simpson, the thickness of the group was estimated from the thickness map (pl. 2) in order to calculate the approximate percentage of carbonate rocks.

Sandstone makes up less than 20 percent of the Simpson Group at many places in the western part of the area (fig. 4). Sample logs of several wells located mainly on the south flank of the Central Kansas uplift indicate a sandstone content of about 5 to 10 percent. The percentage of sandstone is greatest in a poorly defined belt that trends about N. 25° E. across the central part of the area. The Simpson is more than 60 percent sandstone at numerous places in the central and eastern parts of the area. Information is scarce for much of the eastern part, and there may be somewhat more sandstone than indicated in figure 4.

A direct relation between the thickness of the Simpson Group and percentage of sandstone is not apparent in the report area. For instance, the Simpson is thin around the south flank of the Central Kansas uplift where it also generally has only a small amount of sandstone (fig. 4); to the south, in Kiowa, Pratt, and Barber Counties, the percentage of sandstone is also low at many places where the group is much thicker.

Limestone and dolomite compose less than 20 percent of the Simpson in most of the area (fig. 5). Many interpretive sample logs in a large area west and northwest of the Chautauqua arch record no carbonates, and many other logs in this area indicate carbonates in amounts of less than 5 percent. Limestone or dolomite in very small amounts may be present but unrecognized in parts of the area mapped as devoid of carbonates. A thin carbonate bed could be overlooked rather easily in logging most rotary-drilled samples. The absence of carbonates on much of the south flank of the Central Kansas uplift (mainly Tps. 21 and 22 S.) might be ascribed to nondeposition, but their absence more likely is the result of post-Ordovician solution that also dissolved parts of the overlying Viola Limestone, as described in a later part of this report. Limestone and dolomite generally predominate in the Simpson in the northeastern and northern parts of the mapped area and also along the west side, where at several places more than 40 percent of the group is carbonate rock. The percentage of carbonate rock apparently has no relation to the thickness of the Simpson. In a general way, the percentage of carbonate rock is inversely proportional to the percentage of sandstone. This relation is perhaps most noticeable in the western part of the basin where the percentage of sandstone is relatively low, but numerous exceptions are apparent. The inverse relation suggests local facies changes from sandstone to limestone or dolomite.

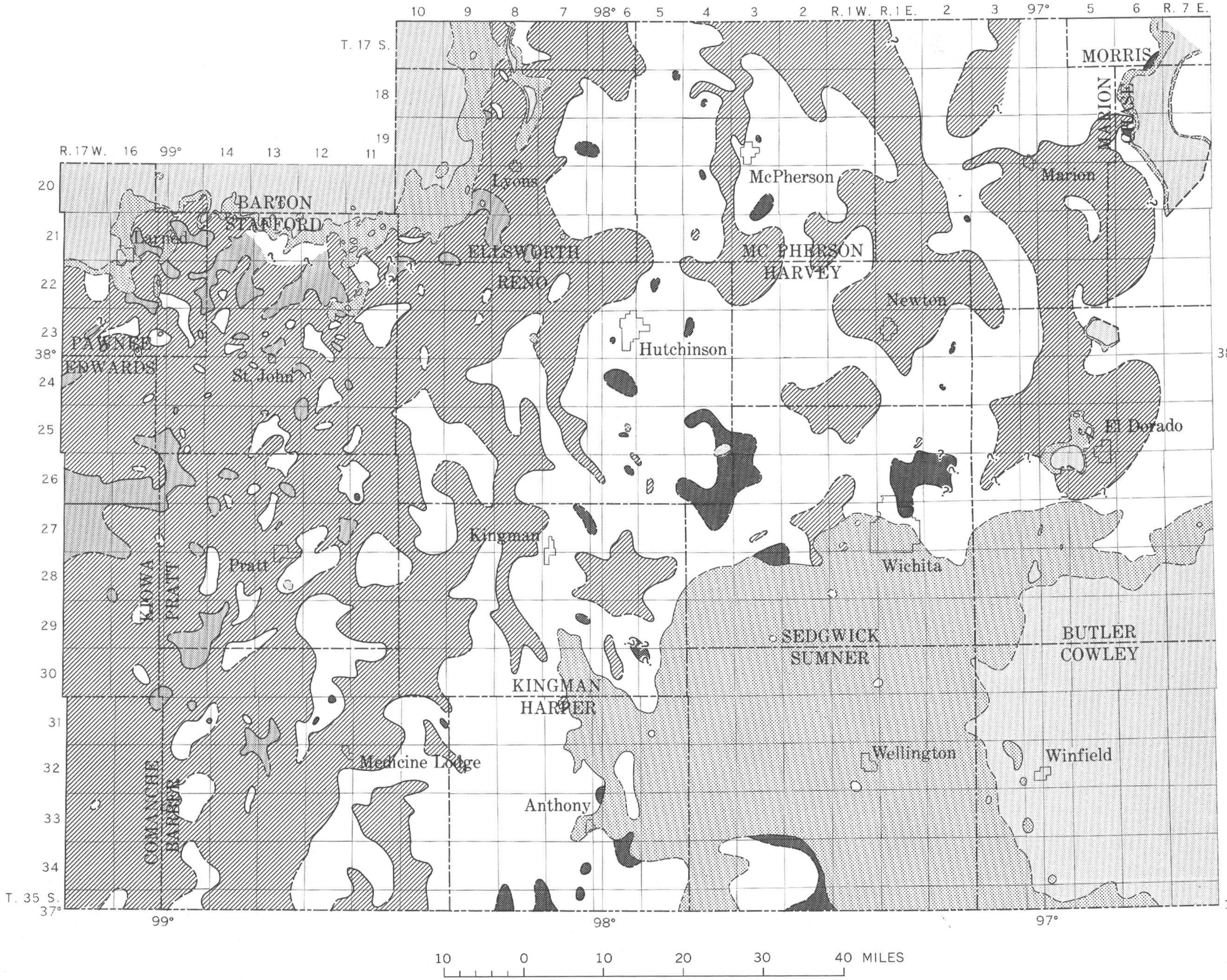
THICKNESS

The thickness of the Simpson Group, where overlain by the Viola Limestone, ranges from 16 feet in southeastern Pawnee County on the south flank of the Central Kansas uplift to 254 feet in southwestern Harper County near the Oklahoma State line (pl. 2). It is commonly 40 to 70 feet thick on the south flank of the Central Kansas uplift and is slightly thicker at the east end of the uplift (pl. 2). The minimum thickness, 16 feet, is in the Stanolind 1 Galliart well, sec. 35, T. 22 S., R. 16 W., Pawnee County. This thickness was determined from a relatively poor electrical log and the well-completion report. The Simpson is 20 feet thick in the Natural Gas and Oil 1 Enlow well, sec. 9, T. 24 S., R. 16 W., northeastern Edwards County (well 2, cross section *E–F*, pl. 1). The thickness increases irregularly eastward from the Central Kansas uplift, through Tps. 17–24 S., and locally exceeds 100 feet in the north-central and northeastern parts of the area. In areas where the Simpson has been thinned by Late Mississippian and Early Pennsylvanian erosion, thickness lines shown on plate 2 are either very generalized or are omitted.

The Simpson is reported to be less than 25 feet thick in a few wells in southeastern Butler County (mainly in T. 26 S., R. 7 E., and Tps. 27 and 28 S., R. 6 E.) on the north flank of the Chautauqua arch. The thickness data in these townships are largely from completion reports. If the reports are correct, the abnormal thinness of the Simpson Group in southeastern Butler County may indicate Early Ordovician topographic relief developed on the underlying Arbuckle Group. Perhaps a more likely explanation is that the strata overlying the Simpson, although identified as Viola Limestone on the completion reports, are actually carbonates of Devonian age that unconformably overlap southward across Silurian and Ordovician rocks on the north flank of the Chautauqua arch, and the thinness of the Simpson is due to Late Silurian or Early Devonian erosion.

The Simpson Group increases in thickness irregularly southward from the Central Kansas uplift toward the Oklahoma State line, where the group is generally more than 200 feet thick (pl. 2). The maximum thickness, 254 feet, is in the Marathon Oil 1 F. Zeller well, sec. 17, T. 35 S., R. 8 W. The rate of thickening is considerably greater in southernmost Kansas (mainly Tps. 33–35 S.) than in the area to the north.

Isopachs of the Simpson Group in much of the western part of the area (mainly Pratt, Barber, and



10 9 8 7 98° 6 5 4 3 2 R.1W. R.1E. 2 3 97° 5 6 R. 7 E.
R.17W. 16 99° 14 13 12 11
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32
33
34
T. 35 S.
37°
99°
98°
97°
MORRIS
MARION
CHASE
Lyons
McPherson
Marion
BARTON
STAFFORD
Larned
ELLSWORTH
RENO
MC PHERSON
HARVEY
Newton
Hutchinson
PAWNEE
EDWARDS
St. John
El Dorado
Kingman
Wichita
Pratt
KIOWA
PRATT
SEDGWICK
SUMNER
BUTLER
COWLEY
KINGMAN
HARPER
Medicine Lodge
Wellington
Winfield
Anthony
COMANCHE
BARBER
10 0 10 20 30 40 MILES

EXPLANATION

Less than 20 percent sandstone

20–40 percent sandstone

40–60 percent sandstone

More than 60 percent sandstone

Area where Simpson Group is unconformably overlain by post-Ordovician rocks, except in sec. 34, T. 26 S., R. 3 W., where Sylvan Shale unconformably overlies the group

Simpson Group absent

?

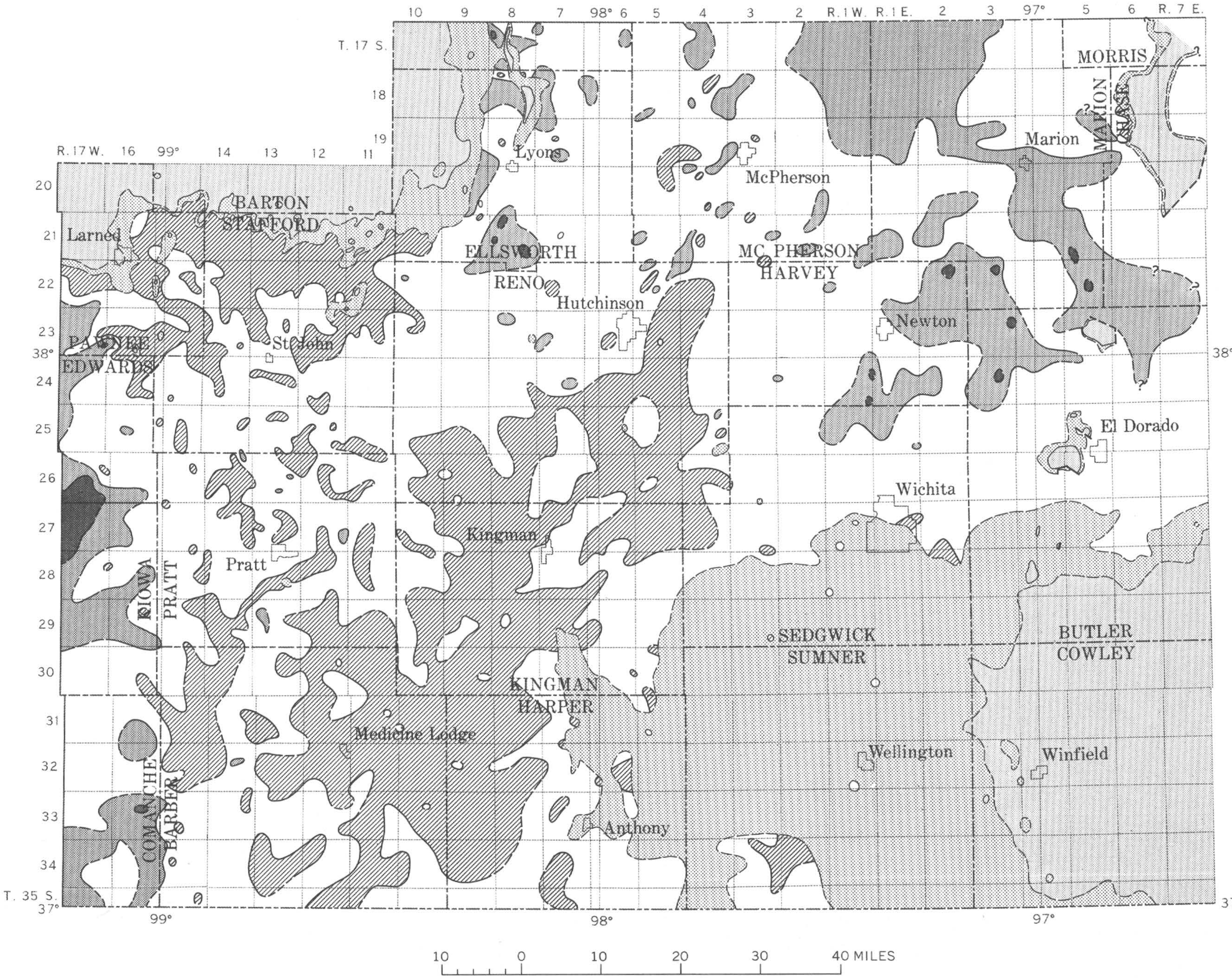
Contact

Dashed or queried where approximately located

Fault

Dashed where approximately located

FIGURE 4.—Percentage of sandstone in the Simpson Group.


10 9 8 7 98° 6 5 4 3 2 R.1W. R.1E. 2 3 97° 5 6 R.7E.
T. 17 S.
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R.17W. 16 99° 14 13 12 11
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33
34
T. 35 S.
37°
MORRIS
MARION
CHASE
Marion
Lyons
McPherson
BARTON
STAFFORD
Larned
ELLSWORTH
RENO
MC PHERSON
HARVEY
Hutchinson
Newton
PAWNEE
EDWARDS
St John
El Dorado
Wichita
Kingman
Pratt
KIOWA
PRATT
SEDGWICK
SUMNER
BUTLER
COWLEY
KINGMAN
HARPER
Medicine Lodge
Wellington
Winfield
COMANCHE
BARBER
Anthony
99°
98°
97°
38°
37°
10 0 10 20 30 40 MILES

EXPLANATION

Carbonate rocks absent

Less than 20 percent carbonate rocks

20–40 percent carbonate rocks

More than 40 percent carbonate rocks

Area where Simpson Group is unconformably overlain by post-Ordovician rocks, except in sec. 34, T. 26 S., R. 3 W., where Sylvan Shale unconformably overlies the group

Simpson Group absent

Contact
Dashed or queried where approximately located

Fault
Dashed where approximately located

FIGURE 5.—Percentage of carbonate rock in the Simpson Group.

western Kingman Counties) delineate a few subparallel elongate areas in which the Simpson is somewhat thinner than in the intervening areas (pl. 2). For example, one area of relatively thin Simpson rocks extends from the southern part of T. 29 S., R. 13 W., southwestward to the northern part of T. 32 S., R. 14 W. These elongate areas of relatively thin Simpson rocks and the intervening areas of thicker rocks mostly strike northeast or north and may mark the location of low rounded ridges separated by shallow valleys formed by Early Ordovician pre-Simpson erosion.

VIOLA LIMESTONE

The Viola Limestone of Middle and Late Ordovician age is an extensive carbonate sequence that is as much as 239 feet thick in Comanche County near the west edge of the area (pl. 3). The Viola Limestone of central Kansas has long been correlated with part of the Viola Limestone at the type locality in southern Oklahoma and with the Kimmswick Limestone of Missouri. A résumé of Middle and Upper Ordovician stratigraphy in the Midcontinent has been given by Ireland (1966, p. 26–40), and a bibliography for these rocks in Oklahoma has been compiled by Triplehorn and Triplehorn (1966, p. 119–127).

Several periods of erosion have reduced the original thickness and areal extent of the formation. In the central part of the area, about 14 miles west of Wichita, pre-Sylvan erosion cut through the Viola at one place. The formation was exposed to erosion on the Chautauqua arch (fig. 3), and an unknown amount was removed before Devonian carbonates of the Hunton Group overlapped southward from the North Kansas basin. Widespread Late Devonian (pre-Chattanooga) erosion cut through the Viola in at least four places in the central part of the area, and the formation was eroded from much of the Chautauqua arch. The Viola in the western part of the area may have been affected by post-Chattanooga pre-Kinderhook erosion, but this is uncertain because the Chattanooga Shale and rocks of Kinderhook age cannot everywhere be clearly differentiated, and the relation between them is obscure. The Viola was stripped by erosion from higher parts of the Nemaha anticline, the Central Kansas uplift, and local areas south of the uplift during Late Mississippian or Early Pennsylvanian time.

The Viola Limestone in central and southern Kansas has been subdivided into informal lithologic units by some geologists, including Taylor (1947a, fig. 3) and Ver Wiebe (1948, fig. 1). On the other hand, Lee (1956, p. 36, 37) wrote that "the Viola sequence does not lend itself to accurate regional zoning" because of facies variations. Only the basal unit of the Viola described below is readily identified in most of the report area.

LITHOLOGY

Limestone, dolomite, and chert compose the Viola Limestone. The carbonates are white to medium gray, buff, and brown, finely to coarsely crystalline, and sucrosic or granular in part. Dark-gray to black mottling and staining is fairly common in the medium and coarsely crystalline rocks. Much of the limestone is dolomitic. The carbonates are generally coarser grained, and dolomite is more abundant, in areas where the Viola is relatively thin. Finely crystalline, granular, or sucrosic textures are more common in the western part of the area where the formation is considerably thicker.

The basal unit of the Viola Limestone consists of light-gray to buff, medium to coarsely crystalline crinoidal limestone about 5 to 30 feet thick. The limestone is free of chert in most wells. This unit is conspicuous because of the abundance of crinoid fragments, absence of chert, and the relatively large grain size, but in some places these characteristics are largely obliterated by dolomitization.

A silty cherty limestone unit overlies the basal crinoidal limestone unit in southernmost Kansas (Tps. 34 and 35 S., Rs. 7–17 W.). The limestone is gray to brownish gray, very fine to fine grained, and very silty in part. The silty limestone unit is 15 to 60 feet thick in wells logged by the writer in southern Barber and eastern Comanche Counties. The northern edge of the unit could not be determined from the sample logs used in the present study. This silty unit probably correlates with the part of the Viola described by Ver Wiebe (1948, p. 126, fig. 1) as either dolomitic and cherty argillite or brown cherty dolomite. He subdivided the Viola in Barber County into six lithologic zones and stated that the argillite or dolomite zone (his zone 5) was erroneously called the Maquoketa Shale (Sylvan Shale) by some geologists and oil scouts. According to Ver Wiebe (1948, p. 127, 128), this zone is 50 to 90 feet thick in Barber County and is also found in Comanche, Edwards, Kiowa, Pawnee, Pratt, and Harper Counties. He considered this zone, with slight facies modifications, the most distinctive part of the Viola Limestone.

The upper part of the Viola in southernmost Kansas consists mainly of light-gray to buff finely to medium crystalline limestone and dolomite. These beds are partly cherty or silty or both, and crinoid fragments are locally abundant. Glauconite in very small amounts is found in the upper part of the formation in some wells.

The chert is light gray to medium gray, buff, and brown, dense, subopaque to opaque, and partly spicular or otherwise fossiliferous. Some chert is white, and some is mottled or streaked dark gray. Black specks are found in some chert, and these aid in distinguishing it from chert of Mississippian age. Lee (1956, p. 35) identified the black specks as disintegrated graptolites.

Chert is found in carbonates in the Viola throughout the western and northeastern parts of the report area and locally elsewhere. A chert-distribution map (fig. 6), based exclusively on interpretive sample logs, outlines areas where the Viola contains at least some chert. Chert generally is present where the formation is thicker than about 20 feet, although there are numerous local exceptions. In the central-northern part of the area, for instance, the formation is 50 to 75 feet thick in numerous wells and is apparently free of chert. On the other hand, chert is present at several places in the central part of the area where the Viola is thin. Some of these exceptions may be the result of logging caved, recirculated, or mislabeled samples.

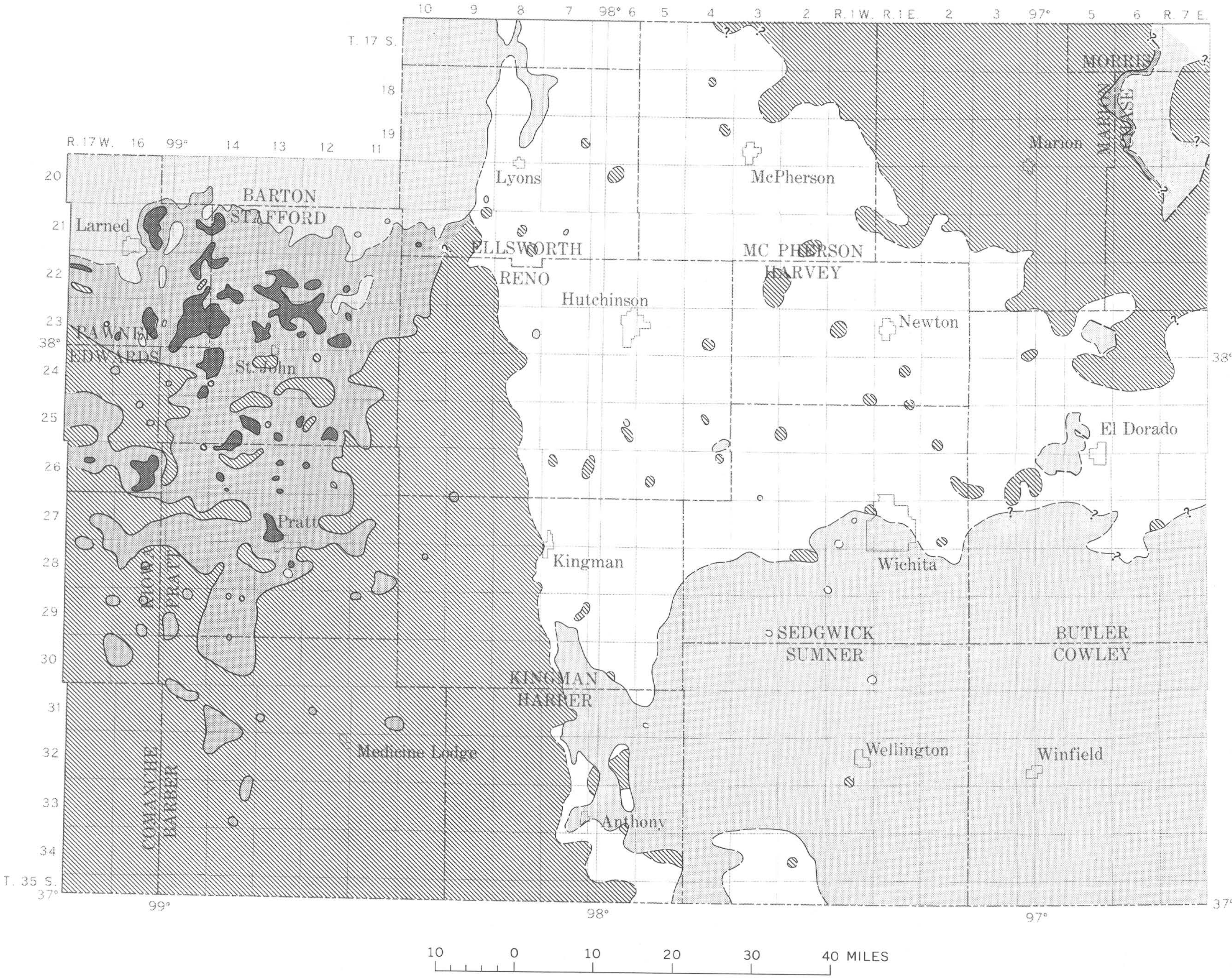
The Viola is partly or entirely residual chert in a triangular area that extends from the south flank of the Central Kansas uplift southward for a distance of about 60 miles in the western part of the mapped area (fig. 6). The chert is the residue remaining after extensive solution of the originally cherty Viola carbonates in Late Devonian (pre-Chattanooga) and Late Mississippian and Early Pennsylvanian times. Sample descriptions suggest that most of the residual chert is very similar to the chert found in the carbonates unaffected by solution. The color is mostly white or shades of gray; varicolored chert is rare. Residual chert of the Viola is generally smooth textured and opaque or subopaque, but some is tripolitic or spongy.

The thickness of residual chert varies greatly within short distances, partly because the solution processes that removed the original carbonate operated to various stages of completion in different places. The thickness of residual chert also reflects the amount of chert originally present in the carbonates. In numerous wells, overlying rocks of Kinderhook age locally consist largely of detrital-chert conglomerate that, in rotary-drilled samples, is difficult to differentiate from residual chert. Because of these variables, areas of residual chert mapped on figure 6 indicate only approximately the areas where post-Viola solution processes operated.

The residual chert is less than 50 feet thick in most of the area, although it is as much as 100 feet thick locally. The proportion of residual chert in the Viola increases irregularly northward toward the Central Kansas uplift, and in numerous wells within a few miles of the formation pinchout, the Viola is represented entirely by residual chert. In this area solution processes that removed the Viola carbonates probably also dissolved underlying carbonates in the upper part of the Simpson Group.

Another area of residual chert as much as 35 feet thick forms a narow band in the northeast corner of the mapped area (fig. 6) along the west flank of the Nemaha anticline. Sample-log information is insufficient to outline accurately the area of residual chert, but it probably extends farther north and south than shown in figure 6. The presence of residual chert in the Stanolind 1 Barr well, sec. 35, T. 17 S., R. 6 E., is questionable. The sample log for this well was made by Kansas Sample Log Service from very poor samples, without electrical-log control. The lithologic sequence for the Viola and the Simpson Group in this well was reinterpreted by the writer to agree more closely with the lithology suggested by the electrical log.

Sample logs indicate the Viola Limestone contains noncarbonate clastic beds generally less than 10 feet thick at a few places in the western part of the area. The clastic material is mostly gray, green, and brown shale and clay and white fine- to coarse-grained quartzose sandstone and shaly sandstone. The shale and sandstone rather closely resemble some of the overlying rocks of Kinderhook age. A somewhat different deposit is indicated by the sample log of the G.M.R. 2 Betzer well in sec. 34, T. 29 S., R. 16 W. (well 2, cross section *A–B*, pl. 1). The log, by J. D. Davies, shows 46 feet of "intra-Viola detritus" resting on the 9-foot basal limestone bed of the Viola. The detritus includes nodules of Viola-type chert and dolomite in varicolored clay and shale overlain by cherty clay and shale with included stringers of vitreous quartzose sandstone. Some of the noncarbonate clastic beds logged in the Viola might be in normal stratigraphic sequence and if so, might indicate intraformational disconformities; however, none seems persistent enough to support this conclusion. Some of the noncarbonate clastic deposits are probably misidentified cavern fillings of post-Viola age.



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STAFFORD
Larned
ELLSWORTH
RENO
MC PHERSON
HARVEY
Hutchinson
Newton
PAWNEE
EDWARDS
St. John
El Dorado
Pratt
Kingman
Wichita
PRATT
SEDGWICK
SUMNER
BUTLER
COWLEY
KINGMAN
HARPER
Medicine Lodge
Wellington
Winfield
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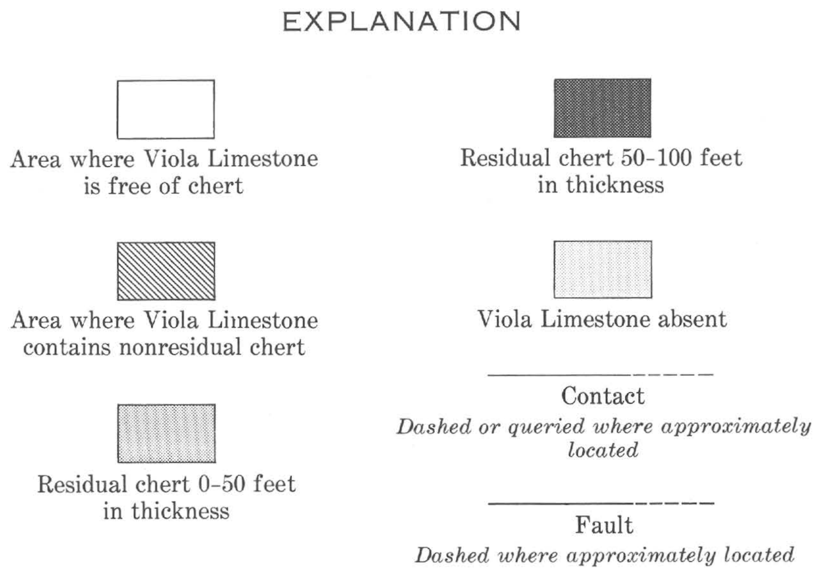

FIGURE 6.—Distribution of chert and thickness of residual chert in the Viola Limestone.

THICKNESS

The Viola Limestone ranges in thickness from 0 to possibly as much as 239 feet in the United Producing 1 L. York well in sec. 6, T. 32 S., R. 17 W. (pl. 3). The top of the formation is difficult to determine in the York well and in numerous other wells in the western part of the area.

The formation is commonly 10 to 30 feet thick in the central part of the report area where it is unconformably overlain by the Sylvan Shale. Before deposition of the Sylvan Shale, erosion removed the Viola in the Cities Service Oil 1 Lorg well in sec. 34, T. 26 S., R. 3 W. The thickness of the Viola increases irregularly from the central part of the area toward the north and northeast beneath the Sylvan, and in a few wells in northern Marion County the thickness is about 100 feet. Taylor (1947a, p. 1282) tentatively attributed the southward thinning of the Viola in central Kansas to nondeposition, whereas Lee (1956, p. 40, 41, 137) attributed thinning to an erosional unconformity between the Viola and the Sylvan, which is the interpretation favored in this report.

The thickness of the Viola is not well known in much of the eastern part of the mapped area, especially in Butler County, where the data are mostly from completion reports. Rocks assigned to the Viola in eastern Butler County (Rs. 5–7 E., inclusive) may be partly or wholly Devonian in age. Carbonate rocks of Devonian age (upper part of the Hunton Group) overlap southward onto the Viola Limestone in Butler County, and the entire carbonate sequence is generally called either Viola or Hunton by drillers and operators. According to Lee (1956, p. 58), the Viola is absent in the Phillips 1 Guilfoyle well in sec. 18, T. 25 S., R. 8 E., as a result of erosion during Late Silurian or Early Devonian time. The Guilfoyle well is near the eastern edge of the map area, and if Lee's interpretation is correct, the Viola was probably removed in an area extending from near the well west-southwestward perhaps as far as the southeastern part of T. 27 S., R. 5 E.

The thickness of the Viola increases rather abruptly from the central part of the mapped area westward across a relatively straight and narrow band that strikes about S. 15° E. from the southeastern part of the Central Kansas uplift (pl. 3). The formation is generally less than 25 feet thick east of this band and is 75 to 200 feet thick in much of the region west of it. The rate of westward thickening is as much as 20 feet per mile (100 ft. in 5 miles) in T. 23 S., Rs. 9 and 10 W.

The area where the Viola varies most in thickness coincides rather markedly with the area where residual chert is present. The thickness of the formation is notably more variable beneath rocks of Kinderhook age than beneath rocks of Pennsylvanian age, as comparison of figure 2 and plate 3 shows. Some local thinning may be a result of anticlinal folding and subsequent erosion during Silurian or Devonian time but, for the most part, it probably represents topographic relief developed on the Viola during Silurian and Devonian times.

SYLVAN SHALE

Rocks of Late Ordovician age above the Viola Limestone in east-central Kansas have been correlated for many years with the Sylvan Shale of Oklahoma and the Maquoketa Shale of Iowa. The Sylvan Shale in the mapped area is chiefly restricted to the area north of the Chautauqua arch and east of the Central Kansas uplift (pl. 4). In this area the formation is as much as 142 feet thick, but it is absent in several places as a result of erosion in Late Silurian, Late Devonian (pre-Chattanooga), or Early Pennsylvanian times. The Sylvan is also found locally in the southwestern part of the area mainly in southern Barber and southwestern Harper Counties in Tps. 34 and 35 S., Rs. 9–14 W. The Sylvan is very questionably identified at several places in the western part of the mapped area, mainly in Tps. 24–27 S., Rs. 14–17 W. At these places the rocks called Sylvan may be a local shaly facies of the rocks of Kinderhook age, which overlie the Viola in much of this area.

The Sylvan may grade westward into the upper part of rocks assigned to the Viola Limestone in this report. Lee (1956, p. 47) noted a westward increase of carbonate rocks in the Sylvan in the Salina basin and suggested that the Sylvan locally may be indistinguishable from the Viola. If the identification of the Sylvan is correct in the western part of the area, the formation was probably deposited on a notably uneven surface over most of or perhaps all the area. The maximum thickness of the Sylvan (about 100 ft) in the Late Mississippian and Early Pennsylvanian syncline (R. 8 W.) at the east end of the Central Kansas uplift (pl. 4) strongly implies that the formation originally extended considerably farther west than shown on plate 4.

LITHOLOGY

The Sylvan Shale consists mainly of shale and dolomite in the area north of the Chautauqua arch and east of the Central Kansas uplift, as shown in the cross sections on plate 1. In this area, the ratio of rock types varies greatly. Lateral gradation of shale into dolomite is probably common, and some geologists describe parts of the formation as marl. The shale is pale green to greenish gray or gray and slightly to very dolomitic. Many logs by Kansas Sample Log Service indicate a microgranular texture for the shale and the presence of graptolite fragments. Taylor (1947b, p. 1596) informally divided the Sylvan in much of central Kansas into an upper hard gray dolomitic shale, locally siliceous to cherty, and a lower soft gray flaky shale that is relatively nondolomitic. This two-fold division is not apparent in many of the sample logs used in this report. In areas where the Sylvan is shale and is thin, it is generally difficult to identify in well samples. As explained by Carmody (1947, p. 159), "it disintegrates rather rapidly in the presence of water and in collision with other particles, and thus most of it is washed out of ordinary rotary samples as mud." The few remaining fragments are easily overlooked, and if this happens, caved samples from younger strata are logged in place of the Sylvan.

Dolomite in the Sylvan is generally gray to buff, finely granular to mealy, and locally speckled. Much of the dolomite is shaly, silty, and siliceous or cherty. In parts of central Kansas, some geologists, including Taylor (1947b, p. 1605), assigned argillaceous carbonate beds in the lower part of the Sylvan to the underlying Viola Limestone. Lee (1956, p. 43) emphasized that impure dolomite belonging to the Sylvan contrasts with clean sucrosic or coarsely crystalline dolomite of the underlying Viola Limestone. Chert in the dolomite of the Sylvan is light gray to dark gray, dense, opaque, and commonly speckled. Some chert contains spicules, other fossil fragments, and disintegrated graptolites.

The Sylvan Shale in southern Barber and southwestern Harper Counties consists of shale and dolomite typical of the formation in the northern part of the mapped area. The dolomite is mostly fine grained and silty to shaly, but it is somewhat less cherty and siliceous than it is to the north. Dolomite probably grades laterally into dolomitic shale at many places. In an earlier report (Adkison, 1960, well 2), dolomite in the Sylvan in the Harbar Drilling and Atlantic Refining 1 Knorp well, sec. 27, T. 34 S., R. 10 W., was erroneously assigned to the Hunton Group of Silurian and Devonian age. As in areas to the north, the contact between the Sylvan and the underlying Viola Limestone in most wells is marked by a conspicuous downward change from shale or silty fine-grained dolomite to white or gray medium to coarsely crystalline limestone.

Rocks questionably correlated with the Sylvan Shale in the western part of the area (mainly Tps. 24–27 S., Rs. 14–17 W.) consist almost entirely of shale that is slightly to very dolomitic. The colors are chiefly pale green to pale greenish gray. Sample logs for several wells describe the texture as microgranular. Thin beds of gray-buff finely granular speckled siliceous dolomite are interbedded with the shale in the Aladdin 1 Jones well in sec. 20, T. 27 S., R. 16 W. The dolomite in the Jones well resembles some of the dolomite in the Sylvan in the area east of the Central Kansas uplift.

THICKNESS

The Sylvan Shale attains a maximum thickness of 142 feet in three wells: T. C. Johnson 1 Good, sec. 13, T. 19 S., R. 3 W.; Aladdin 1 Johnson, sec. 20, T. 19 S., R. 2 W.; and Anschutz 1 Malm, sec. 36, T. 17 S., R. 3 W. These wells lie on the southwestern flank of the North Kansas basin, and in this area the thickness exceeds 100 feet in numerous other wells (pl. 4). The thickness of the Sylvan decreases irregularly northward where overlain by Silurian rocks of the Hunton Group to a minimum of 30 feet in northern Kansas, as described by Lee (1956, p. 47), who wrote that irregularities in thickness of the Sylvan are due in large part to topographic relief on the underlying Viola Limestone. In the mapped area the thickness of the Sylvan also decreases irregularly southward toward the Chautauqua arch as a result of erosion during both Silurian and Late Devonian time. Many Kansas petroleum geologists agree that in the eastern part of the area Devonian carbonates in the upper part of the Hunton Group overlap the Sylvan Shale southeastward and rest on the Viola Limestone in Butler, northeastern Sedgwick, southeastern Marion, and southwestern Chase Counties.

The Sylvan is thin or absent in a generally westward-trending area located mainly in Tps. 19 and 20 S. and east of R. 5 W. (pl. 4). This area was named the McPherson Valley by Lee (1956, p. 65); it was mapped in a general way by McClellan (1930, fig. 2). The McPherson Valley seems to split in R. 5 W., although the sample-log control is hardly adequate for accurate mapping of the two forks. One fork may extend north through R. 5 W., and the other fork probably curves southwestward through Rice County into northern Reno County. Lee (1956, p. 65) suggested the McPherson Valley was formed in Late Devonian time by a river that headed in Lyon County (east-central Kansas), flowed westward to western McPherson County and from there probably drained toward the north or northwest.

From the pinchout in T. 34 S., the formation generally increases in thickness southward to the Oklahoma State line (pl. 4). It reaches a maximum of 67 feet in southern Barber County in the Harbar Drilling and Atlantic Refining 1 Knorp well, sec. 27, T. 34 S., R. 10 W. The Sylvan is 10 to 12 feet thick in two erosional outliers in central Barber County. It is probably more extensive in the central and southwestern parts of the mapped area than is shown on plate 4. Some geologists apparently have correlated the upper part of the Viola Limestone, as delimited in this report, with the Sylvan Shale or have identified the Sylvan in wells not considered here. For example, the Sylvan (Maquoketa) was identified but not mapped in parts of the present Zenith-Peace Creek oil field (mainly in T. 24 S., R. 11 W., and T. 23 S., R. 10 W.) by Imbt (1941, p. 147) and Kornfeld (1943, p. 46). The writer studied samples from the Sinclair Prairie 5 McComb well in sec. 24, T. 24 S., R. 11 W. (Adkison, 1963, pl. 1, well 2), but samples of part of the Viola Limestone and the younger rocks were missing. Imbt (1941, p. 147) indicates a maximum thickness of 35 feet for the Sylvan in the old Zenith oil field.

Rocks questionably correlated with the Sylvan Shale in the western part of the mapped area are 74 feet thick in the Anschutz 1 Barstow well, sec. 5, T. 25 S., R. 15 W. The thickness in other wells in this part of the area is less than 50 feet.

POST-ORDOVICIAN ROCKS

Middle and Upper Ordovician rocks are overlain by beds as old as Silurian and as young as Pennsylvanian in south-central Kansas, as shown in figure 2. In the area north of McPherson Valley (Tps. 17 and 18 S.), the Sylvan Shale is overlain by carbonate rocks of Silurian age which form the lower part of the Hunton Group. (See table 1.) The contact between the Sylvan and the Silurian rocks may be an inconspicuous disconformity in the Salina basin, most of which lies north of the mapped area (Lee, 1956, p. 47).

In a large area south of McPherson Valley (pl. 4), the Sylvan Shale and Viola Limestone are unconformably overlapped southward by partly sandy and cherty carbonates of Devonian age which form the upper part of the Hunton Group. These rocks were mapped separately by McClellan (1930, fig. 2), but their age was controversial for many years. McClellan (1930, p. 1545) credited Charles Ryniker with a Devonian age determination, based on paleontology, for the lower part of these rocks in the Gypsy Oil 1 Hege well, sec. 13, T. 22 S., R. 2 W. Other geologists believed these rocks south of McPherson Valley were either Silurian or Early Mississippian (Kinderhook) in age. A questionable Silurian age was assigned by Taylor (1946, fig. 16, p. 1247) to rocks of the Hunton Group south of the Valley. These rocks were considered Devonian in age by Lee, Leatherock, and Botinelly (1948, p. 52, 127, 128, pls. 2, 4, panel 1), who depicted the southward overlap of the Devonian rocks from the North Kansas basin onto the north flank of the Chautauqua arch. As already mentioned, Devonian rocks are difficult to differentiate from the Viola Limestone at many places where the Sylvan Shale is absent, especially in much of Butler County. For this reason, the southern limit of the Hunton Group is not clearly delineated in central and eastern Butler County, and in this area the group may extend farther south than is shown in figure 2.

The Ordovician rocks in most of the mapped area are unconformably overlain by the Chattanooga Shale of Devonian and Mississippian age (fig. 2). A basal sandstone, generally called the Misener sand by petroleum geologists, is a widespread and useful marker bed, but in many wells it is absent or too thin to be recognized. The thickness of the Misener is commonly less than 10 feet and in many places is probably less than a foot. Much of the sand was probably reworked from previously exposed sandstones of the Simpson Group, and the Misener is locally difficult to differentiate from sandstone of the Simpson on the Chautauqua arch. Distinguishing characteristics of the Misener include relatively poor sorting, fairly abundant black phosphatic(?) grains, and pyritic and siliceous cement.

The Chattanooga in much of the area consists of black shale in the lower part and gray to greenish-gray shale in the upper part. The formation is chiefly or entirely gray to greenish-gray shale in much of the western part of the area and in the area between the Central Kansas uplift and the Nemaha anticline. In these areas, many petroleum geologists use the term "Kinderhook shale" for the Chattanooga Shale. This usage was considered inappropriate by Lee (1956, p. 62, 63), who described in considerable detail his reasons for believing the Kinderhook age designation erroneous.

Ordovician rocks are overlain by a variable clastic sequence generally considered Kinderhook in age at many places in the western part of the area. The rocks consist mainly of interbedded gray to green and rusty brown silty to sandy shale, white to gray fine- to medium-grained glassy sandstone, and shaly detrital-chert conglomerate. Beds of limestone or dolomite are present locally. The relation between the clastic sequence of Kinderhook age and the Chattanooga Shale to the east is obscure, but some petroleum geologists believe the two are equivalent. Lee (1956, p. 64, 65) thought that the clastic sequence is probably a marginal facies of the Chattanooga or a local facies of the Boice Shale that unconformably overlies the Chattanooga in parts of the Salina and Forest City basins. The Kinderhook age of the upper part of the above-described clastic beds was apparently verified by Goebel (1968, p. 1745, 1746), who found Kinderhook conodonts and reworked Devonian conodonts in cores from a well in sec. 8, T. 25 S., R. 17 W., Edwards County.

Ordovician rocks are locally overlain by Mississippian carbonate rocks of probable Osage age at a few places in the southeastern part of the area where the Chattanooga Shale is absent or too thin to recognize (fig. 2). In the Pickrell 1 Potucek "A" well, sec. 14, T. 33 S., R. 1 E., the stratigraphic unit resting on the Simpson Group is difficult to identify from the sample description. The Chattanooga may be present but very thin at this location. Carbonate rocks of Mississippian age overlie the Viola Limestone at two locations in the western part of the area. In the Sinclair 1 Smith well, sec. 17, T. 28 S., R. 13 W., the overlying rocks are described as partly shaly and cherty dense limestone, and in the Lauck 1 Foster well, sec. 13, T. 28 S., R. 14 W., they are dense cherty limestone. These strata in the Smith and Foster wells may be Kinderhook or Osage in age.

Rocks of Pennsylvanian age rest unconformably on Ordovician strata at several places along the Nemaha anticline, on part of the Pratt anticline, over much of the Central Kansas uplift, and at a few other localities in the western part of the area. For the most part, the oldest beds of Pennsylvanian age consist of shaly to sandy detrital-chert conglomerate that is generally called "Pennsylvanian basal conglomerate" or "Sooy conglomerate" (Edson, 1934, p. 30–32). At some places the oldest Pennsylvanian rocks are shale, sandstone, or limestone. The Pennsylvanian strata in contact with the Ordovician rocks are chiefly of Des Moines age but are partly of Missouri age.

STRUCTURE

The geologic structure of south-central Kansas has been of great interest to the petroleum industry since the discovery of oil in the early part of the century. Descriptions of local or regional faults and folds in the mapped area are included in many reports published since about 1920. The major structural features in the mapped area and many smaller features have been generally well known for many years. A very useful lexicon of named geologic structures in Kansas was published by Jewett (1951); his report briefly describes the structural features and cites the references used.

The structural attitude of the post-Arbuckle Ordovician rocks in the mapped area is shown on plate 5 by contours drawn on the top of the Simpson Group. Post-Viola erosion has removed part of the Simpson on the flanks of major uplifts, and where this has occurred, the magnitude of folding in the Simpson and older rocks is greater than is shown by the structure contour lines.

Many wells bottomed in the Viola Limestone, and for these the subsea elevation of the top of the Simpson was estimated by using the thickness map of the Viola (pl. 3) and the subsea elevation at the top of the Viola. This method of obtaining supplementary structural control is obviously least accurate where the thickness of the Viola changes rapidly. The subsea elevation of the top of the Simpson was similarly estimated for several wells that bottomed in the Sylvan Shale and also for a few wells that did not reach Ordovician rocks. These last few wells are near the Nemaha anticline in Chase and northern Butler Counties. Many details of structural attitude in oil- and gas-producing areas are available in the literature.

PRINCIPAL STRUCTURAL FEATURES

The most prominent structural feature in the eastern part of the mapped area is the Nemaha anticline which strikes about N. 20° E. and plunges to the south (pl. 5). Numerous local domes and anticlines are superimposed on the main fold. The east limb of the anticline is notably steeper than the west limb. Many geologists have postulated Early Pennsylvanian faulting at places along the east limb.

The structural interpretation along the Nemaha anticline north of T. 25 S., especially in Chase and southern Morris Counties, is speculative because of sparse data in some areas. The continuity of the Nemaha anticline is apparently broken in southwestern Chase County (pl. 5), but detailed structural relations are not known. Ordovician rocks in the central part of T. 21 S., R. 6 E. are much lower structurally than in the surrounding area, according to the well-completion report for the Dale Frey 2 B. Blosser well located in sec. 16 of this township. A north-northeast-striking fault is questionably mapped in T. 21 S., R. 6 E., west of the Blosser well, and other faults may be present in this township. Somewhat different structural interpretations are shown on maps by Merriam and Smith (1961) and Cole (1962).

The Sedgwick basin, named by Moore and Jewett (1942, p. 487, fig. 8), lies to the west of the Nemaha anticline. It is a broad, relatively shallow southward-plunging northeast embayment of the Anadarko basin of Oklahoma, limited on the west by the Central Kansas uplift and the Pratt anticline and on the north by thinning of Mississippian rocks in an ill-defined west-northwest-trending area that extends through east-central McPherson County on line with the northeastern flank of the Central Kansas uplift (fig. 1) (Lee, 1956, pl. 6, panel 2).

Several major anticlines are present in the subsurface in the Sedgwick basin, especially in the northeastern and eastern parts. The folds are subparallel to the Nemaha anticline for the most part and plunge southward to southwestward. The largest of these folds is the Voshell anticline (pl. 5), which trends south-southwest through McPherson County into eastern Reno County. Hiestand (1933, p. 175–180) described the folding and evidence of faulting and dated the principal folding as Late Mississippian. Bunte and Fortier (1941, p. 110) stated that a reverse fault with a throw of about 400 feet is present on the west side of the Voshell anticline and almost parallel to its axis. The location of the fault south of sec. 15, T. 20 S., R. 3 W. (pl. 5), is adapted from Bunte and Fortier (1941, figs. 5, 6), and the location of the fault north of sec. 15 is modified from Cole (1962) and Merriam and Smith (1961).

The southeastern part of the Central Kansas uplift lies in the northwestern part of the mapped area and, together with the Pratt anticline to the south, limits the Sedgwick basin on the west side. The Pratt anticline is somewhat less sharply defined than the Nemaha anticline to the east, which it parallels. Some geologists consider the Pratt anticline to be a broad southward-plunging extension of the Central Kansas uplift, whereas others, including Jewett and Merriam (1959, p. 34), think it is a separate anticlinal structure. The map (pl. 5) supports the latter interpretation. The dip of the Ordovician rocks on the west flank of the anticline is generally southwestward and somewhat more steep than the dip on the east flank. Local domes and anticlines are superimposed on the Pratt anticline. The south end of the Pratt anticline appears to be defined by a relatively sharp northeast-trending anticline in the northwest part of T. 33 S., R. 15 W. (pl. 5). This anticline may be faulted on one or both flanks, as suggested by relatively steep dips. Cole (1962) mapped a horstlike structure in Precambrian rocks in the vicinity of this anticline and also at several other localities to the north-northeast.

A major unnamed subsurface anticline lies at the east end of the Central Kansas uplift and trends generally southward through Tps. 17–20 S., R. 8 W. (pl. 5). Erosion in Early Pennsylvanian time exposed rocks as old as the Arbuckle Group on the crest of this fold. The anticline and an adjacent area to the east compose a poorly defined structural feature called the Geneseo uplift (not identified on pl. 5). It was described by Clark, Arnett, and Royds (1948, p. 225–248) as a semidetached easternmost lobe of the Central Kansas uplift.

Ordovician rocks on the south flank of the Central Kansas uplift dip generally toward the southeast and south, but several minor folds modify the dip (pl. 5). These folds are outlined, for the most part, as structural noses that strike north to northeast and plunge southward.

Ordovician rocks in secs. 5 and 8, T. 29 S., R. 13 W., are cut by a fault, downthrown on the southeast, that strikes northeast and has a throw of about 400 feet. The length of the trace is unknown. Several faults or suspected faults were mapped in Pratt County by Brewer (1959, fig. 2), and one of these probably is the fault described above.

STRUCTURAL HISTORY

Lee (1956, p. 133–157) recognized three principal periods of folding during Paleozoic time in his study of thickness maps in the Salina basin area, which includes the northern half of the present report area. The first period of folding affected the pre-Simpson rocks (Reagan Sandstone, Bonneterre Dolomite, Arbuckle Group, and older rocks) and formed the Southeast Nebraska arch and a large unnamed southeast-trending syncline in central Kansas (fig. 7). The second period of folding occurred between Middle Ordovician and Early Mississippian time. Major structural features formed in central and eastern Kansas during this period include the North Kansas basin, Chautauqua arch, and the ancestral Central Kansas uplift (fig. 3). The most important period of folding began early in Mississippian time, attained maximum intensity during Early Pennsylvanian time, and gradually diminished in Late Pennsylvanian and Early Permian time. The major structural features of the mapped area formed during this period of folding, including the Nemaha anticline, Central Kansas uplift, Pratt anticline, and

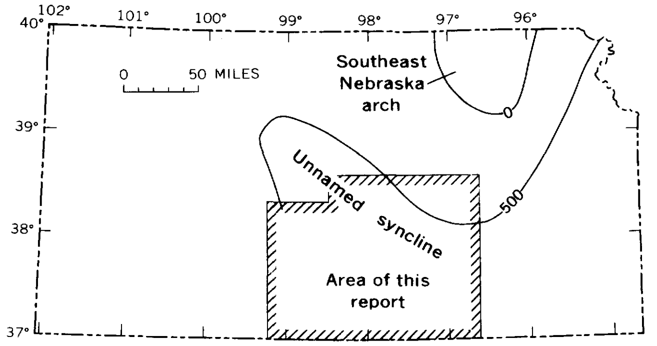

FIGURE 7.—Major pre-Middle Ordovician structural features in central and northeastern Kansas. Folds are outlined by thickness contours (in feet) of the undivided Arbuckle Group, Bonneterre Dolomite, and Reagan Sandstone. (After Lee, 1956, fig. 2A).

the Sedgwick, Salina, and Cherokee basins (fig. 1 and pl. 5).

PRE-SIMPSON FOLDING

Tectonic movements in Kansas during pre-Simpson Paleozoic time are known only in very broad outline, except for relatively local areas, because few wells are drilled to Precambrian rocks and because of the difficulty in identifying formational units in the dominantly dolomite sequence of pre-Simpson age.

A major uplift that formed in northeastern Kansas and southeastern Nebraska before Middle Ordovician time (fig. 7) was named the Southeast Nebraska uplift by Lee (1943, p. 102). The term, "arch," was later substituted for uplift. Pre-Simpson Paleozoic rocks are truncated on the high part of this south-plunging arch, and the Simpson Group rests unconformably on Precambrian rocks in a large area (Lee, 1956, pl. 1, panel 1). Pre-Simpson Paleozoic rocks thicken progressively away from the arch toward the Ozark basin to the southeast and toward the south and southwest. In the Sedgwick basin, pre-Simpson Paleozoic rocks thicken southward to more than 1,100 feet in southwestern Harper County near the Oklahoma State line (Kelly and Merriam, 1964, fig. 3).

The unconformity at the base of the Simpson Group that is so conspicuous on the Southeast Nebraska arch is very extensive in the Midcontinent region. During Simpson time this erosional surface in the mapped area probably sloped very gently southward for the most part, as indicated by northward overlap of the Simpson from Oklahoma into Kansas and by the gradual, though irregular, northward thinning of the group (pl. 2). A general southward slope was suggested by Dapples (1955, fig. 9, p. 466), who believed that during deposition of the Simpson, both coarse and fine clastics were moved southwestward and southward across Kansas toward the Simpson basin in southern Oklahoma. In southern Kansas, the southward slope of the post-Arbuckle erosional surface increased considerably south of T. 32 S., either before or during deposition of the Simpson, as indicated by southward increase in the rate of thickening of the Simpson in Tps. 33–35 S. (pl. 2). A structural hinge line may have passed generally westward through T. 32 or 33 S. and separated a large relatively flat platform area to the north from a more rapidly subsiding basin area to the south in Oklahoma.

FOLDING BETWEEN EARLY ORDOVICIAN AND MISSISSIPPIAN TIME

Major structural features that formed in central and eastern Kansas after the Arbuckle was deposited in Early Ordovician time and before Mississippian time include the North Kansas basin, Chautauqua arch, and ancestral Central Kansas uplift (fig. 3). The northern part of the mapped area lies high on the southwestern flank of the North Kansas basin, and the southeastern part includes the western part of the Chautauqua arch. The extent and precise time of development of the ancestral Central Kansas uplift are not known because extensive uplift and erosion in Early Pennsylvanian time has removed most or all of the older Paleozoic rocks in a very large area of central Kansas. Mainly for this reason, geologists have made different interpretations of the early Paleozoic history of the Central Kansas uplift. Koester (1935, p. 1425, 1426) believed that arching of the uplift had proceeded intermittently since Precambrian time; McClellan (1930, p. 1551) thought that initial movements of the uplift and also of the Chautauqua arch probably began before deposition of the Arbuckle. Both writers postulated arching of the uplift following deposition of the Arbuckle Group. On the other hand, Lee (1956, p. 135, 136) thought that initial upward movements of the Central Kansas uplift and Chautauqua arch occurred in Middle Ordovician time, after most of the Simpson Group was deposited.

Structural movements in the report area during deposition of the Simpson in Middle Ordovician time consisted mainly of gradual regional tilting toward the south, as indicated by the southward thickening of the Simpson Group (pl. 2). The northward thinning and overlap of the Simpson from Oklahoma into Kansas was known as early as 1930 (McClellan, 1930, p. 1540, 1541). The ancestral Central Kansas uplift may have been slightly above sea level during late Simpson time. This possibility is suggested by the general thinness of the Simpson Group on the south flank of the present uplift, compared to thicknesses to the south and east, and by the presence of Precambrian rocks beneath Simpson beds in the Enlow well (sec. 9, T. 24 S., R. 16 W.) and other wells on the south flank of the uplift.

The Simpson Group is thin beneath rocks called Viola Limestone in a relatively small area in southeastern Butler County. The presence of the Viola could not be verified because nearly all the data are from completion reports. If the identification is correct, however, then the thinning of the Simpson implies some buried topographic irregularity on the top of the Arbuckle or possibly slight local uplift and erosion before Viola deposition.

The North Kansas basin and the Chautauqua arch formed more or less contemporaneously. The basin was named by Rich (1933, p. 796, fig. 2) to designate a large subsiding area north and northeast of a west- to northwest-trending arcuate positive area, which he termed the "Central Kansas arch." He included in this arch the Chautauqua arch, an unnamed saddle to the northwest, and the Central Kansas uplift. The Chautauqua arch had been named as a separate feature by Barwick (1928, p. 177) to designate the large westward-plunging pre-Mississippian (pre-Chattanooga) extension of the Ozark uplift along the Kansas-Oklahoma State line. Earlier work by White (1928, pl. 2) had delineated the south flank of such an uplift in northeastern Oklahoma.

According to Lee (1949, p. 15), subsidence of the North Kansas basin began in Middle Ordovician time, as shown by the northward increase in thickness of the Platteville Formation toward the center of the basin. Although the Platteville is not differentiated in the present report, the carbonate-percentage map of the Simpson Group (fig. 5) shows very generally the amount and areal distribution of carbonate rocks that are probably equivalent to part of the Platteville. The scarcity or absence of carbonates in a large area that lies west and northwest of the Chautauqua arch and extends from there northwestward toward the Central Kansas uplift suggest a very broad low arch in this area in latest Simpson time. Any such arch probably did not connect northwestward with the ancestral Central Kansas uplift. The irregular westward increase in the proportion of carbonates near the western edge of the area suggests slight downwarping to form the west flank of the arch described above. The arch was probably an entirely marine feature of very low relief.

Widespread subsidence continued during deposition of the Viola Limestone. Some uplift of the Chautauqua arch in post-Viola and pre-Sylvan time is suggested by the southward thinning of the Viola on the north flank of the arch and by the eastward thinning of the Viola in southeastern Barber and southwestern Harper Counties on the west flank of the arch. The extent and amount of pre-Sylvan erosion on the Chautauqua arch cannot be determined because later uplift and erosion were much more pronounced. The absence of sand in the shale and carbonates of the Sylvan on the north and west flanks of the arch indicates that sandstone of the Simpson Group was not exposed to erosion.

Structural movements in the western part of the mapped area during Viola and Sylvan time are difficult to determine mainly because identification of the Sylvan Shale is uncertain west of R. 10 W. and north of T. 33 S. The Chautauqua arch in the mapped area was probably inactive during Sylvan time, allowing very extensive deposition of the Sylvan Shale from Oklahoma northward through and beyond Kansas. Although the formation is now absent over the arch, a distance of only about 35 miles separates the Sylvan in southwestern Harper County from a large outlier in southeastern Kingman County (pl. 4). The lithologic composition (shale and partly cherty carbonates) in southern Barber and southwestern Harper Counties is about the same as on the north flank of the Chautauqua arch, and terrigenous detritus that would suggest nearby land is lacking in both areas.

Structural development in the mapped area during Silurian time is largely unknown because of the general absence of Silurian rocks. Lee (1956, p. 137, 138) believed that "the North Kansas basin continued to subside either during the deposition of the Silurian, as seems probable from cross section *A–A′* of pl. 3, or certainly preceding Devonian deposition, or both." The rocks referred to by Lee are assigned, in Kansas, to the lower part of the Hunton Group. The Chautauqua arch was uplifted after deposition of the Silurian part of the Hunton Group, and a major unconformity was formed across the north- to northwest-dipping Silurian and older rocks. Erosion on the arch at this time exposed sandstone of the Simpson Group, probably for the first time in the area. The erosional surface was an imperfect plain that had topographic relief of 80 feet or more at some places in north-central Kansas, as revealed by local variations in thickness of the lower part of the Hunton Group (Lee, 1956, p. 53).

The region subsided during the Devonian, and carbonate rocks in the upper part of the Hunton Group, probably of Middle Devonian age, were deposited over a very large area. These rocks thicken irregularly northward into the North Kansas basin (Lee, 1956, p. 138, pl. 3, panel 1). The Devonian carbonates in the eastern half of the mapped area overlap southward across the Silurian rocks, Sylvan Shale, and Viola Limestone. In parts of southeastern Butler County, carbonate rocks assigned to the Viola may actually be Devonian in age and overlapped on the Simpson Group. Devonian rocks overlap on the Simpson Group in sec. 18, T. 25 S., R. 8 E., near the east edge of the area, and in eastern Kansas Devonian rocks locally overlap on the Arbuckle Group (Lee, 1956, p. 58).

After deposition of the Devonian carbonate rocks, the region was uplifted and again extensively eroded. The Chautauqua arch was uplifted considerably more than the North Kansas basin, and erosion on the arch truncated Devonian and older rocks down into the Arbuckle Group. The Chautauqua arch became dormant at about the end of Devonian time or early in Mississippian time. In the northern part of the mapped area, erosion removed the Devonian and Silurian carbonates of the Hunton Group, Sylvan Shale, and parts of the Viola Limestone to form the west-trending McPherson Valley (pl. 4).

A broad, shallow syncline that formed during this Late Devonian (pre-Chattanooga) period of uplift trends north-northeast through central McPherson County. This syncline is indicated by the presence of Sylvan Shale, apparently more than 25 feet thick, in the bottom of McPherson Valley in the western part of T. 20 S., R. 3 W., and in the adjacent part of the township to the west (pl. 4).

Another syncline of pre-Chattanooga age trends north in T. 19 S., Rs. 3 and 4 E., central Marion County (pl. 4), as shown by the preservation of Sylvan Shale in the bottom of McPherson Valley.

An anticline of post-Devonian age in Harvey County was briefly described by Lee (1956, p. 139, fig. 19, pl. 5). This fold trends in a northerly direction.

Structural movements in the western part of the mapped area during Late Devonian time probably formed a broad low arch that plunged gently southward mainly through southern Stafford and western Pratt Counties into northwestern Barber County. The northward extent of the arch is unknown because of widespread erosion in Early Pennsylvanian time on the Central Kansas uplift. Uplift is strongly suggested by the rather extensive karst topography formed on the Viola Limestone and the contemporaneous development of the similarly extensive Viola residual chert before deposition of the Chattanooga Shale and possibly equivalent rocks commonly assigned a Kinderhook age. The presence of thicker and more widespread residual chert toward the north, together with the irregular northward thinning of the Viola beneath the Chattanooga and Kinderhook rocks, suggests that the broad pre-Chattanooga arch in the western part of the area probably extended far to the north and possibly merged with the ancestral Central Kansas uplift.

The history and areal extent of the ancestral Central Kansas uplift in pre-Mississippian time is difficult to determine because of very extensive post-Mississippian uplift and erosion that has resulted in its present configuration. According to Barwick (1928, p. 186), the first folding occurred at about the end of Devonian time. Other geologists, notably McClellan (1930, p. 1551, 1552) and Koester (1935, p. 1425, 1426), suggested earlier uplift and erosion beginning in Late Cambrian (pre-Arbuckle) time. Lee (1953, p. 20) believed that structural movements before Mississippian time were definitely minor in amplitude, compared to later movements.

FOLDING IN LATE PALEOZOIC TIME

The structural development in central and eastern Kansas in late Paleozoic time was more intense and notably different in trend of the folds than in earlier Paleozoic time. Initial movements that produced the Nemaha anticline, which strikes north-northeast across the Chautauqua arch and the North Kansas basin, probably began as early as Kinderhook time (Lee, 1943, p. 112, 113, 115). Regional northward tilting during Kinderhook time, followed by southward tilting in Osage and Meramec time, was described by Lee, Leatherock, and Botinelly (1948, p. 131–133). Evidence for some arching of the Central Kansas uplift in early Osage time was described by Goebel (1968, p. 1755). Many of the other structural features in the mapped area, including the Voshell, Pratt, and Nemaha anticlines, formed mainly in Early Pennsylvanian time. Sedimentation resumed in Middle Pennsylvanian (Des Moines) time, but gentle structural deformation continued at a declining rate into Early Permian time. The major structural features have been somewhat modified by post-Paleozoic regional warping and some local folding.

OIL AND GAS

Exploration for oil and gas in the mapped area apparently began before the turn of the century.

According to Page (1940, p. 1781, 1782), the first gas well in western Kansas was completed in 1888 near Lyons in Rice County, but no additional gas development was recorded for many years. Bass (1929, p. 130–194) summarized the early exploration and development in Cowley County, where small amounts of gas were discovered as early as 1902. In Butler County to the north, exploration in the vicinity of the Nemaha anticline began about 1904 (Berry and Harper, 1948, p. 213), and discovery of the Augusta and El Dorado fields in 1914 and 1915, respectively, marked the beginning of Kansas' importance as a petroleum producer. According to Fath (1921, p. 10), in 1918 the El Dorado field was, by its output of nearly 29 million barrels, the leading field in the Nation. After World War I, the search for petroleum expanded generally westward from the Nemaha anticline, and the greatest petroleum province of the State, the Central Kansas uplift, was broadly defined in the late 1920's and early 1930's. During this time, numerous smaller anticlinal structures were discovered, especially in the northern and eastern parts of the Sedgwick basin, and many have proved productive.

Hundreds of oil and gas fields of widely varying sizes have been discovered within the mapped area. A large number of fields are productive from Middle and Upper Ordovician rocks, and many of these are also productive from older and (or) younger rocks. The location of 263 fields that produced wholly or partly from Middle and Upper Ordovician rocks in 1965 are shown on plate 5 and are listed in table 2. Reports of the Kansas Geological Survey were used in compiling the locations of productive and abandoned fields. The boundaries for fields that produced from two or more stratigraphic units (pl. 5) include all productive areas assigned to a given field without regard to age of the productive rocks.

About a fourth of the fields that yield oil or gas from Middle and Upper Ordovician rocks in the mapped area are also productive from older rocks, chiefly from the upper part of the Arbuckle Group. These fields are principally on or near the Nemaha anticline (south of T. 24 S.), on the Central Kansas uplift, and on or near the Pratt anticline.

About half the fields producing oil or gas from Middle and Upper Ordovician rocks also produce from younger rocks, chiefly of Mississippian and Pennsylvanian ages. Some of the fields are stratigraphic traps in the post-Ordovician rocks, and the productive area of Ordovician rocks is probably small. An example is the relatively large Rhodes oil and gas field in eastern Barber County (field 15, pl. 5). According to Clark (1956, p. 77, 78), oil was being produced from the Viola Limestone in only one well, which was completed in late 1951. Other wells tested the Viola unsuccessfully, and the major production was ascribed to stratigraphic traps in Mississippian and Pennsylvanian rocks. Productive areas of Middle and Upper Ordovician rocks are probably small in several other fields west of the Rhodes field, in the large Spivey-Grabs-Basil field in northwestern Harper (field 10, pl. 5) and southern Kingman Counties, and in the large Lost Springs field which is located mainly in northeastern Marion County (field 8, pl. 5).

Anticlinal structure is probably of major importance in localizing oil and gas in most fields that produce entirely or chiefly from Middle and Upper Ordovician rocks, although not all the known anticlines contain petroleum. For example, the Nemaha anticline north of El Dorado includes two local prominent anticlines where large petroleum accumulations could be logically expected (pl. 5), but these structural features are almost completely unproductive.

Many petroleum accumulations in Ordovician rocks are in anticlines or domes that have only a few tens of feet of structural closure, as has been noted by Beebe (1959, p. 250, 252) who wrote, "The magnitude of structural relief necessary to yield commercial quantities of oil is so small that it is well below the normal limit of error in conventional seismic surveying." Many other geologists and geophysicists have also written about the problems in finding the small subsurface anticlines in much of Kansas.

Stratigraphic traps in the Middle and Upper Ordovician rocks are less well known in the mapped area than are the structural traps. In some fields Ordovician rocks are arched, truncated, and unconformably overlain by impervious strata (commonly of Pennsylvanian age). The trap so caused is partly stratigraphic, but the anticlinal folding is generally considered paramount; therefore most of these fields are classified as structurally controlled.

The Zenith-Peace Creek field in Stafford County (field 59, pl. 5) and adjacent Reno County, described by Imbt (1941), Paddleford (1941), and Kornfeld (1943), is perhaps the best known example of a stratigraphic trap in Ordovician rocks. This field lies on the southeastern flank of the Central Kansas uplift. The principal structural feature is a southeast-dipping monocline. Unconformably overlying the Ordovician rocks are the Misener sand and limestone of local usage and rocks of Kinderhook and

TABLE 2.—*Oil and gas fields that produced from Middle and Upper Ordovician rocks during 1965*

[Data from Beene and Oros, 1967. Fields developed in two or more counties are numbered within the county of discovery]

Number of field, (pl. 5)	Field name and year of discovery	Location of discovery well (sec., T., R.)	Producing rocks	Principal production
		Barber County		
1	Aetna gas area (1935)	13–34S–15W	Viola Limestone [1]	Oil, gas.
2	Bloom (1955)	23–32S–12W	Simpson Group [1]	Oil.
3	Deerhead (1943)	22–32S–15W	Viola Limestone	Oil, gas.
4	Deerhead North (1964)	14–32S–15W	Sylvan Shale,[1] Viola Limestone	Do.
5	DeGeer (1948)	2–33S–15W	Viola Limestone [1]	Gas.
6	DeGeer Southwest (1963)	8–33S–15W	Viola Limestone, Simpson Group	Oil, gas.
7	Eads (1958)	4–30S–14W	do	Oil.
8	Gudeman (1954)	10–35S–10W	Viola Limestone	Do.
9	Lake City (1937)	7–31S–13W	Viola Limestone, Simpson Group [2]	Oil, gas.
10	Little Bear Creek (1954)	12–32S–14W	Viola Limestone [1]	Do.
11	Medicine Lodge-Boggs (1927)	13–33S–13W	Simpson Group [1]	Do.
12	Mingona (1962)	21–31S–13W	do.[1]	Oil.
13	Moffett West (1965)	9–30S–15W	Viola Limestone	Do.
14	Palmer (1958)	30–32S–13W	do.[1]	Do.
15	Rhodes (1949)	15–33S–11W	do.[1]	Do.
16	Skinner (1943)	29–31S–14W	Viola Limestone,[1] Simpson Group	Oil, gas.
17	Stumph (1952)	7–32S–14W	Simpson Group [1]	Oil.
18	Turkey Creek East (1957)	21–30S–15W	Viola Limestone	Oil, gas.
		Barton County		
1	Ash Creek (1947)	31–20S–15W	Simpson Group [2]	Gas.
2	Clarence (1953)	1–20S–15W	do.[1 2]	Do.
3	Jettie (1954)	27–20S–14W	do.[2]	Oil.
4	Pritchard (1944)	34–20S–14W	do.[1 2]	Do.
		Butler County		
1	Augusta (1914)	21–28S–4E	Simpson Group [1 2]	Oil.
2	Augusta North (1914)	28–27S–4E	do.[1 2]	Do.
3	Bausinger (1929)	24–27S–3E	do	Do.
4	Berndsen (1958)	15–26S–4E	do	Do.
5	Elbing (1918)	18–23S–4E	Viola Limestone [1]	Do.
6	El Dorado (1915)	29–25S–5E	Viola Limestone,[1] Simpson Group [2]	Do.
7	Entz (1959)	23–26S–4E	Simpson Group	Do.
8	Four Mile Creek (1951)	5–28S–3E	do	Do.
9	Gelwick (1929)	27S–4E	Viola Limestone	Do.
10	Keighley (1925)	22–27S–7E	Simpson Group [1]	Do.
11	Kramer-Stern (1926)	3–28S–6E	Viola Limestone,[1] Simpson Group [2]	Do.
12	Leon (1922)	19–27S–6E	Viola Limestone [1]	Do.
13	Lietzke (1962)	3–28S–5E	Simpson Group	Do.
14	Reynolds-Schaffer (1922)	9–27S–6E	Viola Limestone [1]	Do.
15	Salter (1946)	23–28S–3E	Simpson Group	Do.
16	Skaer (1961)	21–27S–3E	do.[1]	Do.
17	Smock-Sluss (1917)	2–27S–5E	Viola Limestone [1]	Do.
18	Towanda (1948)	5–26S–4E	do.[1]	Do.
19	Whitewater (1949)	32–25S–4E	do	Do.
		Chase County		
1	Koegeboehn (1959)	19–19S–6E	Viola Limestone	Oil.
2	Koegeboehn North (1961)	8–19S–6E	do	Do.
		Comanche County		
1	Beals (1955)	5–34S–17W	Viola Limestone,[1] Simpson Group	Gas.
2	Yellowstone North (1965)	16–35S–16W	Viola Limestone [1]	Gas.
		Cowley County		
1	Brandenburg (1955)	3–35S–3E	Simpson Group	Oil.
2	Gibson (1941)	29–34S–3E	do.[1 2]	Do.
3	Thurlow (1927)	8–33S–3E	do	Do.
		Ellsworth County		
1	Stoltenberg (1931)	22–16S–10W	Simpson Group [1 2]	Oil.
		Harper County		
1	Banner (1954)	27–32S–7W	Viola Limestone, Simpson Group	Oil.
2	Gerber (1957)	28–31S–5W	Simpson Group [1]	Do.
3	Gish (1957)	17–31S–6W	do.[1]	Do.
4	Goheen (1958)	12–31S–7W	do.[1]	Do.
5	Grant (1957)	20–31S–7W	do	Do.
6	Harper (1958)	11–32S–7W	Viola Limestone,[1] Simpson Group	Oil, gas.
7	Muir (1960)	4–32S–7W	Simpson Group [1]	Oil.

See footnotes at end of table.

TABLE 2.—*Oil and gas fields that produced from Middle and Upper Ordovician rocks during 1965*—Continued

Number of field, (pl. 5)	Field name and year of discovery	Location of discovery well (sec., T., R.)	Producing rocks	Principal production
		Harper County—Continued		
8	Rex (1961)	1–32S–5W	Simpson Group	Oil.
9	Runnymede (1953)	23–31S–6W	do.[1]	Oil, gas.
10	Spivey-Grabs-Basil (1949)	13–31S–9W	Viola Limestone [1]	Oil.
11	Sullivan (1961)	31–32S–8W	do	Do.
12	Zuercher (1959)	9–32S–7W	Simpson Group	Do.
		Harvey County		
1	Alta Mills (1958)	29–22S–2W	Simpson Group	Oil.
2	Halstead West (1960)	10–23S–2W	Viola Limestone,[1] Simpson Group	Do.
3	Hollow-Nikkel (1931)	30–22S–3W	Simpson Group [1]	Do.
4	Sperling South (1957)	23–22S–2W	Viola Limestone [1]	Do.
		Kingman County		
1	Alameda (1958)	23–28S–7W	Viola Limestone,[1] Simpson Group	Oil.
2	Dresden (1951)	13–27S–10W	Viola Limestone [1]	Do.
3	Georgia Spur Northeast (1964)	32–27S–6W	do.[1]	Do.
4	Goetz (1956)	29–29S–9W	do.[1]	Oil, gas.
5	Hostetler (1965)	32–30S–7W	do	Oil.
6	Maple Grove (1965)	36–30S–7W	Simpson Group	Do.
7	Orsemus (1953)	30–29S–5W	Viola Limestone, Simpson Group	Do.
8	Pat Creek (1946)	20–28S–9W	Viola Limestone,[1] Simpson Group	Do.
9	Reida (1955)	18–30S–6W	Simpson Group [1]	Oil, gas.
10	Settle (1956)	18–29S–7W	Viola Limestone [1]	Oil.
11	Spade (1955) (revived)	27–29S–10W	do.[1]	Do.
12	Varner (1964)	8–27S–6W	do.[1]	Do.
13	Willowdale (1954)	11–29S–9W	do.[1]	Do.
		Kiowa County		
1	Belvidere (1962)	17–30S–16W	Viola Limestone	Oil.
		McPherson County		
1	Groveland South (1953)	14–20S–4W	Viola Limestone	Oil.
2	Johnson South (1950)	11–20S–3W	Simpson Group [1]	Do.
3	Lindsborg (1938)	8–17S–3W	Viola Limestone, Simpson Group	Do.
4	Lindsborg South (1955)	6–18S–3W	Simpson Group	Do.
5	McMurtry (1960)	13–18S–4W	Sylvan Shale	Do.
6	McPherson (1926)	29–18S–2W	Viola Limestone [1]	Oil, gas.
7	Paden (1943)	10–18S–1W	do.[1]	Oil.
8	Ritz-Canton (1929)	1–20S–2W	Sylvan Shale,[1] Viola Limestone	Do.
9	Roxbury (1938)	18–17S–1W	Simpson Group [1]	Do.
10	Voshell (1929)	9–21S–3W	Viola Limestone [1]	Do.
		Marion County		
1	Covert-Sellers (1920)	28–21S–4E	Viola Limestone [1]	Oil.
2	Durham (1953)	34–18S–2E	do	Do.
3	Fairplay (1957)	25–21S–4E	do.[1]	Do.
4	Florence (1920)	18–21S–5E	do	Do.
5	French Creek (1955)	22–19S–2E	Simpson Group	Oil, gas.
6	Hillsboro (1928)	7–19S–3E	Viola Limestone [1]	Oil.
7	Lehigh North (1953)	23–19S–1E	do	Do.
8	Lost Springs (1926)	22–17S–4E	do.[1]	Do.
9	Peabody (1920)	9–22S–4E	do	Do.
10	Ratzlaff (1956)	7–19S–2E	do	Do.
11	Youk (1954)	20–18S–2E	do	Do.
		Pawnee County		
1	Evers (1951)	1–22S–16W	Simpson Group [1,2]	Oil.
2	Hearn (1953) (abandoned)	35–23S–15W	do.[1]	Gas.
3	Jay (1954)	3–23S–15W	do.[1]	Oil.
4	Jay South (1956)	9–23S–15W	do	Do.
5	Shady (1945)	34–22S–16W	Viola Limestone [2]	Gas.
6	Sweeney West (1957)	14–21S–16W	Simpson Group [2]	Oil.
		Pratt County		
1	Brachear (1962)	30–28S–13W	Simpson Group	Oil.
2	Brehm (1961)	23–28S–13W	do.[1,2]	Do.
3	Cairo North (1954)	6–28S–11W	Viola Limestone	Do.
4	Carver-Robbins (1955)	21–27S–15W	do.[1]	Do.
5	Chance (1946)	4–27S–13W	Viola Limestone,[1] Simpson Group [2]	Oil, gas.
6	Chance Northwest (1954)	29–26S–13W	Simpson Group	Oil.

See footnotes at end of table.

TABLE 2.—*Oil and gas fields that produced from Middle and Upper Ordovician rocks during 1965*—Continued

Number of field, (pl. 5)	Field name and year of discovery	Location of discovery well (sec., T., R.)	Producing rocks	Principal production
		Pratt County—Continued		
7	Chitwood (1943)	23–28S–12W	Viola Limestone,[1] Simpson Group [2]	Oil, gas.
8	Clara (1948)	36–29S–14W	Simpson Group [1 2]	Do.
9	Coats (1944)	24–29S–14W	do.[2]	Oil.
10	Coats West (1955)	23–29S–14W	do	Do.
11	Cunningham (1931)	7–28S–11W	Viola Limestone [1 2]	Oil, gas.
12	Earl (1954)	36–28S–14W	Simpson Group [1]	Oil.
13	Earl North (1955)	36–28S–14W	do	Do.
14	Fitzsimmons South (1954)	31–27S–13W	do.[1]	Do.
15	Frisbie Northeast (1948)	4–26S–13W	Viola Limestone,[1] Simpson Group	Do.
16	Gereke North (1961)	1–26S–15W	Viola Limestone,[1] Simpson Group	Do.
17	Gereke Northwest (1962)	1–26S–15W	Viola Limestone	Do.
18	Haskins (1956)	5–27S–14W	do.[1]	Do.
19	Iuka-Carmi (1937)	11–27S–13W	Viola Limestone,[1] Simpson Group [2]	Oil, gas.
20	Iuka-Carmi Northwest (1953)	26–26S–13W	do.[2]	Oil.
21	Jem (1957)	28–29S–13W	do	Oil, gas.
22	Ludwick Northeast (1960)	28–28S–13W	Simpson Group [1]	Oil.
23	Lunt (1964)	33–27S–12W	do	Oil, gas.
24	Moore (1949)	1–26S–14W	Viola Limestone,[1] Simpson Group	Oil.
25	Moore Southwest (1953)	11–26S–14W	Simpson Group [1]	Do.
26	Pratt Airport (1963)	8–27S–13W	do	Gas.
27	Rollingson (1958)	30–27S–12W	do.[1]	Oil.
28	Sawyer (1957)	26–29S–13W	Viola Limestone,[1] Simpson Group [2]	Oil, gas.
29	School Teacher (1957)	27–28S–11W	Viola Limestone	Oil.
30	Shriver (1944)	33–29S–14W	Simpson Group	Do.
31	Stead (1964)	27–26S–12W	do	Do.
32	Welli (1964)	7–28S–13W	do	Do.
		Reno County		
1	Albion North (1950)	12–26S–6W	Viola Limestone [1]	Oil.
2	Buhler (1938)	25–22S–5W	Viola Limestone, Simpson Group	Do.
3	Friendship (1941)	19–25S–4W	Viola Limestone [1]	Do.
4	Haven (1951) (abandoned)	9–25S–4W	Viola Limestone,[1] Simpson Group	Do.
5	Hilger (1934)	16–26S–4W	Viola Limestone	Do.
6	Hilger Southwest (1955)	29–26S–4W	do.[1]	Do.
7	Lerado (1937)	10–26S–9W	do.[1]	Gas.
8	Stroud (1958)	34–23S–5W	Simpson Group	Oil.
9	Wisby (1957)	18–22S–9W	do	Do.
10	Wisby North (1957)	6–22S–9W	do	Do.
11	Wisby South (1959)	19–22S–9W	do	Do.
		Rice County		
1	Chase-Silica (1930)	32–19S–9W	Simpson Group [1 2]	Oil.
2	Frederick (1951)	10–18S–9W	do.[1]	Do.
3	Frederick East (1961)	12–18S–9W	do	Do.
4	Geneseo-Edwards (1934)	25–18S–8W	do.[1 2]	Do.
5	Lyons Southwest (1955)	22–20S–8W	do.[1 2]	Gas.
6	Rino (1960)	33–21S–9W	do.[2]	Oil.
7	Schoepflin (1962)	17–21S–9W	do	Do.
8	Shuler (1964)	11–20S–9W	do	Do.
9	Shumway West (1965)	8–20S–8W	do	Do.
10	Tobias (1961)	25–20S–9W	do.[1 2]	Do.
11	Tobias Northwest (1962)	23–20S–9W	do.[2]	Do.
12	Wisby Northeast (1958)	32–21S–9W	do	Do.
		Sedgwick County		
1	Brumley (1955)	19–29S–1E	Simpson Group [1]	Oil.
2	Curry (1947)	11–27S–1W	Viola Limestone [1]	Do.
3	Eastborough (1929)	19–27S–2E	do.[1]	Do.
4	Gillian (1961)	33–29S–1W	Simpson Group	Do.
5	Greenwich (1929)	14–26S–2E	Viola Limestone [1]	Do.
6	Luening (1951)	33–26S–2E	Simpson Group	Do.
7	Minneha North (1960)	2–27S–2E	do.[2]	Do.
8	Minneha West (1965)	15–27S–2E	do	Do.
9	O.S.A. (1962)	10–29S–1W	do	Do.
10	Petrie (1945)	36–26S–1W	Viola Limestone	Do.
11	Valley Center (1928)	1–26S–1W	do.[1]	Do.
12	Wichita (1957)	4–27S–1E	Viola Limestone, Simpson Group	Do.
		Stafford County		
1	Ahnert (1941) (revived)	26–22S–13W	Simpson Group [2]	Oil.
2	Albano (1957)	12–25S–14W	Viola Limestone [1 2]	Do.

See footnotes at end of table.

TABLE 2.—*Oil and gas fields that produced from Middle and Upper Ordovician rocks during 1965*—Continued

Number of field, (pl. 5)	Field name and year of discovery	Location of discovery well (sec., T., R.)	Producing rocks	Principal production
		Stafford County—Continued		
3	Bart-Staff (1951)	4–21S–14W	Simpson Group [1,2]	Oil.
4	Bayer (1951)	16–21S–14W	Viola Limestone,[1] Simpson Group [2]	Do.
5	Bedford (1940)	21–23S–12W	Simpson Group [2]	Do.
6	Cephas (1953)	10–25S–14W	Viola Limestone [1]	Do.
7	Crissman (1952)	16–23S–14W	Simpson Group [1,2]	Do.
8	Drach (1937)	12–22S–13W	do.[2]	Do.
9	Farmington (1943)	34–24S–15W	do.[1,2]	Do.
10	Farmington North (1956)	23–24S–15W	Viola Limestone	Do.
11	Gates (1933)	27–21S–13W	do.[1,2]	Do.
12	German Valley (1951)	4–22S–12W	do.[1,2]	Do.
13	Green Ridge (1953)	30–23S–14W	do.[1]	Do.
14	Harter (1950)	30–24S–13W	Simpson Group [1,2]	Do.
15	Heyen (1943)	24–22S–12W	Viola Limestone [1,2]	Do.
16	Hickman (1951)	27–21S–14W	Simpson Group [1]	Do.
17	Hudson South (1961)	4–23S–12W	Viola Limestone	Do.
18	Kachelman (1950)	7–25S–13W	do. [1,2]	Do.
19	Kipp (1937)	27–25S–14W	Simpson Group [1]	Do.
20	Knoche South (1956)	17–24S–12W	Viola Limestone	Do.
21	Koelsch Southeast (1952)	25–24S–14W	Simpson Group [2]	Do.
22	Kowalsky Southwest (1950)	6–21S–11W	do.[1,2]	Do.
23	Leesburgh (1938)	12–25S–13W	do.[1,2]	Do.
24	Leesburgh West (1964)	11–25S–13W	do	Do.
25	Leiss (1956)	23–25S–13W	do	Do.
26	Leiss Southwest (1963)	26–25S–13W	do	Do.
27	Lincoln (1951)	29–21S–14W	do.[1]	Do.
28	Lutz (1963)	27–23S–13W	do	Do.
29	McCandless (1944)	30–25S–13W	do.[1]	Do.
30	McCandless Northeast (1960)	20–25S–13W	do	Do.
31	Macksville (1960)	3–24S–15W	Viola Limestone [2]	Gas.
32	Macksville East (1954)	14–24S–15W	Viola Limestone, Simpson Group [2]	Oil, gas.
33	Macksville Townsite (1961)	15–24S–15W	Simpson Group	Oil.
34	Max (1938)	35–21S–12W	do.[1,2]	Do.
35	Mershon (1963)	16–24S–12W	Viola Limestone	Do.
36	Moody (1956)	7–25S–14W	do.[1]	Do.
37	Mopac (1954)	30–24S–11W	do	Do.
38	Neola (1948)	15–25S–11W	do	Do.
39	Newell (1953)	7–25S–11W	do.[1]	Do.
40	North Star (1952)	27–24S–12W	Viola Limestone, Simpson Group	Do.
41	North Star North (1953)	21–24S–12W	Viola Limestone [1,2]	Do.
42	O'Connor (1948)	8–24S–15W	Simpson Group [1]	Do.
43	Oscar (1949)	24–22S–14W	Viola Limestone [1,2]	Do.
44	Radium Townsite (1953)	5–22S–14W	Viola Limestone,[1] Simpson Group [2]	Do.
45	Rose Valley (1952)	36–25S–13W	Viola Limestone [1]	Do.
46	Sand Hills (1944)	19–21S–11W	Viola Limestone,[1] Simpson Group [2]	Do.
47	Shaeffer-Rothgarn (1941)	3–21S–13W	Simpson Group [1,2]	Do.
48	Shepherd North (1954)	9–22S–11W	do.[1,2]	Do.
49	Shepherd Northwest (1956)	8–22S–11W	do.[2]	Do.
50	Slade South (1961)	35–25S–12W	Viola Limestone [1]	Do.
51	Snider (1936)	3–21S–11W	Simpson Group [1,2]	Do.
52	Snider South (1938)	16–21S–11W	do.[1,2]	Do.
53	Stafford (1940)	15–24S–12W	Viola Limestone [2]	Do.
54	Strobel (1952)	9–22S–14W	Simpson Group [1,2]	Do.
55	Strobel Northwest (1952)	8–22S–14W	do.[2]	Do.
56	Suiter (1962)	24–24S–15W	Viola Limestone	Do.
57	Taylor (1952)	15–21S–14W	Viola Limestone,[1] Simpson Group.	Do.
58	Wood (1953)	33–22S–14W	Simpson Group [1,2]	Do.
59	Zenith-Peace Creek (1937)	23–24S–11W	Viola Limestone [1]	Oil, gas.
		Sumner County		
1	Attebery (1959)	20–33S–1W	Simpson Group	Oil.
2	Badger Creek (1958)	1–34S–1E	do	Do.
3	Beatie (1956) (abandoned)	21–31S–2W	do	Do.
4	Belle Plaine (1965)	35–30S–1E	do.[1]	Do.
5	Bellman (1945)	15–30S–1E	do	Do.
6	Bellman West (1957)	16–30S–1E	do	Do.
7	Caldwell (1929)	17–35S–3W	do.[1]	Do.
8	Cole (1960)	24–31S–4W	do	Do.
9	Conway Springs (1959)	5–31S–3W	do	Do.
10	Fall Creek (1950)	3–35S–3W	do.[1]	Oil, gas.
11	Gerberding (1954)	6–34S–4W	do	Oil.
12	Guelph (1951)	6–35S–1E	do.[1,2]	Do.

See footnotes at end of table.

TABLE 2.—*Oil and gas fields that produced from Middle and Upper Ordovician rocks during 1965*—Continued

Number of field, (pl. 5)	Field name and year of discovery	Location of discovery well (sec., T., R.)	Producing rocks	Principal production
		Sumner County—Continued		
13	Interchange (1959)	19–32S–1E	Simpson Group	Oil.
14	Markley (1958)	22–30S–1E	do	Do.
15	Mayfield (1957)	19–32S–2W	do	Do.
16	Olive Branch (1960)	11–33S–3W	do.[1]	Do.
17	Oxford West (1926)	17–32S–2E	do.[2]	Do.
18	Padgett (1925)	12–34S–2E	do.[1]	Do.
19	Perth (1945)	12–33S–2W	do	Do.
20	Portland (1950)	16–34S–1E	do.[1]	Do.
21	Priddy (1957)	35–33S–1W	do	Do.
22	Rusk (1959)	8–32S–1E	do	Do.
23	Rutter Southwest (1957)	29–33S–2E	do.[2]	Do.
24	Seydell (1958)	17–30S–1E	do.[1]	Do.
25	South Haven (1954)	2–35S–1W	do	Do.
26	Subera (1957)	22–34S–3W	do	Do.
27	Tate (1938)	31–32S–2E	do	Do.
28	Walta (1959)	25–33S–4W	do.[1]	Do.
29	Zyba (1937)	7–30S–1E	do	Do.
30	Zyba Southwest (1944)	22–30S–1W	do	Do.

[1] Also produced from post-Ordovician rocks.
[2] Also produced from pre-Simpson rocks.

Pennsylvanian ages (Imbt, 1941, p. 143, figs. 9, 10; Kornfeld, 1943, p. 44, 46). The principal reservoir consists of coarsely crystalline limestone or dolomite (called "Fernvale" by some geologists) in the upper part of the Viola Limestone. Imbt (1941, p. 161, 162, fig. 9) attributed the petroleum accumulation chiefly to (1) limited areal distribution of sandstone and limestone assigned to the Misener sand of local usage and dolomite of the Sylvan (Maquoketa) Shale; (2) truncation of Misener, Sylvan, and Viola in the northern end of the field; (3) presence of an impermeable seal above all productive beds; and (4) lateral changes in effective porosity and permeability of the Viola.

Stratigraphic traps in Middle and Upper Ordovician rocks yield petroleum at other places in the report area, but the accumulations are generally much smaller than in the Zenith-Peace Creek field. The Viola was subjected to postdepositional alterations, such as dolomitization and solution, at several times before final burial, and the alterations probably improved the permeability and porosity of the formation at many places, probably much more so than in carbonates of the Simpson Group.

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