The Geology of Riley and Geary Counties, Kansas

By

JOHN M. JEWETT

UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS
Bulletin 39

STATE GEOLOGICAL SURVEY OF KANSAS

RAYMOND C. MOORE, Ph. D., Sc. D.,
State Geologist and Director

JOHN C. FRYE, Ph. D.,
Assistant State Geologist and Assistant Director

BULLETIN 39

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By JOHN M. JEWETT

Printed by Authority of the State of Kansas
Distributed from Lawrence

UNIVERSITY OF KANSAS PUBLICATIONS
DECEMBER, 1941

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By John M. Jewett

INTRODUCTION

This report on the geology of an area somewhat greater than 1,000 square miles is based chiefly on field studies made during the summer of 1930, but supplemented by a few weeks of study in August, 1938. The two counties, selected by the state geologist and assigned to me, have afforded a wide variety of subjects of geologic interest, as the area includes exposures of several hundred feet of strata of Pennsylvanian age, almost the entire thickness of the truly marine Perminan rocks of the state, a few feet of Cretaceous sediments, some glacial drift of the Pleistocene series, and three exposures of igneous rock. The physiography is almost as interesting as the stratigraphy, for the Flint Hills in this part of Kansas are as rugged and as beautiful as any other surface features in the state. The exposed strata are described in detail and their distribution is shown on the accompanying map. The structure is discussed and the physiography is generally described. A portion of the report concerns economic geology. Neither oil nor gas has been found in commercial quantity in the two counties, but the area has been tested by only a few wells, so should not be regarded as having been proved barren.

The layers of rock that are exposed in eastern Kansas are deeply buried in the western part of the state. As an acquaintance with these strata is extremely important to petroleum geologists seeking to discover or extend oil fields in western Kansas, the measurements of thickness and the detailed descriptions of color, texture, and composition of each of the strata outcropping in Riley and Geary counties should be useful to persons so employed.

FIELD WORK

During the field season of 1930, details of stratigraphy were studied and the areal map was prepared. Faunal and lithologic studies begun in the field were continued in the laboratory. Subsequent shorter visits to the two counties and study of the same rock layers in other parts of Kansas, in Nebraska, and in Oklahoma have been helpful. Additional studies were made in the summer of 1938.

One method that was used in mapping rock exposures had not previously been used in Kansas. Aerial photographs, which were prepared by the United States Air Corps in the summer of 1926 and which are now the property of the United States Geological Survey, were lent to the Kansas Geological Survey and were used in making a portion of the map. The scale of the air photographs is 1:17,500. A base map, scale 1:2,000, was obtained from the Federal Survey and after the rock strata had been identified in the field their pattern was transferred from the photographs to the base map. The base map itself had been made from air photographs, so drainage and other features are accurately pictured. The base map covers all the area except that portion north of an east-west line passing through Leonardville in northern Riley county and an area of about 75 square miles south and east of Manhattan. Available air photographs did not cover the whole area of this base map. The portion covered by the large-scale base map, but not by the air photographs, was mapped by using as base maps the State Highway Department map and the soil map of Riley county published by the United States Bureau of Soils. As a check in a few small, scattered areas, maps made by commercial geologists were used. It is believed that the outcrop pattern was almost exactly delineated, especially because of the map's accuracy, within the area of the large-scale base map.

ACKNOWLEDGMENTS

R. C. Moore, state geologist, gave directions, suggestions, and criticisms that were indispensible to the successful completion of the project, and visited areas in the field. G. E. Condra, state geologist of Nebraska, who has given much study to the Permian rocks of the northern midcontinent area, also gave assistance of great value; later he kindly supplied several measured sections that were useful in making correlations. Citizens of the counties were courteous and helpful whenever accosted. J. E. Ames, manager of the Chamber of Commerce, Manhattan, and H. P. Reaume, secretary of the Chamber of Commerce, Junction City, provided data concerning industries and population. John Ockerman, formerly of the Kansas Geological Survey, made the stereoscope that was used in studying the air photographs. M. K. Elias, formerly of the Kansas Geological Survey, was very helpful, sharing his knowledge of the stratigraphy of the "Big Blue" series. Several petroleum geologists have suggested types of data, obtainable by study of the outcrops, that are helpful in their studies of subsurface cuttings. I appreciate the magnitude of the help I have received from these persons.

GEOGRAPHY

LOCATION AND AREA

Riley and Geary counties are situated in northeastern Kansas in the fifth tier of counties west of Missouri river. Riley county is in the second tier of counties south of the Nebraska-Kansas border, and Geary county adjoins Riley county on the south. The eastern boundary of the area is approximately 100 miles west of the Missouri-Kansas state line and the northern border is 30 miles south of the Nebraska-Kansas state line. Riley county is bounded on the north by Washington and Marshall counties, on the east by Pottawatomie county, on the south by Wabaunsee and Geary counties,

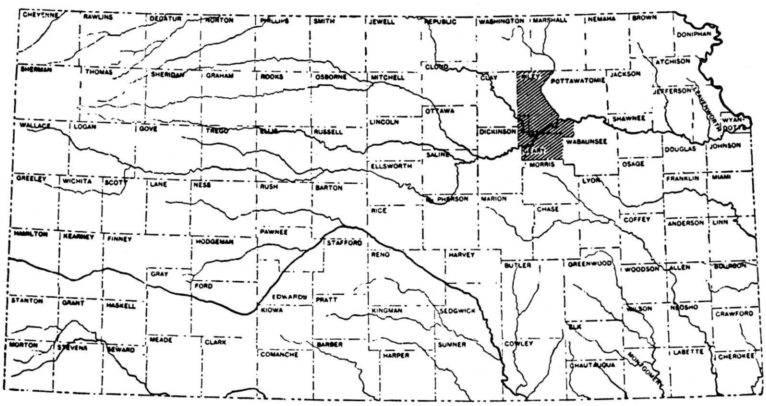

FIG. 1. Map of Kansas showing location of Riley and Geary counties.

and on the west by Geary and Clay counties. It is irregular in shape, but is roughly a truncated triangle having an area of 617 square miles. The north-south dimension is 36 miles and the greatest east-west dimension is 25 miles. The county comprises townships 6 to 11 south in ranges 4 to 9 east. Geary county is bounded on the north by Riley county, on the east by Riley and Wabaunsee counties, on the south by Wabaunsee and Morris counties, and on the west by Dickinson and Clay counties. The area of Geary county is 407 square miles. The greatest north-south dimension is 24 miles, and the greatest east-west dimension is 25 miles. Geary county comprises townships or parts of townships 10 to 13 south in ranges 4 to 8 east. The area covered by this report is bounded approximately by parallels 38°50′ and 39°40′ N. latitude and by meridians 96°30′ and 97° W. longitude. Frequently, but erroneously, the geographic center of the United States is said to lie within the Fort Riley Military Reservation and approximately at the center of the area discussed. Judicially part of the military reservation is in each county. According to information given by the Federal Board of Surveys and Maps (Circular 33484, July, 1929) the geographic center of the United States is in Smith county, Kansas, not far from the village of Lebanon. The point is in latitude 39°50′, longitude 98°35′.

HISTORY

Eighty-three counties, including Riley and Davis, were organized in 1855. The present Geary county was called Davis until 1889, having been named in honor of Jefferson Davis, who was Secretary of War when the counties were organized. The present irregular shape of the counties is the result of several changes in the boundaries.

Before the white settlers came, Indians occupied the river valleys, and remains of their villages can still be found. The present Junction City, county seat of Geary county, was the site of a village of the Kaw tribe as late as 1856. It is probable that Coronado was the first white man to visit the area of the two counties, as he is generally believed to have found *Quivira* some place in this vicinity in 1642. In 1843 John Fremont traveled through this part of Kansas. The first white settler in the area that is now Riley county was Samuel Dyer, who operated a ferry on Big Blue river at Juniata, which is a few miles north of the river's mouth. Several historic roads crossed this part of Kansas. The Leavenworth and Pike's Peak Express passed through Fort Riley, and the fort was a station on the Butterfield Overland Dispatch Route. The south branch of the California Trail passed through Manhattan.

Fort Riley, first called Camp Center, was established in 1852 on a site selected by Major E. A. Ogden, in whose honor the town of Ogden was named. In 1853 the name of the army post was changed to Fort Riley in honor of General Riley, who fought in the war with Mexico and who commanded scouts along the Santa Fe trail. Fort Riley is now one of the nation's large army posts, is the home of the Cavalry School, and is the largest cavalry post in the United States. During World War I, Camp Funston was located on the army reservation east of the post. It was the 14th National Army encampment, and the 7th, 10th, and 89th Divisions were trained there.

Camp Whitside and Marshall Flying Field also are on the reservation, which comprises 22,000 acres.

Manhattan, situated at the confluence of Kansas and Big Blue rivers, is the outgrowth of two towns, Poleska and Canton, which were united in 1855 to form "Boston." Later in the year, 75 people arrived from Cincinnati on the steamship *Hartford*. They had come to Kansas intending to found a town called Manhattan and had brought with them on the boat ten houses ready to erect. The people of Boston gave them half the townsite and the privilege of changing the name to Manhattan. At first Ogden was the county seat of Riley county, but later Manhattan became the county seat.

The valleys of the larger streams and of smaller ones such as Fancy creek and Deep creek were settled early. Settlers came to Deep creek valley in 1845. The town of Zeandale, the name of which means corn valley, was established in 1854 and a Congregational church was established there in the same year. A. W. Tabor, who later became famous as a discoverer of gold at Leadville, as one of the builders of Denver, and as U. S. Senator from Colorado, came to the eastern part of Deep creek valley in 1856 and started farming. Tabor Valley school in sec. 8, T. 11 S., R. 9 E., has been named for him and is near the farm he established. The name of Pillsbury Crossing, which is a beautiful natural ford over Deep creek south of Zeandale, commemorates the founder of Zeandale. In the years after the Civil War many settlers came to northern Riley county from northern Europe. In 1886 the town of Cleburne was founded after the neighboring valleys had been settled by Swedes who came directly from Sweden to establish homes. The descendents of these settlers now own many of the fertile farms there. The several beautiful rural churches in northeastern Riley county bear evidence of their substantiality.

Junction City, which is now the county seat of Geary county, was founded in 1855. It is situated at the junction of Smoky Hill and Kansas rivers. It became the county seat in 1860. The first county seat was Ashland, now a landmark in southern Riley county. Pawnee was established in 1854; its site is between Fort Riley and old Camp Funston on the military reservation. The first legislature of Kansas Territory met there in 1855. The building that served as the first territorial capitol is still standing and was restored to its original condition a few years ago.

POPULATION

According to the 1940 government census, the population of Riley county is 20,617; of Manhattan, 11,659; of Geary county, 15,222; and of Junction City, 8,507.

CITIES AND TOWNS

The largest city in the area is Manhattan. It is situated on the main lines of Chicago, Rock Island, and Pacific and Union Pacific railways, and is the south terminus of the Manhattan and Blue Valley branch of the Union Pacific. Randolph, Cleburne, and Stockdale are towns on the west side of Big Blue river and on Manhattan and Blue Valley railway. Zeandale, in eastern Riley county, Keats in the central part, and Riley and Bala in the western part, are situated on Chicago, Rock Island, and Pacific railway. Leonardville is 5 miles north of Riley. The villages of Walsburg, Lasita, Winkler, Bodaville, and May Day in the northern part of the county are not on railways.

Junction City is the largest city in Geary county and is the county seat. It is situated on the main line of Union Pacific railway and is the terminus of a branch from Belleville. It is the terminus of a Missouri, Kansas and Texas branch line from Parsons, Kan. Milford and Alida are small towns on Republican river on the Belleville branch railway. Wreford is a small town south of Junction City on Missouri, Kansas and Texas railway.

INDUSTRIES

The chief industries of the two counties are agriculture and the industries related to agriculture—general farming, stock feeding and breeding, poultry breeding, and some truck growing. There is a direct relationship between the type of agricultural products and the type of topography within the area. In the river valleys corn, wheat, alfalfa, kafir corn, sorghum, and some fruit are produced. A small amount of truck is grown in Kansas river valley near Zeandale, Manhattan, Ogden, and Junction City. Some cattle and hogs are raised in the creek and river valleys, but large numbers of cattle are pastured on the rough uplands. On the high rolling land, which is generally the dip slope of Fort Riley limestone, corn, wheat, alfalfa, oats, kafir corn, sorghum, and prairie hay are produced and cattle and hogs are fed for market. Urban industries are primarily related to agriculture and general merchandising. Kansas State College of Agriculture and Applied Sciences is situated at Manhattan. The proximity of the army post to Junction City tends to direct activities along lines unusual in most Kansas towns.

The railroads offer adequate shipping facilities throughout the area, but the motor truck has almost superseded the railroad in the hauling of local freight. United States highways 40 and 24 pass through Manhattan. United States highway 77 (Canada to Dallas) passes through the area by way of Junction City. Most of the roads are graveled or hard-surfaced. Others are kept in good repair, and all parts of the area are accessible by automobile. Most of the towns are served by motor stage routes. Manhattan has an airport, and the military flying field at Fort Riley is excellent.

CLIMATE

The area is part of a region in which the climate is marked by extremes of precipitation and temperature. Weather Bureau records show that the annual precipitation at Manhattan has ranged between 17 and 47 inches and that the temperature has ranged from —32° to 115° F. The table (Carter and Smith, 1908, p. 9) below shows the normal monthly and annual temperature and precipitation.

TABLE 1. *Normal monthly and annual temperature and precipitation at Manhattan, Kansas*

Month	Temp., °F.	Prec., inches	Month	Temp., °F.	Prec., inches
January	31.0	0.75	July	79.5	4.67
February	26.6	1.13	August	79.2	3.58
March	42.6	1.35	September	69.0	3.04
April	55.3	2.73	October	61.1	2.24
May	66.8	4.32	November	44.1	1.28
June	74.7	4.42	December	31.2	0.85
Year					30.36

The amount of rainfall varies greatly from year to year and occasional droughts are experienced. The summers of 1930, 1934, and 1936 were extremely dry, and farm crops suffered serious damage. The average growing season (from last to first killing frost) extends from April 20 to October 9 (Carter and Smith, 1908, p. 10).

TOPOGRAPHY

Riley and Geary counties lie within the physiographic province generally called the Central Lowlands, an area bordered by the High Plains on the west and by the Ozark and Appalachian plateaus on the east. This great area, like other natural physiographic units of the United States, has been divided by geographers into sections (Fenneman, 1938). Almost the entire area of the counties treated in this report lies within the section called Osage. A small part of northern and eastern Riley county lies within the limits of the Dissected Till Plains. In general the Osage Plains are best described as "scarped plains," an area in which strata dipping gently to the north of west have been beveled by an erosional plain sloping eastward, and in which the resistant rock layers form eastward- or southeastward-facing escarpments. Streams are incised below the old plain and the topography is semirugged.

This area is part of an older erosional plain that is now being dissected, and maturity has been reached in the present erosional cycle. The erosional history of eastern Kansas is probably very complex and certainly has not yet been satisfactorily deciphered. The crests of the escarpments, which are the physiographic expression of resistant rock layers, lie very nearly in a plane, which slopes gently downward from the eastern border of the Cretaceous sediments eastward to the western boundary of the Ozark plateau. Fenneman (1938, p. 660) indicates that this is probably the westward extension of the Ozark peneplain, which was supposedly completed late in Tertiary time. The overlap of Cretaceous sediments on the beveled Permian strata of Kansas and on older rocks to the north and east indicate that the pre-Cretaceous erosional plain in eastern Kansas may also have been very near this level. In another part of this report it is shown that Dakota sandstone has only recently been eroded from the tops of cuestas in Geary county where it formerly lay not far above the Fort Riley limestone, and that similar Cretaceous rock is still present not far above the Herington limestone in northwestern Riley county. The widespread distribution of Tertiary sediments in the same plane is indicated by the deposits of flint gravels, locally several tens of feet in thickness, capping the cuestas from the Flint Hills to the Ozark plateau. Both Arkansas and Kansas rivers are obsequent to rock structure across central and eastern Kansas and thus have the characters of streams that were superposed upon a plain of deposition. It has been my observation that Marais des Cygnes river has inclosed meanders in eastern Kansas as it has in Missouri (Osage river of Missouri) (Winslow, 1893, pp. 31-32). Flint gravel, very probably of Tertiary age, is still present on the uplands near the inclosed meanders in Linn county, Kansas, and similar gravel is still very widespread on uplands on each side of Kansas river.

The relief of Riley and Geary counties is between 450 and 500 feet. The lowest point is the surface of the water of Kansas river east of Zeandale, on the eastern border of Riley county, normally approximately 1,000 feet above sea level. The highest point, near the southeast corner of Riley county, has an altitude of approximately 1,450 feet.

The topography can very well be divided into three minor types: the high uplands or prairies, which are the cuesta uplands or the "dip-slopes" of resistant limestone layers and for which the term "high" is used in a relative sense; the creek and rivers valleys, including the alluvial floors and terraces; and the broken, hilly country extending from the borders of the uplands downward to the valley floors or to the terraces where present. This last division includes the escarpments, and it includes the Flint Hills, which are discussed separately.

The high prairies of the first division generally lie at an altitude of 1,250 to 1,450 feet above sea level and are above the Fort Riley limestone although small areas below that stratum of rock have similar aspects. Although the uplands are described as dip slopes of the limestone strata, they are almost everywhere covered with a part of the shale unit overlying the scarp-making limestone. Streams cutting into the thick shale above the Fort Riley limestone have carved most of this area into a rolling plateau. In eastern and northern Riley county the Cresswell and Herington limestones and to a minor degree the Towanda limestone, resistant strata above the Fort Riley limestone, form small buttes and sinuous escarpments. The eastern boundary of these uplands is extremely irregular because many streams have cut into and below the Fort Riley limestone. In southern Geary county the uplands are cut into great fingerlike strips pointing toward Smoky Hill river and away from the greater expanse of similar terrain.

The larger stream valleys are those of Kansas, Big Blue, Republican, and Smoky Hill rivers. River valleys range from 1 to 4 miles in width and creek valleys from 0.25 to 0.5 mile or more. River valleys are almost level and are modified by swamps and by a few ox-bow or crescentic lakes. Eureka Lake, a few miles west of Manhattan, and Whisky Lake, south of Fort Riley, are the largest, and lie in Kansas river valley. The flat "bottom land" of the smaller streams is being built up more rapidly by downwash from the valley walls than by deposition by the streams themselves, hence they are principally colluvial and the streams themselves are cutting into bed rock, but these areas are subjected to occasional floods during which alluvium is deposited. Creek valleys are somewhat elevated above the creek beds and generally are somewhat rolling. Although the colluvial and alluvial soil of the small stream valleys conceals the rock strata at the sides of the valley, the resistant layers can generally be seen in the stream beds. In many places the streams are actively widening their valleys and evidence of landslides of considerable magnitude is visible, especially along the right valley walls. At Rocky Ford, north of Manhattan, bed rock is exposed in the channel of Big Blue river, but there the stream is now flowing near its right valley wall and is only locally and temporarily degrading the limestone beds. There is no doubt that soundings on the east side and remote from the river would show that the bed rock is lower there than in the present channel. River channels have shifted actively, even very recently, and pronounced changes have taken place since the area was settled. The channel of Big Blue river has shifted eastward a mile or more at Manhattan since the city was founded and an old mill formerly at a dam on Fancy creek in northern Riley county is now separated from the creek by a wide field.

Valley walls are steep, rugged bluffs 50 to 200 feet high, except locally, as near Zeandale, Manhattan, and Ogden, where the valley of Kansas river is bordered by rolling uplands—a modification of the prevalent type of valley-wall topography due to the presence of deposits of loess. In many places remnants of a former fluvial, or possibly lacustrine filling, now form a distinctive terrace along the sides of the valleys above the present flood plain of the larger streams. Such terraces are noticeable along the west bluff of the valley of Big Blue river a few miles north of Manhattan, and south of Kansas river east of Manhattan. These terraces have yielded mammalian fossils of Pleistocene age. Detailed investigation will probably show that the terraces of the large stream valleys are equivalent to much of the "bottom land" of the small valleys.

The third type of topography is represented between the stream valleys and the high uplands. It is limited generally by the outcrop of Fort Riley limestone, which forms a fencelike wall near the crests of the hills along the eastward extension of its line of outcrop, and farther west, in the direction of the regional dip, forms exposures near the streams. With the exception of stream valleys and other minor areas, the hilly land lies east of the Fort Riley limestone outcrop. Below the Fort Riley limestone is the Florence limestone—a thick layer containing an abundance of flint nodules. It is eroded into rounded hills that are east of the great, flat-topped area capped by Fort Riley limestone. As soon as weathering disintegrates the protective upper limestone, the less resistant flint-bearing rock is rapidly eroded. Strata below the Fort Riley limestone weather to steeply terraced slopes, and it is principally these strata that form the slopes of the Flint Hills in this part of Kansas. The hills capped by Fort Riley limestone and the knobs capped by Florence limestone, however, are a part of the general Flint Hills region.

The northeastern part of Riley county lies within the part of the Central Lowlands known as the Dissected Till Plains. Glacial drift is not thick within the limits of the county, but northern erratics ranging from gravel to large boulders are present.

THE FLINT HILLS

The Flint Hills are a range of hills that has a relief of about 350 feet and crosses the state in an almost north-south direction from Marshall county in the north to Cowley county in the south. This range is one of several eastward-facing dissected escarpments that mark the topography of Kansas. In the western central part of the state are the Blue Hills, marking the eastward limit of the Tertiary-mantled High Plains. In the central part are the Smoky Hills, the dissected escarpment of the Dakota sandstones of Cretaceous age. Those two escarpments bound the physiographic sub-province called the Plain's Border. The Flint Hills are due to the presence of resistant Permian strata and are therefore physiographically like the other ranges named. Farther east is another range trending east of north from about the boundary between Montgomery and Chautauqua counties, which is near the 96th meridian, toward Leavenworth on Missouri river, but becoming less conspicuous to the northward. This ridge is capped by the thick sandstones in the Stranger and Lawrence formations of the Pennsylvanian subsystem. In southern Kansas these hills are called Chautauqua Hills (Adams, 1899, p. 60) and the name may well be applied to the whole range.

PLATE 2. A, A streamcut cliff in Barneston limestone, sec. 1, T. 7 S., R. 5 E., Riley county. B, Characteristic exposure of Threemile limestone, Wreford formation, eastern Riley county.

The escarpments in the Pennsylvanian and Permian areas are capped by westward-dipping resistant strata that are separated by less-resistant beds. Their direction, of course, follows the strike of the beds; their spacing and height are governed by the vertical distance between beds that are strong enough to hold extensive benches or plateaus, and by the inclination of the beds. The height of the Flint Hills, therefore, is due to the presence of a few hundred feet of soft strata beneath a few beds that will hold benches under the conditions of weathering to which they are subjected. In the northern half of the state seemingly it is not flint-bearing limestones that are responsible for the hills, but rather it seems to be the absence of flint in certain limestones. In Riley and Geary counties the nonflinty Fort Riley limestone, the nonflinty part of the Threemile limestone, a bed in the Wreford limestone formation containing no flint, and lower beds, such as the Eiss limestone in the Bader formation, make extensive benches. In the same part of the state the flinty layers are readily weathered into steep slopes and rounded knobs. The Florence limestone is about 35 feet thick and contains an abundance of flint nodules. Above the Florence and separated from it only by a few feet of shale is the Fort Riley limestone, which contains no flint. The Fort Riley limestone holds up benches over hundreds of square miles, but wherever the protective Fort Riley is removed the flinty Florence is reduced to rounded buttes. The same relationship between flinty and nonflinty beds is true in the area of outcrop of the Wreford formation, but not, however, in the southern part of the state, where the Florence member makes hills for many miles. This difference may be due to a very slight difference in climate, but it seems more probable that in southern Kansas a protective covering of Tertiary(?) age protected for a longer time the areas where the Florence is now exposed and hence preserved them. This explanation is supported by the presence of erratic pebbles of presumably Rocky Mountain derivation as far east as sec. 33, T. 27 S,. R. 2 E., in Sedgwick county, and by the presence of deep deposits of flint gravel on the uplands of much of eastern Kansas. The significance of these gravels in the physiographic history of eastern Kansas has already been discussed in this report.

Bass (1929, p. 14) indicated that different formations comprise the upland surfaces of the Flint Hills in different areas. In central Kansas the Florence flint (limestone containing flint nodules) is the capping rock; farther south the Wreford, about 60 feet below the Florence, and still farther south the Foraker, 300 feet below the

PLATE 3. Flint Hills topography. A, A valley eroded in Big Blue strata; Cottonwood and Eiss limestones on the hillside in right background, southeastern Riley county. B, Residual boulders of Fort Riley limestone near Junction City Country Club, Geary county.

Wreford, form the principal rim and upland of the Flint Hills. It should not be assumed that the Flint Hills are developed in lower and lower strata as one goes southward, however, for, although it is true that in Riley county the Fort Riley limestone is the great bench-maker above and west of the dissected escarpment, the belt of hills is nearly 20 miles wide and in the eastern part the steep slopes expose formations from the Tarkio limestone (Wabaunsee group, Pennsylvanian subsystem) to the Americus (Foraker formation) or neighboring strata. Steep slopes downward from higher strata, such as the Fort Riley, are observed near places where major streams cut the escarpment. In such places as the valley of Kansas river the escarpment has been rapidly driven westward so that the steep slopes extend from higher strata to the valley floor. Farther from the rivers the escarpment is older and is more obtusely beveled.

The Flint Hills are nearly coincidental in position with the gentle arch of strata above a buried range of low mountains called Nemaha Mountains (Moore and Haynes, 1917, p. 166), and a small part of the ruggedness of the hills is due to that arching. Relief within the Flint Hills is generally less than 350 feet. The slopes are steep and terraced. As the hills are grasscovered and only slightly forested, the belt is a rich grazing area. It exhibits perhaps the most beautiful natural scenery of the state.

DRAINAGE

A small part of southeastern Riley county is drained by Neosho river, a tributary to Arkansas river. The rest of the area is drained by Kansas river and its tributaries. Kansas river is formed by the confluence of Smoky Hill and Republican rivers at Junction City in Geary county. An important tributary from the north, Big Blue river, empties into Kansas river at Manhattan. An intricate system of smaller streams drains the area. The larger streams are included on the map showing areal geology. The larger streams are mostly near grade and their flood plains are well developed. The smaller streams have predominantly low gradient where they flow on strata above Fort Riley limestone, but are generally more turbulent and occupy narrower canyons where they cut through lower strata.

Smoky Hill river rises in eastern Colorado in Kit Carson and Cheyenne counties. It flows eastward across Kansas to a point near McPherson, thence northward to Salina, and thence northwestward across Dickinson county into Geary county. At Junction City it unites with Republican river to form Kansas river. Smoky Hill

PLATE 4. Flint Hills topography. A, South wall of Kansas river valley, southeast of Manhattan in Riley county. The Falls City limestone forms the point on the skyline near the extreme left. B, Fort Riley limestone forming a natural wall near the top of the north wall of Republican river valley, Fort Riley Military Reservation.

river is 310 miles long and drains 20,480 square miles. It rises in an area of sand, clay, and gravel of Tertiary age and flows through the Cretaceous chalk, limestone, shale, and sandstone, and the Permian shale, limestone, and gypsum. Republican river likewise has its headwaters far east of the Rocky Mountains. It rises in northeastern Colorado and drains 25,840 square miles. Its length is about 500 miles. It flows across Tertiary deposits throughout most of its course. Kansas river flows from Junction City to Kansas City, where it enters Missouri river.

STRATIGRAPHY

Age of rock.—The oldest rock exposed in Riley county belongs to the Pennsylvanian subsystem, but the oldest exposed rock in Geary county is of Permian age. A few feet of Cretaceous sandstone occurs in northwestern Riley county and glacial drift of Pleistocene age is found in the eastern and northwestern part. Aeolian material, commonly called loess, of Recent and Pleistocene age is present in many places in each county. River valleys in both counties contain fluvial and fluvial deposits, parts of which are as old as Pleistocene. The surface rocks in the area as a whole, however, consist principally of Permian shale and limestone, which are exposed along bluffs and in road cuts. There is approximately 1,000 feet of Paleozoic strata exposed, and this report principally concerns the details of those rock layers.

Earlier stratigraphic work.—Several workers have investigated Paleozoic strata in the two counties or along the line of strike in other parts of Kansas. As early as 1866 Swallow (1866, 1867) published results of studies in some of these rocks. Meek and Hayden (1867) published a report in which a description of exposures at Manhattan was included. Broadhead (1883) also described some of the Permian rocks in Riley and Geary counties, and he included a section on Mount Prospect (K. Hill) in Manhattan. Later, Hay (1891, 1893, 1896) published results of studies in Kansas and, especially, a report on the geology of the Fort Riley Military Reservation. In later years many other geologists contributed to the store of knowledge concerning the upper Pennsylvanian and Permian rocks of the region. Here should be mentioned Tschernyschew (1902) who studied the stratigraphic section from Manhattan to Fort Riley. In 1918 Moore (1918) published a report on the environment of Camp Funston, treating subjects of military interest in the geology and topography of the area. Of special interest are reports pertaining to specific areas that lie within the area of outcrop of the rocks that are exposed in Riley and Geary counties. Prosser and Beede (1914) studied and mapped the rocks exposed in the Cottonwood Falls, Kansas, quadrangle, which is about 30 miles south of Geary county. Fath (1921) reported on the El Dorado oil and gas field, an area in Kansas in which Permian rocks crop out; and Bass (1929) described these rock layers as they are exposed in Cowley county, Kansas. In Nebraska, Condra (1927) and Condra and Upp (1931) developed a refinement of Pennsylvanian and Permian stratigraphy such as had not previously been attempted in mid-continent studies. They found remarkable continuity of beds and were able to correlate many strata from Nebraska to Oklahoma. More recently R. C. Moore, M. K. Elias, and R. G. Moss, working as geologists of the Survey, have made careful field investigations of the Upper Pennsylvanian and Permian rocks in Kansas, which have made possible a better classification. In this report terminology and grouping of units mainly conform to a revised classification prepared by Moore (Moore, 1936; Moore, Elias, and Newell, 1934, 1936).

Table 2 shows the salient features of the exposed rocks. Detailed descriptions follow.

TABLE 2. *Stratigraphic section of rocks outcropping in Riley and Geary counties*

	Approximate thickness, feet
QUATERNARY SYSTEM	
Recent series	
Soil, residual and transported, result of rock weathering, deposition by streams and wind	0–50
Recent and Pleistocene series	
Loess, wind-blown clay and fine sand	0–30
Pleistocene series	
Valley fillings (in part)	?
Fluvial or lacustrine terraces, partly conglomeratic	0–75
Kansan drift, scattered northern erratics, sand to boulders, ice-rafted, ice-laid, or water laid.	
TERTIARY SYSTEM	
Gravel reported by Hay in 1896 (probably Pleistocene).	
CRETACEOUS SYSTEM	
Dakota group	
Coarse, ferruginous, quartz sandstone	0–20
PERMIAN SYSTEM	
Leonard series	
Sumner group	
Wellington shale (45.5 feet).	
"Hollenberg limestone" member. Yellow earthy limestone containing casts of pelecypods	0.5
"Pearl shale" member. Varicolored shale	45

	Approximate thickness, feet
Wolfcamp series	
Chase group (348 feet)	
Nolans limestone (24 feet)	
Herington limestone member. Gray and yellow geodiferous limestone	8
Paddock shale member. Gray fossiliferous shale	12
Krider limestone member. Nodular yellow and gray limestone, generally two beds separated by about 1 foot of shale	4
Odell shale. Varicolored shale	30
Winfield limestone (24 feet)	
Cresswell and Luta limestone members. Massive and thin-bedded limestone	13
Grant shale member. Gray fossiliferous shale	10
Stovall limestone member. Flinty limestone	1
Doyle shale (80-90 feet)	
Gage shale member. Varicolored and gray fossiliferous shale,	45
Towanda limestone member. Yellow massive to thin-bedded limestone	5–15
Holmesville shale member. Varicolored shale	30
Barneston limestone (65-71 feet)	
Fort Riley limestone member. Massive and thin-bedded limestone	30
Oketo shale member. Unimportant shale break	0–6
Florence limestone member. Flinty limestone	35
Matfield shale (78 feet)	
Blue Springs shale member. Varicolored shale	45
Kinney limestone member. Gray massive to thin-bedded limestone	3
Wymore shale member. Varicolored shale	30
Wreford limestone (39 feet)	
Schroyer limestone member. Limestone, partly flinty	20
Havensville shale member. Gray shale and some limestone,	10
Threemile limestone member. Limestone, partly flinty	9
Council Grove group (309 feet ±)	
Speiser shale (17.2 feet)	
Gray, fossiliferous shale	2.5
Gray crystalline limestone	0.7
Varicolored shale	14
Funston limestone. Light-colored massive limestone	5
Blue Rapids shale. Gray shale, local limestones	25
Crouse limestone. Brown and gray limestone	10
Easly Creek shale. Varicolored shale, local limestones; gypsum in other areas	17
Bader limestone (18 feet)	
Middleburg limestone member. Varicolored limestone, dark shale	4
Hooser shale member. Green and gray shale	6
Eiss limestone member. Light-colored massive limestone	8
Stearns shale. Mostly gray shale	20
Beattie limestone (17 feet)	
Morrill limestone member. Brown and gray limestone	3
Florena shale member. Gray fossiliferous shale	8
Cottonwood limestone member. Massive limestone, fusulinid-bearing in upper part	6
Eskridge shale. Varicolored shale below, gray shale above, fossiliferous; local limestones	36
Grenola limestone (38 feet)	
Neva limestone member. Light-gray massive to flaggy limestone	20
Salem Point shale member. Gray calcareous shale	9
Burr limestone member. Gray to buff limestone	9

	Approximate thickness, feet
Roca shale. Varicolored shale, local limestones	20
Red Eagle limestone (18 feet)	
Howe limestone member. Gray and brown limestone	3
Bennett shale member. Black and gray fossiliferous shale	13
Glenrock limestone member. Argillaceous limestone	2
Johnson shale. Gray and dark shale, mudstones	16
Foraker limestone (52 feet)	
Long Creek limestone member. Variable limestone	8
Hughes Creek shale member. Fusulinid-bearing shale and limestone	40
Americus limestone member. Massive limestone, two beds separated by dark shale	4
Admire group (95-170 feet)	
Hamlin shale[1]	
Oaks shale member	
Houchen Creek limestone member	40
Stine shale member	
Five Point limestone[1]	
West Branch shale[1]	
Falls City limestone	3
Hawxby shale	30
Aspinwall limestone	2±
Towle shale	
Unnamed shale member	20
Indian Cave sandstone member	75
CARBONIFEROUS SYSTEM	
PENNSYLVANIAN SUBSYSTEM	
Virgil series	
Wabaunsee group (188 feet +)	
Brownville(?) limestone	5.5
Pony Creek shale[2]	?
Caneyville limestone[2]	?
French Creek shale[2]	?
Jim Creek(?) limestone. Limestone and shale containing "*Osagia*" and *Cryptozoa*	3.5
Dry-Friedrich(?) shale. Poorly exposed shale	64±
Dover limestone. Light-gray crystalline limestone	2
Table Creek shale. Greenish-gray clayey shale containing al-algal(?) concretions	16
Maple Hill limestone. Bluish-gray limestone containing small fusulinids	1.5
Pierson Point shale. Light-gray shale containing limonitic concretions	17
Tarkio limestone. Massive, fusulinid-bearing limestone	12
Willard shale. Gray shale, locally sandy	30
Elmont limestone. Dark-blue limestone	2
Harveyville shale. Gray and greenish-yellow shale	20
Reading limestone. Brown and gray limestone	2
Auburn shale. (Upper part only)	12

1. Beds between the base of the Foraker limestone formation and the top of the Falls City limestone formation are very poorly exposed in a small area. The combined thickness is about 40 feet.

2. Beds between upper part of Pony Creek shale and lower part of French Creek shale are concealed by mantle deposits, or removed by interformational erosion.

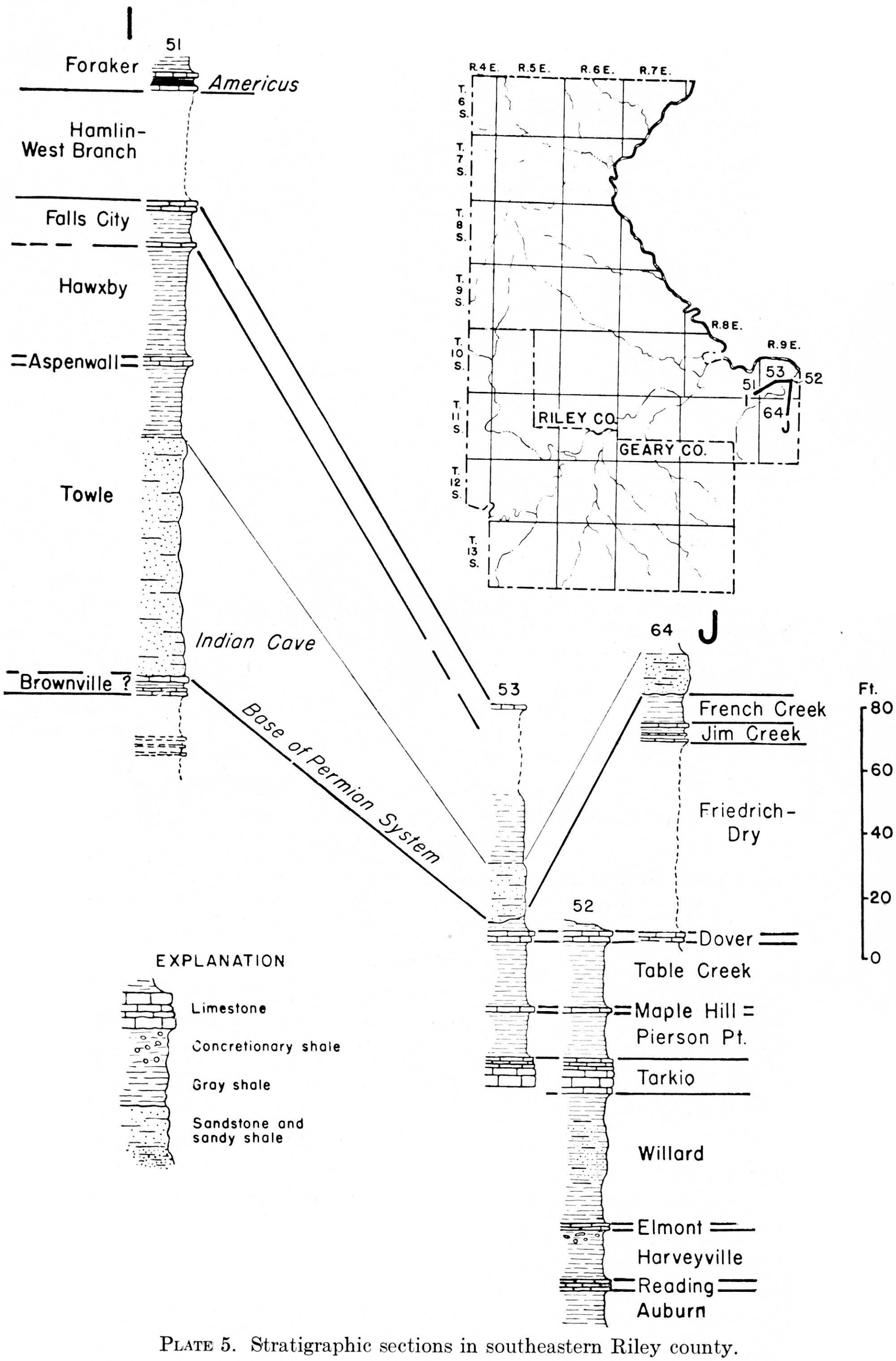

PLATE 5. Stratigraphic sections in southeastern Riley county.

CARBONIFEROUS SYSTEM—PENNSYLVANIAN SUBSYSTEM

The table shows the series and groups now recognized by the Kansas Geological Survey as constituting the Pennsylvanian subsystem in Kansas.

TABLE 3. *Pennsylvanian Subsystem in Kansas*

Pennsylvanian subsystem
- Virgil series
  - Wabaunsee group
  - Shawnee group
  - Douglas group
- Missouri series
  - Pedee group
  - Lansing group
  - Kansas City group
  - Bronson group
  - Bourbon group
- Des Moines series
  - Marmaton group
  - Cherokee group

The groups are divided into formations and many of the formations into members. The classification used in this report is in accordance with that recently established by R. C. Moore (1936).

VIRGIL SERIES

The term Virgil was introduced by Moore (1932) for the uppermost series of the Pennsylvanian rocks in the northern midcontinent region. The name is derived from a town in eastern Greenwood county, Kansas. The series comprises in ascending order three groups, called Douglas, Shawnee, and Wabaunsee. The upper part of the last group is poorly exposed in southeastern Riley county.

WABAUNSEE GROUP

The name Wabaunsee was introduced as a formation name by Prosser in 1895 (p. 688). He fixed the lower boundary of the formation at a coal bed, which is identified as either the Nodaway coal in the Howard limestone or the Elmo coal in the Cedar Vale shale. Prosser thought these two to be the same, but Condra (1927, p. 60) has shown them to be separate strata more than 100 feet apart. Prosser placed the upper boundary of the Wabaunsee at the base of the Cottonwood limestone, but now the term Wabaunsee as used by the Kansas Geological Survey includes all beds between the top of the Topeka limestone and the base of the Indian Cave sandstone in the Towle shale. Hence the base and the top of the group are many

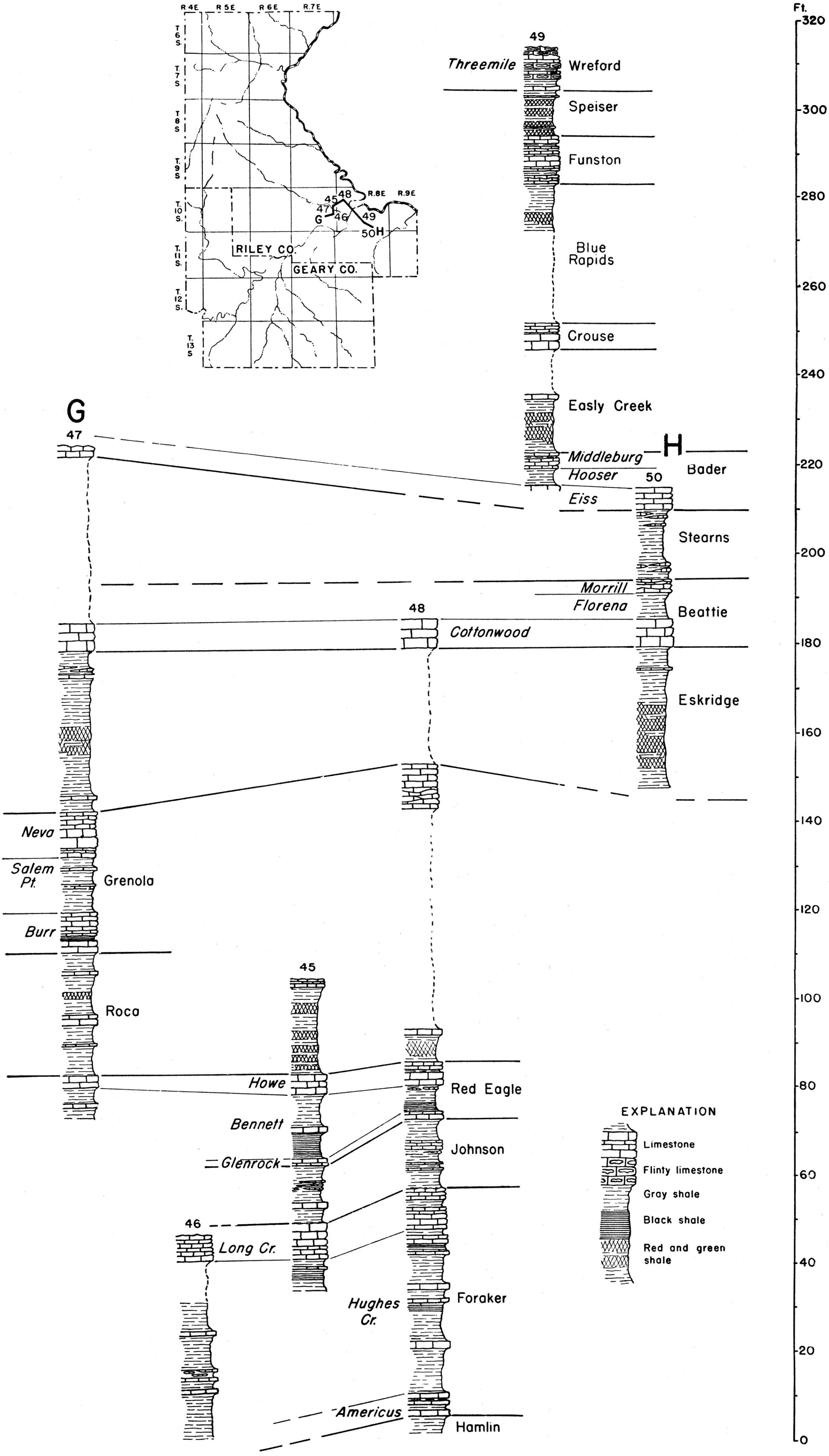

PLATE 6. Stratigraphic sections in eastern Riley county in T. 10 S.

feet lower than the formational boundaries originally defined. The group includes the following formations in ascending order: (1) Severy shale, (2) Howard limestone, (3) White Cloud shale, (4) Happy Hollow limestone, (5) Cedar Vale shale, (6) Rulo limestone, (7) Silver Lake shale, (8) Burlingame limestone, (9) Soldier Creek shale, (10) Wakarusa limestone, (11) Auburn shale, (12) Reading limestone, (13) Harveyville shale, (14) Elmont limestone, (15) Willard shale, (16) Tarkio limestone, (17) Pierson Point shale, (18) Maple Hill limestone, (19) Table Creek shale, (20) Dover limestone, (21) Dry shale, (22) Grandhaven limestone, (23) Friedrich shale, (24) Jim Creek limestone, (25) French Creek shale, (26) Caneyville limestone, (27) Pony Creek shale, and (28) Brownville limestone. The upper portion of the Auburn shale is the lowest stratigraphic unit exposed in Riley county, and the Pennsylvanian strata above the Dover limestone have almost everywhere been removed by erosion that occurred at the end of Pennsylvanian time or they are now concealed by younger deposits, especially by Recent alluvium.

AUBURN SHALE

According to present usage the Auburn shale includes the strata between the Wakarusa and the Reading limestone formations (Moore, 1936, p. 222).

The stratigraphically lowest rock that is exposed in this area crops out along and east of a public road south of Deep creek in the northeast part of sec. 29, T. 10 S., R. 9 E., and in the adjacent northwest part of section 28 of the same township and range. About 12 feet of shale may be seen below the Reading limestone, and because of its position this shale is believed to be the upper part of the Auburn shale.

Lithologic character and distribution.—The shale that is here identified as part of the Auburn is gray, and the upper part of the 12-foot section exposed is darker than the lower part. The outcrop is deeply weathered and few facts concerning the nature of bedding can be determined there. The overlying Reading limestone can be traced from the northeast part of sec. 27, T. 10 S., R. 9 E., to a point near the southeast corner of section 32 of that township and range, but throughout most of this distance of about 3 miles the shale is covered with alluvial material of recent deposition.

Detailed sections.—A section of the Auburn beds just mentioned is given at the end of this report (section 52).

READING LIMESTONE

The term Reading limestone formation is now applied to a limestone that was formerly included in the "Emporia limestone," a term that is no longer used. The name is that of a town in northeastern Lyon county, Kansas.

The Reading limestone is exposed above the alluvium of Kansas river and of Deep creek in the very small area designated in the discussion of the occurrence of Auburn shale in this area. Inasmuch as this area is isolated as a part of an inlier, the correlation is based upon the lithologic character of the rock and upon its position as the second limestone below the more easily recognized Tarkio limestone.

Lithologic character and thickness.—The rock to which the name Reading limestone is here applied is a dense to very slightly crystalline hard massive limestone that breaks with conchoidal fracture. It seems to be more compact in the lower part. In fresh exposures it is generally brown in the upper part and bluish gray in the lower part, but more gray than brown is shown. Crinoid stems are the only conspicuous fossils. The thickness is approximately 2 feet.

Distribution.—The Reading limestone is exposed in this area in Deep creek valley in the inlier formed by the erosion of the broad valley of the creek across an anticline. The formation is exposed only on the right side of the stream and the line of outcrop can be traced from sec. 27 to sec. 32, T. 10 S., R. 9 E. It is shown on the areal geological map that forms a part of this report.

Detailed sections.—The Reading limestone is described in sections 52 and 54 at the end of this report.

HARVEYVILLE SHALE

A shale unit formerly included in the "Emporia limestone" is now called Harveyville, being named for Harveyville station on Atchison, Topeka, and Santa Fe Railway in the Burlingame quadrangle, Wabaunsee county, Kansas.

Lithologic character, thickness, and distribution.—The shale unit believed to be the Harveyville shale is about 20 feet thick in this area, and is greenish-gray below, yellow in the middle part, and gray above. Near the top are small calcareous limonitic concretions about the size of peas. The measurement of thickness may be somewhat inaccurate, as the overlying limestone may be slumped wherever seen. The shale is exposed in secs. 27 and 28, T. 10 S., R. 9 E., a mile east of Zeandale in Riley county on the south side of Deep creek. In sec. 33, T. 10 S., R. 9 E., it is covered with soil, but forms steep slopes between the exposed limestone layers that bound it. No fossils were observed and none are believed to be contained in it.

Detailed sections.—For sections of the Harveyville shale see numbers 52, 54, 61, and 62 at the end of this report.

ELMONT LIMESTONE

According to usage of the Kansas Geological Survey the upper limestone unit of the old "Emporia limestone" is called Elmont, the name being derived from a village of that name in Shawnee county, Kansas.

The name Emporia was introduced as a stratigraphic term by Kirk in 1896, but he did not indicate clearly what strata he intended to include in the unit named. Condra (1927, pp. 78-79) has shown that the "Emporia limestone" is the first limestone below the Tarkio limestone and he stated that the thickness ranges between 6 and 9 feet. Inasmuch as the Tarkio limestone is well exposed and can be identified without hesitation in this area and inasmuch as it lies approximately 30 feet above the unit herein described it seems that this unit is the upper part of the "Emporia." North of Kansas river and a short distance east of Deep creek valley is an exposure of approximately 150 feet of strata capped by Tarkio limestone. In that exposure, which is situated in Pottawatomie county, the bed here discussed lies about 55 feet below the Tarkio limestone and has the same lithologic characters as in Deep creek valley. The Reading, Harveyville, and Elmont formations are differentiated as distinct stratigraphic units because of observations showing deposition in separate marine inundations of the Kansas region.

Lithologic character and thickness.—This unit is a very brittle blue-gray to almost black limestone locally containing calcite crystals. It breaks with wavy, irregular fracture and commonly occurs in beds about 7 inches thick. The total thickness commonly ranges between 22 and 25 inches but locally it is as little as 12 inches. The limestone contains an abundance of small fusulinids and locally contains fragments of other fossils.

Distribution.—The Elmont limestone is exposed in Deep creek valley south and east of Zeandale in Riley county, in secs. 27, 28, 32, and 33, T. 10 S., R. 9 E., and in secs. 5 and 6, T. 11 S., R. 9 E. In several places in the last two sections enumerated, the limestone gives origin to small waterfalls in Deep creek. Along the creek it is either faulted or slightly folded. It forms the natural ford at Pillsbury Crossing in sec. 5, T. 11 S., R. 9 E.

Detailed sections.—For sections showing the Elmont limestone see numbers 52, 54, 61, and 62 at the end of this report.

WILLARD SHALE

The Willard formation, named from a village in Shawnee county, Kansas, was differentiated by Beede in 1898. In some reports of the Kansas Geological Survey an error in correlation of units appears, but the Willard is now recognized as the shale between the Elmont and Tarkio limestones. According to Condra (1927, p. 79) it is composed of bluish and reddish argillaceous shale, some calcareous material, and some sand.

Where exposed in Riley and Geary counties, the strata below the Tarkio limestone and above the Elmont limestone comprise approximately 30 feet of shale, which is mostly argillaceous or entirely argillaceous except for a few thin arenaceous beds about 8 feet from the top.

Lithologic character and thickness.—Gray shale, argillaceous and sandy as stated, comprises the unit where exposed in Riley county. The thickness is approximately 30 feet.

Distribution.—This shale is exposed in a small area on both sides of Deep creek in southeastern Riley county. It can easily be seen at Pillsbury Crossing in sec. 5, T. 11 S., R. 9 E. Its upper boundary is shown on the geologic map as the line that marks the base of the Tarkio limestone formation. Its area of outcrop is very narrow because there is everywhere a steep slope between the two limestones.

Detailed sections.—Sections 52, 54, 60, 61, and 62 at the end of the report show the character and stratigraphic relations of the Willard shale.

TARKIO LIMESTONE

The name Tarkio was introduced as a stratigraphic name by Calvin (1900, p. 416). Moore (1936, pp. 229-230) has explained that the formation long called Tarkio in Kansas is not equivalent to the rock along Tarkio creek in Page county, Iowa, but long usage of the name for the limestone here described makes its retention desirable. Moore has designated a typical exposure of the Tarkio limestone on Mill creek, southwest of Maple Hill, Kan.

Lithologic character and thickness.—In Riley county the Tarkio limestone is conspicuous, forming cliffs that are bold for a limestone

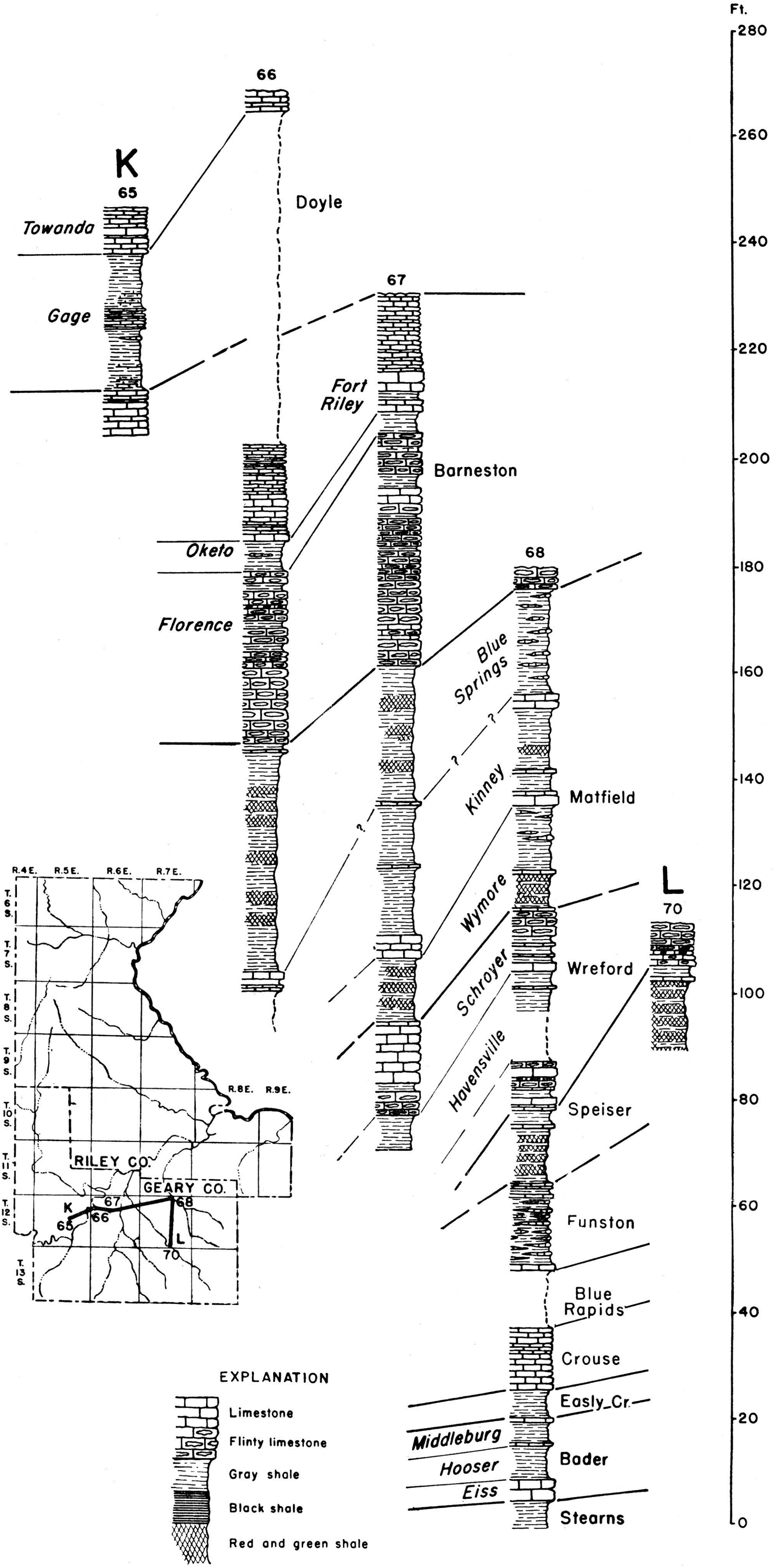

PLATE 7. Stratigraphic sections in Geary county in T. 12 S.

of this thickness. It is brownish gray and commonly consists of two massive beds. Very robust fusulinids, *Triticites ventricosus*, stand out on weathered surfaces and impart a rasplike appearance. Where best exposed the limestone is seen to consist of two beds, each approximately 6 feet thick. The limestone beds are separated by a shaly zone ranging from a few inches to a foot or more in thickness. Upon weathering, the rock assumes a strong rusty-brown color and the fusulinids are locally even darker than other parts of the rock. Large blocks slumped upon the Willard shale slope characterize the exposures.

Distribution.—The Tarkio limestone forms a bench and bold cliff on each side of Deep creek southeast of Zeandale and is exposed along the east-west road in sec. 29, T. 10 S., R. 9 E.; along the north-south road in the southeast part of the same section; along the cliff that crosses secs. 27, 28, and 33, T. 10 S., R. 9 E.; at Pillsbury's Crossing, which is near the northwest corner of sec. 5, T. 11 S., R. 9 E.; along a small northward-flowing creek tributary to Deep creek south of the center of the last-named section, and at intervening points.

Detailed sections.—For sections of the Tarkio limestone, see numbers 52, 53, 54, 60, 61, 62, and 63 at the end of this report.

PIERSON POINT SHALE

The Pierson Point shale, now recognized as a formation of the Wabaunsee group, was named as a subdivision of the "McKissick Grove shale member" of the "Wabaunsee formation" by Condra (1927, p. 80). It was defined as lying above the Tarkio limestone and below the Maple Hill limestone. The term McKissick Grove, which had been introduced by Smith (1908, p. 641) was redefined by Condra to include strata between the top of the Tarkio limestone and the base of the Brownville limestone. The McKissick Grove unit is no longer regarded as a useful subdivision of Kansas stratigraphy.

According to Condra the Pierson Point shale is 8 to 10 feet thick in Kansas and Nebraska and consists of bluish argillaceous shale and some sand. The lower portion is locally almost black.

Lithologic character and thickness.—In the northwest part of sec. 27, T. 10 S., R. 9 E., in eastern Riley county the strata between the Tarkio limestone and the Maple Hill limestone are well exposed, and consist of 16 feet of light-gray to bluish-gray shale containing limonitic concretions. The bedding is noticeably irregular. In other poorer exposures it is about the same. Yellow is noticeable in weathered surfaces.

Distribution.—Although well exposed in only a few places, the unit is present above the cliff-forming Tarkio limestone on each side of Deep creek east and south of Zeandale.

Detailed section.—The Pierson Point shale is included in sections 52, 53, and 63 at the end of this report.

MAPLE HILL LIMESTONE

The first limestone bed above the Tarkio limestone was named Maple Hill from the town in northeastern Wabaunsee county, Kansas, by Condra (1927, p. 80) who indicated that an exposure in Maple creek about 2 miles southwest of Maple Hill is the type exposure. The formation is described as bluish-gray limestone ranging in thickness from 2 to 4 feet.

Lithologic character and thickness.—The exposures of Maple Hill are few in its small area of outcrop in eastern Riley county; however, the formation can be studied easily in a few places such as a point near the northeast corner of sec. 28, T. 10 S., R. 9 E., where it is exposed about 17 feet above the massive, cliff-making Tarkio limestone. It is bluish-gray to yellow and weathers brown. Freshly exposed surfaces have a mottled, granular appearance and show numerous small calcite cleavage faces. The formation contains "cryptozoans" and small fusulinids, most of which weather lighter in color than the matrix. The thickness of the formation is about 1.5 feet.

Distribution.—The exposures of Maple Hill limestone are not far from those of the Tarkio except on the east side of Deep creek, where the distance between the outcrops is almost a mile. The base of the Maple Hill formation is mapped.

Detailed sections.—For details of the Maple Hill limestone where it can be studied in Riley county see sections 52, 53, and 63 at the end of this report.

TABLE CREEK SHALE

The Table Creek shale is defined as including the strata between the Maple Hill and Dover limestones. The formation was named by Condra (1927, p. 80). He regarded the stratigraphic unit as a subdivision of the "McKissick Grove" shale, a larger group that does not seem to be a natural unit in Kansas. The type exposure is near Table Creek, Neb.

Lithologic character and thickness.—The Table Creek shale is concealed under steep sod-covered slopes along a line a few miles in length in the lower valley of Deep creek south and southeast of Zeandale in Riley county and is actually exposed in only a very few places. In sec. 6, T. 11 S., R. 9 E., it is greenish-gray clay shale containing nodular, probably algal, calcareous material in the upper and lower parts. The deep-green color is especially noticeable near the top of the formation. In sec. 28, T. 10 S., R. 9 E., the lower 6 feet is exposed and there the calcareous material is absent and only gray clay shale is present. The thickness is almost uniformly 16 feet. Moore (1936, p. 234) found the thickness to be 50 feet or more in Wabaunsee county. The decreased thickness in Riley county is consistent with the general thinning of shale units in the anticlinal structures above the buried granite hills of the Nemaha Mountains that underlie parts of the Riley and Geary county district.

Distribution.—The Table Creek shale is present but mostly concealed under a steep grass-covered slope along the bluffs of Deep creek in southeastern Riley county. Its upper boundary is shown on the geologic map.

Detailed sections.—Measured sections, in which the Table Creek shale formation is included, are numbers 52, 53, and 63 at the end of this report.

DOVER LIMESTONE

The name Dover, from the town of that name in western Shawnee county, Kansas, was introduced as a stratigraphic term by Beede (1896, p. 31). The Dover limestone is now recognized as a formation.

Moore (1936, p. 236) has found the Dover limestone to be 2 to 4 feet thick in northern Kansas but as much as 20 feet thick in southern Kansas. In small exposure in Riley county the thickness is about 2 feet, but it is not certain that the entire formation is observable.

Lithologic character and thickness.—Where best exposed in Riley county the Dover limestone is light gray and crystalline and contains many fusulinids and small fragments of other fossils. It weathers into characteristic irregular slabs and makes a bench in the bluffs above the cliffs of Tarkio limestone.

The observed thickness of about 2 feet may not represent the entire thickness.

Distribution.—The Dover limestone formation is present at the surface in Riley county in a small area along the valley of Deep creek in the southeastern part of the county.

Detailed section.—See numbers 52, 53, 63, and 64 at the end of this report.

DRY-FRIEDRICH (?) SHALE

The formation overlying the Dover limestone, called the Dry shale, was named by Moore (Moore, Elias, and Newell, 1934). The upper boundary is, by definition, the base of Grandhaven limestone.

Between the Grandhaven limestone and the Jim Creek limestone lies the Friedrich shale (Moore, Elias, and Newell, 1934). Moore (1936, p. 236) has found that from Shawnee county, Kansas, northward the Grandhaven limestone is absent and hence it does not separate the two shale formations.

My observations in southeastern Riley county, wherever these and associated beds crop out, verify the absence of the Grandhaven formation and hence the two shale formations are not differentiated there.

Near the Riley-Wabaunsee county line in Riley county in sec. 9, T. 11 S., R. 9 E., the base of the Indian Cave sandstone is approximately 80 feet above the Dover limestone formation. The lower 65 feet of strata overlying the Dover seemingly contains no limestone, and is believed to be Dry-Friedrich shale. In only this one locality are these strata exposed at the surface. On the west side of the same valley the alluvium covers almost everything below the Brownville (?) limestone upon which the Indian Cave sandstone lies. In an outlier of Indian Cave and other beds in sec. 29, T. 10 S., R. 9 E., the disconformity representing erosion prior to the deposition of the sandstone reaches downward to the Dover formation, the beds discussed here having been removed.

Lithologic character and thickness.—As already explained, the Dry-Friedrich (?) shale reaches the surface in a very small area and it is almost covered by soil, but the gentle slope and local exposures indicate a shale having a thickness of about 64 feet. This thickness may be somewhat too great, owing to possible error in measuring due to dip of the beds.

Distribution.—The beds referred to the Dry-Friedrich shale are present below soil cover in a small area along the east side of Deep creek valley in southeastern Riley county.

Detailed section.—See number 64 at the end of this report.

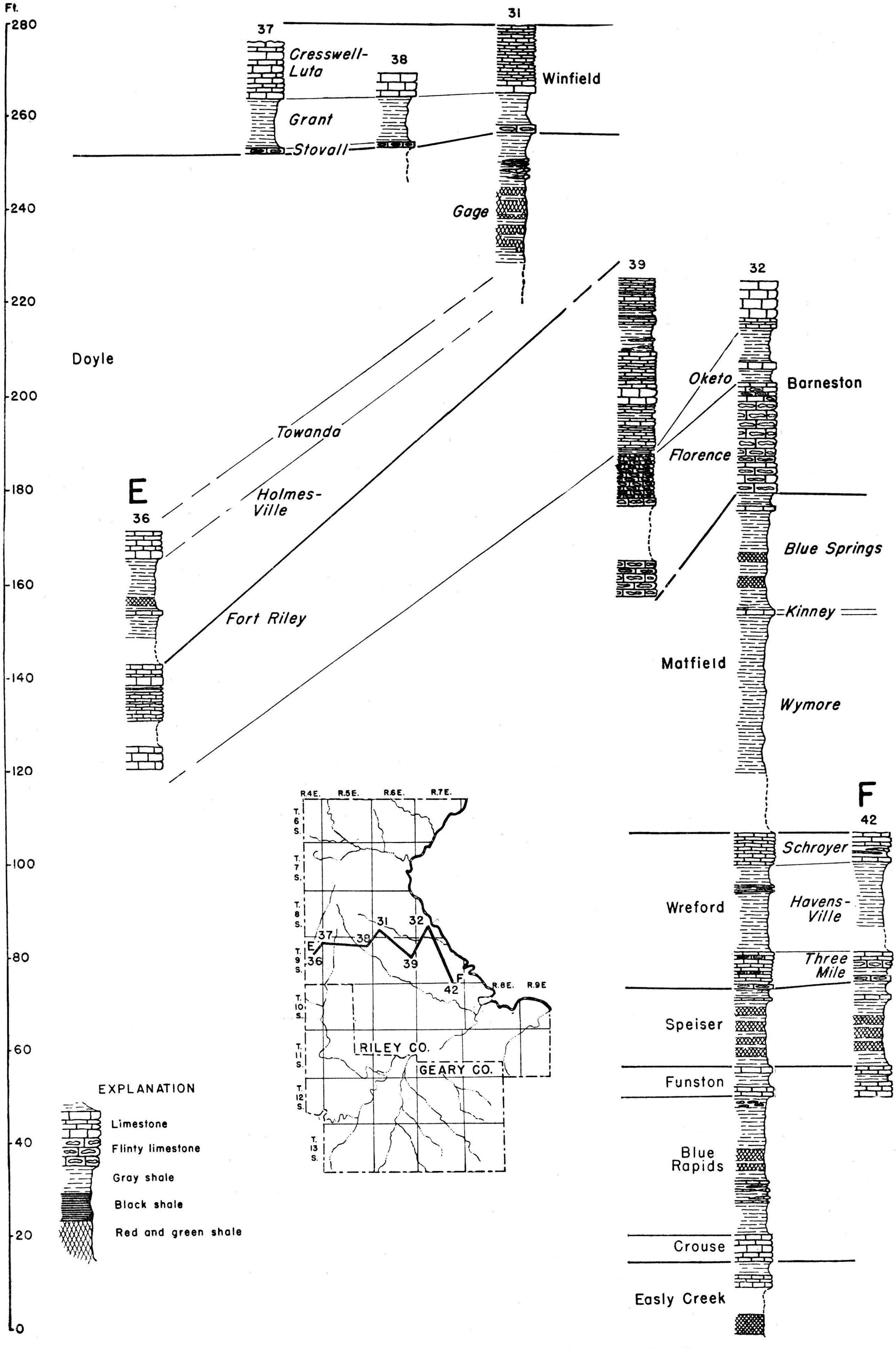

PLATE 8. Stratigraphic sections in Riley county in T. 8 S. and T. 9 S.

JIM CREEK(?) LIMESTONE

Moore (1936, p. 239) has given the name of Jim Creek to the persistent limestone that lies between the Grandhaven or Dover limestone below and the Caneyville limestone above. The type exposure is in sec. 29, T. 7 S., R. 11 E., in Pottawatomie county, Kansas. As already stated, I believe the Grandhaven limestone to be absent in southeastern Riley county and have identified the approximately 64 feet of shale above the Dover limestone as Dry-Friedrich shale, believing that the limestone overlying these shale beds is the Jim Creek. The conclusions are based on very limited observations, owing to the lack of actual exposures and the fact that these beds crop out in an inlier and can be traced only into mantle deposits or into the disconformable Permian beds above. Determination of exact relationship of the Pennsylvanian beds above the Dover limestone in the small area must await preparation of better exposures by road construction or other workings, and very careful study of beds in the same zones farther eastward in Wabaunsee county.

Lithologic character and thickness.—The limestone in southeastern Riley county believed to be the Jim Creek limestone can be seen in a road-side exposure in sec. 9, T. 11 S., R. 9 E. There is exposed a bed of crystalline limestone less than 3 inches thick, overlain by about 1 foot of shale, which is concealed by soil. The next higher bed consists of less than 1 inch of limonitic soft limestone or mudstone, overlain by 2.5 feet of yellow shale, which is overlain by about 6 inches of bluish-brown, nodular limestone bearing "Osagia" and cryptozoans. The total measured thickness of these beds is 3.55 feet.

Distribution.—Like the underlying Dry-Friedrich(?) shale, this formation is exposed only in the small area east of Deep creek.

Detailed section.—See number 64 at the end of this report.

FRENCH CREEK(?) SHALE

Moore (1936, p. 240) has named the shale between the Jim Creek and Caneyville limestone formations the French Creek and has given it formational rank. The name is obtained from French creek in northeastern Pottawatomie county, Kansas.

Lithologic character and thickness.—About 10 or 15 feet of shale below the disconformable base of the Indian Cave sandstone in a very small area in southeastern Riley county is believed to correlate with the lower part of the French Creek formation. The shale is poorly exposed but is principally gray and yellow clay.

Distribution.—The French Creek(?) shale is exposed in a small area in the east wall of Deep creek valley.

Detailed section.—See number 64 at the end of this report.

CANEYVILLE-PONY CREEK BEDS

The base of the Permian system is disconformable in this area, so the base of the Indian Cave sandstone, which is the base of the Permian system, rests upon different beds.

Among the beds believed to have been removed from exposed areas are the upper part of the French Creek shale, all the Caneyville limestone, and the lower part of the Pony Creek shale. In an exposure near the middle of sec. 30, T. 10 S., R. 9 E., about 3 feet of yellow and gray calcareous shale below the Brownville(?) limestone is believed to be the upper part of the Pony Creek shale.

It is not possible to determine the thickness of the beds that are covered by alluvium on one side of Deep creek valley and removed by erosion on the other side as indicated by the disconformity, but from the regional altitude of strata it seems probable that the thickness is between 10 and 20 feet.

BROWNVILLE(?) LIMESTONE

The uppermost formation of the Pennsylvanian subsystem, as now recognized in Kansas, is the Brownville limestone, which was named by Condra and Bengston (1915, p. 17) from exposures in the Missouri river bluffs south of Brownville, Nemaha county, Kansas. The formation is widespread and has been traced by Moore from Nebraska across Kansas and 50 miles or more into Oklahoma. Moore (1936, p. 245) reports the thickness as ranging from 2 to 8 feet.

This is believed to be the limestone exposed in a very small area in southeastern Riley county a short distance west of the middle of sec. 30, T. 10 S., R. 9 E. The formation there exposed underlies the Indian Cave sandstone, the basal unit of the Permian system. The outcrop can be followed for only a few yards where it is not concealed by surficial deposits. This exposure is situated at the junction of Kansas river valley and an abandoned alluvium-filled stream valley west of the present valley of Deep creek. In an outlying exposure of Permian strata slightly more than a mile to the eastward, in sec. 29, T. 10 S., R. 9 E., the Indian Cave sandstone lies upon or almost upon the Dover limestone formation, which is stratigraphically about 75 feet below the Brownville. Farther southeastward, in sec. 9, T. 11 S., R. 9 E., the Indian Cave sandstone lies 10 or 15 feet above a limestone that is tentatively correlated with the Jim Creek. These data indicate the disconformable relationship between the Indian Cave sandstone and the upper Pennsylvanian beds.

Lithologic character and thickness.—The Brownville(?) limestone, as exposed in the very small area described, is deeply weathered and hence the exact thickness is not determinable, but it seems to be approximately 5.5 feet. The exposure shows, at the base, about 2 feet of limestone that weathers brown but is gray and brown where unweathered. The limestone is earthy to crystalline in texture and contains a few *Chonetes granulifer, Marginifera wabashensis,* and fusulinids. Overlying the limestone is about 3 feet of greenish-gray fissile and flaky shale, overlain by approximately 6 inches of limestone, which is probably an algal limestone.

Distribution.—As stated above, the formation reaches the surface only in a very small area in sec. 30, T. 10 S., R. 9 E., in northeastern Riley county, and is questionably correlated with Brownville limestone.

Detailed section.—See number 51 at the end of this report for a detailed section including the Brownville limestone.

PERMIAN SYSTEM

Paleozoic strata above the base of the Indian Cave sandstone, which is locally present in the lower part of the Towle shale, are classified by the Kansas Geological Survey as constituting the Permian system. Moore and Moss (1933, p. 100) have discovered a local disconformity below the Indian Cave member, and that, as they have pointed out, seems to be a logical boundary for the separation of the Pennsylvanian from the Permian. A comprehensive discussion of the Pennsylvanian-Permian boundary in the midcontinent region and other parts of North America has been published recently by Moore (1940). According to Moore and Moss the disconformity has been recognized at Indian Cave and Peru, Neb., and at Dover and Cedarvale, Kan. I have recognized the disconformity in northeastern Riley county, where the Indian Cave sandstone overlies various upper Pennsylvanian beds, the lowest of which is the Dover limestone. In one exposure the Indian Cave overlies the Brownville(?) limestone, and in another, a limestone that has been tentatively classified as Jim Creek limestone. In most of the very small area of outcrop of the Indian Cave sandstone, the base is concealed by Pleistocene and Recent alluvium.

The base of the Indian Cave sandstone and hence the base of the Permian system is shown on the areal geologic map of the counties.

WOLFCAMP SERIES

The Kansas Geological Survey has adopted the term Wolfcamp as the name of the lowest series in the Permian system, in accordance with the recently established standard classification of the Permian section of North America. (Adams, J. E., 1939, pp. 1673-1681.) This supplants the term Big Blue, which has heretofore been used as the name of the lowermost series in the Permian system in the northern midcontinent area. The "Big Blue" series included some higher beds, which now are assigned to the Leonard series above the Wolfcamp. In Kansas the Wolfcamp series is divided into Admire, Council Grove, and Chase groups. Although in Kansas no evidence has been discovered of a disconformity corresponding to the disconformity at the top of the Wolfcamp series in the Glass Mountains in Texas, the boundary between the Wolfcamp and Leonard series in Kansas is drawn at the top of the Nolans formation.

Admire Group

The boundaries of this unit have been changed several times by different geologists, but now the Kansas Geological Survey applies the name, as it was first used by Adams (Adams, Girty, and White, 1903, p. 53), to strata between the base of the Towle shale formation and the top of the Hamlin shale formation. The name Admire is obtained from the village of Admire, in Lyon county, Kansas. Included formations, in ascending order, are: Towle shale, Aspinwall limestone, Hawxby shale, Falls City limestone, West Branch shale, Five Point limestone, and Hamlin shale.

TOWLE-HAWXBY SHALE

The Towle shale was named by Moore and Condra (1932). The type exposure is the Towle farm near Falls City, Neb. The Towle shale is divided into the Indian Cave sandstone member in the lower part, and an overlying unnamed shale member.

The formation reaches the surface and is partly exposed along each side of the lower part of Deep creek valley in southeastern Riley county, but throughout most of its extent it is hidden below a cover of sod and its position is shown only by the sandy residual soil derived from the Indian Cave member. The Indian Cave member is partly exposed in a few places and well exposed near the middle of sec. 30, T. 10 S., R. 9 E., where part of the overlying unnamed shale also is exposed.

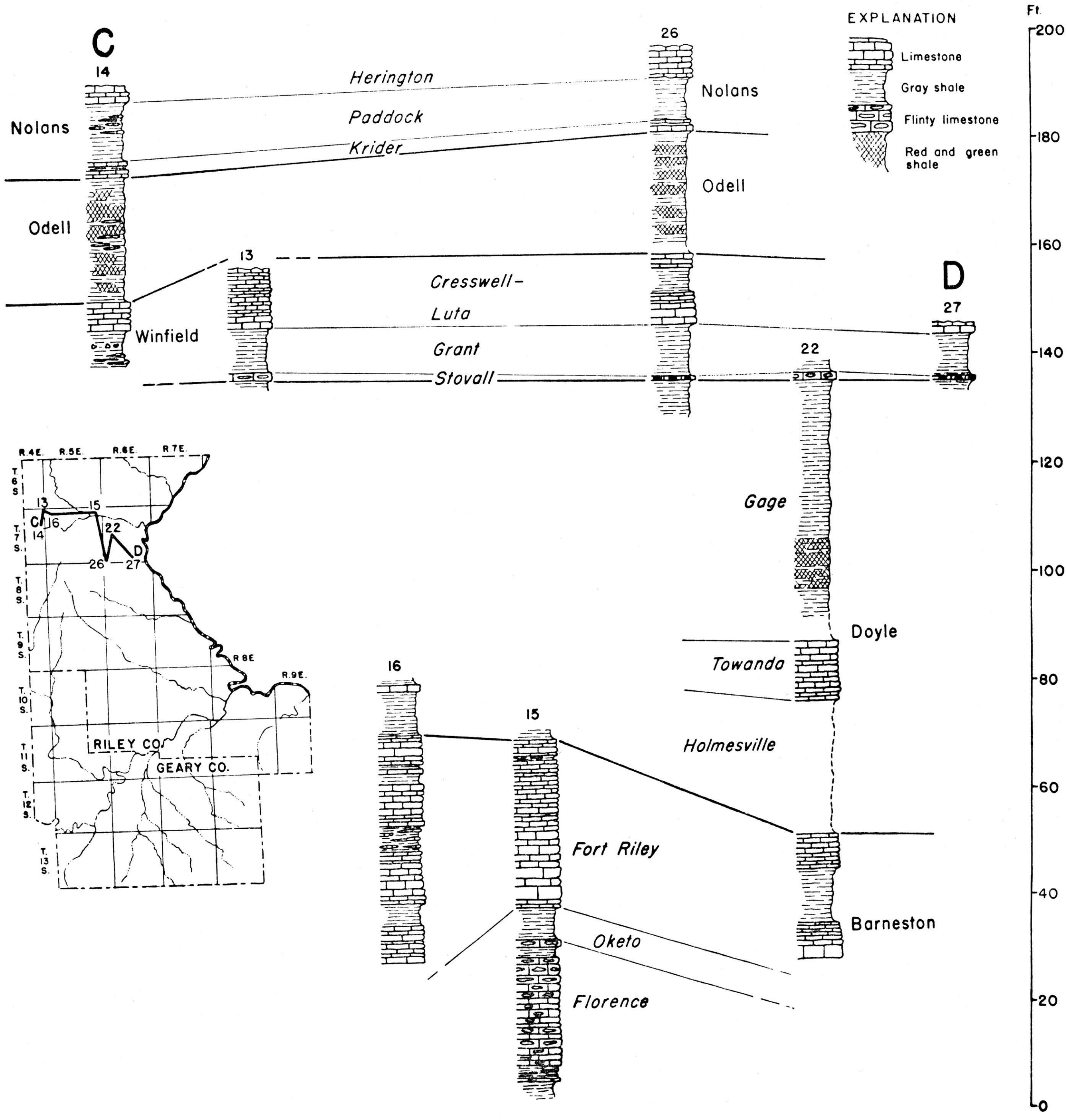

PLATE 9. Stratigraphic sections in Riley county in T. 7 S.

Indian Cave Sandstone Member

The Indian Cave sandstone member was named by Moore and Moss (1933, p. 100), from exposures near Indian Cave, Neb. They discovered its disconformable relationship with underlying Pennsylvanian beds, and recognized the sandstone as the filling in a series of channels that had cut downward as low as the Dover limestone. I have seen the Indian Cave member as far south as Cedarvale, Kan.

In northeastern Riley county the base of the member rests upon the Brownville(?) limestone, the lower part of the French Creek(?) shale, and the Dover limestone at exposures only a few miles apart in the anticline in Deep creek valley. It is very probable that this represents the approximate maximum erosion in the Kansas area at the close of Pennsylvanian time in Kansas.

Lithologic character and thickness.—Where best exposed, in sec. 30, T. 10 S., R. 9 E., the Indian Cave member is found to be composed of very fine quartz and mica sand cemented with iron oxide, but it is probable that unweathered samples would contain calcareous cement. The somewhat weathered outcrop includes firmly and very poorly cemented zones. The quartz grains are extremely angular and range from approximately 0.025 mm. to 0.175 mm. in size. The mica flakes are larger and make up about 0.25 of 1 percent of the whole. The quartz grains are deeply stained with iron oxide. Near the top of the member there are many limonite concretions. Some interbedded layers of sandy shale contain much very fine carbonaceous matter interspersed with mica flakes. The thickness of the member at this exposure is approximately 75 feet.

Distribution.—The base of the Indian Cave sandstone member is mapped as the base of the Permian system on the areal geology map. The member reaches the surface on each side of Deep creek valley not far south of Kansas river near Zeandale.

Detailed sections.—For detailed, measured sections in which the Indian Cave sandstone member occurs see numbers 51, 53, and 64 at the end of this report.

Undifferentiated Towle-Hawxby Beds

According to the present usage of the Kansas Geological Survey, strata above the Indian Cave sandstone include: upper part of Towle shale formation, Aspinwall limestone formation, Hawxby shale formation, and Falls City limestone. Along the outcrop in Kansas and southern Nebraska, these beds below the base of the

Falls City limestone formation have a total thickness of about 35 feet. The Aspinwall limestone, which is approximately 4 feet thick, lies about 15 feet above the top of the Indian Cave sandstone, where it is present.

In the area under discussion these beds are present, but are everywhere concealed in a soil- or grass-covered slope, the Aspinwall(?) limestone forming a bench and a line of limestone boulders along the hillsides. Locally a few feet of the shale is exposed but hardly well enough to warrant an attempt at description.

In sec. 30, T. 10 S., R. 9 E., the upper part of the Towle shale comprises 20 feet of limonitic clay shale, which is sandy in its lower part and grades into sandy shale in the upper part of the Indian Cave sandstone member. The Aspinwall(?) limestone is composed principally of fragments of fossil pelecypods and hence resembles the Falls City limestone, which lies approximately 30 feet higher. A thin coal seam in the Hawxby shale was observed here and at a few other places.

The Aspinwall limestone was named by Condra and Bengston (1915, p. 9) for the town of Aspinwall, Neb., and the overlying Hawxby shale was named by Moore and Condra (1932) from a farm near Nemaha, Neb.

FALLS CITY LIMESTONE

Condra and Bengston (1915, p. 30) named the Falls City limestone from exposures near Falls City, Richardson county, Nebraska. The type exposure is 2.5 miles south and 1.5 miles west from the town.

The Falls City limestone forms a bold outcrop in a small area in eastern Riley county but when traced laterally it loses its outcrop-making characteristics and is believed to become thin or to grade into shaly beds within a short distance.

Lithologic character and thickness.—The Falls City limestone in the small exposures in Riley county is brownish-gray and consists principally of shell fragments, which are not very firmly cemented. It is identified by its coquina-like, brecciated texture, to which the term "oatmeal" rock is appropriate. The exact thickness is perhaps not determinable, but great blocks 3 feet thick, which commonly are 6 to 8 feet across, probably represent almost the entire thickness of the bed, but in sec. 36, T. 10 S., R. 8 E., a thin bed of limestone 10 feet below the main ledge is probably a part of the formation. Along hillsides the blocks are conspicuous and are generally found slumped down the slope below the bench formed by the layer in its true position. Such blocks and good exposure of the unit can be seen in sec. 25, T. 10 S., R. 8 E., and sec. 30, T. 10 S., R. 9 E. Farther southward the limestone becomes much thinner and in sec. 9, T. 11 S., R. 9 E., the Falls City formation is believed to be represented by only a few inches of coquina-like limestone.

In general the Falls City limestone contains many pelecypods, small bellerophontids, bryozoa, and *Chonetes granulifer*.

Distribution.—As indicated in the preceding paragraphs, the Falls City limestone can be traced with a considerable degree of accuracy on each side of Deep creek for a few miles, east and south of Zeandale in southeastern Riley county.

Detailed sections.—For sections of the Falls City limestone see numbers 51 and 53 at the end of this report.

WEST BRANCH-HAMLIN SHALE

In the area of this report there are almost no exposures of the strata lying between the Falls City limestone and the base of the Foraker limestone, *i. e.*, the Americus limestone member. Because the exposures are poor, the entire interval was measured wherever possible and was found to range from 35 to 40 feet. In a few places several feet of strata below the Americus limestone was studied and was found to comprise yellow and gray shale containing a large amount of sand.

Table 2 in this report shows the subdivisions of this part of the section as they are known in other parts of Kansas. They are: (3) Hamlin shale formation, which comprises Oaks shale, Houchen Creek limestone, and Stein shale members; (2) Five Point limestone formation, and (1) West Branch shale formation.

Section.—Section 51, at the end of this report, includes the West Branch-Hamlin shale.

Council Grove Group

Prosser (1902, p. 709) introduced the name Council Grove as a formation name. It was then defined as consisting of two members: Cottonwood limestone below and Garrison shale above. In accordance with the present usage as a group term, strata known to many geologists under the old terms, Americus limestone, Elmdale shale, Neva limestone, Eskridge shale, Cottonwood limestone, and Garrison shale, are included. This means that about 150 feet of older strata are now included in the Council Grove, and the group is defined as including beds between the base of the Foraker limestone (base of the Americus limestone) and the base of the Wreford formation. Inasmuch as it is believed that the rocks previously assigned to the Garrison and Elmdale shales do not constitute natural units, those terms no longer appear in the revised classification, and the Americus, Neva, and Cottonwood limestones are now classified as members of what seem to be more natural formational units. The formations and members of the Council Grove group are listed in Table 2.

FORAKER LIMESTONE

The term Foraker limestone formation as now used by the Kansas Geological Survey includes the Americus limestone and about 45 feet of strata that was formerly assigned to the Elmdale shale. In the present classification the old term "Elmdale" is not used. The application of the term Foraker to strata extending quite across Kansas is due to the researches of N. W. Bass of the United States Geological Survey. He (Bass, 1929, p. 45) introduced the name into Kansas geological literature in 1929 and later was able to indicate, from Oklahoma to Nebraska, the exact equivalents of the formation as it appears in Cowley county, Kansas. The formation was named by Heald (1916, pp. 21-25), the type exposure being near Foraker in Osage county, Oklahoma. In southern Kansas and Oklahoma the formation includes a much larger percentage of limestone than it does in Riley county. These members, in ascending order, are recognized as constituting the formation: (1) Americus limestone, (2) Hughes Creek shale, and (3) Long Creek limestone. The upper two are the lower members of the old "Elmdale" formation as divided by Condra (1927, p. 83).

Americus limestone Member

The Americus limestone was named by Kirk (1896, p. 80) from exposures near Americus in Lyon county, Kansas. Good exposures of the whole unit are scarce in Riley county, but the member is easily recognized and traced along the slopes. A few widely separated exposures show its persistence in both lithology and faunal content.

Lithologic character and thickness.—The member consists of two limestone beds separated by a bed of shale. The lower limestone bed is about 1 foot thick; it is granular and gray and contains fragments of fossils. The shale bed is as much as 2 feet thick and commonly is carbonaceous and fissile. Locally the shale bed is

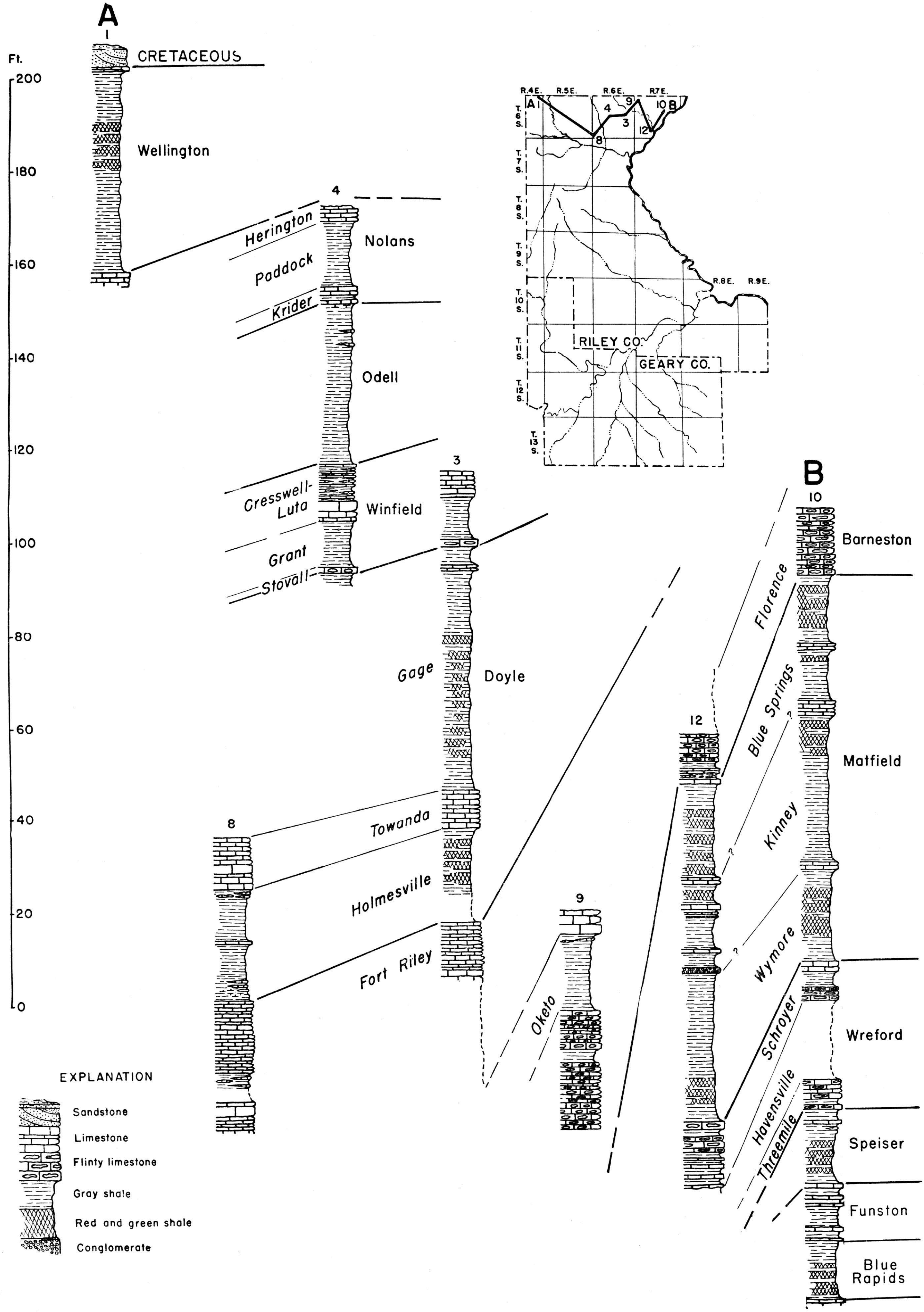

PLATE 10. Stratigraphic sections in Riley county in T. 6 S.

gray and fossiliferous. The upper limestone bed is about 10 inches thick; it is bluish gray, and locally contains an abundance of fusulinids, *Triticites ventricosus,* and fragments of other fossils.

Distribution.—In 1930 the whole member was exposed at the south side of a small stream 24 feet above the stream bed on the northeast side of "K Hill" in sec. 30, T. 10 S., R. 8 E., but this exposure has been covered by a viaduct approach. The member can now be seen a short distance south of the highway junctions at the base of the hill. There is likewise a good exposure of the Americus limestone above the railway track and below the highway at the foot of Blue Mount at the northeast edge of Manhattan. The unit is easily recognizable on each side of Deep creek valley and is fairly well exposed in the drainage furrows on the steep slopes. In sec. 36, T. 10 S., R. 8 E., in several steep gulches there are good exposures. There the shale between the limestone beds is gray and fossiliferous. The Americus limestone is a suitable key bed for detailed structural surveying in Deep creek valley, but it might be confused with higher fusulinid-bearing limestones. Commonly the myriads of free fusulinids in the shale overlying the Americus limestone can be easily seen even on grass-covered slopes and their presence helps to identify the Americus. Positive identification of the Americus limestone in Riley county is assured by its lithologic character, position, and lateral continuity.

Detailed sections.—For detailed sections in which the Americus limestone is described see numbers 48 and 51 at the end of this report.

Hughes Creek Shale Member

The Hughes Creek shale was named by Condra (1927, p. 85) from exposures along Hughes creek in Nemaha county, Nebraska. He recognized it as a natural persistent unit in the old Elmdale formation.

Lithologic character and thickness.—In Riley county the Hughes Creek shale consists of approximately 40 feet of shale and thin limestone beds. As in other units of the old "Elmdale shale," dark carbonaceous shale is present in this member in large amounts, and it is worthy of note that carbonaceous shale in conspicuous quantities does not characterize formations above the Grenola formation. Black shale overlying blue compact limestone is an essential part of the Pennsylvanian cycle of sedimentation described by Moore (1931, pp. 247-257), and in the Red Eagle and Grenola formations mudstones or impure limestones are associated with black shales.

The dense blue "middle" limestones of the Pennsylvanian cycles owe their color to carbonaceous matter. I (Jewett, 1936) have shown that there is evidence of cyclic sedimentation in the Permian of Kansas and that its lowest expression seems to occur in the upper part of the old "Elmdale" formation. Hence this part of the Kansas Paleozoic section may be regarded as transitional between the characteristic lithology of the Pennsylvanian and that of the Permian system as developed in the state. It should be remembered, however, that the characteristic Pennsylvanian cyclothems in the earlier Shawnee and Douglas groups are much better developed.

The Hughes Creek shale is a well-defined faunal and lithologic unit within the limits of Riley county, where exposures are confined to a relatively small area in and near Manhattan and along the hills west of Deep creek in northeastern Riley county. The smaller lithologic units vary somewhat in thickness, and a fusulinid-bearing limestone near the top grades laterally into yellow shale crowded with fusulinid tests. At the base are many small fusulinids and *Crurithyris* sp. in shale just above the Americus limestone. About 12 or 15 feet higher are thin limestones containing *Neospirifer dunbari, Meekopora prosseri, Orbiculoidea missouriensis,* and *Lingula carbonaria.* Near the top in yellow limestone or yellow shale are many fusulinids, mostly *Triticites ventricosus.* Just below the top there are small geades and veins of calcite in yellow and gray shale at some places.

Distribution.—The exposures of Hughes Creek shale in Riley county are limited to a small area in and near Manhattan and on the west side of Deep creek valley. The formation is well exposed at the foot of Blue Mount, at the foot of K Hill, along Union Pacific Railway, and along the highway southwest of Manhattan in sec. 26, T. 10 S., R. 7 E.

Detailed sections.—For sections including the Hughes Creek shale see numbers 45, 46, 48, and 51 at the end of this report.

Long Creek Limestone Member

This limestone was named by Condra (1927, p. 85) from exposures along Long creek in Nemaha county, Nebraska, and he traced the bed into northern Kansas. Bass (N. W. Bass, personal communication) has correlated it with the upper part of the Foraker limestone formation of southern Kansas.

Lithologic character and thickness.—In the area of this report the member consists of thin beds of limestone and some shale; locally it appears on newly exposed surfaces as a blocky yellow shale. Elsewhere it grades into *Triticites*-bearing limestone assigned to the upper part of the Hughes Creek shale. A conspicuous feature is the abundance of small crystals of quartz on weathered surfaces. The upper surface weathers to a honeycomb-like mass of quartz crystals, many of which are pink, embedded in a small amount of yellow limestone. Because of this characteristic appearance of the weathered surface the bed can be recognized over a wide area by its float on grass-covered slopes. Generally the lithology of the unit ranges from alternating beds of yellow shale and yellow limestone to thinly bedded yellow limestone. The abundance of fusulinids is notable, as in the underlying Hughes Creek shale. The thickness of the member in this area is about 8 feet.

Distribution.—The Long Creek limestone is exposed in Manhattan and vicinity. It can be identified on the grass-covered slopes over a considerable area south and east of Manhattan.

Detailed sections.—See numbers 45, 46, and 48 at the end of this report for sections including the Long Creek limestone.

JOHNSON SHALE

The term Johnson shale was introduced as a member name in the old Elmdale shale formation by Condra (1927, p. 86). The type locality is near Johnson in Johnson county, Nebraska. This shale and the strata below and above are well exposed in and near Manhattan.

Lithologic character and thickness.—The Johnson shale is chiefly gray shale but contains several beds of argillaceous limestone, which range from mudstones to well-laminated grayish-yellow limestones, about 1 foot thick. Locally the middle part is somewhat arenaceous and the upper part is carbonaceous, but these conditions are only local variations from the common gray facies. Locally also the mudstones grade laterally into mere calcareous zones in the shale. In places some green material marks the middle part of the formation. The thickness is approximately 16 feet. Fossils are rarely found in the Johnson shale.

Distribution.—This formation is well exposed with other units of the former Elmdale formation in and near Manhattan. The best exposures are those along State highway 13 north of the Manhattan waterworks, and along Rock Island Railway a short distance west of Manhattan along Wild Cat creek. The unit is mostly concealed on grass-covered slopes along its line of outcrop north and southeast of Manhattan.

Detailed sections.—For sections including the Johnson shale, see numbers 45 and 48 at the end of this report.

RED EAGLE LIMESTONE

The term Red Eagle was introduced as a stratigraphic name by Heald (1916, pp. 24-25). The type exposure is near Red Eagle school in Osage county, Oklahoma. Strata in northern Kansas are known to be equivalent to the Oklahoma formation because of the studies of Bass (personal communication). These same strata have been correlated by Condra (personal communication) with the Glenrock limestones, Bennett shale, and Howe limestone of Nebraska. Hence these three beds are classified as members of the Red Eagle limestone.

Glenrock Limestone Member

The lower member of the Red Eagle formation was named by Condra (1927, p. 86) from exposures northwest of Glenrock in Nemaha county, Nebraska.

Lithologic character and thickness.—The thickness of this unit in Riley county is approximately the same as in Nebraska, ranging from 1 to 2 feet. It is inconspicuous because it is thin and is not easily distinguished from the thicker mudstones of the underlying Johnson shale. Within a short distance in the vicinity of Manhattan the member changes from a yellow fusulinid-bearing limestone to what seems to be an intraformational breccia, and elsewhere to a hard gray limestone.

Distribution.—As indicated in detailed sections, this unit is best exposed near Manhattan. It is mostly covered with grass-covered slopes north and southeast of Manhattan along its line of outcrop.

Detailed sections.—The Glenrock limestone is included in sections at the end of this report numbered 45 and 48.

Bennett Shale Member

The type exposure of this member of the Red Eagle formation is south of Bennett in Lancaster county, Nebraska. This member was named and traced into northern Kansas by Condra (1927, p. 86) along with other units of the old Elmdale formation.

Lithologic character and thickness.—Black, carbonaceous shale, especially in the lower part, is characteristic. Locally the entire unit is black, but elsewhere it contains gray and green shale near the top.

A conspicuous feature, locally at least, is the great abundance of small, white brachiopods in the black platy shale. In the exposure on Blue Mount in the northeast part of Manhattan and in an exposure in a small ravine south of U. S. highway 40 in sec. 26, T. 10 S., R. 7 E., a coquina of white brachipods is interbedded with the black shale layers in the lower 1 foot of the unit. The coquina is composed chiefly of *Crurithyris* sp., but *Composita ovata, Composita subtilita, Dictyoclostus americanus,* and *Wellerella truncata* also are abundant. The thickness is variable, ranging from 4.5 feet to 13.5 feet. Near the north side of sec. 24, T. 10 S., R. 7 E., the unit is approximately 13 feet thick and the lower part, the black shale and white shells, is separated from the upper part by about 1 foot of mudstone. In that place the upper part is gray and green shale, and the upper and lower parts are each approximately 6 feet thick. That exposure seems to show a local development and the black shale containing white brachiopods is the characteristic feature of the unit in and near Manhattan.

Distribution.—The best exposures of Bennett shale in Riley county are indicated in the preceding paragraph.

Detailed sections.—Sections numbered 45, 47, and 48, at the end of this report, include the Bennett shale.

Howe Limestone Member

The upper member of the Red Eagle formation was named by Condra (1927, p. 86) from exposures south of Howe, Neb., in T. 4 N., R. 14 E. In Nebraska the unit is a gray massive limestone about 4 feet thick.

Lithologic character and thickness.—In the area of this report the Howe limestone is a massive gray or brown limestone, which locally has the appearance of mudstone. The thickness ranges from 2 to 4 feet. The member is almost or quite barren of fossils.

Distribution.—The Howe limestone is exposed in and near Manhattan in several road cuts. In sec. 26, T. 10 S., R. 7 E., it is exposed near the foot of the hill where U. S. highway 40 leaves Kansas river flood plain and rises eastward over the Cottonwood limestone escarpment. That exposure is west of the American Legion golf course west of Manhattan. In the eastern part of Manhattan it is exposed on Blue Mount near the top of the clean exposure above the street.

Detailed sections.—For detailed sections including the Howe limestone see numbers 45, 47, and 48 at the end of this report.

ROCA SHALE

This term was introduced as a stratigraphic name by Condra (1927, p. 86) and he selected exposures in Lancaster county, Nebraska, as type exposures. At that time strata from the top of the Howe limestone to the base of the Neva limestone were included in the unit. Later Condra and Busby (1933) introduced the term Grenola formation and included in that formation several feet of strata that formerly had been included as a part of the Roca shale. The Grenola formation as then defined comprised, in ascending order: (1) Sallyards limestone, (2) Legion shale, (3) Burr limestone, (4) Salem Point shale, and (5) Neva limestone. At present the Kansas Geological Survey classifies the Sallyards limestone and Legion shale as the upper part of the Roca shale. Hence the upper boundary of the Roca shale is now understood to be the base of the Burr limestone as herein described.

Lithologic character and thickness.—In Riley county the Roca formation does not differ greatly from the strata described in Nebraska as gray, red, and green shale containing thin pelecypod-bearing limestones in the upper part. Where best exposed in Riley county the formation consists principally of varicolored shale and thin beds of impure limestone. Almost 5 feet from the top is a persistent limestone bed, the Sallyards limestone already mentioned, and at the very top is a few inches of black fissile shale similar to the shale in the overlying Burr limestone. The thickness is almost uniformly 25 feet. The lowest 4 or 5 feet is commonly olive-colored and contains some chocolate-colored material. Generally overlying this zone is a thin bed of rusty limestone, and the next 3 or 4 feet is gray shale. Near the middle part is a conspicuous mudstone or impure limestone, which locally is more than 2 feet thick. This limestone weathers into rusty-brown fragments stained with darker splotches. The next 10 feet of the formation is generally varicolored, greens, blues, reds, and grays being prominent. Locally the upper few feet of this zone contains calcareous concretions. Overlying this zone is about 1 foot of argillaceous limestone (Sallyards limestone), then about 4 feet of gray shale overlain in turn by the few inches of black fissile shale previously mentioned.

Distribution.—The Roca shale formation is exposed in and near Manhattan where the Howe limestone member of the Red Eagle formation is exposed. It is partly exposed on Mount Prospect (K Hill) and is very well exposed along U. S. highway 40 in sec. 26,

T. 10 S., R. 7 E. It is partly exposed on Blue Mount and in other places.

Detailed sections.—The Roca shale is described in more detail in numbers 45, 47, and 48 of the sections at the end of this paper.

GRENOLA LIMESTONE

The name Grenola formation was introduced into stratigraphic literature by Condra and Busby (1933). The formation comprises strata lying between the Roca shale formation and the Eskridge shale formation, including the upper 16 feet of the old Elmdale formation and the Neva limestone. As introduced by Condra and Busby it comprised five members, the lower two of which are now regarded as part of the Roca formation, as already explained. The strata that are now included in the formation were recognized as a natural stratigraphic unit by Kirk in 1896 and he (Kirk, 1896, p. 8) applied the name Dunlap formation to them. Dunlap is a town in southeastern Morris county, Kansas. The name Dunlap might well have been retained but was abandoned eight years later when Prosser (1902, p. 709) named the Neva limestone and applied the name Elmdale shale to all strata between the Americus limestone and the Neva limestone. It is fitting to recognize these strata as a formation, as they comprise limestone and fossiliferous shale between the underlying varicolored Roca shale and the overlying varicolored Eskridge shale. The type exposure of the Grenola formation is 4 to 5 miles west of Grenola in Elk county, Kansas. Condra and Busby gave names to the parts of the formation below the Neva limestone, and as now known the Grenola limestone formation includes, in ascending order: (1) Burr limestone, (2) Salem Point shale, and (3) Neva limestone.

Burr Limestone Member

The Burr limestone, lowest member of the Grenola limestone formation as now recognized by the Kansas Geological Survey, was named by Condra and Busby (1933, p. 10) from exposures about 2.5 miles northwest of the town of Burr, in Otoe county, Nebraska. As already explained, at the time the Grenola formation was named it included the upper few feet of the present Roca shale formation as herein described, and the Burr limestone member was then the third unit from the base. Condra and Busby (1933, pp. 17-18) included a detailed section studied about 1.7 miles southwest of Manhattan in Riley county, along or near the line of number 47 of the detailed sections at the end of this report. The Burr limestone is the lowest member of the old Dunlap formation defined by Kirk.

Lithologic character and thickness.—In Riley county this bed is seen to change somewhat between the few good exposures. In an excellent exposure along U. S. highway 40 a short distance southwest of Manhattan the member is distinctly divided into two limestones separated by a bed of shale. There the lower limestone is light in color, massive, and fossiliferous. *Polypora* sp., *Rhombopora* sp., *Septopora* sp., and *Dictyoclostus americanus* are common. The lower unit is about 2 feet thick. The overlying shale bed is about 1.5 feet thick and is mostly black and fissile. Locally at least the upper part of the shale unit is gray and calcareous. The upper bed is finely granular light-gray limestone about 4.5 feet thick. The total thickness of the member is about 8 feet. A few miles farther south, in sec. 7, T. 11 S., R. 8 E., is another clean exposure and there the unit seems to be divided into only two parts, an upper part consisting of about 5.5 feet of gray thin-bedded or laminated limestone and a lower part consisting of 5 feet of gray dense limestone.

Distribution.—The Burr limestone member of the Grenola limestone is exposed in only a few places in Riley county. In general its area of distribution is almost the same as that of the higher Neva limestone member.

Detailed sections.—For sections in which the Burr limestone is described see numbers 45, 47, and 57 among the detailed sections at the end of this report.

Salem Point Shale Member

The exposure chosen by Condra and Busby (1933, p. 10) as the type locality for the middle unit of the Grenola limestone is situated near Salem in Richardson county, Nebraska. A description of the characteristics of the unit as it is exposed near Manhattan in Riley county, Kansas, is presented in their paper, together with descriptions of other units of the Grenola formation.

Lithologic character and thickness.—There are only a few good exposures of the unit in Riley and Geary counties but where best exposed the member is seen to consist of three parts: a lower bed of gray shale containing calcareous material and local seams of limestone; a middle part consisting of more calcareous material; and an upper part composed of gray argillaceous shale. The lower part is 3.5 feet thick, the middle part is 1.5 feet, and the upper part is slightly more than 3 feet. The total thickness is about 8 feet.

Distribution.—The general distribution of the Salem Point shale member of the Grenola formation is the same as that of the formation and its most conspicuous unit, the Neva limestone member.

Detailed sections.—The Salem Point shale is described in detail in sections numbered 47 and 57 at the end of this report.

Neva Limestone Member

Owing to its conspicuous outcrop and perhaps also to its somewhat unusual characteristics upon weathering, the Neva limestone, together with the Cottonwood limestone and the Fort Riley limestone higher in the geologic section, gained the attention of the early investigators in the upper Kansas river valley. Meek and Hayden (1867, p. 17) included it in their strata numbers 26 and 27. They erroneously reported limestone occupying the entire interval of the Eskridge shale formation, between the Neva limestone and the Cottonwood limestone above. Perhaps they included most of the Neva limestone in their number 27 but if so, they underestimated its thickness, as they reported but 6 feet. Swallow (1866, p. 16) made a more careful study and he divided the Neva limestone into three parts: at the base, number 84, "dry bone limestone"; above it, number 83, "1 foot of bluish-brown marls"; and at the top, number 82, "cotton rock". He gave 5 feet as the thickness of the lower part, 6 feet as the thickness of the upper, and a total of 12 feet, leaving 1 foot for the thickness of the middle part. From his descriptions and tabulated sections it is plain that Swallow described the unit that Prosser (1902, p. 709) called Neva limestone.

Condra (1927, p. 87) described the Neva formation in Nebraska, and at the same time described and named units in the old Elmdale formation. Later he found that the upper unit, Roca shale, in the former Elmdale formation did not extend upward to the base of the Neva limestone, and as already explained, he therefore named and defined the Grenola formation. It should be noted, however, that the upper boundary of the Elmdale formation was placed by its authors at the base of the Neva limestone as the term is used in this report. The Neva limestone as it occurs in Cottonwood river valley is well described by Prosser and Beede (1914). Its characteristics where exposed in Cowley county on the southern border of Kansas are well described by Bass (1929, p. 55). The unit is recognizable for about 75 miles into Oklahoma (Miser, 1926).

Lithologic character and thickness.—Beds included in the Neva limestone member of the Grenola limestone formation are excellently exposed along U. S. highway 40 a few miles west of Manhattan. There the unit is seen to comprise, from the base upward: slightly more than 1 foot of gray nodular fossiliferous fusulinid-bearing limestone; slightly more than 3 feet of shale, dark near the base and silty above; about 1 foot of impure, resistant limestone; about 1.5 feet of marlite, or limy shale, which assumes a honeycomb-like appearance on weathering; about 8.5 feet of massive limestone containing shale partings, most of which are irregular but at least one of which about 2 feet from the base is very persistent; 2 feet of gray shale; and about 0.6 foot of light-gray limestone. In several other good exposures the appearance of the member is seen to differ but slightly from the above description. In general the Neva limestone member is brown cancellate limestone, commonly displaying marly facies, and breccias of limestone fragments in a calcareous matrix. Such lithologic characters are best seen in old exposures, and they are not well developed in the exposure described. A large portion of the member becomes very cellular upon long exposure and the weathered stone is to be seen in many artificial walls and in rock gardens. Beds that remain more massive after weathering are quarried locally and are used for general building, but the Neva limestone has not been quarried nearly so much as has the Cottonwood limestone. Shale partings in the member are not persistent over many miles. Plate 11 shows a characteristic weathered exposure. The thickness ranges from 10 to 17 feet in this part of Kansas.

Distribution.—The Neva limestone is well exposed in the place mentioned, likewise on Blue Mount and on Mount Prospect (K Hill), and along the various highways leading into Manhattan. Owing to its peculiar lithologic character and its continuous outcrop, the member is easily traced for many miles at or near the top of the hills between Zeandale and Manhattan, and thence, nearer the valley floors, westward and northward until it disappears under the alluvium of Kansas and Big Blue rivers and their tributary streams. On Blue Mount at Manhattan there is an exposure of Neva limestone a short distance below the word "Manhattan" formed in concrete letters near the top of the hill.

Detailed sections.—For sections in which the Neva limestone member of the Grenola formation is described see numbers 44, 47, 48, 50, and 57 at the end of this report.

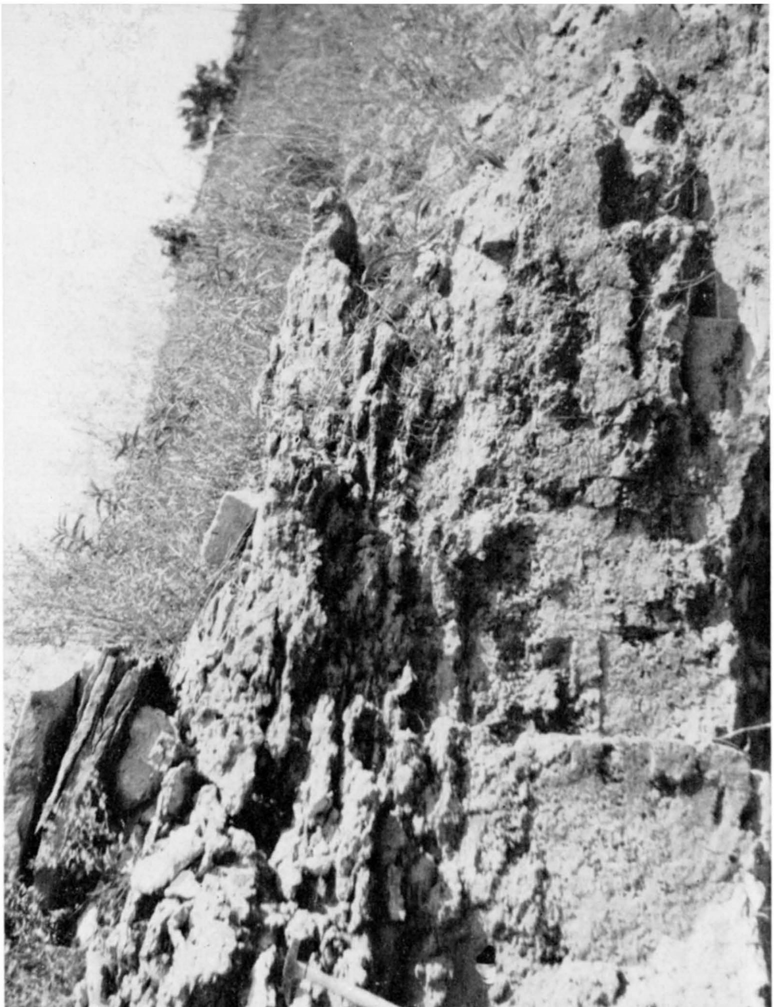

PLATE 11. Characteristic exposure of the Neva limestone, Grenola formation, along state highway 13, south of Manhattan.

ESKRIDGE SHALE

This shale was named by Prosser (1902, p. 709). The type exposure is near the town of Eskridge, Wabaunsee county, Kansas. The unit is well defined, as it lies between the Neva limestone below and the Cottonwood limestone above. It is as persistent in lithologic characters almost across Kansas as are its limiting limestones. In Riley and Geary counties the formation is generally covered by a grass-grown slope, but its position is everywhere known because of the outcropping limestones above and below it. In several places, however, road cuts have exposed the beds and hence their characteristics are well known.

Lithologic character and thickness.—A lower gray shale, containing bands of green and chocolate-colored shale, and an upper gray shale are characteristic. The two parts are commonly separated by a calcareous zone. The upper part is commonly fossiliferous. Wherever the formation is exposed, limestone beds less than 1 foot thick and generally less than 6 inches thick may be seen. These limestone beds are lenticular and impure and most of them occupy the middle part of the formation. The entire thickness is approximately 36 feet and is almost uniform. Fossils are not everywhere conspicuous but in sec. 10, T. 10 S., R. 7 E., along U. S. highway 24 about 3 miles west of Manhattan a limestone lentil about 6 inches thick is exposed. It lies about 13 feet above the Neva limestone, and contains an abundance of pelecypods, principally *Aviculopecten* and *Myalina*. In the same exposure, 1 foot of limestone, about 13 feet below the top of the formation, contains an abundance of ostracodes.

Distribution.—Eskridge shale crops out in the two counties along with the Neva and Cottonwood limestones.

Detailed sections.—Sections numbered 44, 47, 48, 50, and 57, at the end of this report, include the Eskridge shale.

BEATTIE LIMESTONE

The Kansas Geological Survey has adopted the name Beattie limestone to include as members the Cottonwood limestone, Florena shale, and Morrill limestone. The last two of these units were formerly included in the "Garrison formation," a term no longer used. The name is obtained from the town of Beattie in Marshall county, Kansas. Like other limestone formations in the Council Grove group the Beattie separates varicolored shales.

Cottonwood Limestone Member

The name "Cottonwood stone" or "Cottonwood Falls limestone" had been applied commercially to this limestone in the Cottonwood river section many years before the name appeared in scientific publications. Similarly the name "Manhattan stone" was the commercial name for the same limestone stratum in the vicinity of Manhattan. Prosser (1895, p. 40) proposed the name Cottonwood formation for this unit and for the overlying shale, which is now called Florena. He called the former the Cottonwood limestone and the latter the Cottonwood shale. Later Prosser, in collaboration with Beede (1904) dropped the name Cottonwood shale and adopted the name Cottonwood limestone for the unit herein discussed. He then adopted the term Florena for the overlying shale unit formerly called Cottonwood shale. The type exposure is situated along Cottonwood river in the vicinity of Cottonwood Falls in Chase county, Kansas. Prosser and Beede amply described its characteristics as exhibited in that area. Condra and Upp (1931, p. 15) have shown that the member in Nebraska is much the same as it is for a great distance along Cottonwood river and along Kansas river. Bass (1929, p. 59) has found that southward from southern Chase and Lyon counties it loses its distinguishing characteristics, an opinion in accordance with my observations in southern Kansas. Previous reports have probably overestimated the conspicuousness of this limestone in central Kansas. Locally in Riley county the Eiss limestone, which lies approximately 30 feet above the Cottonwood limestone, is more prominent in the Flint Hills slopes than is the Cottonwood, especially in the southeastern part of Riley county. In Riley and Geary counties the Cottonwood is only one of several limestones that form shoulders and outcrops on the Flint Hills slopes.

For many years the Cottonwood limestone has been quarried along its line of outcrop. The buildings of Kansas State College at Manhattan are constructed almost entirely of this rock, and a small quantity of it has been used in the buildings of the State University at Lawrence. Its lithologic characters make it one of the best building stones in the state. It is not now being extensively quarried, but in the two counties old quarries, large and small, are to be seen on nearly every hill capped by this stratum.

Lithologic character and thickness.—Wherever seen the Cottonwood limestone is almost uniformly 6 feet thick. It is everywhere massive and commonly seems to consist of only one or two beds. It

PLATE 12. A, An exposure at Pillsbury's Crossing on Deep creek, sec. 5, T. 11 S., R. 9 E., Riley county. Elmont limestone at base, Tarkio limestone at top. B, An exposure of Cottonwood limestone along state highway 13, south of Manhattan, Riley county.

is buff, but weathers almost white. Fusulinids are common, especially in the upper part, and siliceous nodules project from weathered surfaces. In this area the Cottonwood is not a flinty limestone but nodules of partly silicified material that weather more slowly than the rest of the rock give it the flinty appearance. Plate 12B shows the general appearance of the member. Plate 3A shows the characteristic physiographic expression.

Many springs issue beneath the massive ledge, and along the hills it is everywhere marked by a line of shrubs forming a fringe that can be seen for many miles. Close observation removes any likelihood of confusing the Cottonwood limestone with any other layer in this part of Kansas. Its distinguishing characters are the massive ledge of uniform thickness, the silicified nodules, and the abundance of fusulinids, *Pseudofuslina emaciata,* chiefly in the upper part.

Distribution.—The Cottonwood limestone is easily traced in the Flint Hills south of Kansas river and east of Manhattan. At Manhattan it lies near the top of the hills and is a part of the natural beauty of Sunset Park in the western part of the city. It lies slightly above the word "Manhattan" formed in concrete on Blue Mount in the northeast corner of the city and it forms the second bench on K Hill (Mount Prospect). The line of outcrop is a tortuous one extending several miles from Manhattan up Kansas and Big Blue rivers and their tributaries, and the upper part of the member is exposed west of Big Blue river in the extreme northeastern part of Riley county.

Detailed sections.—The Cottonwood limestone is described under sections numbered 44, 47, 48, 50, and 57 at the end of this report.

Florena Shale Member

For many years the upper surface of the Cottonwood limestone was regarded as the base of a formational unit called Garrison shale. The base of the Wreford limestone marked the top of the formation. Prosser (1902, pp. 712-713), who named these strata as a formation, divided them into two very unequal parts, which he called Florena and Neosho. The former is the lower and is 2 to 13 feet thick; the latter is about 130 feet thick. The type exposure for the lower unit, Florena shale, is a quarry near Florena on Big Blue river. The terms Garrison and Neosho are no longer employed in Kansas stratigraphic nomenclature.

The Florena member of the Beattie limestone is known entirely across Kansas and into Nebraska and Oklahoma. It is not well exposed in many places in the two counties discussed here, but nevertheless it is known to be persistent in its characters.

Lithologic character and thickness.—In Riley and Geary counties the Florena member is a gray argillaceous shale not more than 10 feet thick and generally less. It contains myriads of the little brachiopods, *Chonetes granulifera,* but few other fossils. Judging from the best exposures, the fossils seem to be limited to the lower part, their zone of abundance extending perhaps not more than 2 feet above the base. In one exposure the shells were not seen but their seeming absence may be due to poor exposure of the lower part of the member. In several places on grass-covered slopes the abundance of the fossils can be detected, and in small ravines on the Flint Hills slopes they are everywhere present just above the Cottonwood limestone. Road cuts make excellent exposures where the perfectly preserved little shells can be collected in great quantity.

Observations elsewhere in the state have revealed that this member is one of the most persistent stratigraphic units. Its fauna is widespread, for the zone of abundance of *Chonetes* can be followed quite across the state. Farther south in Kansas, in Cowley and Elk counties, the variety of fossils is greater, and most of the Permian Pelecypods and brachiopods are included. In those counties and in Greenwood county, Kansas, the Florena shale is remarkable for the presence of excellently preserved complete specimens of a small trilobite.

Distribution.—The Florena shale is coexistent with the Cottonwood limestone and the Morrill limestone, other units of the Beattie formation.

Detailed sections.—For sections including the Florena shale see numbers 47, 50, and 57 at the end of this report.

Morrill Limestone Member

The Morrill limestone was named by Condra (1927, p. 234) when he described and named several other units of the former Garrison formation. The type exposure is near Morrill, Brown county, Kansas. This unit, which is inconspicuous in northern Kansas, becomes more noticeable in the southern part of the state. According to Bass (personal communication), it is more conspicuous than the Cottonwood limestone in Cowley county.

Lithologic character and thickness.—Although in many places it is concealed under grass-grown slopes, wherever it is exposed this limestone exhibits lithologic characteristics that are remarkably persistent. It is brownish-gray and it contains many calcite crystals. It weathers into a mass of irregularly pitted, granular brown limestone without apparent bedding, and the openings that produce the pitted appearance are partly filled with crystalline calcite. Although it is hard, it is not resistant to weathering, and nearly everywhere on the Flint Hills slopes it is covered by sod except where exposed artificially or cut by ravines. Generally a thickness of about 3 feet or less is visible, but this may be somewhat reduced by leaching. Weathered, isolated outcrops or blocks of floats are not unlike parts of the Neva limestone.

Distribution.—In the two counties Morrill limestone can best be seen about 10 feet above the Cottonwood limestone in road cuts. Its distribution is approximately the same as that of the Cottonwood limestone.

Detailed sections.—The Morrill limestone is included in sections numbered 47, 50, and 57 at the end of this paper.

STEARNS SHALE

The shale between the easily identified Morrill limestone below and the Eiss limestone above was named Stearns shale as a unit of the old Garrison formation by Condra (1927, p. 234), the type exposure being situated near Stearns School near Humboldt, Neb. Strata in this interval are now recognized by the Kansas Geological Survey as comprising a formation.

Lithologic character and thickness.—Like other shale units, the Stearns formation is rarely well exposed in Riley and Geary counties. Where best exposed, it is seen to consist of about 20 feet of gray shale, seemingly barren of fossils. Locally it is believed to contain thin beds of limestone, but this may not be true, as the limestone may be part of the overlying Eiss limestone.

Distribution.—The Stearns shale formation is distributed in the same area as are the Cottonwood and Eiss limestones.

Detailed sections.—For sections including the Stearns shale see numbers 47, 50, 57, and 68 at the end of this report.

BADER LIMESTONE

The Kansas Geological Survey recognizes the Bader limestone as a formation. It contains the Eiss limestone, Hooser shale, and Middleburg limestone, units that were named by Condra as members of the old Garrison formation. The type exposure is near Bader, in Chase county, Kansas.

Eiss Limestone Member

The Eiss limestone was named by Condra (1927, pp. 233-234), from exposures on the Eiss farm about 8 miles south of Humboldt, Neb.

In Riley and Geary counties the Eiss limestone forms the first outstanding bench above the Cottonwood limestone, and throughout the area its physiographic expression rivals or locally surpasses that of the resistant Cottonwood beds. It seems strange that this prominent limestone should have received so little attention while the Cottonwood was receiving so much. Perhaps the economic use of the Cottonwood, involving extensive quarrying, brought it to the attention of geologists.

Lithologic character and thickness.—For many miles south and southeast of Manhattan and north along the west valley wall of Big Blue river the line of outcrop of the Eiss limestone is marked by blocks of white, pitted, partly silicified limestone. The blocks are commonly about 1.5 feet thick, 2 feet wide, and 3 feet long. In this area the Eiss limestone consists of three parts: lower limestone beds, gray, thinly bedded, altogether about 20 inches thick; about 30 inches of gray shale; and at the top slightly less than 3 feet of limestone, the upper part of which is very resistant, crops out prominently, and is the source of the weathered blocks. Pitted surfaces, which are more strongly developed along joint planes than along bedding planes, are characteristic, and weathered blocks are commonly chalky in appearance. The Eiss limestone is more noticeable south of Kansas river, but nowhere does it lack topographic expression. Its line of outcrop lacks the persistent fringe of shrubs that marks that of the Cottonwood 30 feet lower in the slopes.

Distribution.—The Eiss limestone is readily traced along the slopes of the Flint Hills east and southeast of Manhattan, and up Big Blue and Kansas rivers and their tributaries.

Detailed sections.—The Eiss limestone is included in sections numbered 47, 49, 50, 57, and 68 at the end of this report.

Hooser Shale and Middleburg Limestone Members

The term Hooser shale has been applied by Condra and Upp (1931, p. 20) to the shale unit above the Eiss limestone and below the Middleburg limestone, which they have found to be persistent over a wide area. Previously Condra (1927, pp. 233-234) had named the strata from the Eiss limestone to the Sabetha (now Crouse), the Easly Creek shale. The Hooser shale is the lower unit of the Easly

Creek as first defined. Later Condra and Upp (1931, pp. 19-20) redefined the Easly Creek to include only the upper part of the unit as first defined, *i. e.*, the strata between the Middleburg limestone and the Crouse (formerly Sabetha).

In Riley and Geary counties the rock between the Eiss limestone and the Sabetha limestone, which has been correlated with the Crouse of Oklahoma, is exposed in only a few places, but in some of the Flint Hills slopes a limestone above the Eiss and below the Crouse limestone produces a bench; the same limestone is exposed in a few road cuts, and it has been identified by the Nebraska geologists as the Middleburg limestone. The underlying shale is therefore correlated with the Hooser shale.

The type exposure of the Hooser shale is near the town of Hooser in Cowley county, Kansas, and that of the Middleburg limestone near Middleburg School in Richardson county, Nebraska.

Lithologic character and thickness.—Where best exposed the Hooser shale in this area is about 6 feet thick and is green and gray. The colors are believed to be characteristic. In the few good exposures in this part of Kansas, the Middleburg limestone, which lies about 6 feet above the top of the Eiss limestone, is divided into two parts, separated by about 6 inches of dark or black shale. The lower limestone bed is dark at the top, but is mostly yellow and the thickness is about 3 feet. The upper limestone is more variable from exposure to exposure, ranging from a yellowish-brown limestone to a red and green brecciated limestone. The thickness of the upper bed is about 7 inches. According to Condra and Upp, this unit at the type exposure consists of an upper bed 16 inches thick; an underlying bed 18 inches thick, containing many small high-spired gastropods; and a shale bed 6 to 12 inches thick underlain by 2 or 3 inches of dark limestone. In Riley county there is a thin limestone bed containing myriads of similar gastropods, but the bed is believed to lie a few fet above the top of the strata that are referred to the Middleburg limestone. Similar gastropod-bearing limestone is to be seen at many places high in the Flint Hills, especially in southeastern Riley county. F. M. Swain (personal communication) has found small gastropods in several thin limestones within the Council Grove beds in the Cottonwood river region.

Distribution.—The Hooser shale and Middleburg limestones are nearly coexistent along the line of outcrop with the Eiss limestone below them.

Detailed sections.—For sections in which the Hooser shale and Middleburg limestone are described see numbers 49, 57, and 68 at the end of this report.

EASLY CREEK SHALE

The Kansas Geological Survey recognizes the Easly Creek shale, as redefined by Condra and Upp, as a formational unit. The name was first applied by Condra to a larger unit but later he and Upp redefined the term to include strata between the Middleburg limestone below and the Crouse limestone above (Condra and Upp, 1931).

Lithologic character and thickness.—In Riley and Geary counties the shale in this interval is predominantly gray and green, but contains local bands of chocolate-colored material above and of yellow and red below. Myriads of small, high-spired gastropods locally characterize a thin bed of limestone, which may not be continuous. The thickness of the Easly Creek shale ranges between 15 and 20 feet.

Distribution.—The Easly Creek shale formation in the Flint Hills slopes can be traced for many miles and can be recognized because of its position between its limiting limestones, which in turn can be easily recognized because of their position with reference to the well-known Cottonwood and Wreford limestones.

Detailed sections.—For sections including the Easly Creek shale see numbers 32, 49, 57, and 68 at the end of this report.

CROUSE LIMESTONE

Condra (1935, pp. 4, 6) employed the term Bigelow limestone as comprising three units previously named, in ascending order: (1) Sabetha limestone (Crouse limestone), (2) Blue Rapids shale, and (3) Funston limestone. Moore (1936a, fig. 4, p. 12; and 1940, fig. 16, p. 44) used the name in the same way. The Bigelow limestone thus included strata between the Easly Creek shale and Speiser shale. The Bigelow limestone was named from Bigelow, Marshall county, Kansas.

To be consistent with the classification applied to strata above and below them, these beds should be divided into three formations. This reasoning is based on the observation that the Blue Rapids shale is a comparatively thick unit of varicolored clastic material separating two limestones. In accordance with the present state of knowledge of cyclic deposition (Jewett, 1933; Elias, 1934) it corresponds genetically to the Roca, Eskridge, Stearns, and Easly Creek shales below it and to the Speiser shale above. It may be true that the limestones below and above the Blue Rapids shale are not so divisible as are other limestones in this part of the geologic column to which formational rank is assigned, but the Funston limestone comprises more than one limestone bed, and the Crouse limestone seems to be regionally divisible into three or more units. It is therefore proposed that Bigelow be dropped as a stratigraphic term and that Crouse limestone, Blue Rapids shale, and Funston limestone be recognized as formations. The Director of the Kansas Geological Survey concurs in this opinion (Moore, R. C., personal communication).

Condra (1927, p. 234) named the Sabetha limestone as a member of the Garrison formation and selected a type exposure near Sabetha, Nemaha county, Kansas, but later Condra and Upp (1931, p. 21) found that the Sabetha limestone is the same as the Crouse limestone in Osage county, Oklahoma, which has been traced into southern Kansas by Bass (1929, pp. 66-67). The Crouse limestone was named by Heald (1917, p. 22) from Crouse Hill near the northwest corner of the Foraker quadrangle in Osage county, Oklahoma.

Lithologic character and thickness.—In Riley and Geary counties the chief characteristic of the Crouse limestone is the platy structure of the upper part, which is manifest in all weathered exposures. The member is somewhat massive in the middle part, and it is granular and has a sandy appearance throughout. The color ranges through grays and browns. Fossil fragments are common, but well-preserved specimens are almost lacking. Owing to the pronounced weathering of all exposures, the true thickness is hard to measure, but probably averages 10 feet and is believed not to deviate greatly from that amount. From descriptions of the Crouse limestone in Oklahoma and southern Kansas it is evident that the lithology changes greatly along the strike of the beds. In the counties discussed in this report the member makes a prominent bench, but is not so expressive as the Cottonwood and Eiss limestones.

Distribution.—Like other units in this part of the geologic section, the Crouse limestone is present below the Wreford limestone beds and above the Cottonwood limestone throughout a large area in the Flint Hills. Its float is easily recognized along the slopes.

Detailed sections.—Numbers 10, 49, 57, 66, and 68 of the stratigraphic sections at the end of this report give detailed descriptions of the Crouse limestone.

BLUE RAPIDS SHALE

In Riley and Geary counties the strata between the top of the Crouse limestone and the base of the Wreford formation are divided into five easily recognizable units. These units are persistent over the entire area in which I studied the outcrops and I have seen them as far south as Greenwood county, Kansas. Condra (1927, p. 234) called the strata in the entire interval Speiser shale. Later he and Upp (1931, pp. 22-24) divided these beds into three parts: (1) Blue Rapids shale, (2) Funston limestone, and (3) Speiser shale. The Crouse limestone, Blue Rapids shale, and Funston limestone were grouped as the Bigelow limestone formation. The type exposure of the Blue Rapids shale is near Blue Rapids, Marshall county, Kansas, 8 miles north of Riley county.

Lithologic character and thickness.—The Blue Rapids shale is well exposed in a few places. It is mostly gray although locally it contains some bands of red material. A thin unfossiliferous limestone bed is locally present in the lower part of the member. The thickness ranges between 20 and 30 feet.

Distribution.—The Blue Rapids shale is mostly concealed under grass-covered slopes in the Flint Hills, but its position is revealed by the limestone outcrops and terraces between the bold outcrops of Eiss and Wreford limestones.

Detailed sections.—For sections of the Blue Rapids shale see numbers 10, 32, 49, 57, 66, and 68 at the end of this report.

FUNSTON LIMESTONE

Condra and Upp (1931, p. 23) chose an exposure within the area discussed in this report as the type for this limestone, which they believed to be persistent over a wide area. The type exposure is described as being "in bluffs of Kansas River valley, south of Funston, Kansas," but the exact location is not stated. The type exposure is described as follows:

Limestone, gray, massive, fossiliferous, 1′ 6″.
Shale, badly covered, greenish-gray, argillaceous, about 1′.
Limestone, gray, massive, fossiliferous, 1′ 6″.
Shale, greenish, 6″-1′.
Limestone, medium dark gray, massive, blocky, sandy at places, 3′.

Lithologic character and thickness.—Throughout the area of outcrop in the two counties the thickness of this member varies and averages probably slightly more than 5 feet. Generally less distinct limestone beds overlie and underlie the more persistent one; they are perhaps included in the Funston limestone at its type exposure, but they are very lenticular. If these lenticular beds are included, the formation has irregular boundaries that are not stratigraphic horizons. The limestone that mainly comprises the unit is somewhat massive, but somewhat powdery, and is light in color and locally resembles an oölite.

Distribution.—Like other units in the old Garrison formation, the Funston limestone crops out in only a narrow area limited by more resistant limestones above and below it. The Funston limestone commonly forms a terrace on the slopes below the more boldly outcropping Threemile limestone in the base of the Wreford formation.

Detailed sections.—The Funston limestone is described in detail in sections 10, 32, 42, 49, 57, 66, and 68 at the end of this report.

SPEISER SHALE

The rock between the Funston limestone and the base of the Wreford formation was called Speiser shale by Condra and Upp (1931, p. 23) when they redefined the term. The term Speiser had formerly been applied by Condra (1927, p. 234) to the strata between the Sabetha (now Crouse) limestone and the base of the Wreford formation. The Speiser shale, now recognized as a formation, has its type exposure in Speiser township in Richardson county, Nebraska.

Lithologic character and thickness.—There are three persistent units within the Speiser formation. They are indicated in table 2 as unnamed units. The lower is generally about 14 feet thick and comprises varicolored materials, grays, reds, greens, and purples being noticeable. The middle part of this lower unit includes brightly colored zones and the upper and lower parts are commonly gray. The upper part is very fossiliferous. Moore recently found fish and amphibian remains in these beds. The colored beds are partly or well exposed in many places below the overlying limestone unit. The second unit of the Speiser formation, a thin limestone, was studied in numerous exposures in the two counties. In fact, wherever the Threemile limestone at the base of the Wreford formation is exposed one may expect to see this limestone bed. I have seen it as far south as sec. 27, T. 27 S., R. 8 E., in Greenwood county, Kansas, more than 80 miles south of Geary county. In this place and at places farther northward the thickness and lithology of the member are almost the same as they are in Riley and Geary counties. For many miles this unit separates the underlying varicolored shale beds from the gray and yellow shale of the third or upper unit. This limestone bed is generally less than 1 foot thick and is barren of fossils except for a few brachiopods. In lithology it varies somewhat, but is generally gray and crystalline. It represents the limestone member or very calcareous shale that constitutes the unit lying between the varicolored shales and the fossiliferous shales in a typical rhythmic cycle of sedimentation as described by me (Jewett, 1933, pp. 137-140). The upper part of the Speiser shale formation is gray or yellow, fossiliferous, and generally less than 3 feet thick. The shale is well bedded and somewhat flaky. Common fossils of the unit are Productids, *Derbyia* sp., *Composita* sp., and a few bryozoa.

Distribution.—Wherever the lower part of the Wreford formation is exposed above the valley floors the Speiser shale is present. In many places, such as road cuts and stream banks, the brightly colored shales of the lower unit and the thin, persistent limestone are visible. Plate 14 shows a characteristic exposure.

Detailed sections.—Sections 2, 10, 11, 32, 42, 49, 57, 59, 66, 68, 69, and 70 at the end of this report give a detailed description of the Speiser shale.

Chase Group

The Chase group was named from Chase county, Kansas, by Prosser (1902, pp. 713-714). He included beds from the base of the Wreford formation to the top of the Winfield formation (not including Luta limestone). The upper boundary of the group is now placed higher—at the top of the Herington limestone, the upper member of the Nolans formation. As originally defined the Chase group was said to be a well-defined lithologic and faunal unit, but there seems to be no good reason for excluding strata between the top of the Winfield and Nolans formations. Flint-bearing limestones are characteristic of the group, but it includes limestones that are not flinty and shales of various colors. Flint is abundant in the Florence limestone in the Barneston formation, in the Wreford limestone, and locally in the Winfield and Nolans limestones. Flint in the Kansas Permian rocks, however, is not confined to the Chase group. In southern Kansas various limestones in the Council Grove group are locally flinty.

WREFORD LIMESTONE

Hay has been given credit for naming the Wreford limestone formation, but he merely suggested the name with reservations. In 1891 he (Hay, 1891) suggested Wreford or Ogden as a suitable name for these strata and again in his posthumous paper (Hay, 1896) he says:

"If another name were required for these strata we might still call the lower flint the Wreford formation; however . . . some other greographic term would perhaps be more appropriate."

In spite of his statement the name has become firmly established. The name is unfortunately chosen, as the type exposure in the old quarries at Wreford, a village in Geary county 5 miles south of Junction City, is very poor.

The Wreford limestone formation is composed of three members, which Condra and Upp (1931, p. 31) have named, in ascending order: (1) Fourmile limestone, (2) Havensville shale, and (3) Schroyer limestone. Because the term Fourmile had previously been applied to a Pennsylvanian sandstone in the Osage Reservation, Oklahoma (Bowen, 1922, p. 19), the Kansas Geological Survey has substituted the term Threemile, the name of a creek that crosses Fort Riley Military Reservation and is tributary to Kansas river a few miles southwest of Odgen.

Threemile Limestone Member

The term Fourmile limestone was applied to the lower member of the Wreford formation by Condra and Upp in 1931, from Fourmile creek near the Kansas-Nebraska boundary, south of Humboldt, Neb. As stated, the name Fourmile was used by Bowen to designate a sandstone formation of Pennsylvanian age in Oklahoma. The name Threemile is taken from a creek that crosses Fort Riley Military Reservation and empties into Kansas river a few miles southwest of Ogden.

Lithologic character and thickness.—The lowest 2 or 3 feet of the lower member of the Wreford formation consists of thin beds of limestone containing abundant nodules of flint. The overlying bed is lighter in color and contains little or no flint. In most places where the bed can be seen there is no flint; the limestone is massive and everywhere makes a bold outcrop. The thickness is almost uniform and is approximately 7 feet. Because of the lack of flint, this bed is resistant to weathering and forms a dip slope over a wide area in the Flint Hills. As already explained under the heading "Flint Hills" in this report, it is not the flint-bearing limestones that are most resistant to weathering in this part of Kansas. This nonflinty limestone bed is conspicuous whether high or low topographically and is by far the most noticeable part of the Wreford formation. The overlying part of the Threemile limestone in the two counties is flinty and thin-bedded. The thickness of the entire member is approximately 9 feet. Plates 2B, 13, and 14A show various parts of the Wreford limestone.

Distribution.—A line marking the base of the Threemile limestone appears on the geologic map (Pl. 1) as the base of the Wreford formation. The distribution of the three members is nearly the same and is discussed after the description of the upper member.

Detailed sections.—For detailed sections of the Threemile limestone see sections 2, 10, 11, 32, 42, 49, 57, 59, 66, 68, 69, and 70 at the end of this report.

Havensville Shale Member

Condra and Upp (1931, p. 32) chose exposures near Havensville in Pottawatomie county, Kansas, as typical for the middle member of the Wreford formation. It is described as olive-colored argillaceous shale containing fossiliferous transitional zones at top and bottom, 18 or more feet thick at the type locality.

Lithologic character and thickness.—In Riley and Geary counties the Havensville shale is approximately 10 feet thick or locally slightly thicker. It is gray, argillaceous, and fossiliferous. Brachiopods, pelecypods, and a few bryozoa are characteristic. The fossils are almost confined to the upper and lower parts.

Distribution.—The Havensville shale is almost coexistent with the upper member of the Wreford formation.

Detailed sections.—For sections including the Havensville shale see numbers 11, 32, 42, 66, 67, and 68 at the end of this report.

Schroyer Limestone Member

The type exposure of the upper member of the Wreford formation is "about 1¼ miles below Schroyer," a town in Marshall county, Kansas, about 8 miles north of Riley county (Condra and Upp, 1931, p. 32).

Lithologic character and thickness.—The Schroyer limestone is mostly flinty, but contains generally a bed of nonflinty limestone, which crops out more prominently than the rest of the member. The bed containing no flint lies at or near the top and is commonly about 3 feet thick. The thickness of the member is about 18 feet.

Distribution.—The various members of the Wreford limestone formation are exposed near the tops of the hills a few miles east and a few miles north of Manhattan. The formation is easily traced up the streams tributary to Kansas river. It is partly exposed at Ogden and north of U. S. highway 40 north of Camp Funston. Back of the remount station near the west gate of Camp Funston it is partly exposed in a quarry. At the bridgehead on the east bank of Smoky Hill river east of Junction City the base of the Threemile limestone is slightly higher than the level of the bridge and most of the formation is concealed. The formation extends northward up Big Blue river beyond the north boundary of Riley county. The Wreford limestone is easily traced because of the resistant nonflinty bed in the Threemile member and the similar one in the Schroyer member. The line of outcrop follows Big Blue river for most of the distance along the eastern edge of Riley county except in those places where it extends westward up eastward-flowing streams tributary to Big Blue river, such as Baldwin creek, Fancy creek, and Sweed creek. Near Winkler on Fancy creek, exposures near the water level show that the Wreford formation is well below the valley fill. Westward a few miles upstream and in the direction of the regional dip the formation appears well above water-level again, indicating the presence of an anticlinal structure.

Detailed sections.—Sections 10, 12, 32, 42, 57, 58, 66, 67, and 68 at the end of this report include the Schroyer limestone.

MATFIELD SHALE

Prosser (1902, p. 714) applied to the strata between the underlying Schroyer limestone and the overlying Florence limestone the name of Matfield, from Matfield township, Chase county, Kansas. Condra and Upp (1931, pp. 38-40) divided the formation into three parts, named in upward order: (1) Wymore shale, (2) Kinney limestone, and (3) Blue Springs shale. Later the Kansas Geological Survey recognized these three units as formations and dropped the term Matfield from stratigraphic nomenclature. Because both on the surface and in the subsurface the Kinney limestone is difficult to define, retention of the name Matfield as a formation name seems advisable, the smaller units being regarded as members of the formation. The flinty limestones next below and above the Matfield shale are easily recognized and Matfield is a useful name.

Wymore Shale Member

The type exposure of the Wymore shale is near Wymore, Neb. (Condra and Upp, p. 37). The Wymore shale is defined as the shale lying between the Wreford and Kinney limestones, and as the basal member of the Matfield formation.

Lithologic character and thickness.—The Wymore shale consists of varicolored shales. Shades of red are perhaps the most common

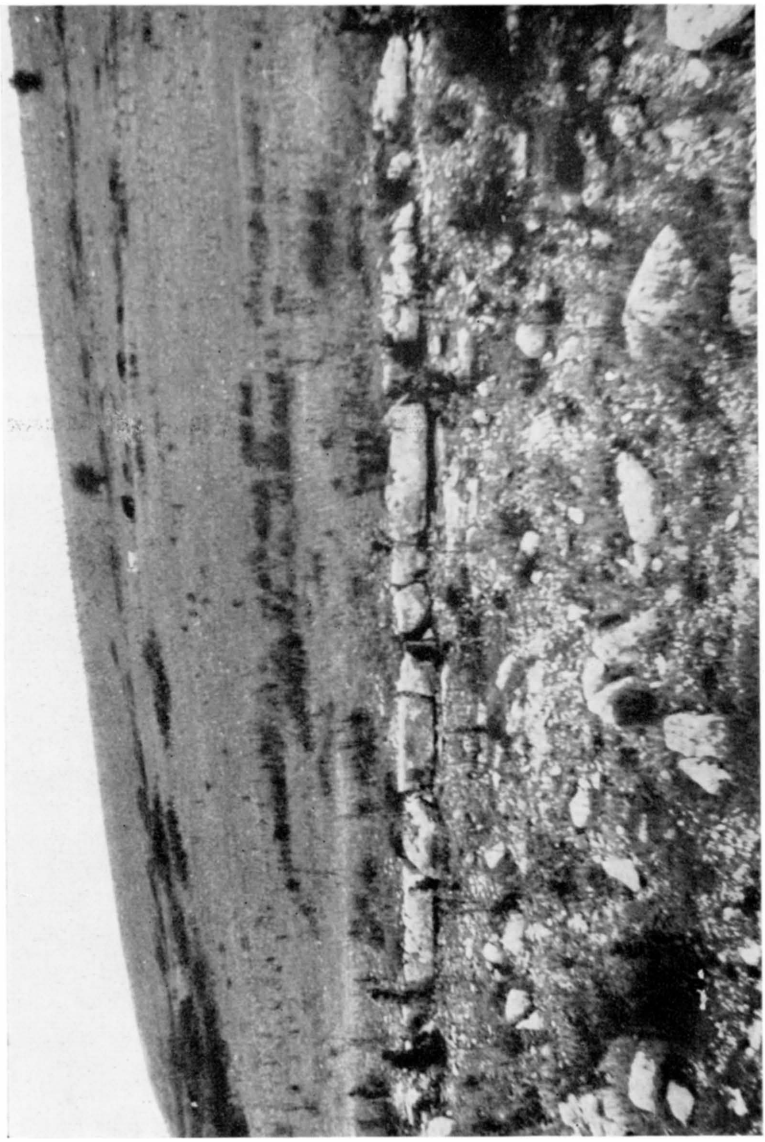

PLATE 13. Characteristic exposure of the Schroyer limestone, Wreford formation, eastern Riley county.

colors other than gray, but purple, green, and chocolate-color are common. The approximate average thickness of the member is 20 feet.

Distribution.—The members of the Matfield formation lie between two very resistant series of strata and are generally concealed under grassy slopes between the more bold limestone outcrops, but there are some good exposures, such as those in sec. 32, T. 6 S., R. 7 E., along the bluff of Big Blue river between Randolph and Cleburne and in sec. 29, T. 8 S., R. 7 E., about 2 miles northwest of Stockdale.

Detailed sections.—For sections of the Wymore shale see numbers 6, 10, 12, 32, 56, 58, 66, 67, and 68 at the end of this report.

Kinney Limestone Member

The type exposure chosen by Condra and Upp (1931, p. 37) for the Kinney limestone of the Matfield shale is near Kinney, Gage county, Nebraska. The Kinney limestone is defined as the middle member of the Matfield shale and as lying between the Wymore and Blue Springs shales.

Lithologic character and thickness.—After studying all available exposures in Riley and Geary counties, I conclude that in that part of Kansas the Kinney limestone formation is best described as a calcareous fossiliferous zone containing limestone lenses. Farther south in Kansas the member more persistently maintains its massive character. Sections at the end of this report giving detailed descriptions of exposures show the variable character of the member. Along U. S. highway 40 in Fort Riley, a short distance west of the Ogden monument, is an exposure of a part of the Wymore shale and of the Kinney limestone. There is exposed a bed of limestone 4 feet 4 inches thick, which lies approximately 83 feet below the base of the Fort Riley limestone and probably about 50 feet below the base of the Florence limestone. From sections it can be seen that the thickness of the member ranges from a few feet to perhaps as much as 22 feet.

Distribution.—The Kinney limestone member is well exposed in the places mentioned under the discussion of the Wymore shale member. Its distribution in the two counties is nearly the same as that of the base of the Florence limestone of the Barneston formation.

Detailed sections.—For sections including the Kinney limestone see numbers 5, 6, 10, 12, 32, 56, 58, 66, 67, and 68 at the end of this report.

Blue Springs Shale Member

The type exposure of this member is southwest of Blue Springs, Neb. (Condra and Upp, 1931, p. 38). It is the top member of the Matfield shale.

Lithologic character and thickness.—The Blue Springs shale is persistently varicolored below and yellow and gray above. The upper part is more calcareous than the lower. The thickness is variable, ranging from approximately 25 feet to 45 feet. The brilliantly colored material in this formation and in the underlying Wymore shale exhibit the brightest colors found in rocks in this part of Kansas and the brightest in the state in any rocks other than the "redbeds" higher in the Permian system. Red, purple, chocolate color, and shades of green are very noticeable in the lower part of the Blue Springs shale.

Distribution.—The Blue Springs shale is exposed in many road cuts and elsewhere along the Flint Hills where the Fort Riley and Florence limestones cap the hills. It is present over a wide area below the more resistant limestones.

Detailed sections.—For sections of the Blue Springs shale member see numbers 5, 6, 10, 12, 15, 32, 56, 58, 66, 67, and 68 at the end of this report.

BARNESTON LIMESTONE

Condra and Upp (1931, p. 41) erected a formation to include two well-known Kansas stratigraphic units, the Florence and Fort Riley limestones. The formation was named Barneston from the town in Gage county, Nebraska. Later the Kansas Geological Survey recognized a shale member between the limestones. Hence the Barneston formation is now divided, in ascending order, into: (1) Florence limestone, (2) Oketo shale, and (3) Fort Riley limestone.

Florence Limestone Member

The Florence limestone was named by Prosser (1895, p. 773) from exposures near Florence in Marion county, Kansas. Because of the large amount of flint or chert it contains, the limestone has been generally known as the Florence flint.

Lithologic character and thickness.—The Florence limestone is very noticeable because of the large amount of steel-gray flint imbedded within the limestone. The thickness ranges from 33 feet to 45 feet. The flint consists of very irregular nodules, which are arranged in layers 1 to 6 inches thick. The nonflinty limestone layers are characteristically 9 inches thick. The member is in reality a series of beds of limestone and beds of flint, but shale breaks are common near the top. If the uppermost flint-bearing limestone bed is regarded as the top of the member, there are commonly two shale breaks within the uppermost 10 feet. A characteristic exposure shows a shale bed 18 inches thick about 2 feet below the top and another, 3 feet thick, about 10 feet below the top. Commonly the limestone is somewhat powdery and weathers easily. The Florence member is somewhat fossiliferous. An exposure southeast of Winkler in sec. 1, T. 7 S., R. 5 E., along Fancy creek, is perhaps the best place within the two counties at which to collect fossils from the Florence member. The common lower Permian brachiopods, pelecypods, and bryozoa are plentiful there. Fusulinids are present in the member but are scarce.

Distribution.—The resistant Fort Riley limestone, which lies a few feet above the Florence limestone, is the bold outcrop-maker and forms the floor of extensive dip slopes, whereas the Florence limestone itself is more commonly concealed under steep slopes. That the flinty limestone although 40 feet thick is unable to form dip slopes is demonstrated in the hundreds of rounded buttes that fringe the Fort Riley limestone outcrop. From the top of all these buttes the Fort Riley member is absent, and as soon as the Fort Riley stratum weathers away the Florence limestone is rapidly dissected, and topography is developed that is very different from that in the extensive areas underlain by the Fort Riley. The height of the buttes capped by the flinty Florence limestone is generally slightly less than the thickness of the interval between the Schroyer limestone and the Florence. The Kinney limestone does not protect dip slopes.

The Florence limestone is partly exposed in many places below the "rim rock" or main ledge of the Fort Riley limestone. In only a few places is the whole member exposed. Representative exposures are described among the detailed sections that are included at the end of this report. As already explained, the member caps hundreds of rounded buttes east of and below the Fort Riley line of outcrop. These constitute a part of the Flint Hills. Where streams are actively eroding, the Florence stands in sheer cliffs; examples of such topographic expression are to be seen on Fourmile creek near the northwest edge of the Fort Riley Military Reservation and on Fancy creek near Winkler. Plate 2A shows the exposure near Winkler. In the general Flint Hills type of topography there are few natural exposures of the flint-bearing ledge, so one must rely upon artificial exposures for places in which to study it. The numerous artificial exposures have uncovered many good sections; an old quarry along the right valley wall of Smoky Hill river opposite Junction City is pictured in Plate 14B.

Detailed sections.—For complete descriptions of exposures of Florence limestone see numbers 5, 6, 9, 10, 12, 15, 32, 39, 56, 58, 66, 67, and 68 among the sections at the end of this report.

Oketo Shale Member

A definition of the Oketo shale, which is the middle member of the Barneston formation, has not heretofore appeared in geologic literature. It is well established, however, as a stratigraphic name because of its use on several published graphic sections (Moore, 1936a, figs. 4 and 45; 1940, fig. 15) and Moore is the author of the term. The name is derived from the town Oketo, Marshall county, Kansas. It may be defined as the middle member of the Barneston limestone, a bed of shale separating the flinty Florence limestone below from the Fort Riley limestone. Its thickness ranges from a feather edge to several feet. It is calcareous and locally contains one or more beds of limestone. The top of the Florence limestone is placed at the top of the uppermost flint-bearing beds in the Barneston limestone, and the base of the Fort Riley limestone is placed at the base of the lowermost limestone layers directly below the strata to which the name Fort Riley was originally applied. Wherever shale occurs between the Florence and Fort Riley limestones, as their boundaries are thus defined, the shale is properly called Oketo. The Oketo shale is present over a wide area in Kansas but is absent in some exposures of the Barneston limestone, especially in the southern part of the state.

Lithologic character and thickness.—The thickness of the Oketo shale ranges in Riley and Geary counties from a mere sheet to 17 feet. The shale is bluish-gray and yellow; local limestone beds are light in color and somewhat earthy. The greatest thickness in the area studied was the 17 feet of fossiliferous gray shale containing some dark carbonaceous material in the lower part, which was measured in sec. 6, T. 6 S., R. 7 E. In sec. 13, T. 9 S., R. 6 E., the Fort Riley and Florence limestones seem to be in direct contact. Gray-blue shale 6 or 8 feet thick containing thin limestone beds near the top and calcareous material in the very uppermost part is characteristic of the Oketo shale in the two counties.

Distribution.—The Oketo shale has the same distribution in the two counties as has the base of the Fort Riley limestone. The distribution of the Fort Riley member is hereinafter discussed in some detail.

Detailed sections.—For sections including the Oketo shale see numbers 6, 9, 15, 32, 56, 66, and 67 at the end of this report.

Fort Riley Limestone Member

Much of the beauty of the Flint Hills country near the larger streams is due to the presence of the Fort Riley limestone, a part of which forms hundreds of miles of outcrop line in the form of a natural wall of white limestone.

Swallow (1866, p. 14) used the name Fort Riley limestone in 1866, but he applied the name to only the more conspicuous part, which crops out more commonly. Meek and Hayden (1859, p. 79) had used "bed No. 12" to designate the same part. Hay (1896, p. 18) wrote of the "Fort Riley main ledge" in reference to the same part, which is so prominent along the river bluffs on and near Fort Riley Military Reservation. Prosser (1895, p. 773) used the term "Florence limestone" for the same part, but Prosser and Beede (1904, p. 4) extended the name Fort Riley "to include the thinner bedded limestone both above and below the massive Fort Riley main ledge." The type locality is the Fort Riley Military Reservation.

Lithologic character and thickness.—The lower beds of the Fort Riley limestone are so nearly constant in their wall-like outcrop that travelers are inclined to believe that they are looking at an artificial wall. Plate 4B shows this remarkable feature. This portion of the Fort Riley limestone, which crops out so conspicuously and so constantly, is often termed the "Fort Riley rim rock." It is a massive ledge lying not far above the base of the member. It has been extensively quarried and used in building, particularly in Junction City and Fort Riley, as it is well adapted for cutting into dimension blocks. There are still numerous quarry sites in the two counties. Plate 3B shows an exposure of the "rim rock" after it has been subjected to prolonged weathering. Blocks of this kind form the natural walls around the hills. Beds below the massive outcrop maker are composed of thinner, argillaceous layers. The thickness differs at different exposures.

Above the massive beds are thinner beds of limestone and shale. Not far from the middle of the Fort Riley limestone is a very persistent zone of extremely platy beds of argillaceous limestone or calcareous shale of light color, ranging from gray to yellow. The thickness of these light-colored, platy beds is not uniform, as is shown in detailed sections at the end of this report, but the beds are never missing. They are commonly seen along roadside ditches some distance from the "rim rock." The beds near the top are generally massive, more resistant than those directly underlying them, but less resistant than those lower in the member.

In northern Riley county there is less limestone in the middle part of the member, part of it being replaced by calcareous shale.

The massive "rim rock" has been very extensively used for building in both counties. Many farm buildings constructed as early as the 1860's are still in excellent condition.

Fossils are not common in the Fort Riley limestone as a whole, but the common lower Permian brachiopods and pelecypods are to be seen at various exposures. Farther south in the state the massive lower part exhibits a pisolitic structure, which is probably due to algal remains.

Bedding and joint planes in the thinner-bedded and more argillaceous strata below the "rim rock" carry a great amount of water and many springs issue from that zone. The summer of 1930 was extremely dry in this area as well as in the country as a whole, but in the two counties hundreds of springs were seen flowing with only slightly diminished volume. One of the larger springs is situated south of May Day in sec. 6, T. 7 S., R. 5 E., along a northward-flowing stream tributary to Fancy creek.

It is difficult to measure exactly the thickness of the Fort Riley member because the more massive beds near the base form such great dip slopes; however, 35 feet is an approximate average thickness.

Distribution.—The Fort Riley member, near the top of the Flint Hills in the western part of the region, skirts narrow canyons extending far back into the nearly level tract west of the outcrop. As already explained, it makes a natural wall around the hills on each side of Kansas, Smoky Hill, and Republican rivers. Massive beds near the top generally mark the beginning of long gentle slopes, rising to the Towanda limestone, which lies about 25 feet above the top of the Fort Riley.

Detailed sections.—The Fort Riley limestone is included in sections 3, 6, 8, 9, 15, 16, 17, 22, 23, 24, 29, 30, 32, 35, 36, 39, 41, 43, 56, 65, 66, 67, and 71 at the end of this report.

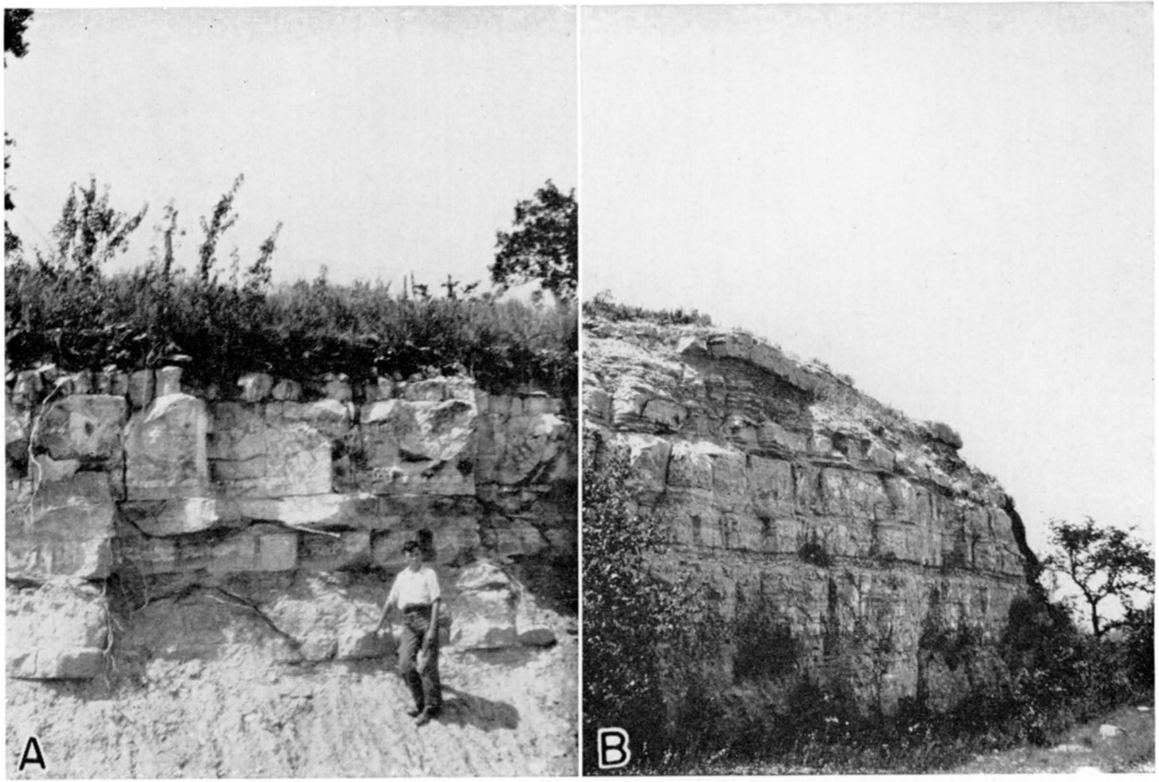

PLATE 14. A, A characteristic exposure of the upper part of the Speiser shale and the basal part of the Wreford limestone. The limestone under the boy's hand is a persistent one in the Speiser shale; west wall of the Big Blue river valley in northeastern Riley county. B, An exposure of Barneston limestone in an old quarry above the right bank of Smoky Hill river opposite Junction City, Geary county.

DOYLE SHALE

For many years strata between the top of the Fort Riley limestone and the base of the Winfield formation were known as Doyle shale. The name was given by Prosser (1902, p. 715). Later it was found that the Doyle formation is divisible into three units, each of which was regarded as deserving formational rank, but it now seems desirable to retain the name in its original sense and to classify the three parts of the formation as members. Like the name Matfield, Doyle shale is a useful term. The three members are, in ascending order, (1) Holmesville shale, (2) Towanda limestone, and (3) Gage shale.

Holmesville Shale Member

The Holmesville shale was named by Condra and Upp (1931, p. 43) from exposures near the town of Holmesville, Gage county, Nebraska. It is defined as the basal part of the Doyle formation, overlying the Fort Riley limestone and underlying the Towanda limestone.

Lithologic character and thickness.—The Holmesville shale, together with the Gage shale above, is important in Riley and Geary counties as it underlies great areas of agricultural land. It is generally covered by a mantle of soil, but despite the general covering of residual soil, the unit is exposed in many places. It consists of argillaceous shale, gray, yellow, green, and red, gray predominating. The uppermost few feet, exposed in hundreds of places, is everywhere green, a characteristic that helps to identify the overlying Towanda limestone. The thickness of the Holmesville shale in the area is 20 to 25 feet. In a few places it seems to be less than 20 feet, probably, however, owing to slumping.

Distribution.—As already stated, the Fort Riley limestone forms a great line of outcrop, and everywhere above and to the west are the gentle slopes underlain by the Holmesville shale, which weathers into a deep, fertile, residual soil. The line of outcrop of Towanda limestone, generally nearer to the Fort Riley limestone outcrop than to the Winfield outcrop above and to the west, marks the westward extension of the Holmesville area.

Detailed sections.—For sections of the Holmesville shale see numbers 3, 8, 16, 17, 22, 24, 29, 30, 35, 36, 40, 41, 43, 56, 65, 66, and 71 at the end of this report.

Towanda Limestone Member

Prosser (1902, p. 715) recognized a middle member in the old Doyle formation as early as 1902. It was named Towanda limestone by Fath (1921, p. 54) from exposures near Towanda, Butler county, Kansas. The unit was recognized in Cowley county, Kansas, by Bass, and in Nebraska by Condra and Upp (1931, p. 44).

Lithologic character and thickness.—In Riley and Geary counties the Towanda limestone is a conspicuous unit and is easily traceable on the landscape. Locally, as near Milford in Geary county, it is very conspicuous, having a thickness of approximately 15 feet. The thickness throughout the area ranges from a few feet to 15 feet or more. The limestone is generally nonresistant to weathering and marks the Holmesville-Gage slope with a band of debris of limestone fragments; along the roadside its presence is revealed by thin beds of yellow limestone in the ditches, or in the earth roads by a band of crushed, yellow limestone. It is visible wherever a road crosses its line of outcrop. Although the Towanda limestone is nowhere missing it is less conspicuous in southern Riley county than in the northern part of the area. In northern Geary county, especially near Milford, it forms massive bluffs, but that topography is an expression of an extraordinary facies. In one exposure, in the middle of sec. 23, T. 7 S., R. 5 E., north of Leonardville in northern Riley county it appears as a slightly flinty limestone weathering very rough. The unusual presence of flint in this member was observed at only this one of hundreds of exposures. The characteristic lithology is yellow unfossiliferous limestone in thin beds, which locally presents a porcellaneous appearance when weathered.

Distribution.—As stated, the Towanda limestone occupies a narrow outcrop band in a large area in the western parts of the two counties. It is generally nearer to the outcrop of the massive Fort Riley limestone below than to that of the Winfield formation above.

Detailed sections.—For sections of the Towanda limestone member see numbers 3, 8, 17, 22, 24, 29, 30, 35, 36, 40, 41, 43, 56, 65, 66, and 71 at the end of this report.

Gage Shale Member

This unit was named as a member in the Doyle formation by Condra and Upp (1931, p. 45), from the type exposure in Gage county, Nebraska. It lies between the top of the Towanda limestone and the base of the Winfield limestone formation, which in northern Kansas is the Stovall limestone member.

Lithologic character and thickness.—In Riley and Geary counties the Gage shale forms gently rolling slopes, and with the underlying Holmesville shale it forms an area of gently rolling topography. Almost everywhere along the strike there is a wide area occupied by the members of the Doyle formation. The average thickness of the Gage shale in the two counties is slightly less than 50 feet. The member is itself divisible into two, perhaps three natural parts: the lower and greater part, consisting of varicolored shale; a thin calcareous zone, or locally a massive limestone bed less than 1 foot thick; and an upper part, less than 10 feet to 15 feet thick, consisting of yellowish-gray shale containing abundant fossils. The colored shales, red, green, purple, and chocolate-color, in the lower part are interbedded with more somber gray and yellow. Fossils are found only in the upper part and the brachiopod *Derbyia* is the most abundant. In several places in the two counties the upper part contains coquinas.

Distribution.—On the map showing areal geology (pl. 1) the base of the Fort Riley limestone and the base of the Winfield formation are shown. The area between these lines is occupied chiefly by the members of the Doyle formation, and the Gage shale occupies the western part of the band. At a few places the Winfield beds crop out within 0.25 mile of the Fort Riley outcrop, but that is an exceptional condition.

Detailed sections.—For sections of Gage shale see numbers 3, 22, 24, 26, 27, 30, 31, and 38 at the end of this report.

WINFIELD LIMESTONE

The term Winfield was introduced as a stratigraphic name by Prosser (1897, p. 64). He (Prosser, 1895, p. 772) had formerly called the same strata "Marion chert and concretionary limestone." He changed the name to Winfield because he had already erected the name Marion to include strata above those that he renamed Winfield. Although the name Winfield was applied because of exposures near Winfield in Cowley county, Kansas, Prosser's original type exposure near Marion in Marion county, Kansas, should still be regarded as typical for the formation. In northern and central Kansas the formation is clearly divided into three or (differentiating and including the Luta limestone) four members. These members are not so clearly defined in the southern part of the state. When the formation was first named and when the name was changed to Winfield the formation included three members, which are now known as (1) Stovall limestone, (2) Grant shale, and (3) Cresswell limestone. The Kansas Geological Survey now includes as a fourth member the limestone beds above the Cresswell limestone, *i. e.*, the Luta limestone, named by Beede (1908, p. 251). This uppermost member was formerly regarded as a part of the overlying Sumner group. The lower three members, to which Prosser believed he was applying the name Winfield, were named by Condra and Upp (1931, pp. 49-51). It is unfortunate that the formation does not bear the name of some place farther north than Cowley county, as the members are not very clearly separated in exposures near Winfield, although Condra and Upp (1931, p. 53) believed that they can be differentiated there and they distinguished them in a section studied there. These same geologists (Condra and Upp, 1931, p. 50) state that the Grant shale member "plays out between there (Winfield) and Arkansas City, Kansas." Arkansas City is about 12 miles south of Winfield in Cowley county. I have studied these strata in southern Kansas and have come to the conclusion that the upper part of the underlying Gage shale is represented there by thin fossiliferous limestones and calcareous shales below the more massive beds visible in the exposures near and in Winfield. Hence it might seem that the upper part of the Gage shale is really a part of the Winfield formation as described at Winfield. This opinion seems to accord with that of Bass (1929, p. 93) who states "The lower part of his (Prosser's) Winfield formation may then correspond to the uppermost part of the Doyle shale. . . ." The upper part of the Doyle shale is now known as Gage shale, but, as already explained, the formation was first described from exposures in Marion county, Kansas, and there the limestone that is now called Stovall is clearly the base of the formation. Bass (oral communication) has good evidence that the limestones that limit the strata originally included in this formation converge north of Cowley county.

The Stovall limestone, Grant shale, and Cresswell limestone members are well defined in Geary and Riley counties.

For several years strata called Luta limestone have been regarded as the basal member of the group of rocks overlying the Winfield formation. As already stated, the Kansas Geological Survey now regards these beds as constituting the uppermost or fourth member of the Winfield formation. I contend that these strata should be included with the more massive beds below them as a single member at the top of the formation. Although it is generally believed that Prosser did not include them in his "concretionary limestone" of the Marion and later the Winfield formation, it is probable that he did, for in northern Kansas they contain many more conspicuous concretions than do the more massive beds below them. In Riley and Geary counties these upper beds comprise about 10 feet of thin-bedded limestone and shale that contains many calcareous concretions and calcite-filled geodes, some of which are almost a foot in diameter. Locally this part of the stratigraphic section contains a shale bed as much as 5 feet thick. These concretion-bearing beds of limestone and shale have the same relationship to the more massive limestone beds below them as has the upper or middle part of the Fort Riley limestone to the more massive "rim rock." It is evident that unless there is an unconformity between the two series of beds, inasmuch as the shale break is not persistent, they comprise a single stratigraphic unit and might well be known under a single name. According to Boos (1929, p. 242), who studied the Luta limestone in southern Kansas, the Luta member rests conformably upon the Winfield limestone, the contact being slightly irregular. She indicated some differences in lithology. According to Condra and Upp (1931, p. 57) the contact of the Luta limestone with the Cresswell limestone is even, but is marked by a change from massive limestone below the earthy limestone above. Beede (1908, p. 253), in his section studied at the type exposure of the Luta limestone, did not show an unconformity. Students of Kansas stratigraphy know of many vertical changes in lithology and many irregular contacts within beds in the Pennsylvanian and Permian rocks and within stratigraphic units that are known by single member names. Very persistent strata exhibiting differences in lithology are present in the Fort Riley member. In this report these upper beds are described with the more massive ones below them as the Cresswell and Luta limestone members of the Winfield formation.

Stovall Limestone Member

The type exposure of the lower member of the Winfield limestone formation is situated on the Stovall farm 7 miles southwest of Florence, Marion county, Kansas (Condra and Upp, 1931, p. 49).

Lithologic character and thickness.—In Riley and Geary counties the base of the Winfield formation is marked by a flinty limestone, the maximum thickness of which is 18 inches. This is the Stovall limestone. The flint content is characteristic of the member throughout the area. Like the other flinty limestones, the Stovall limestone is nonresistant to weathering. The flint is not greatly different from that in lower flint-bearing limestones. The limestone itself is generally light in color, but in a few places it is light yellow mottled with dark, partly silicified areas. The flint commonly forms one or two bands within the limestone. Fossils are not abundant, but Productids, echinoid spines, Rhomboporoids, and a few others are noticeable.

Distribution.—The members of the Winfield limestone formation are exposed in the western part of both counties and in northern Riley county. The outcrops of the three or four members are generally very near each other. The limestones form more outliers than do any others of the area except perhaps the Florence limestone. On the high area above the escarpment of the Fort Riley limestone are many small buttes held by the resistant Cresswell limestone. The Stovall occurs about 10 feet below and very near the Cresswell outcrop. The Grant shale is commonly exposed between them. The base of the Winfield formation is indicated on the map showing areal geology (pl. 1). Hence the line showing the base of the formation is the line of outcrop of the Stovall limestone.

Detailed sections.—For sections of the Stovall limestone see numbers 3, 4, 7, 13, 18, 22, 24, 25, 26, 27, 30, 31, 33, 34, 37, 38, and 55 at the end of this report.

Grant Shale Member

The name Grant shale for the middle member of the Winfield formation comes from Grant township in Marion county, Kansas (Condra and Upp, 1931, p. 50).

Lithologic character and thickness.—This member is exposed in many places in the two counties. Locally it is somewhat calcareous, but that is an unusual phase. The thickness ranges from 9 to 12 feet, but is commonly approximately 10 feet. *Derbyia crassa* is the most common fossil, but *Myalina* sp. and Productids are common.

The distribution of the Grant shale is the same as that of the Stovall limestone previously discussed. Plates 16B and 17 show views of the Winfield limestone.

Detailed sections.—For sections of the Grant shale see numbers 3, 4, 7, 13, 18, 25, 26, 27, 30, 31, 33, 34, 37, 38, and 55 at the end of this report.

Cresswell and Luta Limestone Members

The name Cresswell was given by Condra and Upp (1931, p. 51) to the third member of the Winfield formation from exposures in Cresswell township in Cowley county, Kansas. The type exposure

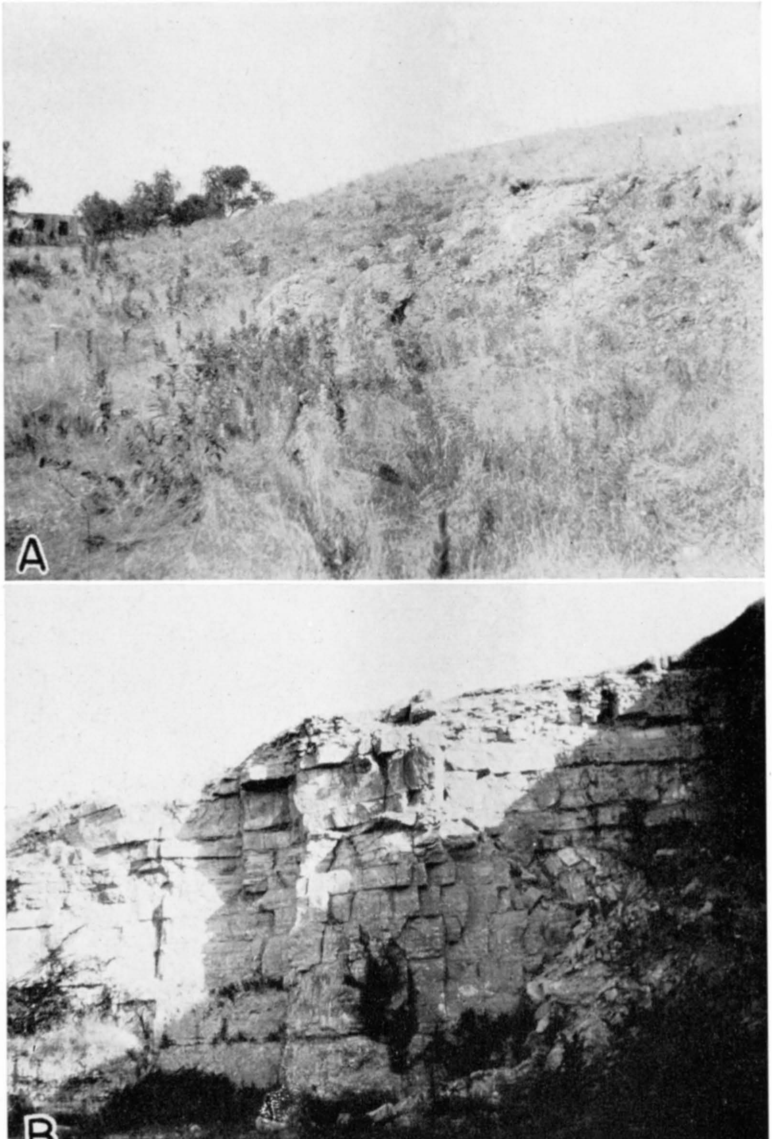

PLATE 15. A, A portion of a small hill, physiographic expression of an igneous intrusion, sec. 6, T. 9 S., R. 5 E., Riley county. B, An exposure of Barneston limestone in an old quarry, sec. 20, T. 11 S., R. 5 E., Geary county.

is near Arkansas City. It seems that an exposure farther north, in some place where there can be no dispute concerning the correlation of the distinct units as they are in Marion county and elsewhere, would be more fitting as the typical exposure. There is some doubt as to whether the first and third (ascending) members of the formation converge in Cowley county or farther to the north. In this report the terms Cresswell and Luta are used to designate the limestone beds above the definitely defined Grant shale. These beds obviously belong within the same formation with the Grant shale and the underlying Stovall limestone. As already stated, the name Luta has been applied to beds of limestone and calcareous shale that were formerly included in the overlying group of rocks, but that are now regarded as part of the Winfield formation. It may be that these beds were included by Prosser in his "Marion concretionary limestone," although it has been generally supposed that he excluded them and applied that name only to the more massive underlying beds that Condra and Upp have correlated with the Cresswell limestone at its type exposure near Arkansas City. The type exposure of the Luta beds is situated about 5 miles northeast of Marion, Kan., on Chicago, Rock Island, and Pacific Railroad. The name is from Luta brook (Beede, 1909, p. 251). I repeat that it would be better that a single name be employed to designate these upper beds of the Winfield formation.

Lithologic character and thicknesses.—The lower part of this succession of beds is a very persistent, resistant, light-colored limestone generally less than 3 feet thick. Where weathered it commonly shows reddish-brown splotches. There are many fragments of fossils; echinoid spines are especially abundant. The fossil fragments are resistant to weathering and project in relief on the weathered surfaces. The thickness of this massive part ranges from about 1.5 to 3 feet. In a few places, notably in the western part of Riley county, the lower, massive part forms cliffs that rival those of the Fort Riley "rim rock." Overlying this limestone are thinner beds of limestone, which characteristically contain calcite concretions and geodes. This zone of thinner beds locally contains shale; in sec. 31, T. 7 S., R. 6 E., there is as much as 5 feet of shale in this part. The shale there is underlain by about 2 feet of thin-bedded limestone and overlain by almost 10 feet of similar limestone. Generally where present the shale contains concretions. The thickness of this, the part above the massive beds, is generally about 14 feet. In all probability the upper part of this formation, consisting of thin-bedded limestone and shale, comprises what has been generally called Luta limestone. The lower, massive part is what has been called Cresswell limestone.

Distribution.—The general distribution of the members of the Winfield formation is discussed under the discussions of the distribution of the Stovall limestone and of the Grant shale.

Detailed sections.—For sections of the Cresswell and Luta limestones in which more details are presented see numbers 3, 4, 7, 13, 14, 18, 21, 25, 26, 27, 30, 31, 33, 34, 37, 38, and 55 at the end of this report.

ODELL SHALE

Beede (1908, p. 253) applied the name Enterprise shale to all strata between the top of the Luta limestone and the base of the Herington limestone. He regarded those strata as comprising a member in Prosser's Marion formation. The term Marion formation was applied to all strata between the top of the present Winfield formation and the top of the Pearl shale. Neither the former Enterprise shale member nor the Marion formation are now regarded as useful divisions and hence are excluded from the present classification. The Odell shale member comprises the lower part of the old Enterprise shale and lies between the top of the Winfield formation and the base of the Krider limestone, which lies about 11 feet below the base of the Herington limestone. The name Odell comes from the town of Odell, Gage county, Nebraska (Condra and Upp, 1931, p. 59).

Lithologic character and thickness.—The lower part of the Odell shale is mostly yellow and gray shale containing some calcareous beds, and the middle and upper parts are varicolored, the more brightly colored materials predominating in the middle part. Of colors other than gray and yellow, red is dominant, and the green, purple, and even blue to be seen in shales somewhat lower in the section are almost or quite absent. The thickness is variable, ranging from about 20 feet to 40 feet. The average thickness is probably not much greater than 20 feet. Fossils are rare or absent.

Distribution.—The Odell shale occupies a large area in northwestern Riley county and it underlies a fertile soil. It seems to me that the Odell shale and the higher Paddock shale form better soil than do the Holmesville and Gage shales lower in the section. The area underlain by the Odell member lies west of and above the line of outcrop of the base of the Winfield formation, which is indicated on the map showing areal geology. The greater part of the area represented between the line showing the base of the Winfield formation and the line showing the base of the Nolans limestone is occupied by Odell shale.

Detailed sections.—Sections 4, 7, 14, 19, 20, 21, 25, 26, and 28 at the end of this report include the Odell shale.

NOLANS LIMESTONE

Not far below the base of the Herington limestone is a persistent limestone member, which was called Krider by Condra and Upp (1931, p. 60). Inasmuch as this limestone bears the same cyclic relationship to the Herington as the lower member of the Winfield formation bears to the overlying Cresswell limestone, it is fitting that the Kansas Geological Survey has included these limestones and the intervening shale member in a single formation. This is called the Nolans formation (Moore, 1936b, pp. 5-9). It may be defined as including, in ascending order: (1) Krider limestone, (2) Paddock shale, and (3) Herington limestone. The term Nolans comes from a railway siding near Emmons, Washington county, Kansas.

Krider Limestone Member

The type exposure of the lower member of the Nolans formation is near Krider in Gage county, Nebraska (Condra and Upp, 1931, p. 60).

Lithologic character and thickness.—The Krider limestone is well exposed in many places in the northern part of Riley county. In numerous roadside exposures it can be seen about 11 feet below the thicker beds of Herington limestone. It ranges from a hard gray limestone to a sandy-appearing yellowish-brown limestone and locally is very nodular. Locally, and probably characteristically, there are two beds of limestone separated by a shale bed not more than 1 foot thick. It contains a few brachiopods, and pelecypods are common. The thickness ranges from 1 to 2 feet or slightly more.

Distribution.—The Krider limestone is exposed in many places in Riley and Geary counties and lies about 11 feet below the Herington limestone. Its position can be easily determined because of the noticeable red shale of the Odell formation. On the map showing areal geology its position is shown as the base of the Nolans formation. Its line of outcrop is many miles long in the escarpment held by the formation and it is present with the other members of the formation in a few outliers in northern Riley county. It occupies a small area in western Geary county.

Detailed sections.—For sections including the Krider limestone see numbers 4, 7, 14, 19, 20, 21, 25, 26, and 28 at the end of this report.

Paddock Shale Member

The Paddock shale, a stratigraphic unit between the underlying Krider limestone and the overlying Herington limestone, was named by Condra and Upp (1931, p. 61) from exposures in Paddock township, near Krider, Gage county, Nebraska.

Lithologic character and thickness.—This unit is very distinctive in Riley county, as it consists of gray shale containing layers and stringers of calcite, and near its upper part there is an abundance of fossil pelecypods. The most prominent of the fossils is *Aviculopecten* sp. The average thickness of the member is approximately 11 feet but as much as 13 feet was measured locally.

Distribution.—The distribution of the members of the Nolans formation has been discussed and is also described under the discussion of the Herington limestone.

Detailed sections.—For sections in which more details of the Paddock shale member are presented see sections 4, 7, 14, 19, 20, 21, 25, 26, and 28 at the end of this report.

Herington Limestone Member

The Herington limestone, now known as the upper member of the Nolans formation, was named by Beede (1908, p. 253) from Herington, Dickinson county, Kansas. It is easily traced as a stratigraphic unit across Kansas.

Lithologic character and thickness.—The limestone is resistant to weathering and hence holds an escarpment and small buttes. It is yellow and sandy-appearing. Locally, the pelecypod fauna of the underlying Paddock shale ranges into the Herington limestone. The exact thickness of this limestone is difficult to determine, but it is probably 6 or 7 feet. Locally, the lower 2 or 3 feet of the limestone is very shaly, and the more resistant massive layers overlie this zone.

Distribution.—As already stated, the members of the Nolans formation occupy a wide area in northern Riley county and a small area in western Geary county. The line on the geologic map showing the base of the Nolans formation is nearly the same as the line of outcrop of the base of the Herington member, as the zone of outcrop of the thin Krider limestone and the nonresistant Paddock shale members is very narrow. The members of this formation are suitable key beds in mapping the structural altitude of strata in the territory in which they are exposed.

Detailed sections.—The Herington limestone is included in sections 4, 7, 14, 19, 20, 21, 25, 26, and 28 at the end of this report.

LEONARD SERIES

The Kansas Geological Survey has adopted the term Leonard as the name of the second series from the base in the Kansas Permian section, in accordance with the classification of the North American Permian rocks published in 1939 by Adams and others (1939, pp. 1673-1681). The base of the Leonard series in Kansas is somewhat arbitrarily placed at the top of the Nolans formation, which is the top of the Herington limestone. As already explained, the Odell shale and Nolans limestone are lithologically similar to the beds lower in the Chase group and hence there is no reason for placing a group or series boundary in this part of the section lower than the top of the Herington limestone.

Sumner Group

The term Sumner, from Sumner county, Kansas, was introduced as a stratigraphic name by Cragin (1896, p. 9). He defined the "division" as including strata between the "Marion concretionary limestone" and the "redbeds." This placed the lower boundary at the top of the Winfield formation. Bass (1929, p. 93) defined the group to include the Luta limestone, the Enterprise shale, the Herington limestone, and the Wellington formation. The first three of these names had been introduced by Beede (1908, p. 253), and at the same time Beede had introduced the name Pearl shale for strata lying between the Herington limestone and the Wellington formation as it had been defined by Cragin in 1896. Bass did not recognize the Pearl shale as a natural unit and redefined the Wellington formation, fixing its base at the upper surface of the Herington limestone. Condra and Upp (1931, p. 63) believed that the Pearl shale is a well-defined unit and that it is overlain by a persistent limestone, which they named Hollenberg and which later was called the basal member of the "Donegal formation" by Moore, Newell, and Elias (1934). The "Hollenberg" limestone is several scores of feet below the top of the Pearl shale as defined by Beede. Recent studies by Moore, however, reveal that it is not certain that the "Donegal formation" is well defined, and hence the Wellington formation is now understood to lie directly above the Herington limestone and is not definitely divided into smaller units.

As already explained, the base of the Leonard series is placed at the top of the Herington limestone. The Sumner group, as the term is now being used, lies between the Herington limestone and the Harper sandstone. It comprises the Wellington shale, Ninnescah shale, and Stone Corral dolomite. The lower 45 or 50 feet of the

Wellington shale is present in the extreme northwestern part of Riley county. Permian beds above the lower part of the Wellington shale were eroded from western Riley county before Cretaceous sediments were deposited.

WELLINGTON FORMATION

The term Wellington was introduced as a stratigraphic name by Cragin (1896, pp. 16-18). The original definition placed the base of the formation at the top of the "Geuda salt" (within the Wellington formation as now defined) and the top was placed at the base of the Harper sandstone. The base of the Harper sandstone is now regarded as the top of the Sumner group. As explained under the heading, Sumner group, Beede applied to the strata between the Herington limestone and Cragin's Wellington formation the name "Pearl shale." Bass (1929, p. 99) redefined the Wellington formation as extending downward to the top of the Herington limestone. Later, Condra and Upp redefined the "Pearl shale" as lying between the top of the Herington limestone and the base of the "Hollenberg limestone"; and the Kansas Geological Survey later erected the "Donegal formation," of which the "Hollenberg limestone" was the lowest member. According to such a classification the present Sumner group includes in ascending order: Pearl shale, Donegal limestone, and Wellington shale, each as a formation. Recent investigation by Moore (oral communication), however, throws doubt on the validity of such a classification, and now the Wellington formation is regarded as conforming to the definition of Bass and it is not deemed expedient to subdivide the formation until more detailed studies can be made.

In the northwestern part of Riley county about 45 feet of variegated shale is exposed above the Herington limestone. Next above this shale is a few feet of limestone and shale that probably correlates with limestone that has been called "Hollenberg." Hence this shale comprises the lower part of the Wellington formation as it is now defined.

Lithologic character and thickness.—The lower part of the Wellington shale formation in western Riley county is predominantly red, but there are noticeable amounts of gray and green shale. The shale is well bedded and is blocky. It consists of very fine silt and clay particles. The thickness of the variegated shale lying between the top of the Herington limestone and the next limestone above is approximately 45 feet. The limestone just mentioned is yellow and earthy where exposed. It contains casts of small pelecypods. The observed thickness is 6 inches. Sandstone of the Dakota group lies upon this limestone.

Distribution.—The beds assigned to the lower part of the Wellington formation crop out only in secs. 1 and 2, T. 6 S., R. 4 E., in the northwest corner of Riley county. It is probable that a few feet of Wellington shale is present under soil cover in a fairly large area in northern and western Riley county in the uplands above the Herington limestone.

Detailed sections.—For a detailed section including a part of the Wellington shale see number 1 at the end of this report.

CRETACEOUS SYSTEM

Dakota Group

Coarse ferruginous quartz sandstone, identified as belonging to the Dakota group is present on the uplands in the extreme northwestern portion of Riley county. This rock lies disconformably upon Permian strata and in one exposure can be seen to rest upon a few inches of limestone approximately 45 feet above the Nolans formation. Exposures of Dakota sandstone *in situ* in the two counties are believed to be confined to secs. 1 and 2, T. 6 S., R. 4 E., in Riley county. The contact between Permian and Cretaceous sediments is shown on the geologic map (pl. 1).

About 2 miles west of Junction City in Geary county the extremely sandy soil on the uplands above the Fort Riley limestone seems to be residue from weathered Dakota sandstone and the same kind of soil is present on uplands above the Towanda limestone about 5 miles northwest of Junction City. It is possible that Cretaceous beds are concealed by soil in those places. It should be noted that Hay (1896, p. 23) reported finding Dakota sandstone 2 miles west of Junction City and showed two areas marked "Cretaceous outcrop" a short distance south of Junction City on the map accompanying his report on the Fort Riley Military Reservation. It is possible that bed rock has been transformed into sandy soil during the years since Hays studied there. The known facts, however, point to the conclusion that erosion had lowered the Paleozoic beds almost to the horizon of Fort Riley limestone or even lower before Cretaceous deposition, and that the Dakota sediments overlap the Permian from the west.

TERTIARY SYSTEM

During my field studies in the two counties I did not identify Tertiary sediments, but it must be mentioned that Hay reported rocks younger than Cretaceous occurring as bed rock within this area. In his paper of 1896 he described a "mortar-bed-like conglomerate" resting upon shale, which lies probably in the upper part of the Garrison formation. He reported it to be 30 feet above a river bed and east of the 97th meridian and within the area of his report, the limits of which are somewhat indefinite, but enclose only the vicinity of Fort Riley. He concluded that the deposit is "preloess if not actually Miocene." I have seen well-cemented gravel, which is mostly flint, in the higher parts of the valley fillings near the major streams in Riley and Geary counties. Such gravels and conglomerates now form the stream terraces, which are higher than the more recent alluvial deposits, and I regard them as being Pleistocene in age.

About 40 feet above drainage in the valley of Deep creek in southeastern Riley county south of Zeandale is a terrace consisting of several feet of water-worn flint gravel. This material is overlain by a deposit of northern erratics of undoubted Pleistocene age and it is probable that the flint gravel bed is an earlier Pleistocene deposit.

QUATERNARY SYSTEM—PLEISTOCENE SERIES

The area described in this report lies along the border of the glaciated plains and evidence of ice invasion is not lacking. The area in which glacial drift is present is not extensive and no attempt was made to show drift on the map showing areal geology. Drift is present in two areas in conspicuous quantities, both as fine material and as great boulders of quartzite as large as 12 feet in diameter. One is an area in Riley county south and east of Deep creek in secs. 27 and 34, T. 10 S., R. 6 E. There the drift overlies Tarkio limestone and a flint gravel deposit. Boulders of deeply weathered quartzite as large as 12 feet in diameter occur there. The other is an area in the northeastern part of Riley county and extends southward skirting the eastern edge of the uplands above Big Blue river as far as Manhattan. No glacial till was identified and no glacial striae on bed rock were observed, so direct evidence of ice invasion is lacking, but it is very probable that the large boulders were actually deposited by ice.

The glacial drift was probably deposited in the Kansas stage of Pleistocene time, although the deep weathering of quartzite boulders might suggest earlier deposition, *i. e.*, the Nebraska stage.

LOESS

Loess, wind-blown clay and fine sand, in large or small quantities is associated with almost all of the larger streams in the area and especially in the part north of Kansas river. The loess is wind-blown material, which was probably first deposited on the flood plains of streams swollen by the melting of glacial ice, but which was later moved and redeposited on higher ground by the wind. The loess is not restricted to that part of the two counties that is north of Kansas river, but the greater amount of it is to be found there. The largest areas covered by this material are situated near Manhattan, Ogden, and Fort Riley. There the loess generally modifies the prevailing type of topography and partly obscures the exposures of harder rock. The thickness of the loess is probably nowhere more than 50 feet and generally is much less. This loess contains an appreciable amount of very fine sand, estimated at 15 percent or less, and most of the rest is silt and clay. An area lying north of Ogden on each side of Sevenmile creek and extending westward beyond Threemile creek is the largest expanse of loess-covered territory within the two counties. The present altitude of the loess ranges between approximately 1050 and 1200 feet above sea level. It constitutes one of the best kinds of soil in this part of Kansas.

In Riley county the loess has been mapped (Carter and Smith, 1908) with the other soils and it is called "Marshall silt loam." In the report that accompanies the soil map it is said to be an alluvial deposit and is explained as being a lacustrine-lake deposit. The absence of bedding and the sizes of the particles, however, lead me to believe that this material was deposited by wind. Similar deposits are still accumulating although the source is mostly cultivated fields rather than river flood-plain deposits. The loess is probably partly Pleistocene and partly Recent in age. As mentioned in another part of this report, there are remnants of former valley fillings that may be in part lake deposits. These are bedded and are now exposed in terraces above the present river flood plains; hence they differ from those that are described as being loess.

A deposit of water-worn flint gravel several feet thick in Deep creek valley in southeastern Riley county, has been shown on the accompanying geologic map along with other alluvial deposits. As explained, these flint gravels are probably early Pleistocene in age.

RECENT DEPOSITS

On the map showing areal geology (pl. 1) the flood-plain deposits of the major streams are shown as *alluvium.* As stated elsewhere in this report, almost all of the streams have developed flood plains, but the nature of the deposits along the smaller streams is very different from the sandy alluvial material in the flood plains of Kansas, Big Blue, Republican, and Smoky Hill rivers. In the valleys of the smaller streams the flood-plain material has been accumulated primarily by the downwash of weathered shale and loess from the valley walls, although in part it comprises material deposited when more active sedimentation was in progress during and soon after the glaciation of the area not far to the northward. In the valleys of the major streams, the alluvium near the surface is silt, very fine sand, and sand, but at greater depth coarser material predominates. The average thickness of alluvial deposits along the larger streams is perhaps 50 feet. The thickness is generally much less in the valleys of the smaller streams. This material occupies narrow belts along the streams and these belts range in width from a few scores of feet to a few miles.

The residual soil, which is described hereinafter under the heading Economic Geology, is a part of the recent deposits of the two counties, and as previously explained, the loess is partly of Recent origin.

IGNEOUS ROCK

In three places in Riley county igneous rock, obviously intruded from below, is exposed at the surface: in sec. 6, T. 9 S., R. 5 E., in sec. 23, T. 8 S., R. 6 E., and in sec. 22, T. 8 S., R. 5 E. All three of these bodies are similar, and consist of dark-green fine-grained ground-mass of igneous rock containing many fragments of the neighboring sedimentary rock.

The exposure in sec. 6, T. 9 S., R. 5 E., is situated near the northwest corner of the section, between a railroad and highway, and about 1 mile east of Bala. This exposure is frequently called the Riley county igneous exposure, but inasmuch as there are at least two other bodies of igneous rock exposed at the surface in Riley county it should be called the Bala igneous exposure. The rock was described by Moore and Haynes (1920, pp. 183-187) and they gave credit for its discovery to T. S. Harrison of Denver, Colo. The rock is an igneous breccia or agglomerate comprising a ground-mass of basalt and inclusions consisting principally of shale in various stages of alteration. Fissures caused by jointing have become filled with calcite. The presence of the rock is expressed physiographically by a rounded knoll about 10 feet high and less than an acre in extent. The exposures are confined to small areas on the west and north sides of the hill. The age of the rock is probably Cretaceous. The contact with surrounding country rock is not exposed, but about 0.1 mile west of the exposure the Stovall limestone member of the Winfield formation is sharply folded and about 0.25 mile west of the outcrop the members of the Winfield formation are cut by a small fault. Folding and faulting of minor magnitude are somewhat common in that area, however, and the condition is probably not due to igneous intrusion. Along the west side of sec. 33, T. 8 S., R. 6 E., about 8 miles east of the Bala exposure and about 5 miles southwest of the igneous body near Stockdale, the Winfield beds are strongly crumpled and faulted. The nature of the rocks underlying this area is not known as there are no entrenching streams nearby. It is probable that solution of some underlying beds has caused this condition, although it may be due to igneous rock intrusion.

Another body of igneous rock is exposed in Riley county in sec. 23, T. 8 S., R. 6 E., about 5 miles northwest of Stockdale. It is about 0.25 mile west of the east end of the east-west line that bisects the section. The exposure was discovered several years ago by Professor G. H. Failyer of Manhattan. The igneous mass is exposed in a stream bed in an area about 50 by 150 feet, and seems to be only slightly more resistant to erosion than is the surrounding Holmesville shale. The contact with surrounding sedimentary rock is not exposed, so it is not definitely known that the igneous body is intrusive rather than a surface flow. Its position in the stream, however, indicates that it is not a flow on the present topographic surface. The rock is exposed in a small stream that is cutting the Holmesville shale. The Towanda limestone caps the hills on each side of the stream and about 20 feet above it. The rock is an igneous breccia or an agglomerate; a ground mass of dark-green material contains a great many inclusions of sedimentary rock in various stages of alteration, and shale, flint, and limestone can be recognized in hand specimens. Numerous crystals of wine-colored garnet are present, but they are small and are badly shattered. Some joints are filled with calcite. The rock is weathering rapidly into small fragments. One fragment of granular igneous rock composed principally of quartz, but containing a minor amount of ferromagnesian minerals, was

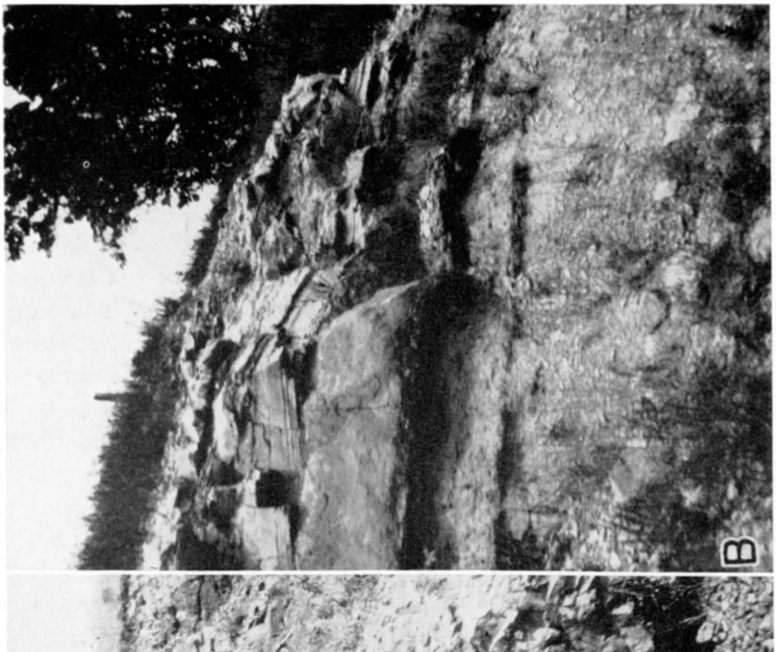

PLATE 16. A, An exposure of basic igneous rock, sec. 6, T. 9 S., R. 5 E., Riley county. B, An exposure of Winfield limestone, sec. 1, T. 9 S., R. 4 E., Riley county. Grant shale in the lower part of the picture and Cresswell-Luta limestone in the upper part.

found at the outcrop. This suggests that possibly two generations of igneous rock are present there.

A third body of igneous rock similar to the two just described has been found in sec. 22, T. 8 S., R. 5 E.

The igneous rock is shown on the geologic map (pl. 1). Plates 15A and 16B show views of the Bala igneous exposure. Plate 17 shows the faulted Winfield limestone beds near the Bala igneous exposure.

STRUCTURAL GEOLOGY

No attempt was made to construct a map showing primarily the attitude of rock layers. To do so would be a simple engineering project, as there are numerous good "key beds," and the intervals between prominent limestone beds are remarkably constant. Geologists of several oil-producing companies have worked in the two counties and it is very probable that accurate information concerning geologic structure is available to those persons most interested in having it. For that reason the structure is discussed in only a general way and from the viewpoint of those features that were obvious to me when I made the areal geologic map.

The consolidated rocks are structurally included in the Prairie Plains monocline, *i. e.*, beds dipping westward or slightly north of westward from the Ozark plateau. The general inclination is about 30 feet per mile. This dipping of beds can be plainly observed; for example, the Cottonwood limestone high on the hills at Manhattan disappears under the alluvial filling of Kansas river valley a short distance west of Eureka Lake (Odd Fellows' Home), and the Fort Riley limestone descends nearer and nearer the floor of the river valley as one goes westward from Junction City along Smoky Hill river. Other beds of stratified rock are approximately parallel to those just cited. There are minor distortions in the position of the layers of rock, and hence in places the general westward dip is steepened or locally the beds dip in some other direction. In southeastern Riley county there is a structural dome or anticline and the valley of Deep creek is superposed upon it. This upwarping of strata is nearly in superposition on the buried Nemaha Mountains and is a part of the anticlinal structure that crosses the state above the buried mountains. From the distribution of outcrops in relation to topography it seems that the crest of the fold in Deep creek valley is probably a few miles southeast of Zeandale, but the alluvium of Deep creek valley has obscured the bed rock over an extensive area, so the statement must be qualified. Exposures in the Flint Hills west of Zeandale show a steep westward dip and the rocks there lie upon the west limb of the Deep creek fold. Plate 4A shows this condition.

The buried mountains occupy a band a few miles wide crossing Kansas from Cowley county to Nemaha county, along which the surface of the very ancient crystalline rocks, above which were deposited younger stratified sediments, is much higher and hence much nearer the present land surface than it is on either side. The mountains were described by Moore and Haynes (1917, p. 173) and are well known to all students of the subsurface geology of the Mid-continent region. The Nemaha Mountains extend well into Oklahoma and into Nebraska. The mountains were named Nemaha because they are not many hundreds of feet below the surface in Nemaha county, Kansas. Many geologists have discussed the probable origin of the superposed folds in relation to the buried topography. It is very probable that the flexures in rock layers above the buried hills and valleys are at least partly due to differential compaction and settling of the younger rock layers above the rigid crystalline rocks forming the uneven surface below. It is likewise probable that the distortion is partly due to tangential compressive forces acting on the rocks. Bass (1929, pp. 126-128) has discussed the origin of structural features in southern Kansas, and inasmuch as structural features above the buried hills in Riley county are very similar, his discussions should be consulted by those who are concerned with the origin of the folds in the area of this report.

There is a noticeable arching of beds in the vicinity of Winkler, in northern Riley county in the southeast part of T. 6 S., R. 6 E. Near the town, exposures of Florence limestone in the Barneston formation show that the Wreford limestone beds must lie well below the surface of the alluvium of the flood plain of Fancy creek; but only a short distance westward the Wreford formation lies well above the almost flat flood plain, and still farther westward it dips below the stream again. The same reversal of dips can be plainly seen in the bluffs forming the walls of Fancy creek valley and even more plainly along streams tributary to Fancy creek on the north. As the base of the Wreford formation is indicated on the map showing areal geology, the arch near Winkler is indicated on the map by an inlier of the Wreford formation along Fancy creek. The fold described here is a part of the Abilene anticline, which extends from a point near Kingman in Kingman county in the south-central part of Kansas northward into Nebraska. In Nebraska it is commonly called the Barneston arch. Probably it is no more acute near Winkler than elsewhere along its axis, although elsewhere the flat topography may not reveal the arching so well.

A considerable amount of faulting on a minor scale has occurred in the region of the Abilene arch. In several road cuts, especially in T. 6 S., R. 6 E., exposures of Towanda and Winfield beds show many small normal faults, having a few feet of throw. Reverse faults, one of which has an apparent throw of about 11.5 feet, are exposed in a railroad cut in sec. 1, T. 9 S., R. 4 E. There the apparent angle of faulting is about 22 degrees, and the strata are overthrust to the westward. Because many of the better exposures in an area of several square miles exhibit faulting, it may be assumed that there are many concealed faults. Plate 17 shows the faulted rock layers in sec. 1, T. 9 S., R. 4 E.

ECONOMIC GEOLOGY

Soils

The natural resources of greatest value in Riley and Geary counties are the soils. Soil is derived primarily from disintegrating rock, hence the properties of the soils depend upon the rock from which the soils are derived. A large part of this area, however, is covered with a mantle of soil that was not derived from rocks that disintegrated where the soil now is found. In other words, many soils are not residual, but have been transported from a distance and hence are called transported soils. Materials comprising such soils have been moved by running water, wind, creeping ice, or even by the pull of gravity down steep slopes. Of the eight types of soil mapped by the United States Department of Agriculture (Carter and Smith, 1908) in Riley county, only two are called residual, the other six being regarded as transported. It is plain, however, that the underlying rock does have an important bearing on the agricultural productivity of a large part of the two counties.

Soil is composed of particles of rock in various stages of decomposition, matter derived from the decay of organisms, low forms of plant and animal life, and gases. Hence a soil may well be regarded as a mineral framework, the particles of which are coated with matter, much of which is probably colloidal. No doubt there are many controlling factors that determine the qualities of a soil. Climate must be very important and it is plain that the composition of

PLATE 17. Faulted Winfield beds, sec. 1, T. 9 S., R. 4 E., Riley county. The Stovall limestone is overthrust toward the west.

the parent rock is only one of many factors. The components of transported soils characteristically are sorted or selected as to kinds of material or as to grain size within certain limits. The water-deposited soils are principally composed of sand or even gravel whereas wind-deposited loess consists of silt and clay or extremely fine sand.

In the two counties residual soil produced chiefly by the weathering of shales is the most important in number of acres covered. Associated with it is soil derived from weathered limestones. This too is residual, but it is stony and hence poorly suited to agriculture. In number of acres covered, this stony soil is perhaps second. This is the type that supports the extensive pastures in the Flint Hills and occasions the name "Blue-stem belt." The more tillable residual soil derived from shales is almost confined to the area above and west of the Flint Hills; the stony residual soil to the Flint Hills; the wind-deposited loess, by superposition, to the steep slopes; and the water-deposited soils to the river valleys, but at least small areas of each of these soils are found in all parts of the two counties. In fertility the soils of the stream valleys, which specialists divide into several types, perhaps rank first, and the loess ranks second. The alluvial soils in the valleys of the major streams are very different from those in the valleys of the smaller creeks. In the latter, much of the soil has been produced by the weathering of near-by rock and by the erosion of loess from the valley walls or near-by areas. In part, this creek-bottom soil is colluvial rather than alluvial.

The soils of the two counties may be roughly correlated with the topography and classified with it as (1) that of the uplands, (2) that of the valley walls, including the superposed loess, and (3) that of the river valleys. Upland soil is adapted to cultivation of small grain, corn, alfalfa, sorghums, and prairie hay; stream valley soils are adapted to production of corn, alfalfa, and truck corps according to the soil types; valley walls are generally uncultivated but are valuable grazing lands. Loess is suitable for growing vegetables and small fruits, but is commonly utilized in growing general farm crops.

Building Stone

Abundant limestone suitable for building stone is available in the two counties. Only a small amount is being quarried, but great quantities have been quarried in the past. The Cottonwood, Fort Riley, and Neva limestones have been most extensively quarried, although a few others, such as the Falls City limestone, have been used locally. Neva and Cottonwood limestones have been quarried in great quantities in and near Manhattan. Most of the buildings of

Kansas State College are made of these rocks, principally of Cottonwood limestone. At Junction City and at Fort Riley much Fort Riley limestone has been used in buildings. There are now more suitable quarry sites along the exposure of Fort Riley limestone than along the exposures of the other workable ledges. Cottonwood limestone is the most satisfactory for use as building stone; Fort Riley limestone is perhaps second. Flinty limestones in the Wreford formation and Florence limestone are not suited to the making of dimension stones. Massive, non-flinty ledges in the Wreford formation, and massive ledges in the Cresswell limestone afford much material suitable for building stone. In southeastern Riley county the Eiss limestone member of the Bader formation is suitable for building blocks.

Limestone for Other Purposes

Limestone is put to many uses other than the fashioning of building blocks. It is one of the raw materials from which various kinds of cement are manufactured; it is used as a flux in blast furnaces and in metallurgy; it is used in the making of lime, agricultural limestone, concrete aggregate, ballast, and riprap and rubble; its products are used for refining sugar, manufacturing refractories, paper, and glass, and for making whiting and fillers. It is one of the materials in filter beds. There are great quantities of limestone in the two counties and undoubtedly much of it is adapted to some of these uses. At present much limestone is being quarried and crushed for use as road metal.

Clay

Clay in the form of shale and loess is available in great abundance in Riley and Geary counties, and although the material is not being used for industrial purposes it is perhaps well adapted to some uses.

Raw Material for Cement Manufacture

Portland cement is made from limestone or some other form of calcium carbonate, clay or shale, and a comparatively small amount of gypsum. The first two, which are the important raw materials, are present in the two counties in almost unlimited quantity. Many years ago cement was made at Manhattan, but the plant was dismantled long ago. Cement, like other bulky products made from cheap raw material, can be made at a profit only near a sufficient market. Should there be an increase in the demand for cement, owing to extensive paving or other uses, quarry sites are available near adequate shipping facilities. Of course, the raw material should be tested before extensive plans are made. As in the taking of other earth materials from an open mine, in the quarrying of limestone and shale for cement-making the amount of overburden that must be removed is an important factor, but the topography of Riley and Geary counties is such that numerous sites are available in which the removal of overburden would not be expensive.

Raw Material for the Manufacture of Rock Wool

Rock wool is a mass of fibers formed by passing air or steam through a stream of molten rock material of proper composition. The molten material is broken into small droplets by the blast of steam or air and the droplets are drawn out into fine threads as they are propelled through the air. The threads freeze into glassy fibers. According to Landes (Plummer, 1937, p. 5) rock wool is composed of silica and lime in approximately equal proportions. Alumina may be present with the silica, and magnesia with the lime, but neither of these two oxides is essential. The chief use of rock wool is for heat insulating.

A few years ago Norman Plummer, ceramic geologist of the Kansas Geological Survey (Plummer, 1937), investigated the rock wool resources of Kansas. He collected samples from all the promising rock formations in the state and from widely scattered areas. The samples were tested in an experimental plant at the University of Kansas. Plummer's report shows that the resources of the state in raw materials suitable for making rock wool are almost unlimited. Artificial mixtures of limestone, shale, loess, and alluvial clay were found to be satisfactory. Some Kansas rocks are natural "woolrocks," containing the proper mixture of lime and silica.

Plummer (1937, pp. 41-43) tested samples collected in Geary county in the SW ¼ sec. 21, T. 12 S., R. 5 E., southwest of Junction City. A very fine, white wool containing only a small amount of shot was made from a mixture of Florence limestone, Oketo shale, Fort Riley limestone, and alluvial clay. A somewhat coarser wool was blown from the Florence limestone without additional material. It is probable that the Florence limestone could be used as a natural "woolrock" if a temperature somewhat higher than that employed for the test were used (Plummer, oral communication).

In Kansas the fuel best adapted for making rock wool is natural gas. In Riley and Geary counties pipe lines connect the principal cities with the large gas fields farther southwest in Kansas.

Coal

With the exception of a very thin seam of coal in the lower part of the Permian beds in eastern Riley county, no coal was seen during the course of my field studies in the two counties. Hay (1896, pp. 17 and 21) reported a seam of coal 12 inches thick exposed at one place on Humboldt creek and another, slightly lower stratigraphically, a few miles away. According to his sections the horizon of the one bed seems to be not far from the base of the Wreford formation. Unfortunately he did not state an exact location, and although I have seen many good exposures of the base of the Wreford formation and of the strata above and below that horizon, I saw no coal. The coal reported by Hay must be very local in occurrence. The coal seen by me in eastern Riley county is so thin that it is not economically important.

Oil and Gas

Subsurface Rocks.—On previous pages I have discussed only those rocks that are exposed in Riley and Geary counties. It may be noted from the discussion and from the correlated stratigraphic sections and from the geologic map that the rocks cropping out in the eastern part of the area are the older ones, and that farther west they are buried under younger rock layers. The oldest rock exposed—Auburn shale—crops out in one small area in the extreme eastern part of Riley county and the youngest of the bed rock formations—Cretaceous sandstone—occurs at the surface in the northwest corner of Riley county (geologic map, pl. 1, and pls. 5-10). Rocks still older are exposed in eastern and southeastern Kansas, in the Ozark region in Missouri, in the Arbuckle Mountains in southwest Oklahoma, and in other more remote areas. Table 4 lists the larger divisions of subsurface rocks in Riley and Geary counties. These beds contain the potential oil and gas reservoirs of the area.

TABLE 4. *Subsurface rocks of Riley and Geary counties, Kansas*[1]

	Approximate thickness, feet
Carboniferous system	
Pennsylvanian subsystem	
Virgil series	
Wabaunsee group	
Shale, limestone, and sandstone	575
Shawnee group	
Shale, limestone, and sandstone	320
Douglas group	
Shale, sandstone, and limestone (unconformity)	
Missouri series	50
Pedee group	
Shale and limestone	
Lansing group	
Limestone and shale	
Kansas City group	
Limestone and shale	335
Bronson group	
Limestone and shale	
Bourbon group	
Shale and sandstone (unconformity)	110
Des Moines series	
Marmaton group	
Shale and limestone	100
Cherokee group	
Shale, sandstone, and conglomerate (unconformity)	130
Mississippian subsystem[1]	
Osage series	
Burlington and Keokuk limestones	
Limestone (unconformity)	85
Osage or Kinderhook series	
Gilmore City limestone	
Limestone (unconformity)	30
Sedalia limestone	
Limestone	15
Kinderhook series	
Chattanooga shale	
Shale (unconformity)	150
Devonian system	
Hunton limestone	
Limestone and dolomite (unconformity)	420
Ordovician system	
Cincinnatian series	
Maquoketa shale	
Shale and sandstone (unconformity)	75
Mohawkian series	
Viola limestone	
Limestone and dolomite (unconformity)	150
Chazian series	
Simpson sandstone	
Sandstone and shale (unconformity)	40
Ordovician and (or) Cambrian systems	
Canadian and (or) Ozarkian series	
Arbuckle limestone	
Limestone, dolomite, and sandstone	100
Pre-Paleozoic	
Granite and metamorphic rocks	

1. Subdivisions of Mississippian subsystem by Wallace Lee.

Of the rocks listed in table 4 it is only the pre-Paleozoic rock and rocks younger than some part of the Missouri series that are continuous across the buried Nemaha Mountains. The crest of the buried mountains trends to the southwest along a line passing near the southeast corners of both counties. A well drilled near Zeandale reached granite at a depth of 958 feet. Lansing beds rest on the pre-Paleozoic granite there. As shown by Wallace Lee (1939, pl. 1), Mississippian limestones are absent from all, but the western part of Riley county and from the eastern part of Geary county. Hugh W. McClellan (1930, fig. 2) has shown that pre-Mississippian rocks are upturned and beveled along the west side of the Nemaha Mountains in both counties. The beveled edges of the Mississippian and pre-Mississippian rocks are covered by rocks chiefly of Pennsylvanian, probably Marmaton and Cherokee, age. The exact distribution of rocks older than Mississippian is far from perfectly known.

Oil and Gas Test Wells.—Figure 2 shows the locations of the 23 wells drilled for oil and gas in the two counties. Large areas are still untested and only 7 of the wells thus far drilled constitute adequate tests of the possible producing rocks in their vicinity, in this area of more than 1,000 square miles. Tables 5 and 6 list the wells that have been drilled in Riley and Geary counties. The tables, which were prepared by R. P. Keroher of the Division of Subsurface Geology of the State Geological Survey, show the lowest formation reached in each well according to his interpretation of the well logs. Nine wells were drilled into pre-Paleozoic rock, but in two of these, rocks of the Lansing group lie upon the granite. Hence these two wells, Cain Bloom No. 1 and No. 2 Zeandale, tested only Lansing and younger rocks. Three wells were abandoned before reaching the base of the Pennsylvanian rocks. One of these reached only as deep as the Douglas group. Two wells were stopped in the Mississippian limestone and eight in either the Hunton or Maquoketa formations, leaving untested the Viola, Simpson, and Arbuckle formations, all three of which are important producing zones elsewhere in Kansas.

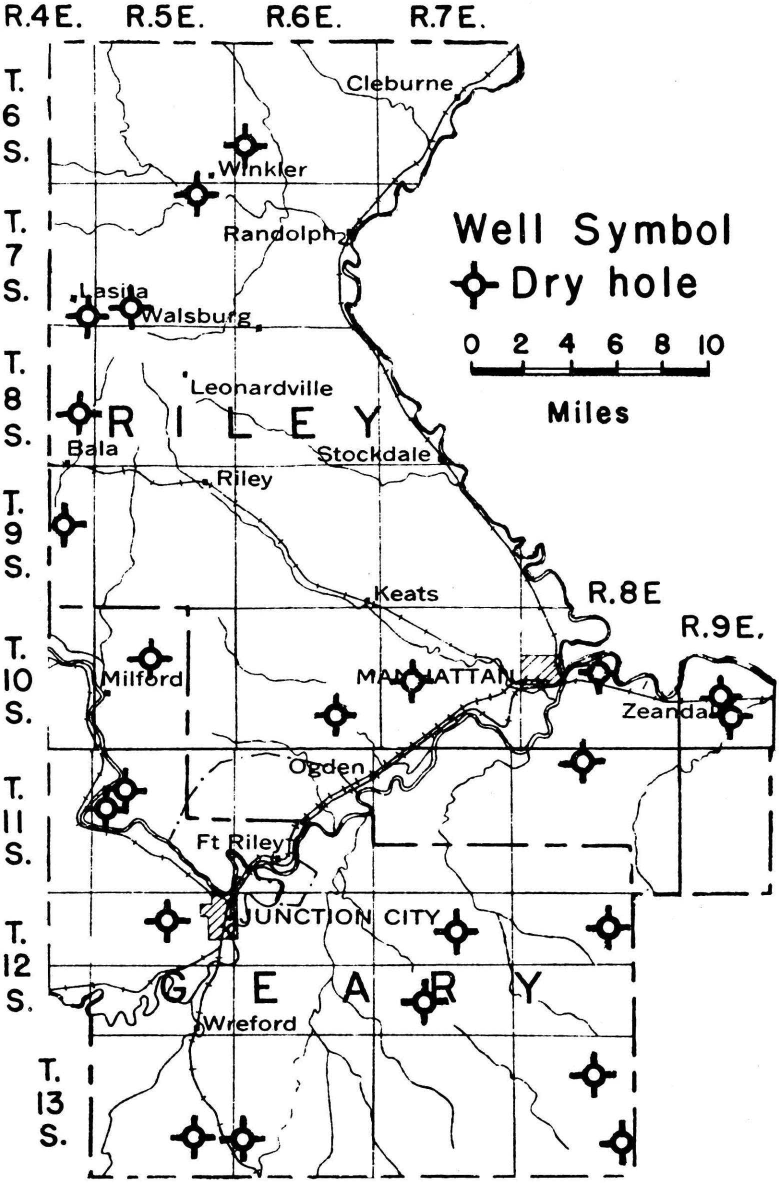

FIG. 2. Map of Riley and Geary counties showing locations of wells drilled to test for oil.

TABLE 5. *Test wells drilled for oil and gas in Riley county*[1]

Company farm	Location, S., T., R.	Completion date, total depth, ft.	Lowest formation, production
General Utilities et al...	NEc SW	11/23/29	Arbuckle
Hay 1	30–6–6E	2,535	Dry
C. Gentler et al.........	SEc SE	8/1/24	Maquoketa
Doyle 1	36–7–4E	2,601	Dry
Gypsy Oil Co...........	SE SW NW	6/30/17	Pre-Cambrian
Droll 1	2–7–5E	2,520	Dry
Derby Oil Co...........	NEc NE	10/9/29	Hunton?
Lindstrom 1	32–7–5E	2 226	Dry
Arkansas Fuel Oil.......	SE NE SW	1/11/30	Pre-Cambrian
Martin 1	24–8–4E	2,942	Dry
Empire Oil & Refg......	SWc NE	4/29/25	Pre-Cambrian
Woodbury 1	14–9–4E	2,804	Dry
Pawnee Oil & Gas.......	NE SW NW	12/22/23	Mississippian?
Marks 1	26–10–6E	1,853	Dry
F. J. Heeley et al........	NW NE NW	5/23/29	Pre-Cambrian
Thier 1	20–10–7E	2,965	Dry
Coronado Oil	CSE SE	7/28/38	Pre-Cambrian
Parks 1	16–10–8E	1,989½	Dry
Cain Bloom	NWc SW	–/—/14	Pre-Cambrian
Zeandale 1	28–10–9E	1,020	Dry
Cain Bloom	NW NE NE	–/—/15	Pre-Cambrian
Zeandale 2	28–10–9E	1,020	Dry
W. R. Wilson et al......	SE SW NW	9/12/28	Hunton
Rannels 1	4–11–8E	2,310	Dry

TABLE 6. *Test wells drilled for oil and gas in Geary county*[1]

Company farm	Location, S., T., R.	Completion date, total depth, ft.	Lowest formation, production
Brinkley et al..........	NWc NE	8/9/27	Maquoketa
Fawley 1	16–10–5E	2,501	Dry
Wright et al............	CNL NE NW	9/24/30	Pre-Cambrian
Younkin 1	17–11–5E	3,240	Dry
Kerby & Wright.......	CNL SW SE	6/4/27	Hunton
Kurtze 1	18–11–5E	2,652	Dry
Carter Oil	NE NW NW	9/28/05	Mississippian
Munson 1	10–12–5E	1,930	Dry
Pioneer Petroleum	SEc SE	1/15/29	Pre-Cambrian
Chase Ranch 1.........	10–12–7E	3,638	Dry
Pioneer Petroleum	SWc NE	....	Cherokee
Zumbrum 1	28–12–7E	1,895	Dry
Scheu & Teague........	NW SW NW	8/2/39	Maquoketa
Aye 1	10–12–8E	2.239	Dry
Manhattan Oil	SW NE NW	8/2/27	Hunton
Foster 1	26–13–5E	2,382	Dry
Liberty-Texas Co.	NEc SW	8/24/26	Marmaton?
Foster 1	30–13–6E	2,412	Dry
Empire Gas & Fuel.....	NE SE SW	4/27/17	Hunton?
Stellwagen 1	9–13–8E	2,763	Dry
L. E. Dornes et al......	CSE NE	11/15/33	Douglas group
Fechner 1	27–13–8E	1 220	Dry

1. Compiled by R. P. Keroher.

Commercial accumulations of oil and gas are generally found in more or less minute openings in rocks buried below the surface. "Oil sands" are, as a rule, porous rocks, but not all are sandstones. Because oil and gas are lighter than water they will rise to the surface of any body of water, and because gas is lighter than air it will escape into the atmosphere if free to do so. As water fills almost all rock openings, it is necessary that something prevent the upward movement of oil and gas if they are to accumulate in natural reservoirs. It is believed that oil and gas, if present, migrate upward through the ground water in a dipping bed of porous rock until stopped by some obstruction. Hence, if a bed of sandstone containing water, oil, and gas underlies a bed of impervious shale and is arched into a dome or anticline, the gas will accumulate below the impervious shale at the crest of the upfold, the oil will collect a little farther down, and the water will remain in the lower parts of the sandstone. The petroleum geologist therefore seeks anticlines and domes in his quest for new fields. Several, perhaps nearly all, of the wells in Riley and Geary counties were drilled on surface anticlines, but it should be noted that in some cases the crest of an anticline as it appears at the surface does not lie directly above the crest in deeper rocks.

There are, however, several other types of structural features that are favorable for the accumulation of oil and gas. When sedimentary formations are uplifted and subjected to erosion and on these warped and eroded beds is deposited another succession of strata, the overlying rocks are said to be unconformable with respect to the underlying beds. When beds are more or less sharply upturned below an unconformity and are sealed by overlying rocks, the resulting structure may constitute a "stratigraphic trap" for oil or gas. Impervious layers above obstruct the upward migration of gas and oil in the beds below the unconformity. In fact some of the largest oil fields of the world are the result of accumulation below unconformities or along the unconformable contacts.

On both sides of the Nemaha Mountains pre-Pennsylvanian rocks are believed to be in positions that might have formed stratigraphic traps. All such structures along the east side of the buried mountains probably lie east of Riley and Geary counties, but it may be said that there is a possibility—even a probability—that oil will be found in these counties in this type of structure west of the Nemaha Mountains. It is especially noteworthy that a small amount of oil was produced from the upper part of the Mississippian limestone in the Roth and Faurot No. 1 Brandbury well in sec. 21, T. 9 S., R. 4 E., Clay county, almost on the Geary county line. Shows of oil were reported from several other formations in wells in both Riley and Geary counties.

The two counties should not be regarded as proved barren of oil and gas. Large areas are untested and most of the deeper rocks are almost untested. It is not certain that all surface anticlines have been drilled or have been drilled in the most favorable locations. Because of the several unconformities and attitude of the rocks in the stratigraphic succession there may be favorable structures that cannot be detected from surface investigations.

Sand and Gravel

There are large quantities of river-deposited sand in the stream beds and below the surface of the valley fillings of the major streams. As stated in another section of this report, the thickness of these alluvial deposits in the valleys of the larger streams, Kansas, Big Blue, Smoky Hill, and Republican rivers, is at least 50 feet. The material constituting the fills in the valleys of the smaller streams is more generally silt. In the valley fillings of the larger streams one generally finds the coarser sand and gravel near the base of the deposit, and the silt and fine sand near the top. In the river beds there are great quantities of sand and gravel almost free from silt. These river sands are well adapted to many commercial uses but are not adapted to special uses for which an almost pure quartz sand is required. The sands and gravels are composed of fragments of quartz, feldspar, and other resistant minerals. Inasmuch as river sands are constantly replaced, the supply is virtually inexhaustible. Ray Whitla, of the Kansas Geological Survey, is investigating the glass and molding sand resources of Kansas. According to Whitla (personal communication) small amounts of molding sand from Riley county are being marketed.

Water Resources

The principal cities obtain water from the alluvium in the valleys of the major streams. The alluvial fillings of the valleys of Kansas, Big Blue, Smoky Hill, and Republican rivers hold a supply of water that is ample for almost any ordinary industrial purpose. In the fillings of smaller stream valleys are smaller amounts of water. The valleys of minor sreams are filled principally with silt and redeposited loess, which are almost impervious, and hence there may be no water available below the smaller floodplains. Repeated testings in small valley fillings in many parts of eastern Kansas have shown, however, that excellent water supplies can be obtained from very small alluvial fills, so in seasons of extreme drought the investigation of the fillings of small, even intermittent, streams should not be neglected.

The depth at which water is found in areas remote from the stream valleys depends upon the geologic formations and their structural condition and relationship to the topography. In ordinary seasons water for farm and domestic use is found almost everywhere at a comparatively shallow depth. The Cottonwood limestone and the Fort Riley limestone are the chief aquifers. Numerous springs issue from ledges of these two limestones, and in many places where these two strata are high on hillsides it is possible to obtain a large supply of water under pressure at farm plants near the foot of the hills. This is especially true along westward-facing hillsides, as in general the strata dip to the west.

Many persons interested in obtaining water are not aware of the important bearing of stratigraphic geology on the occurrence of ground water. To the careful observer this importance becomes very patent in seasons of extreme drought such as occur all too often in eastern Kansas. Water can be obtained only from rocks that contain openings large enough to allow the water to emerge when a well penetrates the rock. Although a bed of clay or shale may contain a great volume of water held in microscopic interstices between the clay particles, the water will not move readily through these minute spaces, and hence the material is said to be relatively impermeable. Other rocks may be so compact that there is room for very little if any water between particles of solid material. The foregoing descriptions of rock layers in Riley and Geary counties show that the individual strata vary widely, and as it is extremely important that the well digger know the rock layer that he expects to reach, maps showing areal geology have practical usefulness.

Moore (1940) has recently contributed a general discussion of the ground-water resources of Kansas, a report that should be of interest to almost all citizens of the state. The State Geological Survey in coöperation with the Federal Geological Survey began a systematic program of ground-water investigations in 1937. Extensive and detailed studies have been made in several parts of Kansas and it is planned to extend the ground-water survey to various other parts of eastern and western Kansas. These studies are being made by a staff of geologists and engineers specially trained in hydrology and are under the supervision of S. W. Lohman of the Federal Geological Survey.

Water in shale.—About two-thirds of the rock that is close enough to the surface in the two counties to be reached by ordinary dug wells is shale and hence is not, in general, a good aquifer, but in areas where shale lies below the soil over a wide expanse, as in the places where shales like the Holmesville and Gage formations occur, there are fair supplies of water at shallow depth. This condition obtains because the shale is somewhat weathered and water moves along bedding and joint planes. Wells situated in such areas may be prolific if located down dip from an extensive catchment area. Shales that are topographically low and exposed only in narrow belts in valleys or along hillsides are generally very poor aquifers, because they have neither a large catchment basin nor open texture such as results from prolonged weathering. Water is commonly encountered at the top of shale layers where they are overlain directly by limestone, the water having migrated laterally and downward in scattered solution channels in the limestone and having spread laterally at the plane of contact between the limestone and the virtually impermeable shale bed below.

Water in limestone.—As a rule the several limestone layers in the part of Kansas considered in this report carry water. Limestone if unbroken and unweathered is virtually impermeable, but, as it is slightly soluble in ground water, solution channels develop along bedding and joint planes when the rock has been in contact with water for some time. Hence, like the shales, in the plateau-like uplands where limestone lies just below the surface soil mantle it can be expected to carry large quantities of water. The city of Riley, in western Riley county, which lies at about the horizon of the Winfield limestone, obtains its water from a well that penetrates the Barneston limestone at a depth of 128 feet. The well produces 25 to 45 gallons of water a minute through a 10-inch drill hole. Leonardville, in the western part of Riley county, obtains water for the municipal system from two wells, drilled into the Barneston limestone at depths of 157 and 160 feet. The surface formation is the Nolans formation and overlying shale. One of these wells produces as much as 89 gallons a minute. The two wells are said to have produced 23,874,800 gallons of water in one year. These city wells give evidence of the large supply of fresh water obtainable from limestone beds below extensive dip slopes, and the importance of this supply was noted by Haworth (1913, pp. 87-89), when he cited the many farm wells near Leonardville and in similar geological surroundings near Winfield, Cowley county, Kansas. In Riley and Geary counties, the Cottonwood limestone, Fort Riley limestone, and Florence limestone are the most important water-bearing limestones. Locally other limestone beds are aquifers.

Water in sandstone.—Farther east and west in Kansas massive sandstones lying near the surface are excellent aquifers, but there is virtually no sandstane among the rocks that lie within the zone of fresh ground water in these two counties. Those sandstone layers that can be reached by drilling are so deeply buried that their water is strongly mineralized and unfit for ordinary use. In the very small area in northwestern Riley county where the Dakota sandstone is present it probably contains some water, and it is very probable that the lenticular Indian Cave sandstone member in the basal part of the Towle shale formation at the base of the Permian system in southeastern Riley county is locally a good aquifer.

Surface water.—As indicated on foregoing pages of this report, the two counties are well watered by the various major streams and their tributaries. As in other parts of Kansas, the retention and utilization of the water that enters the region in the streams and that falls as rain are jointly engineering and geological problems. There are many dry water courses that can be dammed and used as farm ponds. In that kind of project geology is an important factor, because the ability of the pond to hold water depends upon the nature of the underlying rock. Properly constructed earth dams in sites selected by well-trained geologists provide excellent ponds, which can be expected to exist for many years and hence to be a source of permanent benefit to rural communities. Another type of dam that would augment the water supply during dry seasons is the low concrete or masonry dam built from bank to bank in the more nearly permanent streams that seldom become completely dry but cease to flow during dry seasons. Such dams should impound water only between the stream banks and not above tillable soil. Low dams of this kind require no spillways nor sluice gates. Attention is called to a recent publication, *Dams on dry watercourses*, of the Kansas State Board of Agriculture (Mohler, 1939) that contains the Kansas water-storage law and much helpful information on dam construction.

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DETAILED SECTIONS

The following stratigraphic sections, measured in Riley and Geary counties, are arranged in consecutive sections and ranges in each township. The average unit thickness of all stratigraphic units separately described is 6.13 feet.

(1) NE¼ sec. 1, T. 6 S., R. 4 E.

	Feet
CRETACEOUS SYSTEM	
Dakota group	
Sandstone, coarse, mostly quartz sand, ferruginous cement	4 ±
PERMIAN SYSTEM	
Donegal(?) limestone	
Hollenberg(?) limestone member	
Limestone, yellow earthy, cast of pelecypods	0.5
"Pearl shale"	
Shale, partly covered, yellow in upper part, mostly red in middle and lower part, some gray	45
Nolans limestone	
Herington limestone member	
Limestone and thin beds of clay shale, yellow, sandy-appearing	3
(Rest of member concealed)	

(2) C S line sec. 34, T. 6 S., R. 5 E.

	Feet
Wreford limestone	
Threemile limestone member	
Limestone, light in color, flinty	4
Speiser shale (18 feet exposed)	
Shale, gray fossiliferous	2
Limestone, gray	1
Shale, red, green, and gray, to water of creek	15

(3) W line sec. 13, T. 6 S., R. 6 E.

	Feet
Winfield limestone (11.5 feet +)	
Luta(?) and Cresswell limestone members	
Weathered shale and limestone fragments	?
Limestone, light in color, spines and other fragments of fossils	1
Grant shale member	
Shale, gray calcareous zone at top, brachiopods	9.5
Stovall limestone member	
Limestone, gray flinty broken	1
Doyle shale (73.3 feet)	
Gage shale member (46.2 feet)	
Shale, light-gray, fossiliferous; layers of coquina	8.5
Limestone, brown	0.6
Shale, variegated	37.1
Towanda limestone member (7.6 feet)	
Limestone, light-gray and yellow, somewhat platy	6
Limestone, bluish-gray, weathers lighter in color, laminated	1.6
Holmesville shale member (19.5 feet)	
Shale, covered	5
Shale, yellow, a few bands of red	9
Covered interval	5.5
Barneston limestone	
Fort Riley limestone member (11.8 feet exposed)	
Limestone, yellow shaly, thin beds	10.8
Limestone, more massive than unit above	1

(4) South of C W line sec. 15, T. 6 S., R. 6 E.

	Feet
Nolans limestone (20.3 feet exposed)	
Herington limestone member	
Limestone, yellow, sandy-appearing, upper part a mass of casts of pelecypods, shaly throughout	3 ±
Paddock shale member	
Shale, gray and yellow, "box work" of calcareous material	16
Krider limestone member	
Limestone, yellow, soft, massive	1.3
Odell shale (35.7 feet)	
Shale, mostly gray, some red, decidely calcareous in upper part, more or less calcareous throughout	6 ±
Shale, mostly red, thin nodular layers of calcareous material in upper part	29.7
Winfield limestone (22.4 feet exposed)	
Luta and cresswell limestone members (12 feet)	
Limestone, light-gray earthy	2 ±
Limestone and shale, thin beds	6
Limestone, light-gray massive, deeply weathered	4
Grant shale member	
Shale, gray, mostly covered on account of slumping of limestone above	10 ±
Stovall limestone member	
Limestone, yellow to gray flinty	0.4

(5) South of C W sec. 17, T. 6 S., R. 6 E.

	Feet
Barneston limestone (74.9 feet exposed)	
Florence limestone member	
Limestone, extremely flinty	15
Blue Springs shale member	
Shale, covered	38
Kinney limestone member(?) (21.9 feet exposed)	
Limestone, light-gray massive	2 ±
Shale, green and gray	12
Limestone, light-gray dense	0.9
Shale, green and red	4
Conglomerate, green clay matrix, pebbles of worn limestone ⅛ to ½ inch in diameter	1
Conglomerate, semioölitic light-green limestone matrix, pebbles of worn limestone and worn fossils	2

(6) C sec. 17, T. 6 S., R. 6 E.

	Feet
Barneston limestone	
Fort Riley limestone member	
Limestone, light in color, massive "rim rock"	4
Oketo shale member(?)	
Florence limestone member	
Covered interval	30
Matfield shale (66.5 feet exposed)	
Blue Springs shale member (62 feet)	
Covered interval	40
Limestone, yellow granular, grades into shale below	2
Shale, yellow near top, purple, gray, red, and steel-blue bands	20
Kinney limestone member	
Limestone, light-gray crystalline, granular	2.5
Wymore shale member	
Shale, green and dark-gray bands to water of creek	2

(7) SW sec. 30, T. 6 S., R. 6 E.

	Feet
Nolans limestone (15 feet exposed)	
Herington limestone member	
Limestone, yellow, more or less massive, arenaceous-appearing	2
Paddock shale member	
Shale, yellow, mostly covered	12
Krider limestone member	
Limestone, yellow, in thin beds	1
Odell shale	
Shale, covered	35
Winfield limestone (14.5 feet + exposed)	
Luta(?) and Cresswell limestone members	
Limestone, covered	?
Limestone, light in color, very rough, silicified spines of echinoids, breaks down readily	1.5

Grant shale member	
Shale, gray, abundant fossils	11.5
Stovall limestone member	
Limestone, gray flinty, echinoid spines, *Linoproductus* sp., *Rhombopora* sp.	1.5

(8) SW sec. 31, T. 6 S., R. 6 E.

	Feet
Doyle shale (34.5 feet exposed)	
Towanda limestone member (11.4 feet exposed)	
Limestone, yellow, and calcareous shale, calcite veins and stringers,	10
Limestone, blue to gray, massive	1.4
Holmesville shale member (23.1 feet)	
Shale, yellow, calcite-filled veins	3
Shale, yellow and green	8
Limestone, one bed	0.1
Shale, greenish-gray argillaceous	7
Shale, calcareous platy, partly covered	5
Barneston limestone	
Fort Riley limestone member (25.8 feet exposed)	
Limestone, brown to yellow, granular, weathers to pitted surfaces, massive to thin beds, grades into unit below	10
Limestone, light-gray platy	5.4
Limestone or platy shale, light in color	3
Covered interval	2.4
Limestone, brown soft	1
Limestone, yellowish-gray massive "rim rock"	2
Limestone, yellowish-gray, thin beds	2

(9) Sec. 6, T. 6 S., R. 7 E.

	Feet
Barneston limestone (43 feet + exposed)	
Fort Riley limestone member	
Limestone, light in color, more or less massive	?
Oketo shale member(?)	
Shale, yellow, grades into thin beds of limestone above, some dark gray fossiliferous, part of interval probably belongs in Fort Riley limestone member	17
Florence limestone member (26 feet exposed)	
Limestone, light in color, little or no flint	1
Limestone, light in color, blue flint, fossiliferous	2
Shale, calcareous below, some flint	2
Limestone, light in color, dark-blue flint	3
Shale, gray, not well exposed	3
Limestone and flint, more than 50% flint; limestone is yellow and pitted, flint is light gray	15

(10) C S line sec. 10, T. 6 S., R. 7 E.

	Feet
Barneston limestone	
Florence limestone member	
Limestone, flinty	15 ±
Matfield shale (62.45 feet)	
Blue Springs shale member (41.15 feet)	
Shale, mostly variegated, gray and platy in upper part	15 ±
Limestone, red soft	1.6
Shale, gray, red zone near top	10.8
Limestone, yellow to gray, massive	1.85
Shale, green	0.4
Limestone, chocolate-color, weathers red	0.5
Shale, upper part green and purple, lower part gray	11
Kinney limestone member	
Limestone, light-gray massive, earthy in texture	1.3
Wymore shale member	
Shale, upper part gray, mostly red, lower 5 feet gray	20
Wreford limestone (32.5 feet)	
Schroyer limestone member	
Limestone, gray, granular to crystalline, porous	2
Shale, gray	3
Limestone, gray flinty	3 ±
Schroyer limestone (lower part), Havensville shale, and Threemile limestone (upper part) covered	20
Threemile limestone member	
Limestone, gray flinty	3 ±
Shale, gray	0.5
Limestone, gray flinty	1
Speiser shale (15.6 feet)	
Shale, gray fossiliferous	2
Limestone, gray	0.6
Shale, gray in upper part, mostly red, nodules of calcareous material in upper part	13
Funston limestone (12.2 feet)	
Limestone, gray semioölitic	0.9
Shale, gray	1.5
Limestone, dove-gray hard nodular	0.6
Shale, gray	1
Limestone, limonitic	0.5
Shale, gray fissile	4
Limestone, gray, rough-weathering, granular, fragments of fossils,	1.4
Shale, gray	2
Limestone, gray	0.3
Blue Rapids shale	
Shale, gray in upper part, red and green in lower part	12.5
Crouse limestone	
Limestone	1
(Rest of formation concealed)	

(11) SE sec. 31, T. 6 S., R. 7 E.

	Feet
Wreford limestone (10.3 feet exposed)	
Havensville shale member	
Shale, calcareous	5
Threemile limestone member (5.3 feet)	
Limestone, light in color, one band of flint nodules	3
Limestone, light in color, no flint	1
Shale, gray flaky	0.5
Limestone, light in color, one band of flint nodules	0.8
Speiser shale (33.4 feet exposed)	
Shale, gray fossiliferous	2
Limestone, light-gray crystalline, hard	0.7
Shale, purple, chocolate-color, and gray	9
Limestone, chocolate-color, grades laterally into shale and weathers as shale	0.7
Shale, red in upper part, green in lower part	2
Limestone, gray massive, earthy texture	1
Shale	1.5
Limestone, gray, two beds	0.8
Shale, greenish-gray, somewhat blocky	1.5
Limestone, light-gray in color, weathers yellow, dense in texture,	1.15
Shale, yellow and gray	5.75
Sandy shale to shaly sandstone, gray, ripplemarked	1.3
Shale, gray, limonitic in upper part	6

(12) NW sec. 32, T. 6 S., R. 7 E.

	Feet
Barneston limestone	
Florence limestone member (11.3 feet exposed)	
Limestone, flinty	6.7
Shale and limestone, gray	1.7
Limestone, gray	0.7
Shale and thin limestone	1.6
Limestone, gray	0.6
Matfield shale (74.25 feet)	
Blue Springs shale member (22.5 feet)	
Shale, gray	6.5
Shale, red and gray	16
Kinney limestone member (18.35 feet)	
Limestone, soft and earthy, geodiferous	1
Shale, green and gray	5
Limestone, crystalline to earthy	1
Limestone and shale, thin beds	2
Shale, gray	5.75
Limestone, gray crystalline	0.3
Shale, gray	2.5
Conglomerate of limestone pebbles in calcareous matrix	0.8
Wymore shale member (33.4 feet)	
Shale, gray, blocky in upper part	22.6
Shale, chocolate-color in upper part, gray in lower part	10.8

Wreford limestone	
Schroyer limestone member (13.45 feet exposed)	
Limestone, light in color, flinty	1.4
Shale, gray	1.6
Limestone, gray flinty	3
Shale, gray and yellow	0.6
Limestone, gray, slightly crystalline	0.3
Shale, yellow	0.7
Limestone, gray, slightly crystalline	0.4
Shale, greenish-yellow	1.2
Limestone, yellowish-gray	0.5
Shale, yellow calcareous	2
Limestone, yellow and gray, shaly	1.75

(13) NW sec. 1, T. 7 S., R. 4 E.

	Feet
Winfield limestone (20.9 feet exposed)	
Luta(?) limestone member (9 feet exposed)	
Limestone, slightly yellow, thin beds, partly covered, may be some shale	8
Limestone, slightly yellow, thin beds, poorly exposed	1
Cresswell limestone member	
Limestone, yellow massive, gray on fresh surfaces, appears as one bed, but breaks into several beds	2.4
Grant shale member	
Shale, yellow, argillaceous and calcareous, more calcareous near base, fossiliferous	8.5
Stovall limestone member	
Limestone, gray flinty	1

(14) Sec. 12, T. 7 S., R. 4 E.

	Feet
Nolans limestone (17.4 feet exposed)	
Herington limestone member	
Limestone, yellow, in three beds	3
Paddock shale member	
Shale, gray fossiliferous, few calcareous zones, some carbonaceous matter	13
Krider limestone member (1.4 feet)	
Shale, calcareous	0.6
Limestone, gray hard, in two beds	0.8
Odell shale	
Shale, gray near top and base, mostly red, but some gray throughout, few thin calcareous beds	23
Winfield limestone	
Luta(?) and Cresswell limestone members (11 feet exposed)	
Limestone, nodular, rough-weathering, mostly in thin beds	5
Shale, yellow, soft arenaceous-appearing, blocky, few concretions, grades into the limestone above	6

(15) Sec. 1, T. 7 S., R. 5 E.

	Feet
Barneston limestone (64.5 feet exposed)	
Fort Riley limestone member (31.5 feet exposed)	
Limestone, yellow, thin beds	3
Limestone, yellow, beds thinner than those in units above or below	15
Limestone, massive, thinner beds near top	6
Limestone, yellow massive	6
Shale, calcareous	1
Limestone, light in color	0.5
Oketo shale member	
Shale, gray and blue	6
Florence limestone member (27 feet)	
Limestone, sparse flint	2
Shale, bluish-gray	2
Limestone, gray and yellow, abundance of flint except in upper 3 or 4 feet, flint in layers a few inches thick and very irregular,	20
Limestone, gray, arenaceous-appearing, somewhat shaly	3
Blue Springs shale	
Shale, gray, to water of creek	7

(16) Sec. 6, T. 7 S., R. 5 E.

	Feet
Doyle shale	
Holmesville shale member (10.5 feet exposed)	
Limestone, yellow crystalline, thin beds	1.5
Shale, gray, some green and red	9
Barneston limestone	
Fort Riley limestone member (44.2 feet exposed)	
Limestone, yellow and brown, nodular, arenaceous	5
Shale, blue and gray	2.5
Limestone, nearly white, tough	0.6
Shale, light in color, calcareous, platy	2.6
Limestone, yellow arenaceous-appearing	2
Limestone, yellow arenaceous-appearing, weathers to pitted surface, massive in upper part, thin beds in lower part	4.5
Limestone, granular hard	1
Limestone, platy, may be some shale near top	10
Limestone, light in color, weathers to pitted surface, "rim rock"	5
Shale, gray	4
Limestone, thin beds	7

(17) NW sec. 8, T. 7 S., R. 5 E.

	Feet
Doyle shale	
Towanda limestone member	
Limestone, poorly exposed	?
Holmesville shale member (42 feet +)	
Shale, gray	6
Limestone, light in color 0.5 to	1
Shale, gray, not well exposed	5
Shale, brown calcareous	1

Shale, gray	2
Limestone, white soft	0.5 to 0.6
Shale, red, gray, and green	27
Barneston limestone	
Fort Riley limestone member (12.5 feet exposed)	
Limestone, yellow, shaly near top, thin beds	10
Shale, yellow	0.5
Limestone, impure, beds about 0.5 feet thick	2

(18) NE sec. 19, T. 7 S., R. 5 E.

	Feet
Winfield limestone (12.7 feet exposed)	
Cresswell limestone member	
Limestone, thin-bedded to massive, somewhat chalky	2
Grant shale member	
Shale, gray	10
Stovall limestone member	
Limestone, shaly broken, nodules of blue flint in middle part	0.7

(19) NW sec. 28, T. 7 S., R. 5 E.

	Feet
Nolans limestone (10.5 feet exposed)	
Herington limestone member	
Limestone, gray to brown, sandy-appearing, massive	2 ±
Paddock shale member	
Shale, gray, calcite in strata and veins	8 ±
(Total thickness of member shown here probably is too small, owing to slumping)	
Krider limestone member	
Limestone, gray hard crystalline	0.5±
Odell shale	
Shale, red and gray	15

(20) NW sec. 31, T. 7 S., R. 5 E.

	Feet
Nolans limestone (14.6 feet exposed)	
Herington limestone member	
Limestone, light in color, weathers porous	3 ±
Paddock shale member	
Shale, mostly gray clayey, blocky layers in lower part	11
Krider limestone member	
Limestone, nodular, yellow to gray	0.6
Odell shale (42 feet exposed)	
Shale, gray	6
Shale, mostly red	36

(21) Sec. 32, T. 7 S., R. 5 E.

	Feet
Nolans limestone (15.6 feet exposed)	
Herington limestone member	
Limestone, yellow, arenaceous-appearing, massive, few geodes	3
Paddock shale member	
Shale, gray, arenaceous near top	12
Krider limestone member	
Limestone, gray, hard crystalline	0.6

Odell shale (40 feet)	
Shale, gray	4
Shale, red and gray	6
Covered interval	30
Winfield limestone	
Luta(?) and Cresswell limestone members (7 feet exposed)	
Limestone, weathers yellow, massive, concretionary	3
Limestone, yellow, simulates a very-fine-grained sandstone	4

(22) C S sec. 17, T. 7 S., R. 6 E.

	Feet
Winfield limestone	
Stovall limestone member	
Limestone, gray flinty	1
Doyle shale (85 feet)	
Gage shale member	
Shale, gray and yellow, thin beds, myriads of fossils near top, red and green below, covered near base	49
Towanda limestone member	
Limestone, yellow, mostly covered	11
Holmesville shale member	
Covered interval	25
Barneston limestone	
Fort Riley limestone member (22 feet exposed)	
Limestone, yellow arenaceous-appearing, calcite-filled geodes	6
Shale, yellow near top, gray below, very platy	9.5
Limestone, light in color, thin beds	3.5
Limestone, yellow massive, weathers to pitted surfaces	3

(23) Sec. 19, T. 7 S., R. 6 E.

	Feet
Barneston limestone	
Fort Riley limestone member (12.6 feet exposed)	
Limestone, or calcareous shale, almost white, platy	2
Limestone, yellow on fracture, weathers gray	1.5
Limestone, similar to unit above, more massive	1.5
Limestone, similar to unit above, thinner beds	1.2
Limestone, massive	1.4
Limestone, shaly in middle part, fossiliferous	5

(24) Sec. 20, T. 7 S., R. 6 E.

	Feet
Winfield limestone	
Stovall limestone member	
Limestone, flinty	1 ±
Doyle shale (85 feet)	
Gage shale member (49 feet)	
Shale, yellow and gray, myriads of *Derbyia* and other fossils	5 ±
Shale, red and green, mostly covered	44
Towanda limestone member	
Limestone, mostly covered	11 ±
Holmesville shale member	
Shale, covered	25 ±
Barneston limestone	
Fort Riley limestone	
Limestone (top of member exposed)	

(25) SE¼ sec. 30, T. 7 S., R. 6 E.

	Feet
Nolans limestone (15 feet exposed)	
Herington limestone member	
Limestone, yellow arenaceous-appearing	2
Paddock shale member	
Shale, gray, mostly covered	12
Krider limestone member	
Limestone, yellow, in thin beds	1
Odell shale (40.5 feet)	
Shale, yellow	3
Shale, gray	1.5
Shale, red	3
Shale, covered	33
Winfield limestone (14.5 feet + exposed)	
Luta(?) and Cresswell limestone members	
Limestone, covered	?
Limestone, light in color, rough-weathering, breaks down readily,	1.5
Grant shale member (11.5 feet)	
Shale, covered	5
Shale, gray fossiliferous	6.5
Stovall limestone member	
Limestone, gray flinty, echinoid spines, *Rhombopora* sp., and *Linoproductus* sp.	1.5

(26) C S line sec. 31, T. 7 S., R. 6 E.

	Feet
Nolans limestone (16.1 feet exposed)	
Herington limestone member	
Limestone, gray, slightly flinty, weathers gray and brown, few calcite geodes, hard and granular in upper part	6
Paddock shale member	
Shale, containing nodular fossiliferous zone in the upper part, mostly gray, some green near upper part, sparse carbonaceous matter	8
Krider limestone member (2.1 feet)	
Shale, yellow calcareous	1
Limestone, yellow arenaceous-appearing, in thin beds	1.1
Odell shale	
Shale, gray and green in upper part, mostly red, blocky, lower 5 feet covered	23
Winfield limestone (22.15 feet)	
Luta(?) and Cresswell limestone members (13.75 feet)	
Limestone, hard	0.7
Limestone, shaly, weathered	2
Shale, yellow	5
Limestone, yellow, very shaly	2
Limestone, yellow massive	2.5
Limestone, gray, weathers somewhat brown, echinoid spines and other fragments of fossils project on rough surface	1.55
Grant shale member	
Shale, gray, *Derbyia crassa* abundant	9.5

Stovall limestone member	
Limestone, light-yellow; dark-gray mottled, dark part partly silicified, small amount of flint	0.9
Gage shale	
Shale, yellow and gray, myriads of fossils	5

(27) Sec. 34, T. 7 S., R. 6 E.

	Feet
Winfield limestone (10.2 feet exposed)	
Cresswell limestone member	
Limestone, gray, weathers rough, massive	1.4
Grant shale member	
Shale, yellow, partly gray, *Derbyia crassa, Rhombopora,* sp., crinoid columnals	8
Stovall limestone member	
Limestone, bluish-gray flinty, breaks readily, silicified fossils	0.8
Gage shale	
Shale, yellow, echinoid spines, pelecypods, crinoid columnals	5

(28) C S SE sec. 1, T. 8 S., R. 5 E.

	Feet
Nolans limestone (18.9 feet exposed)	
Herington limestone member (6.4 feet exposed)	
Limestone, yellow nodular	0.2
Limestone, yellow massive	2.1
Limestone and shale; limestone, blocks	1.3
Shale, calcareous	0.6
Limestone, impure	0.4
Shale	0.2
Shale, calcareous	0.4
Shale, gray	0.8
Limestone, impure fossiliferous	0.4
Paddock shale member	
Shale, gray	11.8
Krider limestone member	
Limestone, light-gray, two beds	0.7
Odell shale (23 feet exposed)	
Shale, gray	3
Shale, mostly red	20

(29) C N line sec. 25, T. 8 S., R. 6 E.

	Feet
Doyle shale (41.6 feet exposed)	
Towanda limestone member	
Limestone, yellow granular, weathers gray, weathers into blocks less than 1 foot thick	3
Holmesville shale member (38.6 feet)	
Shale, mostly grass-covered, some green shale	17
Shale, mostly gray and yellow, some bands of red	10.9
Limestone, brown	0.2
Shale, gray	3
Shale, yellow calcareous	7.5

Barneston limestone	
Fort Riley limestone member (15.5 feet exposed)	
Limestone, blue shaly	1.5
Limestone, yellow arenaceous, pelecypods as casts	1.5
Limestone and shale; limestone is blue, hard, not well exposed, shale is gray, both in thin beds	7.5
Limestone, yellow granular, massive, thin beds in lower part, weathers with deep pits, springs issue below	5

(30) W line sec. 28, T. 8 S., R. 6 E.

	Feet
Winfield limestone (21.2 feet exposed)	
Cresswell limestone member	
Limestone, poorly exposed	8
Grant shale member	
Shale, covered	12
Stovall limestone member	
Limestone, gray flinty	1.2
Doyle shale (90 feet +)	
Gage shale member (50 feet)	
Shale, gray fossiliferous, abundant *Derbyia* sp.	11
Shale, covered	39
Towanda limestone member	
Limestone, yellowish-brown, massive	?
Holmesville shale member	
Shale, covered, in long slope	40
Barneston limestone	
Fort Riley limestone member (31 feet exposed)	
Limestone, massive, one bed, grades into shale below	2.5
Shale, gray, dark at top, calcareous, carbonaceous near top	4
Shale, yellow	3
Limestone, soft arenaceous-appearing	2
Limestone, massive	1.5
Limestone, massive	4
Covered interval	6
Shale, yellow, thin beds	6.5
Limestone, light gray chalky fossiliferous	1.5

(31) NW sec. 32, T. 8 S., R. 6 E.

	Feet
Winfield limestone (23.7 feet exposed)	
Luta(?) and Cresswell limestone members (14.2 feet exposed)	
Limestone, light in color, thin beds	12
Limestone, gray crystalline hard, red splotches, echinoid spines	2.2
Grant shale member	
Shale, gray fossiliferous	8
Stovall limestone member	
Limestone, gray, lighter-colored flint, fossiliferous	1.5
Gage shale (23.3 feet exposed)	
Shale, or thin beds of limestone, calcareous, fossiliferous	5.4
Limestone or calcareous shale, yellow	5.5
Shale, gray, green and red near top	7
Shale, gray, some yellow and red	5.4

(32) C sec. 29, T. 8 S., R. 7 E.

	Feet
Barneston limestone (45.5 feet exposed)	
Fort Riley limestone members	
Limestone, "rim rock," light in color, massive in upper part, thinner beds below	10
Oketo shale member	
Shale, gray	7.5
Florence limestone member (28 feet)	
Limestone, gray	1
Shale, gray	3
Limestone, abundant flint, partly covered, may contain some shale beds	24
Matfield shale (71.9 feet)	
Blue Springs shale member (24.9 feet)	
Shale, gray calcareous	3
Limestone, gray impure	0.9
Shale, gray, green and chocolate-color in lower part	21
Kinney limestone member	
Limestone, argillaceous	1
Wymore shale member	
Shale, gray, lower 15 feet mostly covered	46
Wreford limestone (33.9 feet)	
Schroyer limestone member (7 feet)	
Limestone, gray, weathers white, no flint	1
Limestone, gray flinty, thin beds	6
Havensville shale member (19 feet)	
Shale, calcareous, thin beds of limestone near base	6
Shale, gray and yellow	13
Threemile limestone member (7.9 feet)	
Limestone, light in color, no flint	0.5
Limestone, flinty	0.4
Limestone, white, no flint	1.2
Limestone, flinty	0.1
Limestone, no flint	2.2
Limestone, flinty	0.5
Limestone, gray, in thin beds	1.5
Shale, gray fossiliferous	0.5
Limestone, gray flinty	1
Speiser shale (17.4 feet)	
Shale, gray fossiliferous	2.5
Limestone, gray, one bed, fossiliferous	0.4
Shale, gray, red, purple, brown, and green	14.5
Funston limestone (7 feet)	
Limestone, light-gray, weathers brown, massive	1.5
Shale, gray, purple bands	3.5
Limestone, brown powdery arenaceous, weathers brown	2
Blue Rapids shale (28.3 feet)	
Clay, nodular calcareous, may belong to Funston limestone	3.6
Shale, calcareous, contains iron rust	1.2

Shale, mostly gray, calcareous and varicolored in lower 3 feet....	16
Shale, yellow and gray, calcareous..........................	1.5
Shale, yellow and gray, somewhat less calcareous than unit above,	6
Crouse limestone	
Limestone, poorly exposed, brown crystalline..................	7
Easly Creek shale (18.4 feet + exposed)	
Shale, gray	2
Covered interval, some limestone............................	5.6
Covered interval, some red shale............................	10.8

(33) C W line sec. 1, T. 9 S., R. 4 E.

	Feet
Winfield limestone (18.4 feet exposed)	
Luta(?) and Cresswell limestone members	
Limestone locally thin beds, but mostly massive, weathering into white blocks, splotches of red, many echinoid spines..........	5
Grant shale member	
Shale, light-gray, thin beds, somewhat calcareous near top, very fossiliferous	12
Stovall limestone member	
Limestone, abundance of flint................................	1.4

(34) NE sec. 1, T. 9 S., R. 4 E.

	Feet
Winfield limestone (16.5 feet exposed)	
Luta(?) and Cresswell limestone members	
Limestone, thin beds, somewhat shaly.........................	2
Limestone, massive, rough-weathering, echinoid spines..........	2
Grant shale member	
Shale, gray, fossils abundant, *Derbyia crassa*..................	11
Stovall limestone member	
Limestone, very flinty.......................................	1.5

(35) C W line sec. 12, T. 9 S., R. 4 E.

	Feet
Doyle shale (47 feet exposed)	
Towanda limestone member (10 feet exposed)	
Limestone, light-gray, thin to massive beds....................	5
Limestone, light in color, impure, somewhat brecciated, pitted in middle part	4
Limestone, yellow laminated arenaceous.......................	1
Holmesville shale member (37 feet)	
Shale, yellow and green, partly covered.......................	12
Covered interval	25
Barneston limestone	
Fort Riley limestone member	
Limestone, bed rock in stream................................	

(36) SW sec. 12, T. 9 S., R. 4 E.

	Feet
Doyle shale (28.8 feet exposed)	
Towanda limestone member	
Limestone, yellow, massive to thin beds	6
Holmesville shale member (22.8 feet)	
Shale, yellow, some red near base	11
Limestone, yellow impure	1
Shale, not well exposed	5.4
Covered interval	5.4
Barneston limestone	
Fort Riley limestone member (22.9 feet exposed)	
Limestone, gray crystalline, fossils as fragments	3
Limestone, light-yellow massive	2
Limestone or limy shale	1.7
Limestone, many pelecypods as casts	0.5
Limestone, light in color, argillaceous, platy	4.5
Limestone, partly covered	0.2
Covered interval	6
Limestone, light in color, pitted, "rim rock"	5

(37) C E SE sec. 6, T. 9 S., R. 5 E.

	Feet
Winfield limestone (24.1 feet exposed)	
Luta(?) limestone member	
Limestone, brown soft, harder near top, many calcite-filled geodes	10
Cresswell limestone member	
Limestone, light in color, red splotches, lower part slightly silicified, many echinoid spines	2.5
Grant shale member	
Shale, yellow and gray, fossils as fragments	10.8
Stovall limestone member	
Limestone, light in color, abundant flint	0.8

(38) C N line sec. 12, T. 9 S., R. 5 E.

	Feet
Winfield limestone (16 feet exposed)	
Cresswell limestone member	
Limestone, light in color, many spines, other fossils as fragments,	5
Grant shale member	
Shale, yellow fossiliferous	10
Stovall limestone member	
Limestone, gray flinty	1
Gage shale	
Shale, poorly exposed	

(39) Sec. 13, T. 9 S., R. 6 E.

	Feet
Barneston limestone (63.6 feet exposed)	
Fort Riley limestone member (36.3 feet exposed)	
Limestone, thin beds, some shale	10
Shale and shaly limestone	6
Limestone, yellow and gray, thin beds, but somewhat massive near top	6
Limestone, light in color, yellow on fresh surfaces, pitted, massive "rim rock"	3.5
Limestone, thin beds, a small amount of shale	5.4
Limestone, light-gray chalky, thin beds, some shale	5.4
Florence limestone member (27.3 feet exposed)	
Limestone, flinty, fossils as fragments	10.8
Partly covered interval, some flinty limestone	5.5
Covered interval	3
Limestone, gray, abundant flint	8

(40) Sec. 17, T. 9 S., R. 6 E.

	Feet
Doyle shale (22 feet exposed)	
Towanda limestone member (6 feet exposed)	
Limestone, poorly exposed	3
Marl, yellowish-brown, thin beds of limestone near base	3
Holmesville shale member	
Shale, greenish-yellow, some bands of red, few irregular calcareous layers, somewhat marly, some stringers of limestone	16

(41) W line sec. 28, T. 9 S., R. 6 E.

	Feet
Doyle shale (46.9 feet exposed)	
Towanda limestone member	
Limestone, yellow, weathers brown, argillaceous	6
Holmesville shale member (40.9 feet)	
Shale, yellow calcareous	7.5
Covered interval, some impure limestone at top	11
Covered interval, some brown pitted limestone near base	5.4
Partly covered interval, some brown limestone in middle part, some calcite geodes and a small amount of limonite near base,	11
Shale, gray	6
Barneston limestone	
Fort Riley limestone member (16 feet exposed)	
Limestone, chalky, calcite geodes	4
Limestone, thin beds, platy, chalky, calcite geodes	6
Limestone, yellow on fresh surfaces, somewhat chalky	6

(42) S sec. 35, T. 9 S., R. 7 E.

	Feet
Wreford limestone (32.6 feet exposed)	
Schroyer limestone member (6.3 feet exposed)	
Limestone, flinty	3
Shale, gray calcareous	2.6
Limestone, light in color, tough, powdery	0.7
Havensville shale member	
Shale, gray, covered near base	20
Threemile limestone member (6.3 feet)	
Limestone, light in color, no flint	2
Limestone, gray, steel-gray flint, fossil fragments	1.7
Shale, gray fossiliferous	1.2
Limestone, gray, steel-gray flint, fossil fragments	1.4
Speiser shale (18.8 feet)	
Shale, gray, thin beds, fossiliferous, most fossils fragments of brachiopods	2.4
Limestone, light-gray, somewhat chalky	1
Shale, mostly gray, some red and green	15.3
Funston limestone (6.1 feet exposed)	
Limestone, irregular beds	1.2
Shale, gray	1.9
Limestone, brown pitted	3

(43) Sec. 31, T. 10 S., R. 6 E.

	Feet
Doyle shale (28 feet exposed)	
Towanda limestone member	
Limestone, yellow, thin beds	10
Holmesville shale member	
Shale, yellow and green, bright-green bands locally	18
Barneston limestone	
Fort Riley limestone (30.5 feet exposed)	
Limestone or calcareous shale, or shale containing a few limestone beds	5
Limestone, yellow, thin beds	0.5
Shale, gray and yellow	5
Shale, gray, calcareous, small calcite-filled geodes and more calcareous matter near top	7
Limestone, light-gray dense massive, forms line of outcrop around hills	1.5
Shale, yellow argillaceous, thin beds	1.5
Limestone, gray very platy	1
Shale, not well exposed	2
Limestone, white to yellow, thin beds, easily weathered, in gentle slopes	3
Limestone, light in color, massive "rim rock"	4

(44) Sec. 10, T. 10 S., R. 7 E.

	Feet
Beattie limestone	
Cottonwood limestone member	
Limestone, light in color, massive, partly silicified, fusulinids in upper part	6
Eskridge shale (36 feet)	
Shale, gray	13.8
Limestone, gray laminated, ostracodes	1
Shale, green and gray near top, mostly gray; blocky	6
Limestone	0.2
Shale, gray, somewhat blocky	1.5
Limestone or calcareous shale, many pelecypods, *Aviculopecten, Myalina*	0.5
Shale, green, gray, and chocolate-color, calcareous in lower part	13
Grenola limestone	
Neva limestone member (8.1 feet exposed)	
Limestone	0.9
Shale, calcareous	1.2
Limestone, gray, massive	6

(45) N line sec. 24, T. 10 S., R. 7 E.

	Feet
Grenola limestone	
Burr limestone member	
Limestone	2
Roca shale	
Shale, green, blue, and chocolate-color, blocky, weathers into irregular fragments stained with rusty splotches	20
Red Eagle limestone (20.5 feet)	
Howe limestone members	
Limestone, gray massive	4.6
Bennett shale member (14.4 feet)	
Shale, mostly gray	7
Limestone, gray	1.4
Shale, black fossiliferous	6
Glenrock limestone member	
Limestone, yellow fossiliferous	1.5
Johnson shale (13.5 feet)	
Shale, mostly gray, green near base, calcareous zone near middle part	8.5
Mudstone	1.5
Shale, gray	3.5
Foraker limestone (18.1 feet exposed)	
Long Creek limestone member	
Limestone, yellow, red quartz crystals on weathered surface, fusulinids	8
Hughes Creek shale member (10.1 feet exposed)	
Shale	1.6
Limestone	3
Shale, black near top, gray and yellow below	5.5

(46) S line sec. 24, T. 10 S., R. 7 E.

	Feet
Foraker limestone (45.7 feet exposed)	
Long Creek limestone member	
Limestone, yellow, thin beds	6
Hughes Creek shale member (39.7 feet exposed)	
Shale, upper part covered, abundant fusulinids	16
Limestone	0.8
Shale, fossiliferous	8
Shale, calcareous, fossiliferous	1.5
Limestone, fossiliferous	1
Shale, gray blocky	1.5
Limestone, yellow	0.9
Shale, gray, many fossils near base: *Derbyia* sp., *Hustedia mormoni, Chonetes granulifer,* and crinoid stems	10

(47) C N½ sec. 26, T. 10 S., R. 7 E.

	Feet
Loess	25
Bader limestone	
Eiss limestone member	
Limestone, light in color, pitted, poorly exposed	2
Stearns shale	
Covered interval	25
Beattie limestone (19 feet)	
Morrill limestone member	
Covered	2
Florena shale member	
Covered interval	11
Cottonwood limestone member	
Limestone, characteristic Cottonwood limestone of the area	6
Eskridge shale (32.9 feet)	
Shale, green and gray, limy concretions	5.5
Limestone, thin beds	0.7
Shale, gray, green, chocolate-color, more gray near top, chocolate-colored layers stand out as miniature cliffs	26.7
Grenola limestone (33.9 feet)	
Neva limestone member (17.7 feet)	
Limestone, light-gray, dense	0.6
Shale, gray	1.5
Limestone, light-gray massive; irregular shale partings, a persistent parting 2.1 feet above base	8.3
Marlite, limy, weathers as shale, more or less honeycombed	1.6
Limestone, impure resistant	1.2
Shale, gray, dark near base, siltstone near top	3.2
Limestone, gray nodular fossiliferous, small fusulinids	1.3
Salem Point shale member (8.3 feet)	
Shale, gray, slightly calcareous	3.2
Shale, more limy than above	1.5
Shale, gray	3.6

Burr limestone member (7.9 feet)	
Limestone, light-gray, somewhat laminated, ostracodes in upper part	4.5
Shale, black, locally gray in upper part, fissile	1.4
Limestone, light in color, impure argillaceous fossiliferous, *Rhombopora* sp., *Septopora* sp., *Polypora* sp., *Dictyoclostus americanus*	2
Roca shale (25.8 feet)	
Shale, black in upper part, mostly gray, lower part more calcareous, weathers yellow near base	4.5
(Formerly called Legion shale)	
Limestone, light-gray fossiliferous	1
(Formerly called Sallyards limestone)	
Shale, varicolored, mostly green, limy nodules in part	7
Shale, red and green, some gray	1.5
Mudstone, gray, irregular uper contact, variable thickness..about	2
Shale, greenish-gray argillaceous	3.5
Limestone, dark-gray	0.3
Shale, mostly greenish-gray, some red near top	6
Red Eagle limestone (10.9 feet exposed)	
Howe limestone member	
Limestone, impure, or siltstone	3
Bennett shale member (7.9 feet exposed)	
Shale, light in color	0.8
Shale, black	0.2
Shale, dark-gray, brachiopods, though not as abundant as in black shale below	1.4
Shell bed, brachiopods, predominantly *Composita subtilita*	0.5
Shale, black fissile, fossils	0.8
Shell bed, mostly brachiopods, *Crurithyris* sp., *Linoproductus prattenianus, Composita subtilita*	0.2
Shale, black, more or less fissile, lower part blocky and nonfissile	2
Limestone, nearly white, few fossils, mostly as fragments, *Pinna* sp.	2

(48) On Blue Mount in northeast part of Manhattan, sec. 7, T. 10 S., R. 8 E.

	Feet
Beattie limestone	
Cottonwood limestone member	
Limestone, light in color, massive, many fusulinids in upper part, siliceous nodules	6
Eskridge shale	
Shale, under covered slope, word "Manhattan" in concrete letters on the slope	27
Grenola limestone	
Neva limestone member	
Limestone, partly exposed in old quarry	10
Lower part of Grenola limestone and upper part of Roca shale	
Covered slope	50 ±

Roca shale	
Limestone, probably not all exposed	0.8
Shale, green and chocolate-color	7
Red Eagle limestone (11.9 feet)	
Howe limestone member (4.8 feet)	
Limestone, massive	1.3
Limestone, shaly	0.8
Limestone, impure, grading into cancellate shale below	2.7
Bennett shale member (5.4 feet)	
Shale, green and gray, darker near base	4.2
Shale, black, white brachiopod fossils	1.2
Glenrock limestone member	
Limestone, gray, weathers brown, locally a limestone breccia	1.7
Johnson shale (18.1 feet)	
Shale, gray, some black near base	5.5
Limestone, gray and yellow, laminated	2
Mudstone	0.6
Shale, arenaceous	1
Shale, gray	2
Mudstone	1
Shale	0.5
Mudstone	0.5
Shale, not well exposed	5
Foraker limestone (47.4 feet exposed)	
Long Creek limestone member (4.9 feet)	
Limestone, thin beds, weathers cellular, pink quartz crystals projecting from surface; locally weathers as shale	2
Shale, gray argillaceous blocky	0.9
Shale, dark calcareous	0.5
Limestone, light-brown and gray, thin beds, more massive in lower part, weathers as shale	1.5
Hughes Creek shale member (38.4 feet)	
Shale, gray and yellow, small geodes and calcite veins	1.9
Mudstone, brown	0.3
Limestone or blocky shale, weathers as shale	1.5
Shale, gray, locally dark	1
Limestone, abundant fusulinids	0.9
Shale, gray, abundant fusulinids, locally with unit next above stands out as limestone	0.5
Shale, mostly dark, carbonaceous	6
Limestone, dark-gray fossiliferous, weathers light in color	0.7
Shale, black, lighter near top, fossils, *Orbiculoidea* sp. and *Lingula* sp.	0.2
Shale	2.2
Limestone, light-gray fossiliferous	1.2
Shale, dark near top, lower part not well exposed	8.7
Limestone, dark	1.3
Limestone, gray granular, fossiliferous at top	1
Shale, mostly covered	11

Americus limestone member (4.1 feet exposed)	
Limestone, impure	0.4
Shale, greenish-gray	0.2
Limestone, blue	1
Shale, carbonaceous, thin beds	1.6
Limestone, gray granular	0.9

(49) C S line sec. 28, T. 10 S., R. 8 E.

	Feet
Wreford limestone	
Threemile limestone member (8.05 feet exposed)	
Limestone, light in color, flinty	2
Limestone, light in color, no flint, weathers to pitted surfaces, ledge-making	1.8
Limestone, flinty	1.55
Shale, gray fossiliferous	0.8
Limestone, flinty	1.9
Speiser shale (13 feet)	
Shale, gray fossiliferous, *Chonetes granulifer,* Productids, few pelecypods	2.3
Limestone, light in color, granular, weathers yellow	1.1
Shale, gray, calcareous seams	1.45
Limestone, gray, thin beds, weathers brown	0.2
Shale, green and gray	2.7
Shale, chocolate-color	2
Shale, green calcareous	0.75
Shale, green and red, red in splotches	1.2
Shale, greenish-gray calcareous	1.3
Funston limestone (10.6 feet)	
Limestone, white chalky, nodular	1.8
Shale, gray and green	0.7
Limestone, light in color, more massive in upper part, almost a fine-grained oölite	5.5
Shale, gray	1.1
Limestone, brown, calcite-filled geodes in upper part, coquina in lower part	1.5
Blue Rapids shale	
Shale, upper 10 feet mostly gray, some red about 10 feet from top, rest of unit covered	29.1
Crouse limestone	
Limestone, brown granular, upper part tabular, lower part massive	6
Easly Creek shale (23.6 feet)	
Covered interval, mostly shale	10.2
Limestone, gray muddy laminated	0.9
Shale, gray, chocolate-colored bands	12.5

Bader limestone (18.4 feet exposed)	
Middleburg limestone member (3.9 feet)	
Limestone, brown granular	0.4
Shale, mostly black	0.6
Limestone, light in color, granular, rough to touch, shaly in lower part	2.9
Hooser shale member	
Shale, green and gray	4.5
Eiss limestone member	
Limestone, light in color, not well exposed	10
(Note: Top of Cottonwood limestone member of Beattie limestone formation is 37 feet below base of Eiss limestone in this section)	

(50) Sec. 34, T. 10 S., R. 8 E.

	Feet
Bader limestone	
Eiss limestone member	
Limestone, light in color, not well exposed, makes topographic bench on hills	5
Stearns shale (16.1 feet)	
Shale, mostly gray, calcareous, some thin beds of limestone near top	13
Limestone and shale, olive-green shale near top; irregular mass of veins of calcite and limestone, somewhat indefinite top	1.6
Shale, gray	1.5
Beattie limestone (15 feet)	
Morrill limestone member	
Limestone, brownish-gray hard, weathers into irregular masses of calcite-filled pits	3
Florena shale member	
Shale, gray, fossiliferous near base, *Chonetes granulifer,* bryozoa, crinoid stems	6
Cottonwood limestone member	
Limestone, light in color, massive, slightly silicified nodules, fusulinids	6
Eskridge shale (31.8 feet)	
Shale, gray calcareous, pelecypods in lower part	5.5
Limestone, gray silty	0.3
Shale, gray, red, and green, some calcareous material	26
Grenola limestone	
Neva limestone member (14.7 feet exposed)	
Limestone, light in color, massive, brittle, and somewhat nodular,	8
Shale, yellow and gray, fossiliferous in upper part, *Triticites obesus, Triticites ventricosus, Axophyllum* sp., crinoid stems, plates, and columnals, *Lissochonetes geinitzianus, Chonetes granulifer, Hustedia mormoni, Crurithyris* sp.	1.7
Limestone, gray hard; more or less nodular and brecciated, upper part weathers as shale and grades into nodular shale above	5

(51) Sec. 36, T. 10 S., R. 8 E.

	Feet
PERMIAN SYSTEM	
Foraker limestone (33.9 feet exposed)	
Hughes Creek shale member	
Covered interval, myriads of fusulinids	30
Americus limestone member (3.9 feet)	
Limestone, bluish-gray, fusulinids, crinoid stems, *Chonetes granulifer*	0.9
Shale, almost black, fossiliferous	2
Limestone, impure, not well exposed	1
Hamlin shale	
Five Point limestone	
West Branch shale	
Covered interval	38
Falls City limestone (11.7 feet)	
Limestone, dense gray argillaceous, flecks of limonite	0.9
Shale, calcareous, nodules	0.3
Limestone, few brachiopods, pelecypods	0.5
Shale not well exposed	10
Hawxby shale	
Shale not well exposed	34 ±
Aspenwall limestone	
Limestone, very poorly exposed	?
Towle shale	
Unnamed shale member	
Mostly covered, limonitic shale; where seen grades(?) into Indian cave sandstone member below	20 ±
Indian Cave sandstone member	
Sandstone and sandy shale, gray, weathers brown, micaceous, grains of quartz stained with iron rust, clay matrix; limonitic concretions in upper part, dark shaly layers in upper part	75 ±
CARBONIFEROUS SYSTEM	
PENNSYLVANIAN SUBSYSTEM	
Brownville(?) limestone (5.5 feet)	
Limestone, brown, deeply weathered	0.5±
Shale, greenish-gray fissile	3 ±
Limestone, brown and gray, deeply weathered, *Chonetes* sp., *Marginifera wabashensis,* fusulinids	2 ±
Pony Creek shale	
Shale, gray to yellow, calcareous	3 ±

(52) NE sec. 28, T. 10 S., R. 9 E.

	Feet
Dover limestone	
Limestone, light in color, crystalline fossil fragments	2 ±
Table Creek shale (18 feet)	
Shale, covered	12 ±
Shale, gray	6
Maple Hill limestone	
Limestone, bluish-gray to yellow, weathers brown, small fusulinids numerous, granular, showing calcite cleavage faces, fusulinids weather lighter in color than matrix	1.4

Pierson Point shale	
Shale, yellow and gray, limonitic concretions, irregular beds.....	17
Tarkio limestone (11 feet)	
Limestone, light in color, thin beds, fragments of other fossils and *Triticites ventricosus*..................................	5
Limestone, gray, weathers brown, cliff-forming, massive throughout but more massive in lower part, irregular beds, stylolites along planes, *Tricitites ventricosus* abundant.................	6
Willard shale (32 feet)	
Shale, yellow and gray, blocky, argillaceous.....................	8.5
Shale and sandstone, micaceous sandstone in a few thin beds, mostly shale	23.5
Elmont limestone	
Limestone, drak-blue to almost black in part, and brownish-blue to purplish-brown, weathers gray, deeply stained with iron rust, calcite cleavage faces on fracture, clusters of fossil fragments on bedding planes, *Triticites acutus* abundant..........	2
Harveyville shale	
Shale, gray in upper part, yellow in lower part, hard calcareous and limonitic concretions in upper part......................	15
Reading limestone	
Limestone, brown and gray, slightly crystalline, crinoid stems...	2.1
Auburn shale	
Shale, gray, upper part dark..................................	12

(53) Near the C sec. 29, T. 10 S., R. 9 E.

	Feet
Permian System	
Falls City limestone	
Limestone, gray brecciated, in part a coquina of pelecypods, exposed in old quarry at top of hill...........................	1.5
Covered slope	48 ±
Indian Cave sandstone	
Sandstone, fine gray micaceous, partly covered.................	18
Carboniferous System	
Pennsylvanian Subsystem	
Dover limestone	
Limestone, light-gray, mostly covered..........................	2 ±
Table Creek shale	
Shale, covered	10 ±
Maple Hill limestone	
Limestone, light in color, crinoid columnals and *Triticites acutus*, almost covered, makes bench on hillside.....................	?
Pierson Point shale	
Shale, covered	15 ±
Tarkio limestone	
Limestone, gray and brown, massive but deeply weathered, giant fusulinids, *Triticites ventricosus*............................	10

(54) SE sec. 32, T. 10 S., R. 9 E.

	Feet
Tarkio limestone	
Limestone, brown massive, giant fusulinids	6
Willard shale	
Covered slope	20
Elmont limestone	
Limestone, dark-blue to almost black, brittle, massive, weathers gray to brown, shows splotches of iron rust, calcite cleavage on fresh surfaces, small fusulinids	1.5
Harveyville shale	
Shale, (mostly covered)	20
Reading limestone	
Limestone, brown dense hard, beds 6 to 7 inches thick	2

(55) C N sec. 14, T. 11 S., R. 4 E.

	Feet
Winfield limestone (27.2 feet exposed)	
Luta(?) limestone member (12.7 feet)	
Limestone, almost white, chalky, large calcite geodes	4
Shale, white powdery, beds of limestone near top, geodes	0.5
Limestone, almost white, chalky, yellow calcite concretions, locally a chalky shale	5
Shale, very chalky, small calcite geodes	3.2
Cresswell limestone member	
Limestone, light-gray, weathers white, massive, shaly in lower part, uneven contact with Grant shale member below, echinoid spines	3.5
Grant shale member	
Shale, gray	10
Stovall limestone member	
Limestone, gray fossiliferous flinty	1

(56) Sec. 22, T. 11 S., R. 5 E.

	Feet
Doyle shale	
Towanda limestone member	
Limestone, mostly covered	
Holmesville shale member	
Covered interval	22.5
Barneston limestone (49.3 feet)	
Fort Riley limestone member (17.3 feet)	
Limestone, light in color, pitted, thinner beds in upper part	1.6
Covered interval	12
Limestone, light in color, massive "rim rock," pitted upon weathered surfaces	3.7
Oketo shale member(?)	
Covered interval	5
Florence limestone member (27 feet)	
Covered interval	12
Limestone, massive, no flint at top; shaly, no flint at base, flinty in other parts	15

Matfield shale (47.6 feet exposed)	
Blue Springs shale member (35.3 feet)	
Shale, gray, red, and green	20
Limestone, light in color, weathers red	0.8
Shale, gray, some red and green	14.5
Kinney limestone member (6.3 feet)	
Limestone, impure, weathers as shale, grades into shale below	3
Shale, gray calcareous fossiliferous	1.3
Limestone, impure granular, grades into shale below	2
Wymore shale member	
Shale, gray, somewhat blocky near base	6

(57) C S line sec. 7, T. 11 S., R. 8 E.

	Feet
Wreford limestone (38.8 feet exposed)	
Schroyer limestone member	
Limestone, flinty	2
Covered slope, concealing lower part of Schroyer limestone, Havensville shale, and upper part of Threemile limestone	30
Threemile limestone member	
Limestone, white, no flint	2
Limestone, flinty	2.3
Shale, gray fossiliferous	0.9
Limestone, flinty	1.6
Speiser shale (14.4 feet)	
Shale, gray fossiliferous	2.1
Limestone, light in color, dense	0.7
Shale, red and green	11.6
Funston limestone	
Limestone, light in color, chalky, massive	3.3
Blue Rapids shale	
Shale, mostly gray, some bands of chocolate-color	20
Crouse limestone	
Limestone, gray to brown, tabular, laminated, more massive in lower part	10
Easly Creek shale (22 feet)	
Shale, yellow nodular	6
Limestone, gray, shaly in upper part	2
Shale, gray and green, lower 5 feet covered	14
Bader limestone (17.8 feet)	
Middleburg limestone member (5.4 feet)	
Limestone, brecciated	0.5
Shale, black	0.5
Limestone, dark, partly covered	3.6
Limestone, argillaceous	0.8
Hooser shale member	
Shale, gray	5.6

Eiss limestone member (6.8 feet)	
Limestone, pitted where weathered	2.7
Shale, gray	2.7
Limestone, gray earthy fossiliferous	1.4
Stearns shale	
Shale, gray	20
Beattie limestone (17.5 feet)	
Morrill limestone member	
Limestone, brown, weathers into irregular mass, hardly more than a calcareous zone	2
Florena shale member	
Shale, gray fossiliferous, not well exposed	10
Cottonwood limestone member	
Limestone, light in color, massive, fusulinids	5.5
Eskridge shale	
Shale, mostly gray, not all exposed	21.7
Grenola limestone (31.7 feet exposed)	
Neva limestone member (13.1 feet)	
Limestone, gray granular	1.5
Limestone, gray, mostly in thin beds	4.1
Limestone, gray brecciated	4.5
Shale, yellow and gray	2.5
Limestone, gray	0.5
Salem Point shale member	
Shale, gray, calcareous at top	8.1
Burr limestone member (10.5 feet exposed)	
Limestone, gray, thin beds, laminated	5.5
Limestone, gray dense	5

(58) Sec. 19, T. 11 S., R. 8 E.

	Feet
Barneston limestone	
Florence limestone member	
Covered interval	40
Matfield shale (83.5 feet)	
Blue Springs shale member	
Shale, green, chocolate-color, and gray, not well exposed	55
Kinney limestone member (3.8 feet)	
Limestone, thin-bedded and shaly	3
Limestone, yellow to gray, massive, one bed	0.8
Wymore shale member	
Shale, gray, green, chocolate-color, and yellow	24.7
Wreford limestone	
Schroyer limestone member (6 feet exposed)	
Limestone, light in color, no flint	2
Covered interval	4
Limestone, flinty	?

(59) Sec. 31, T. 11 S., R. 8 E.

	Feet
Wreford limestone	
Threemile limestone member (9.5 feet exposed)	
Limestone, thin beds	1
Limestone, flinty	1
Limestone, light in color, weathers gray, no flint, fossils as fragments	2.2
Limestone, light in color to white, flint in bands 1 to 7 inches thick	2.3
Shale, gray fossiliferous	0.6
Limestone, gray flinty, crinoid stems in flint	2.4
Speiser shale	
Shale, dark-gray, brachiopods	3

(60) C S sec. 5, T. 11 S., R. 9 E.

	Feet
Tarkio limestone (13.2 feet exposed)	
Limestone, light-gray, small amount green and brown, granular, *Triticites ventricosus, Rhombopora* sp.	2.1
Limestone and calcareous shale, mostly limestone, weathers as shale, very brown in lower part	2.7
Shale, gray	2.2
Limestone, brown massive, giant fusulinids	6.2
Willard shale	
Shale, gray	5

(61) NW sec. 5, T. 11 S., R. 9 E.

	Feet
Tarkio limestone (12.5 feet exposed)	
Limestone, brown granular, thinner beds than in unit below, fusulinids smaller than in unit below	4
Limestone, shaly	2
Limestone, brown massive, giant fusulinids	6.5
Willard shale	
Shale, gray, blue when wet, somewhat blocky	25
Elmont limestone	
Limestone, dark-blue to gray, brittle, fossils and fossil fragments,	2.1
Harveyville shale	
Shale, gray	5

(62) S line sec. 6, T. 11 S., R. 9 E.

	Feet
Tarkio limestone	
Limestone, very brown	0.7
Willard shale	
Shale, gray and green	20 ±
Elmont limestone	
Limestone, dark-blue, calcite crystals, fusulinids	1
Harveyville shale	
Shale, gray, to water of Deep creek	2

(63) NE sec. 6, T. 11 S., R. 9 E.

	Feet
Dover limestone	
Limestone, light in color, weathered into slabs, fusulinids	2 ±
Table Creek shale	
Shale, greenish-gray, more green in upper part, nodular, calcareous zones near top	16 ±
Maple Hill limestone	
Limestone, dark-gray to yellow, granular, calcite crystals, mottled on fresh exposures, small fusulinids	1.4±
Pierson Point shale	
Shale, partly covered	20
Tarkio limestone	
Limestone, brown, giant fusulinids, (top only exposed)	

(64) C sec. 9, T. 11 S., R. 9 E.

	Feet
PERMIAN SYSTEM	
Towle shale	
Indian Cave sandstone member	
Sandstone, gray fine micaceous, covered in road but exposed in weathered condition in cultivated field south of road	12
CARBONIFEROUS SYSTEM	
PENNSYLVANIAN SUBSYSTEM	
French Creek shale	
Shale	10 to 15
Jim Creek limestone (4.65 feet)	
Limestone, blue to brown, nodular, *"Osagia"* and cryptozoa	0.55
Shale, yellow	2.5
Limestone or mudstone, soft yellow limonitic	0.1
Limestone, crystalline	0.2
Covered	1
Limestone, blue to gray, hard crystalline, pelecypods	0.3
Dry-Friedrich shale	
Covered slope	64
Dover limestone	
Limestone, covered	

(65) SE sec. 15, T. 12 S., R. 5 E. (Measured by M. K. Elias)

	Feet
Doyle shale (31.1 feet exposed)	
Towanda limestone member (9.1 feet exposed)	
Limestone, solid, coquina-like to fine conglomerate, cross-bedded,	2.5
Limestone, somewhat porous, small *Murchisonia*	3.8
Shale, calcareous	0.8
Limestone	2
Holmesville shale member (22 feet)	
Mudstone, geodiferous in lower half	8
Shale, calcareous	1
Shale, small geodes	0.5
Shale, calcareous, to mudstone	1.5
Limestone, porous, geodes	0.5
Shale, calcareous	0.5

Limestone, in two beds, small geodes	3
Shale, calcareous, *Pleurophorus* and *Aviculopecten,* and rod-like impressions	2.5
Shale, calcareous	4.5
Barneston limestone	
Fort Riley limestone member (9.0 feet exposed)	
Limestone, massive, *Derbyia, Meekella, Aviculopecten,* and *Straparollus*	1.8
Limestone, shaly	0.5
Limestone, massive	6.7

(66) C sec. 7, T. 12 S., R. 6 E.

	Feet
Doyle shale	
Towanda limestone member	
Holmesville shale member	
Barneston limestone	
Covered interval, Towanda limestone at top; upper part of Fort Riley limestone member of Barneston limestone at base	65
Barneston limestone (55 feet exposed)	
Fort Riley limestone member (18 feet exposed)	
Limestone, thin beds	10
Limestone, "rim rock," massive near top, thinner beds below	8
Oketo shale member(?)	
Shale, some limestone	5.5
Florence limestone member (31.5 feet)	
Limestone, small amount of flint	2
Shale	1.5
Limestone, flinty	5
Shale	1.5
Limestone, flinty	3
Shale, calcareous	1.5
Limestone, very flinty, limestone and flint in beds, limestone, granular, weathers into pitted blocks; limestone in beds about 0.7 foot thick; flint in bands and nodules 0.1 to 0.5 feet, few fossils	17
Matfield shale (48.6 feet exposed)	
Blue Springs shale member (44.6 feet)	
Shale, calcareous	1.4
Limestone, impure silty gray	0.5
Shale, gray, chocolate-color, and green, gray near base, fossiliferous and calcareous near top	42.7
Kinney limestone member (4 feet)	
Limestone, gray dense, fossils as fragments	0.9
Shale, yellow to gray	1.6
Shale, calcareous	1.5
Wymore shale member	
Wreford limestone	
Speiser shale	
Covered slope, part of Blue Rapids shale and Crouse limestone exposed at base	

(67) Sec. 9, T. 12 S., R. 6 E.

	Feet
Barneston limestone (70.4 feet exposed)	
Fort Riley limestone member (22.2 feet exposed)	
Limestone, light in color, thin beds	15
Limestone, massive "rim rock"	4
Shale, yellow	1.6
Limestone, yellow	0.6
Limestone, yellow impure	1
Oketo shale member	
Shale, bluish-gray to yellow, calcareous	4
Florence limestone member (44.2 feet)	
Limestone, yellow soft, small amount of flint	2.3
Shale, calcareous	1
Limestone, small amount of flint	3
Limestone, much flint	1.4
Shale, fossiliferous	3
Limestone, thin beds near base, flint near base	5
Shale, yellowish-gray	0.8
Limestone, somewhat thin-bedded, flinty	5
Limestone, shaly	1
Limestone, light in color, weathers brown, steel-gray flint	19
Limestone, impure flinty fossiliferous	1.6
Limestone, shaly fossiliferous	1.1
Matfield shale (75 feet)	
Blue Springs shale member (26.6 feet)	
Shale, yellow and gray, calcareous concretions	3
Shale, varicolored, mostly red and green	23.6
Kinney limestone member (31.4 feet)	
Limestone, fossiliferous	0.5
Shale	10.8
Limestone, yellow flaky, pelecypods	0.6
Shale, yellow to gray, fossiliferous	7.5
Shale, gray blocky	1.5
Shale, gray	5.5
Limestone, covered	5
Wymore shale member (17 feet)	
Shale, purple near top, red and green	12
Covered interval	5
Wreford limestone (24.3 feet exposed)	
Schroyer limestone member (18.3 feet)	
Limestone, gray crystalline	0.8
Limestone, flinty, large bryozoa	11
Shale, light-gray, maximum thickness	2
Limestone, yellow to brown, steel-gray flint, shaly near base, productids	4.5
Havensville shale member	
Shale, gray, soft and powdery near top, more calcareous near base	6

(68) NE sec. 3, T. 12 S., R. 7 E.

	Feet
Barneston limestone	
Florence limestone member	
Limestone, flinty	
Matfield shale (61.7 feet)	
Blue Springs shale member (20 feet)	
Shale, yellow, calcareous zones	10
Shale, mostly red, calcareous zones	10
Kinney limestone member (22 feet)	
Limestone, chalky, stained red from shale above	2.5
Shale, gray, some red and green, not well exposed	12
Limestone, gray, pelecypods	0.5
Shale, gray	4
Limestone, gray, massive in lower part	3
Wymore shale member (19.7 feet)	
Shale, gray, calcareous zones	6
Shale, calcareous	0.1
Shale, mostly gray, small amount of red	6.5
Limestone, gray	0.6
Shale, gray, green, and red	6
Limestone, red, chalky	0.5
Wreford limestone (35.1 feet)	
Schroyer limestone member (10.9 feet)	
Limestone, abundant flint	5
Shale, light-yellow powdery	1.5
Limestone, yellow, thin beds	0.4
Shale, green nodular	2
Limestone, partly silicified	0.2
Shale, gray calcareous	0.6
Limestone, gray, weathers brown	1.2
Havensville shale member (16 feet)	
Shale, gray to yellow, thin limestone in middle part	6
Covered interval	10
Threemile limestone member (8.2 feet)	
Limestone, abundant flint	1
Limestone, light in color, soft, tough, no flint, weathered to pitted surfaces, makes bold outcrop line	2
Limestone, flinty	0.8
Limestone, three bands of flint	1.7
Limestone, yellow impure	0.4
Shale, gray, abundant fossils	0.9
Limestone, light-gray, steel-gray flint	1.4
Speiser shale (15.6 feet)	
Shale	0.1
Limestone	0.2
Shale, yellow and gray, many fossils, more abundant in upper part	2.5

Limestone, very persistant over entire area	0.5
Shale, gray, bands of red and green	10.6
Limestone, in thin beds, interbedded with shale	0.7
Shale, green and yellow	1
Funston limestone (15.4 feet)	
Limestone, yellow dense	0.6
Shale, few limy zones or limestone beds	14
Limestone, nonresistant to weathering	0.8
Blue Rapids shale	
Shale, not well exposed, green near top, weathers into gentle slope	11
Crouse limestone	
Limestone, not well exposed, brown and platy near top, more massive in lower part	12
Easly Creek shale	
Shale, gray, not well exposed	5
Bader limestone (15.3 feet)	
Middleburg limestone member	
Limestone, gray, some iron rust, massive in lower part, fragments of fossils	1
Hooser shale member (9.8 feet)	
Shale, yellow, bands of green	4
Limestone, impure shaly	0.3
Shale, yellow and gray, bands of red	5.5
Eiss limestone member	
Limestone, light-gray, in thin beds, weathers lighter in color, upper part slightly limonitic and irregular in mode of weathering	4.5
Stearns shale	
Shale, yellow and gray	5

(69) C S line sec. 18, T. 12 S., R. 7 E.

	Feet
Wreford limestone	
Threemile limestone member	
Limestone, light in color, massive, small amount of flint	3
Limestone, abundant flint	3.5
Limestone, shaly fossiliferous	0.5
Shale, gray	0.2
Limestone, few thin beds	?
Speiser shale	
Funston limestone	
Blue Rapids shale	
Crouse limestone	
Easly Creek shale	
Bader limestone	
Covered slope, Crouse limestone and Eiss limestone member of Bader limestone partly exposed, latter at base	50

(70) C S line sec. 34, T. 12 S., R. 7 E.

	Feet
Wreford limestone	
Threemile limestone member (8 feet exposed)	
Limestone, flinty	5
Limestone, small amount of flint	3
Speiser shale (15 feet exposed)	
Shale, gray fossiliferous	2
Limestone, gray crystalline	1
Shale, red and green	12

(71) E line sec. 33, T. 13 S., R. 7 E.

	Feet
Doyle shale (27.9 feet exposed)	
Towanda limestone member	
Limestone, yellow impure, contains some red, green, and yellow shale	5.4
Holmesville shale member	
Covered interval, (measurement may be too small because of slumping of Towanda limestone)	22.5
Barneston limestone	
Fort Riley limestone member (12.5 feet exposed)	
Limestone, somewhat silicified	2
Covered interval	4.5
Limestone, yellow, in thin beds	1
Shale, yellow chalky	5
Limestone, light-yellow, weathers white, massive "rim rock"	?

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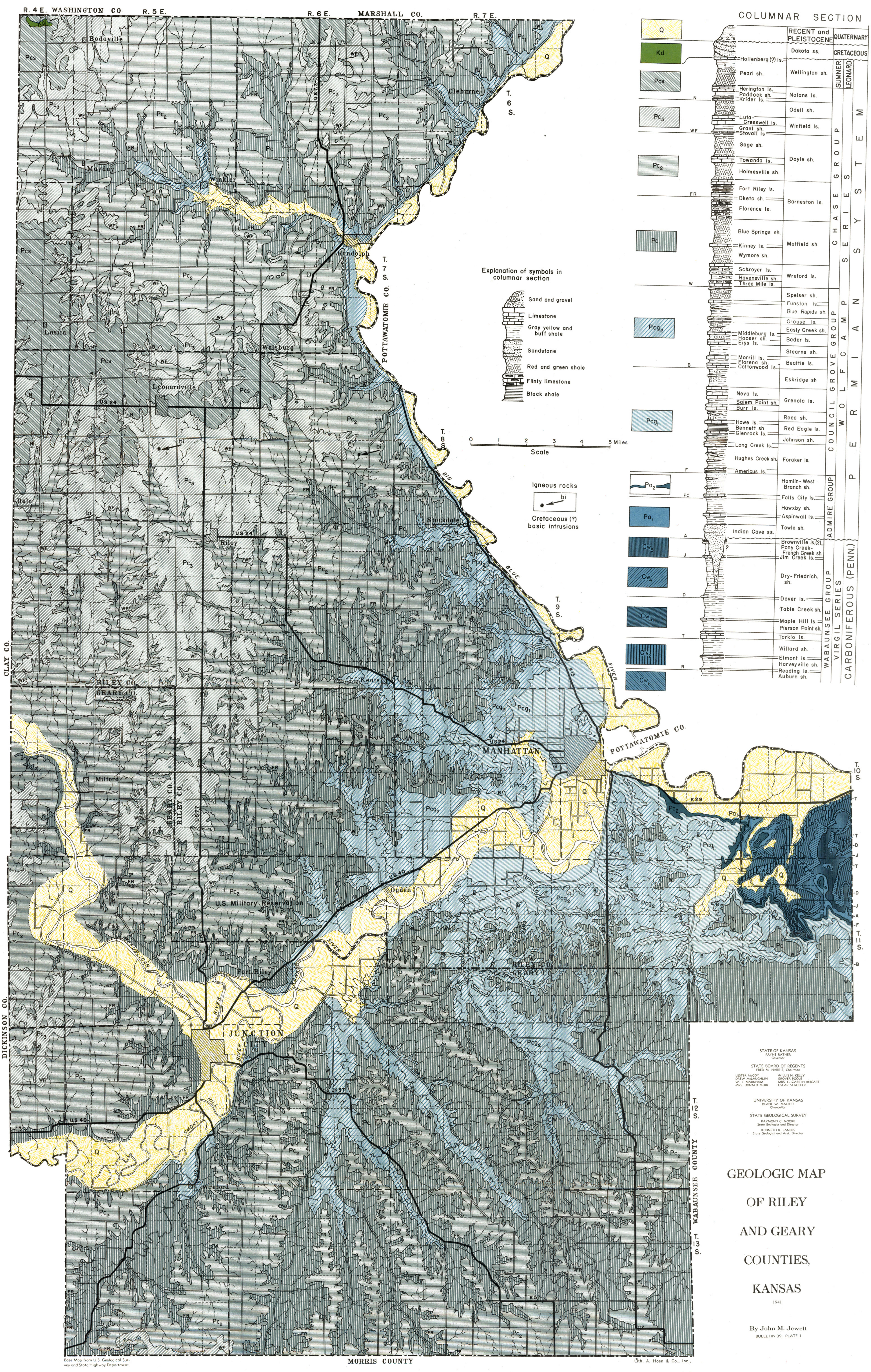
PRINTED BY KANSAS STATE PRINTING PLANT
W. C. AUSTIN, STATE PRINTER
TOPEKA 1941
19-793



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GEOLOGIC MAP OF RILEY AND GEARY COUNTIES, KANSAS

1941

By John M. Jewett

BULLETIN 39, PLATE 1