Geology and Ground-Water Resources of Neosho County, Kansas

By William L. Jungmann

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ABSTRACT

Neosho County has an area of 576 square miles and is within the Osage Plains section of the Central Lowlands province of eastern Kansas. Sedimentary rocks of Cambrian, Ordovician, Devonian(?), Mississippian, Pennsylvanian, Tertiary, and Quaternary ages overlie the Precambrian basement complex, and they have a thickness of 2,100 feet. Rocks exposed in the County are of Pennsylvanian, Tertiary, and Quaternary ages that attain a thickness of 700 feet. Structure is controlled by the Prairie Plains Monocline in which the exposed Pennsylvanian rocks dip northwest at about 20 feet per mile.

Wells in consolidated rocks of Pennsylvanian age yield less than 1 gallon per minute of water from some limestone and shale aquifers to more than 30 gallons per minute from sandstone aquifers. The water from the consolidated aquifers is highly mineralized, but the sandstones tend to yield a softer, less mineralized water. Wells within unconsolidated Pleistocene alluvial deposits yield up to 30 gallons per minute.

The chief use of the ground water is for domestic and stock purposes, whereas all municipal systems use treated surface water. The estimated total use of ground water in 1961 was 109 million gallons (334 acre-feet).

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The investigation of the geology and ground-water resources of Neosho County was made in order to determine the quantity and quality of ground water available for domestic, stock, municipal, and industrial uses. The investigation upon which this report is based is part of a continuing program of ground-water investigations in Kansas begun in 1937 by the U. S. Geological Survey and the State Geological Survey of Kansas in cooperation with the Environmental Health Service of the Kansas State Department of Health, and the Division of Water Resources of the Kansas State Board of Agriculture.

LOCATION AND EXTENT OF AREA

Neosho County, in southeastern Kansas, is bounded on the east by Bourbon and Crawford counties, on the north by Allen County, on the west by Wilson County, and on the south by Labette County (Fig. 1); it has an area of about 576 square miles.

PREVIOUS INVESTIGATIONS

The rocks that crop out in Neosho and adjacent southeastern Kansas counties have been studied and described by many workers. Some of the most significant reports are by Haworth (1915), Sayre (1930), Moore (1936), Jewett (1941), 1945, 1951) Keroher and Kirby (1948), Howe (1956), Farquhar (1957), and Harbaugh (1959).

Studies pertaining to the ground-water resources of the area have been made by Bailey (1902), Haworth (1913), Moore, *et al.* (1940), Lohman, *et al.* (1942), and Williams (1944, 1948).

The oil and gas resources of Neosho County and adjacent areas have been discussed by Moore and Haynes (1917), Moore and Elledge (1920), Lee (1939), Jewett and Abernathy (1945), Jewett (1954), and Runnels, *et al.* (1952). Coal resources of the area have been studied by Whitla (1940), Schoewe (1944, 1955), Abernathy, *et al.* (1947), Hambleton (1953), and Schleicher and Hambleton (1954).

METHODS OF INVESTIGATION

Field work was begun in Neosho County in July of 1960. The geology was mapped in the spring and summer of 1961 and in the spring of 1962. Test holes were drilled in November of 1960 and July of 1964. Data were collected on 171 wells, which included the depth of the well and the depth to water in each well. Data concerning yield, type and depth of water-bearing material, and general quality of the water were obtained from well users. Fifteen test holes were augered and two were drilled with a cable-tool machine in the valley of the Neosho River to determine the thickness and lithologic properties of the alluvial material. Logs of the test holes were prepared in the field, and the drill cuttings were studied microscopically in the labora-

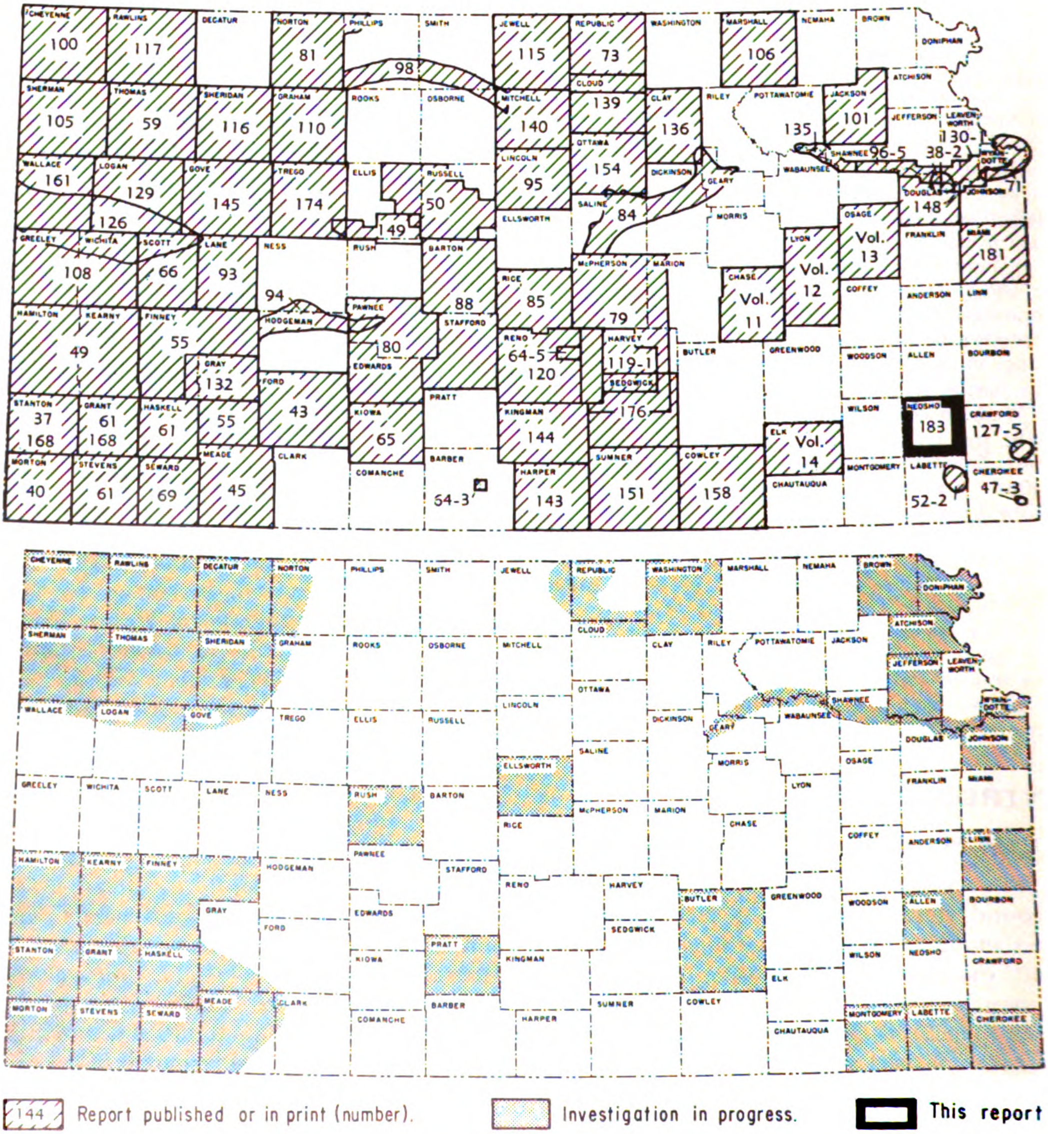

FIGURE 1.—Map showing area discussed in this report and other areas in Kansas for which ground-water reports have been published or are in preparation.

tory. Altitudes at the augered test holes were determined using an alidade and plane table. Altitudes of inventoried wells and the cable-tool test holes were interpolated from topographic maps of the area. Samples of water were collected from 42 selected wells. Chemical analyses of the water were made by the Environmental Health Service Laboratory of the Kansas State Department of Health.

WELL-NUMBERING SYSTEM

The well numbers used in this report are based on the location of each well according to the General Land Office survey of the area. The number contains, in abbreviated form, the township, range, section, quarter section, and quarter-quarter section of each location. When two or more wells are within the same 40-acre tract, they are numbered serially according to the order in which they were inventoried. The quarter sections within each mile section are designated *a*, *b*, *c*, and *d* in a counterclockwise direction, with *a* indicating the northeast quarter. The 40-acre tracts within each quarter section are designated in a similar manner. For example, well 27-18-22caa (Fig. 2) is in the NE NE SW sec. 22, T 27 S, R 18 E.

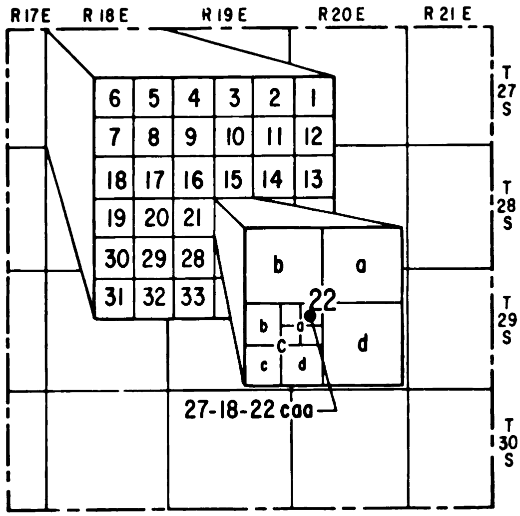

FIGURE 2.—Map of Neosho County, Kansas, illustrating well-numbering system used in this report.

ACKNOWLEDGMENTS

Appreciation is expressed to the many residents of Neosho County who supplied information concerning local geology, wells, and water supplies. John Bashor and Robert Williams, geologists, of the District Office of the Kansas State Department of Health at Chanute, supplied much information concerning the quality of ground water from wells in Neosho County. Sutcliffe Pipe and Supply and James E. Guinotte, consulting geologist, contributed many driller's logs and other stratigraphic information. Jungmann Brothers Drilling Company, Inc., of Carbondale, Kansas, drilled the two cable-tool test wells in the Neosho River valley. The State Highway Department of Kansas made available much geologic information from their files, including geologic profiles of several highway projects. Stratigraphic sections and other unpublished data on the geology and ground-water resources of the area collected by members and former members of the U. S. and State Geological Surveys were utilized in the preparation of this report; their assistance is gratefully acknowledged.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Neosho County is near the southeast edge of the Osage Cuesta division of the Osage Plains section of the Central Lowlands physiographic province (Schoewe, 1949). The major topographic features are the southeast-trending valley of Neosho River and the gentle, rolling hills and low cuestas formed on the uplands by differential erosion of limestone, sandstone, and shale.

The highest point in Neosho County, about 1,090 feet above mean sea level, is in the northeast corner near Bourbon County. The lowest point in the County is about 840 feet just west of the Crawford County line on the southern boundary of the County. Thus, the maximum relief is about 250 feet.

Neosho County is drained by the Neosho River and its tributaries, except for the southwest corner, which is drained by tributaries of the Verdigris River.

CLIMATE

Neosho County has a humid, continental climate. The mean annual precipitation at Chanute is 37.88 inches and the mean annual temperature is 57.6° F (Records, U. S. Weather Bureau). About three-fourths of the annual precipitation falls during the growing season, which averages 194 days. The average date of the first killing frost in the fall is October 21, and the average date of the last killing frost in the spring is April 10.

POPULATION

Neosho County had a population of 19,455 in 1960, ranking 28th among the counties of the State. Chanute, the largest city, had a population of 10,849. Erie, the county seat and second largest city in the County, had a population of 1,309. Other communities and their 1960 populations are: St. Paul, 675; Thayer, 396; Galesburg, 128; Earlton, 104; and Stark, 96.

AGRICULTURE AND INDUSTRY

Agriculture is an important part of the economy of Neosho County. Machinery and tools for the petroleum industry, cement, fertilizer, waxes, and processed food products are manufactured.

MINERAL RESOURCES

Oil and gas.—Oil was discovered in the County in 1899 east of Chanute along the Neosho River valley. In 1961, oil production from 1,920 wells in nine fields amounted to 477,038 barrels of which about 80 percent was obtained from 33 secondary recovery projects. Gas production, which began in the County in 1894, amounted to 84,703,000 cubic feet during 1961. Nearly all petroleum and gas production in the County is from the "Bartlesville sand," a sandstone in the middle part of the Cherokee Group.

Investigations by the State Geological Survey of Kansas (Runnels, *et al.*, 1952) show that black shale of the Pleasanton Group may yield as much as 6.47 gallons of oil per ton when subjected to distillation processes.

Limestone.—In 1961, limestone quarried for various purposes amounted to 935,615 tons valued at $935,609. Lime for agricultural purposes accounted for 64,571 tons of the total production. This tonnage, valued at $88,685, made Neosho County the largest producer of agricultural lime in the State.

Ceramic materials.—In 1961 no shale cropping out in Neosho County was utilized for ceramic purposes. However, both the Lane and Bonner Springs shales and shale from the Pleasanton Group have good firing properties (Norman Plummer, personal communication). In the early part of the twentieth century a brick plant operating near Chanute used the Lane and Bonner Springs shales as raw material. This shale was used as a source of alumina and silica for the manufacture of cement in 1961.

STRATIGRAPHY OF SUBSURFACE ROCKS

Sedimentary rocks of Paleozoic and Cenozoic ages overlie the basement complex of Precambrian age in Neosho County. The subsurface Paleozoic rocks of Cambrian, Ordovician, Devonian(?), Mississippian, and Pennsylvanian ages have an average thickness of 2,100 feet, as shown by logs and drill cuttings from oil and gas wells in the area.

PRECAMBRIAN ROCKS

The Precambrian rocks of Kansas, as shown by drill cuttings from wells, consist of quartzite, schist, slate, marble, prophyry, and granite. The Precambrian surface in Neosho County slopes to the west from about 1,000 feet below sea level at the Crawford county line to about 1,200 feet below sea level at the Wilson county line. An apparent ridge of low relief on the Precambrian surface trends east-west through central Neosho County (Jewett, 1954, fig. 9).

CAMBRIAN SYSTEM

The Lamotte Sandstone of Late Cambrian age unconformably overlies the Precambrian rocks and is conformable with the overlying Bonneterre Dolomite. The Lamotte is an unsorted quartzose sandstone with an arkosic zone in the basal part. The sandstone is thought to be present and to have a thickness of less than 20 feet throughout Neosho County. In the Dack *et al.* # 1 Arnett well (NE NW SW sec. 8, T 30 S, R 18 E) in southwestern Neosho County, 65 feet of Bonneterre Dolomite of Late Cambrian age underlies the Arbuckle Group and is conformable with it.

CAMBRIAN AND ORDOVICIAN SYSTEMS

In Neosho County four subdivisions of the Arbuckle Group of Late Cambrian and Early Ordovician ages are recognized. The Eminence Dolomite of Late Cambrian age is 39 feet thick in the Dack *et al.* # 1 Arnett well. The subdivisions of rocks of Early Ordovician age in the well are: the undivided Gasconade Dolomite and Van Buren Formation with a slight thickness of the Gunter Sandstone Member at the base, 295 feet; the Roubidoux Formation, 30 feet; and the undifferentiated Cotter and Jefferson City dolomites, 483 feet. In Neosho County, Upper Ordovician rocks and Silurian rocks are missing (Lee and Merriam, 1954).

DEVONIAN OR MISSISSIPPIAN SYSTEM

The Chattanooga Shale of Late Devonian and Early Mississippian age is represented by 5 feet of black shale in Neosho County. The shale is conformably overlain by rocks of Early Mississippian (Kinderhookian) age.

PENNSYLVANIAN SYSTEM

Pennsylvanian rocks in Neosho County are represented by the Desmoinesian and Missourian stages. The Desmoinesian Stage comprises the Cherokee Group and Marmaton Group. Rocks of the Pleasanton Group and the Kansas City Group and part of the Lansing Group represent the Missourian Stage.

No rocks older than the Pawnee Limestone of the Marmaton Group crop out in the County. Test holes in the Neosho River valley in T 31 S, R 21 E, Labette County, 3 miles south of the Neosho and Labette county line, encountered limestone and shale members of the Fort Scott Limestone.

STRATIGRAPHY OF OUTCROPPING ROCKS [1]

The terminology used to describe the bedding of the several geologic units is that proposed by McKee and Weir (1953) and modified by Ingram (1954). Grain sizes used in the descriptions of sandstones, siltstones, and alluvial deposits are those given in the Wentworth Grade Scale as modified by Dunbar and Rodgers (1957, p. 161). The texture of limestones has been described according to an adaptation of the Wentworth Grade Scale proposed by Payne (1942, p. 1706). A graphic column of outcropping rocks in the County is shown in Figure 3.

PENNSYLVANIAN SYSTEM—MIDDLE PENNSYLVANIAN SERIES

Desmoinesian Stage—Marmaton Group

Pawnee Limestone

The Pawnee Limestone is the oldest rock that crops out in Neosho County. Only the Laberdie Limestone Member of the Pawnee is seen in the County.

Laberdie Limestone Member

Medium-bedded to thick-bedded, light-gray, medium-crystalline limestone about 20 feet thick comprises the Laberdie in Neosho County. Massive colonies of the coral *Chaetetes* are abundant near the top of the Laberdie. Gray clay-shale partings occur between the limestone beds. The only outcrop of the Laberdie found in Neosho County is in the SE sec. 31, T 30 S, R 21 E.

Bandera Shale

The Bandera Shale, which is composed of three lithologic units, ranges in thickness from about 60 feet near the Crawford county line to about 90 feet at the Labette county line. Excellent exposures of the formation are found along the Neosho River in the southeastern part of the County.

The lower unit of the Bandera is a brownish-yellow to dark-brown, medium-bedded quartzose sandstone with predomi-

1. The classification and nomenclature of rock units described in this report follow that of the State Geological Survey of Kansas and differ somewhat from the classification and nomenclature of the U. S. Geological Survey.

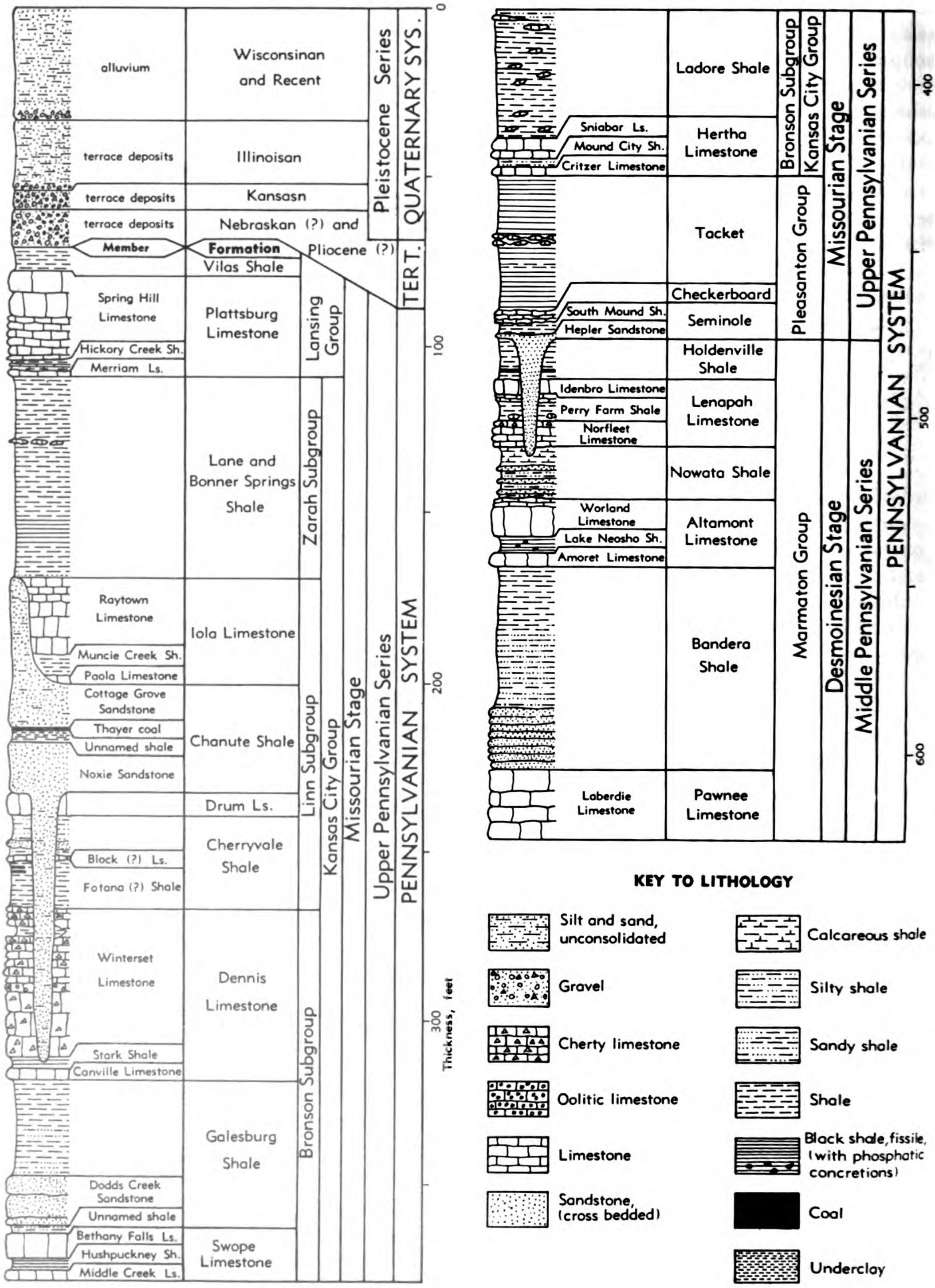

FIGURE 3.—Graphic column of outcropping rocks, Neosho County, Kansas.

nantly iron-oxide cement. Thickness of this sandstone ranges from 30 to 45 feet. Individual sandstone beds have an average thickness of about 1 foot and are separated by brownish-yellow, sandy shale partings. In some localities near the southern boundary of the County, the interbedded, sandy shale is the dominant lithology. Where this occurs the sandstone beds are about 3 inches thick. The sand is moderately sorted with a grain size ranging from less than 0.1 mm to 1.0 mm in diameter. The base of the Bandera is covered by terrace and alluvial deposits in the Neosho River valley except in SE sec. 31, T 30 S, R 21 E, where the underlying Pawnee Limestone is exposed.

Overlying the sandstone is a dark brownish-orange, medium-bedded, sandy shale that ranges from 20 to 30 feet in thickness. Current-formed ripple marks are common on bedding planes. The sand grains are predominantly of quartz, moderately rounded, and generally less than 0.5 mm in diameter.

The upper portion of the Bandera is a dark-gray, blocky clay shale ranging in thickness from 10 to 15 feet. Marine fossils such as brachiopods and crinoid columnals are sparsely distributed at the top of this unit in a 0.5-foot yellow clay-shale zone.

Altamont Limestone

The Altamont Limestone in Neosho County comprises two limestone members separated by a shale member. In ascending order, the members are: Amoret Limestone, Lake Neosho Shale, and Worland Limestone. The formation is as much as 30 feet thick in some areas, but the average thickness is about 20 feet. Excellent exposures of the Altamont occur in the southeastern part of the County where it forms prominent bluffs along the west side of the Neosho River valley.

Amoret Limestone Member

The Amoret Limestone Member in Neosho County consists of one bed of massive limestone or, locally, of two limestone beds separated by a thin shale. The two limestone beds are best exposed in the vicinity of Neosho County State Lake. Near the lake the lowermost limestone is a wavy-bedded, light-gray limestone about 10 feet thick that weathers tan on the outcrop. Jewett (1941, p. 332) reported the brachiopod *Mesolobus* in the basal portion of this bed. A zone of light-gray clay shale about 1 foot thick separates the lower limestone from an overlying massive, light-gray to bluish-brown limestone about 5 feet thick. The texture of the upper limestone ranges from finely-crystalline to marly. Locally, a 0.5-foot gray shale bed is found about 1.5 feet below the top of this limestone. Crinoid columnals and brachiopod fragments are the most common fossils. Northeast of the lake along the outcrop of the Altamont, a 3-foot massive-bedded limestone is the only bed representing the Amoret.

Lake Neosho Shale Member

The Lake Neosho Shale Member is well exposed only in the vicinity of the type section near the Neosho County State Lake. In this area the Member consists of about 3 feet of black fissile shale. Locally, discontinuous lenses of dark-blue, blocky shale occur at the top. Oblate, phosphatic concretions about 0.5 inch thick and uniformly about 1.5 inches in their longest dimension are common throughout the bed. Northeast of the lake, along the line of outcrop of the Altamont where the limestone members are not everywhere well exposed, the approximate stratigraphic position of the Lake Neosho Shale may be inferred from the presence of the phosphatic concretions weathered from the outcrop.

Worland Limestone Member

The Worland is a light-gray, very finely crystalline, massive limestone, which weathers almost white on the outcrop. Average thickness of the Member is about 9 feet. Locally, the upper 3-4 feet of the Worland is thin bedded with gray, clay-shale breaks. Transparent void-filling calcite is found throughout the Member but is more common in the upper, thin-bedded limestone. Fossils such as the brachiopod *Mesolobus* and crinoid columnals which have been replaced by crystalline calcite are common. Where the Worland is composed of a single massive bed, two sets of vertical joints enlarged by solution activity are a conspicuous feature. The major joint set has an average bearing of N 40° E and the minor set about N 45° W. The Worland is the prominent escarpment-forming member of the Altamont Limestone.

Nowata Shale

Yellowish-brown to tan shale is the dominant lithology of the Nowata Shale. The thickness of the unit ranges from about 16 feet in the vicinity of Neosho County State Lake to a maximum of 22 feet east of St. Paul. The basal part of the Nowata is commonly a zone of yellowish-brown clay shale about 9 to 15 feet in thickness. Thin flags of very fine-grained brown sandstone are found throughout this zone. The upper 5 to 7 feet of the formation is light-tan, calcareous clay shale. Lenses of very fine-grained quartzose sandstone about 0.5-inch in thickness are interbedded in the shale. This light-tan shale grades downward into a zone of yellow, calcareous clay shale about 1.5 feet thick. Dark-gray, very finely crystalline limestone nodules occur locally in this yellow shale.

Lenapah Limestone

The Lenapah Limestone in Neosho County consists of two limestone members separated by a shale member. The members are, in ascending order, the Norfleet Limestone, Perry Farm Shale, and Idenbro Limestone. Locally, the Idenbro Limestone and the Perry Farm Shale members as well as part of the Norfleet Limestone Member have been removed by pre-Missourian erosion. In the southern part of T 28 S, near the Crawford county line, the Lenapah Limestone and the overlying Holdenville Shale have been completely removed, and rocks of the Pleasanton Group rest disconformably upon the Nowata Shale. In the same area, the Lenapah is represented by a thin zone of dark-gray, fine-grained, unfossiliferous limestone rubble, which is probably the basal part of the Norfleet Member. No complete section of the Lenapah Limestone was found at any one outcrop in Neosho County; however, each member occurs in at least one locality. Although only 5 to 10 feet of the Lenapah can be seen at any one outcrop, a total thickness of 20 feet for the formation can be inferred from drillers' logs.

Norfleet Limestone Member

In Neosho County the Norfleet Limestone Member is represented by a thin-bedded, dark-gray, tan-weathering, finely crystalline fossiliferous limestone bed that ranges in thickness from 0.5 foot to 7 feet. Locally, where the Norfleet is as thick as 7 feet, small productid brachiopods and broken crinoid columnals are abundant in the basal part of the Member and light-gray chert nodules are distributed sparsely throughout the upper 2 feet. Where the Norfleet is represented by about 0.5 foot of limestone, the bed is predominantly crinoidal. The crinoidal bed is probably equivalent to the lowermost portion of the Norfleet observed elsewhere.

In some areas the Norfleet was not deposited and the Perry Farm Shale Member directly overlies the Nowata Shale. Locally, the Perry Farm Member contains nodular limestone, as does the upper part of the Nowata Shale, and it is difficult to define the contact between them. However, as the upper part of the Nowata contains some sandy shale interbedded with the limestone nodules, the contact probably lies in the zone of gradation from the sandy shale to the overlying clay shale.

Perry Farm Shale Member

The Perry Farm Shale Member is not well exposed in Neosho County. It is generally a tan to light-gray calcareous shale that contains dark-gray, very finely crystalline limestone nodules. The thickness of the shale ranges from about 0.8 foot to 4 feet.

Idenbro Limestone Member

The Idenbro Limestone Member is the most conspicuous member of the Lenapah where it is present at the outcrop. Average thickness of the Idenbro in Neosho County is about 6 feet. The dominant lithology of the Member is a medium-crystalline to semilithographic light-gray limestone that weathers to a grayish-white on the outcrop. Some coarsely crystalline, translucent, void-filling calcite is present near the base. In some outcrops the lower 1.5 feet is a thin-bedded limestone with thin (0.25-inch) gray, clay-shale partings.

Vertical joints, a conspicuous feature of the Idenbro, have been widened by solution so that the limestone weathers into blocks 5 to 8 feet in length, 3 to 4 feet in width, and about 6 feet in thickness. The upper surface of the Member, where it is exposed, develops a characteristic hummocky, pitted appearance. Large productid brachiopods are common throughout the limestone.

Holdenville Shale

The Holdenville Shale occurs only locally in Neosho County. Thickness of the formation, where present, ranges from a few inches to as much as 15 feet. At the base of the Holdenville a 1-foot bed of greenish-gray, limonite-stained clay shale occurs. At most outcrops of the formation in Neosho County, a 0.4-foot coal bed overlies the thin, basal clay-shale zone. Above the coal is an 0.8-foot bed of black, carbonaceous shale. The black shale contains abundant fragments of the fossil plant *Calamites*. Locally, the black shale and plant fossils are silicified, and finely crystalline quartz is found on the bedding planes. The Holdenville above the black shale is yellowish-gray, variegated clay shale which weathers to a very pale greenish gray.

Pre-Missourian erosion has removed the Holdenville in many localities in the County and rocks of the overlying Pleasanton Group rest on the Lenapah Limestone or lower beds.

PENNSYLVANIAN SYSTEM—UPPER PENNSYLVANIAN SERIES

Missourian Stage—Pleasanton Group

The Pleasanton Group comprises three formations which are, in ascending order: Seminole Formation, Checkerboard Formation, and Tacket Formation (Jewett, *et al.*, 1964). Thickness of the Pleasanton Group at the outcrop in Neosho County ranges from 30 feet near the Labette County line in T 30 S, R 20 E to 60 feet in T 27 S, R 21 E.

Seminole Formation

The Seminole Formation of the Pleasanton Group comprises two members which are, in ascending order, the Hepler Sandstone and South Mound Shale. The thickness of the formation in Neosho County ranges from 1 foot to 4 feet.

Hepler Sandstone Member

The Hepler Sandstone Member is a blanket-type deposit that is present nearly everywhere in eastern Kansas as the basal unit of the Missourian Stage. Thickness of the Member in Neosho County ranges from 0.3 foot to 3 feet. The dominant lithology of the Hepler is a moderately sorted, very fine-grained to fine-grained quartzose sandstone that is well-cemented with calcium carbonate. The Member is generally reddish-brown on weathered surfaces but in fresh exposures it is gray to yellowish-gray. Silt is a minor constituent of the Hepler in Neosho County. The sandstone is generally thin bedded to very thin bedded, but locally, as in the creek bed in the southern half of sec. 18, T 30 S, R 20 E, the Hepler is an homogeneous unit about 0.75 foot thick.

The Hepler was deposited upon an erosional surface formed during pre-Missourian time. This surface has a local relief of about 30 feet, as inferred from elevations of the contact of the Hepler with underlying beds.

South Mound Shale Member

The South Mound Shale Member in Neosho County is a gray clay shale. Locally, the basal part of the Member is slightly silty. The thickness of the South Mound is uncertain in much of the County, as the overlying Checkerboard Limestone is missing and the South Mound Shale Member is overlain by the lower shale member of the Tacket Formation. Where the Checkerboard is present, as in the southern half of the County, the Member can be differentiated, and the thickness ranges from about 0.3 foot to 2 feet.

Checkerboard Limestone

South of Neosho County in Labette and Montgomery counties, the Checkerboard Limestone comprises two unnamed limestone members separated by an unnamed shale member (Jewett, *et al.*, 1964). In Neosho County, only the lower member is found locally at the outcrop south of sec. 28, T 29 S, R 20 E.

The Checkerboard in Neosho County ranges in thickness from about 0.4 foot to 2 feet. Where the thickness is about 2 feet, as in T 29 S, R 20 E, the formation consists of medium-gray, brown-weathering, thin-bedded limestone. Bryozoan fragments, crinoid columnals, brachiopods such as *Composita* and *Derbyia*, and other fossils are so abundant that the bed is almost a coquina. In sec. 10, T 30 S, R 20 E to the south of the above outcrop, the bed is a 0.4-foot, brownish-yellow, very silty limestone that contains abundant *Composita* and *Derbyia*.

Tacket Formation

The Tacket Formation, the most conspicuous part of the Pleasanton Group in Neosho County, forms gentle slopes below the overlying Hertha Limestone. The Formation consists of two unnamed shale members separated by an unnamed limestone member and ranges in thickness from about 25 feet in the south-central section of the County near the Labette County line to nearly 60 feet in the northeastern part of the County. Where the Checkerboard Limestone is absent, as north of T 29 S, R 20 E, the South Mound Shale Member of the Seminole Formation is not differentiated, and rocks of the Tacket Formation apparently rest directly upon the Hepler Sandstone Member of the Seminole Formation.

Lower unnamed shale member

Thickness of the lower shale member ranges from about 20 feet in the southern part of Neosho County to nearly 40 feet in the northern part of the outcrop area; the average thickness is about 25 feet. Dark-gray to black, fissile to blocky, carbonaceous, clay shale makes up nearly all the member.

In northeastern Neosho County, a 2-foot, medium-bedded, gray, brown-weathering, poorly sorted, quartzose sandstone is found locally about 25 feet above the top of the Hepler Sandstone. The sandstone contains fragments of brachiopods and remains of plants. In the SW sec. 27, T 27 S, R 21 E, a 0.3-foot, gray silty limestone is found above the sandstone. Crinoid columnals and fragments of small brachiopods are abundant in this limestone. Locally, in the northern part of the outcrop, a thin zone of black fissile shale containing phosphatic nodules is found at the top of the member.

Middle unnamed limestone member

The limestone member of the Tacket Formation is the most persistent of all the units in the Pleasanton Group. This member consists of 2 feet of dark-gray, tan-weathering, very fine-grained, ellipsoidal limestone nodules. The nodules range in size from about 0.3 foot to as much as 2 feet along their longest axis. The average size of the nodules increases from north to south in Neosho County. However, at any one outcrop these nodules are about the same size. Megafossils are rare, but Emery (1962, p. 34) has found fragments of arenaceous foraminifers in several nodules.

Upper unnamed shale member

Dark-gray to black, light-gray-weathering, blocky clay shale is the dominant lithology of the upper member of the Tacket Formation. Thickness of the member ranges from about 6 feet in the southern part of the County near the Labette county line to about 15 feet in the northeastern part near the Crawford county line.

In some localities, especially in the southern part of the outcrop, a 1-foot zone of light-gray, yellow-weathering, silty shale is found at the top of the member just below the Hertha Limestone. Phosphatic nodules as much as 0.5 inch in diameter are common in the black shale. Fossils in the member consist of a few casts of a small pelecypod and a few dwarfed specimens of dictyoclostid brachiopods.

Missourian Stage—Kansas City Group (Bronson Subgroup)

Hertha Limestone

The Hertha Limestone is a prominent escarpment-forming unit in Neosho County. Thickness of the formation ranges from about 7 feet in the northeastern part of the outcrop in the area south and east of Kimball to about 14 feet at the type section north of the old townsite of Hertha in the south-central part of the County. The Hertha Limestone comprises three members which are, in ascending order, the Critzer Limestone, Mound City Shale. and Sniabar Limestone.

Critzer Limestone Member

The Critzer is a medium-crystalline, bluish-gray limestone with an average thickness of about 3 feet. Locally, in the central part of the County, the Critzer is a silty, yellowish-brown limestone in which crinoid remains are common. In the northeastern part of the County, the Critzer and the overlying Mound City Shale were apparently not deposited, and the Sniabar rests on rocks of the Pleasanton Group. The Critzer Member supports the prominent escarpment formed by the Hertha south of T 27 S.

Mound City Shale Member

The Mound City Shale Member is very thin or absent in outcrops of the Hertha Limestone in Neosho County. At the type section of the Hertha, NE sec. 20, T 29 S, R 20 E, the Mound City is represented by 1.5 feet of silty shale. There, the upper 0.5 foot is a light-gray shale that grades abruptly downward into black platy shale. South of the type section of the Hertha, the Mound City thickens. Core samples taken by the Kansas Highway Department along U. S. 59 south of Erie show the Mound City to be about 6 feet of black platy shale. In the northeastern part of the County the Mound City is missing and the Sniabar Limestone Member of the Hertha rests directly on rocks of the Pleasanton Group.

Sniabar Limestone Member

Medium-gray, tan-weathering, finely crystalline, medium-bedded limestone is characteristic of the Sniabar Member of the Hertha. Average thickness of the Member is about 7 feet, although in the northern part of the County the Member attains about 4 feet. Chert nodules, a prominent feature of the Sniabar in the northern part of the County, weather locally from the limestone and compose nearly the entire outcrop. Stringers of very finely crystalline calcite are abundant and brachiopods are fairly common in the lower part of the Member.

Ladore Shale

The Ladore Shale consists predominantly of medium to dark-gray clay shale throughout its outcrop area in Neosho County. The thickness of the formation is uniformly about 40 feet. Oblate, dark-gray to dark-bluish-gray, argillaceous limestone concretions, 0.5 inch to 3 inches in thickness, are found in the lower 36 feet of the shale. Locally, these concretions are the dominant lithology in the Ladore. A few miles south of Erie, these concretions form residual deposits which resemble the mounds of Tertiary(?) chert gravel found to the northwest along the bluffs bordering the Neosho River valley. The concretions in these deposits are extensively weathered and much of the calcium carbonate has been removed, leaving a soft light yellowish-brown clay. Samples from test holes augered through the alluvium of the Neosho River valley indicate that the basal 5 feet of the Ladore is a light-gray, silty shale.

Above the zone of limestone concretions is a 3-foot yellow clay shale with interbedded 0.5- to 1.5-inch limestone lentils. An 0.8-foot zone of yellowish-brown, sandy shale is commonly found at the top of the Ladore just below the overlying Middle Creek Limestone Member of the Swope Limestone. Many brachiopods, fenestrate bryozoan fragments, and crinoid columnals are found in this shale.

Swope Limestone

The Swope Limestone comprises the following members, in ascending order: Middle Creek Limestone, Hushpuckney Shale, and Bethany Falls Limestone. The formation ranges in thickness from about 7 feet to nearly 13 feet.

Middle Creek Limestone Member

The Middle Creek Limestone Member is a 3-foot bed of medium to dark-gray, finely crystalline limestone. Fragments of brachiopods, crinoids, and bryozoans largely replaced by coarsely crystalline calcite occur sparsely throughout the Member. In a southwesterly direction along the strike of the Swope from T 28 S, R 20 E, the Middle Creek Member is missing at many outcrops. Where the Middle Creek is absent, the Hushpuckney Shale Member is also missing, and the Bethany Falls Limestone Member is found in contact with the underlying Ladore Shale.

Hushpuckney Shale Member

Dark-gray to black, fissile shale is characteristic of the Hushpuckney Shale Member in Neosho County. Small amounts of pyrite may be found between laminae of the shale. The average thickness of the Hushpuckney is about 3 feet. In the south-central and southern part of the County, the Member is locally absent.

Bethany Falls Limestone Member

The Bethany Falls Limestone is the only member of the Swope that is everywhere present along the outcrop. Massive, very finely crystalline, light-gray limestone is characteristic of the Member throughout most of Neosho County. However, in the central part of the County the Bethany Falls is a medium-crystalline, light-brown, tan-weathering limestone. The Member ranges in thickness from about 7 feet in the northeastern and central part of the County to more than 10 feet in the south-central part near the Labette county line.

Galesburg Shale

Sandy shale and very thin-bedded to thick-bedded sandstone is the dominant lithology of the Galesburg Shale in Neosho County. In addition, the Dodds Creek Sandstone Member is present at the base of the formation in most localities. The overall thickness of the formation ranges from about 20 feet in the northeastern part to as much as 80 feet in the central and southern parts of the County. Most of the change in thickness is the result of the pronounced thickening of the Dodds Creek Sandstone Member.

Very thick-bedded, fine-grained to very fine-grained, buff to brown, slightly-rounded, quartzose sandstone is characteristic of the Dodds Creek. The grains are normally cemented by silica or silty clay, and all exposures of the sandstone appear to be case-hardened by iron oxide. Small-scale cross bedding occurs in the sandstone in the northern part of the outcrop. The Member thickens from an average of about 20 feet in T 27 S, R 20 E to nearly 60 feet in T 30 S, R 19 E.

Only the upper few feet of the part of the Galesburg Shale that overlies the Dodds Creek Sandstone Member is well exposed in Neosho County. In T 27 S, R 20 E the upper 4 to 6 feet of the formation consist predominantly of light-gray, blocky, clay shale. Plant fossils, tentatively identified as *Alethopteris*, are found on the bedding planes. Southwest of T 27 S, R 20 E, along the outcrop, the clay shale apparently grades laterally into brownish-red, sandy shale and thin-bedded, brown sandstone that increases in thickness to about 20 feet in the south-central part of the County.

Dennis Limestone

The Dennis Limestone in Neosho County consists of three members. They are, in ascending order: the Canville Limestone, the Stark Shale, and the Winterset Limestone. The formation ranges in thickness from about 6 feet to as much as 70 feet.

Canville Limestone Member

The Canville Limestone Member is composed of a single massive, medium- to light-gray, finely crystalline limestone that weathers to a light dove-gray color. Widely spaced vertical joints are common in the Member. Thickness of the unit averages about 3 feet and locally is as much as 5 feet. Where the increased thickness is observed at the outcrop, the Canville has apparently been deposited in slight depressions in the upper surface of the underlying Galesburg Shale. The limestone is relatively unfossiliferous with only sparsely distributed brachiopod, crinoid, and bryozoan fragments found near the base of the unit at some outcrops.

Stark Shale Member

Black, carbonaceous, blocky to fissile, clay shale composes the Stark Shale Member in Neosho County. In some outcrops a 0.5-foot zone of medium- to light-gray, clay shale is found above the black shale. Very finely crystalline pyrite is commonly found on bedding planes in the black shale. Closely-spaced vertical joints give a columnar appearance to the black shale at some localities. The average thickness of the Member is about 3 feet. Locally, along the outcrop in Neosho County, the thickness is as much as 5 feet. Thickening of the upper clay shale zone from 0.5 to as much as 2 feet is the apparent reason for the change in the overall thickness of the Member.

Winterset Limestone Member

The Winterset Limestone Member crops out over about 20 percent of the surface of Neosho County (Pl. 1). Maximum thickness of the Member is about 60 feet although in most localities the thickness is about 35 feet. Where pre-Chanute erosion has cut into the Winterset, as seen in the bluff along Neosho River east of Chanute, the Member is represented only by a zone of limestone rubble about 1 foot thick.

For purposes of discussion, the Winterset may be divided into a lower, very thick-bedded zone and an upper, thin-bedded to medium-bedded zone. The lower thick-bedded portion of the Winterset is a massive, medium-gray, finely crystalline limestone with an average thickness of about 20 feet. Weathered surfaces of the rock are light-gray or almost white. Fossils such as the brachiopod *Echinaria*, crinoid columnals, and fragments of fenestrate bryozoans are common. White, nodular chert is abundant in the limestone; and although the chert is not bedded, some horizons are locally almost entirely chert. Commonly an oölitic zone from 3 to 5 feet in thickness is found at the top of the unit.

The upper thin-bedded to medium-bedded portion of the Winterset is a light-gray to brownish-gray limestone that ranges in thickness from about 15 feet to as much as 30 feet. The limestone is very finely crystalline and almost semi-lithographic in texture. Very coarsely crystalline, void-filling calcite is found throughout the thin-bedded zone. Dark brownish-yellow mottling, probably due to oxidation of included iron, is conspicuous on broken surfaces of the light-tan fragments found in the zone of weathering. In some localities part of the upper zone appears to be composed of algal material. Dark-gray undulating plates of fine-grained calcite, 1 to 3 inches long and about 0.1-inch thick, are found throughout the rock oriented approximately parallel to the bedding planes. These stringer-like forms are slightly darker than the matrix in which they are found. Harbaugh (1959) has discussed the Plattsburg Limestone, which is apparently quite similar to the Winterset with respect to the occurrence of algal remains. Some replacement of calcite by dolomite has occurred in the algal zone. The dolomite is bone white to light pink in color. Distorted dolomite rhombohedrons are seen in some hand specimens.

In the northeastern quarter of the County, a 3-foot bed of light-gray, silty, clay shale is found approximately 12 feet above the base of the thin-bedded zone of the Winterset. This shale bed is well exposed only in the area around and to the northeast of Stark where it weathers into small blocks or cubes about 1 inch square. Laminae of sandy shale are interbedded with the clay shale. These laminae are less easily weathered than the clay shale and stand out in relief on the face of the outcrop.

Above the shale, the Winterset contains several oölitic horizons. At most localities the oölites are in the upper 3 to 4 inches of the limestone slabs. Small-scale cross bedding of the oölites is seen at some outcrops.

Echinaria is abundant in the upper medium-bedded part of the Winterset; however, its average size is somewhat less than in the lower massive zone. Other marine fossil remains such as crinoid columnals and bryozoan fragments are about as abundant as in the lower zone. White and gray chert nodules are more abundant in the thin-bedded part than in the massive, lower part of the Winterset. At some outcrops of the Winterset in northeastern Neosho County, residual chert deposits weathered from the upper zone are as much as 5 feet in thickness.

Missourian Stage—Kansas City Group (Linn Subgroup)

Cherryvale Shale

Five members ordinarily make up the Cherryvale Shale. They are, in ascending order: the Fontana Shale, the Block Limestone, the Wea Shale, the Westerville Limestone, and the Quivira Shale. In Neosho County, the Westerville Limestone Member is missing, and a limestone tentatively identified as the Block Limestone Member is seen only in the northeastern part of T 30 S, R 18 E.

A greenish-gray, blocky, clay shale about 15 feet thick lies at the base of the Cherryvale throughout most of the County. The shale is not well exposed except in T 30 S, R 18 E. The shale is overlain in T 30 S, R 18 E by a dark-gray, thick-bedded, fine-grained limestone about 3 feet thick, which is probably an equivalent of the Block. Two lenticular 0.1-foot coal beds separated by about 0.5 foot of yellow, sandy, clay overlie the basal clay shale zone in the southern part of T 29 S, R 18 E. Elsewhere in the County, a fine-grained, thick-bedded, quartzose sandstone occurs above the basal clay shale zone in the approximate stratigraphic position of the Block Limestone Member. Above the Block, the Cherryvale is predominantly a light-tan to reddish-brown, thin-bedded, sandy shale. In T 28 S, R 18 E a massive bed of sandstone about 3 feet thick occurs about 10 feet below the overlying Drum Limestone. In T 28 S, R 18 E, 0.5 foot of fossiliferous, yellow clay shale is at the top of the Cherryvale and directly underlying the Drum Limestone. Large crinoid columnals (0.5-0.75 inches in diameter), brachiopod fragments, and fenestrate bryozoan fragments are common in this shale.

East of the Neosho River, in T 27 S, R 18 E and T 27 S, R 19 E, pre-Chanute erosion has removed the Cherryvale and the overlying Drum Limestone, and the Chanute Shale rests directly upon the Dennis Limestone.

Drum Limestone

The Drum Limestone is comprised of two members which are, in ascending order, the Cement City Limestone and the Corbin City Limestone. In Neosho County differentiation of the members is difficult as much of the Drum has been removed by pre-Chanute erosion.

In T 28 S, R 18 E the Drum is a light-brown, thin-bedded, fossiliferous limestone that weathers dark brown. Thickness of the unit in this area is about 3 feet. Large crinoid columnals and fenestrate bryozoan fragments are abundant and brachiopods such as *Dielasma* and *Hustedia* are common. Sayre (1930, p. 1-129) has described the fauna of the Drum Limestone.

Farther to the southwest, there is a facies change in the Drum. The light-brown, thin-bedded limestone present in T 28 S, R 18 E apparently grades laterally into a medium-gray to yellow-gray, very thick-bedded, finely crystalline, sparsely fossiliferous limestone. The formation ranges in thickness from about 4 feet in T 30 S, R 17 E to 10 feet in T 29 S, R 19 E.

Chanute Shale

Two sandstone members and an intervening shale member comprise the Chanute Shale in Neosho County. The members are, in ascending order, the Noxie Sandstone, an unnamed shale member, and the Cottage Grove Sandstone.

Noxie Sandstone Member

Thin-bedded to medium-bedded, fine-grained to very fine-grained, quartzose sandstone is characteristic of the Noxie Sandstone Member in Neosho County. Individual sand grains are well rounded to subangular. Silt, silica, and iron oxide are the common cementing materials in this Member. Calcium carbonate cement is rare and is abundant only locally. The thickness of the Noxie ranges from less than 1 foot in the central part of T 27 S, R 19 E to about 30 feet in the southeastern part of T 27 S, R 18 E. Elsewhere along the outcrop, the Noxie has an average thickness of about 6 feet.

In T 27 S, R 18 E the Noxie Sandstone lies unconformably upon the Stark Shale Member of the Dennis Limestone. Drillers' logs of wells drilled southwest and west of

Chanute indicate that in the subsurface the Chanute ranges in thickness from about 30 feet to as much as 110 feet. In this area the Noxie appears to have been deposited in a channel about 4 miles wide with a northeast-southwest orientation through the northwestern corner of the County (Fig 4).

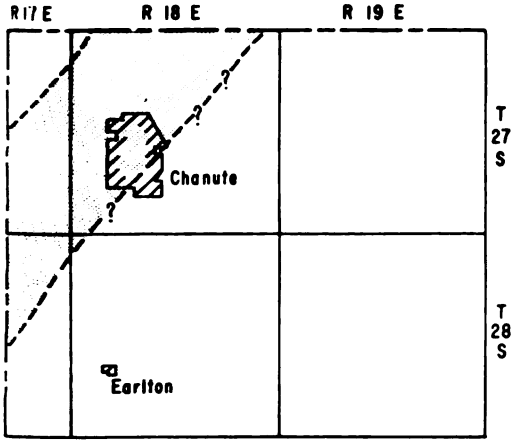

FIGURE 4.—Generalized map of the northwest quarter of Neosho County Kansas, showing the approximate location of the ancient channel in which the Noxie Sandstone Member of the Chanute Shale was deposited.

Unnamed shale member

The upper portion of the Noxie Sandstone Member grades into an unnamed shale member. Locally, in the subsurface southwest of Chanute, this unnamed member consists of as much as 7 feet of light grayish-green clay shale which is slightly silty in the upper 2 feet. Drillers' logs show that the Thayer coal commonly lies at the top of this shale and ranges in thickness from 0.4 foot to 2 feet. At outcrops of the Thayer coal the underlying shale is generally less than a foot thick and in some locations a few inches of underclay is seen beneath the coal. This clay shale is not a continuous bed in western Neosho County, and, where it is absent, differentiation of the Noxie and Cottage Grove sandstone members is limited to localities where the Thayer coal is present.

Cottage Grove Sandstone Member

The lithology of the Cottage Grove Sandstone Member is nearly indistinguishable from that of the Noxie Member. However, the Cottage Grove is very thick-bedded in contrast to the generally thin-bedded or laminated Noxie. The massive character of the Cottage Grove Sandstone is well seen in the spillway of Santa Fe Lake at the south edge of Chanute. The weathered surfaces of both the Cottage Grove Sandstone and the Noxie Sandstone are yellowish-orange to deep brownish-red. When unweathered the sandstones of the Chanute Shale are very light gray. This color is the criterion for the well driller's term "white water-sand" commonly applied to the Cottage Grove and Noxie members.

Iola Limestone

Three members comprise the Iola Limestone in Neosho County. The members are, in ascending order: the Paola Limestone, the Muncie Creek Shale, and the Raytown Limestone. The formation ranges in thickness from about 8 feet near the Wilson county line west of Thayer to about 38 feet in the Ash Grove Cement Company quarry northwest of Chanute.

Paola Limestone Member

Light tannish-gray, finely crystalline, yellowish-brown-weathering limestone is characteristic of the Paola in Neosho County. Small crinoid columnals and brachiopod fragments are common near the base. White, ellipsoidal, phosphatic concretions about 1 inch in their longest dimension occur on the weathered upper surface of the limestone in the west-central and southwestern part of the County. In T 28 S and T 29 S, where the Iola was apparently deposited around erosional remnants of the Chanute Shale, the Paola is slightly sandy. The Member has an average thickness of 2 feet, but in some localities in the southern part of the outcrop the Paola is represented by only a few inches of flaggy, finely crystalline, crinoidal limestone.

Muncie Creek Shale Member

The Muncie Creek Shale Member is dominantly a clay shale that ranges in thickness from about 3 feet in the northern part of T

29 S near the Wilson county line to 5 feet in the western part of T 27 S, R 18 E. In the vicinity of Chanute the Member consists of about 3 feet of light-gray, calcareous clay underlain by approximately 2 feet of black, fissile, carbonaceous shale that contains sparsely distributed, ellipsoidal, phosphatic concretions. Farther to the south along the outcrop the black shale is missing and the Muncie Creek is represented by 2 to 3 feet of gray clay shale.

Raytown Limestone Member

In T 27 S, R 18 E the Raytown Limestone Member consists of about 35 feet of massive-bedded, light-gray, tan-weathering, finely crystalline limestone. Dark-brown, coarsely crystalline veinlets of calcite are seen throughout the Member. Although the Raytown generally is very thick-bedded, bedding planes about 8 inches apart may be seen where the limestone has been exposed to weathering. Southward the Raytown decreases uniformly in thickness so that in the northeastern part of T 29 S, R 17 E, the thickness is about 8 feet. In this area the Raytown is a single massive bed which lacks the bedding planes seen on weathered outcrops farther to the north.

Missourian Stage—Kansas City Group (Zarah Subgroup)

Lane Shale and Bonner Springs Shale

The Lane Shale and the Bonner Springs Shale are considered as a single unit in Neosho County because they are indistinguishable without the intervening Wyandotte Limestone. The sequence is conformably overlain by the Plattsburg Limestone and rests conformably on the Iola Limestone. Total thickness of the Lane and Bonner Springs shales is about 60 feet.

The lower part of the Lane-Bonner Springs is dominantly a blocky, gray to light-gray clay shale. In T 27 S, R 18 E a dark-gray to black shale about 8 feet thick is found in a position 10 feet above the top of the underlying Iola Limestone. Locally, in the northwestern part of the County, a sandy, yellowish-gray shale about 1 foot thick is found immediately overlying the Iola.

The Wyandotte Limestone, a formation that normally lies above the Lane Shale and below the Bonner Springs Shale, is not identifiable in Neosho County. However, a zone of tabular, argillaceous limestone concretions approximately 1 foot thick found above the lower shale unit and about 20 feet below the base of the Plattsburg may represent the normal stratigraphic horizon of the Wyandotte Limestone.

Above the limestone nodules, the shale is yellowish-brown in color and is unfossiliferous except for a 1-foot zone just beneath the Plattsburg where brachiopod and crinoid fragments are common.

Missourian Stage—Lansing Group

Plattsburg Limestone

The Plattsburg Limestone is the youngest limestone unit in Neosho County. The area of outcrop of the Plattsburg is not extensive, being limited to about 4 square miles in T 27 S, R 17 E, and T 28 S, R 17 E (see Pl. 1).

The three members of the formation, in ascending order, are: the Merriam Limestone, the Hickory Creek Shale, and the Spring Hill Limestone. The thickness of the formation is about 25 feet in the extreme northwest corner of the County and is as much as 50 feet in T 28 S, R 17 E near the Wilson county line.

Merriam Limestone Member

A very finely crystalline, gray to dark-gray bed of fossiliferous limestone that has an average thickness of about 1.5 feet represents the Merriam Limestone Member in Neosho County. The bed weathers to a light grayish-tan color. Marine fossils such as brachiopods, fragments of horn corals, sponges, and crinoid columnals are sparsely distributed throughout the Member.

Vertical joints about 4 feet apart cause the Merriam to appear as discrete blocks at the outcrop. These joints are part of a system, of which one set trends about N 45° W, and the other, which is more obvious on air photographs, trends about N 40° E.

Hickory Creek Shale Member

The middle member of the Plattsburg Limestone is not well exposed in much of its outcrop area. The best exposure of the Hickory Creek Shale Member is southwest of Chanute in a quarry in the SW sec. 25, T 27 S, R 17 E, where it is 3.5 feet thick and consists predominantly of calcareous shale. The shale is light gray but weathers to a light greenish-gray. Very thin laminae of limestone are interbedded with the shale in the lower 2 feet, above which is found a 0.6-foot bed of medium-gray unfossiliferous limestone. In some parts of the quarry a gray shale layer about 1 inch thick is found in the middle of the thin limestone. The upper 1 foot of shale contains more interbedded limestone laminae than does the lower part. In this zone are a few crinoid columnals and fenestrate bryozoan fragments.

Although the Hickory Creek is not well seen in other outcrops of the Plattsburg, especially where the overlying Spring Hill Limestone Member has been removed by erosion, a weathered zone of gray, calcareous material above the Merriam probably represents the Member.

Spring Hill Limestone Member

The upper member of the Plattsburg caps several prominent escarpments along the Wilson county line. The thickness of the Member is about 3 feet where it caps Plattsburg erosional outliers in T 27 S, R 17 E to 20 feet in T 28 S, R 17 E. The 3 feet of Spring Hill probably does not represent the original thickness of the Member in T 27 S, R 17 E. In some localities, the Spring Hill is missing entirely and the Plattsburg escarpments are supported by the Merriam Limestone Member.

The lower portion of the Spring Hill is generally finely crystalline, light bluish-gray to medium-gray, thin-bedded limestone that weathers to a light tan. Yellow clay shale partings are found between the beds in nearly all outcrops. *Enteletes* and *Composita* are common in the limestone, and *Heterocoelia beedei* occurs in the lower part of the Member.

About 8 feet of very thick-bedded limestone is found at the top of the Plattsburg in T 28 S, R 17 E. The lithology is similar to the lower, thin-bedded portion of the Member, except for cross-bedded oölites that are found some places in the upper 2 to 3 feet.

Vilas Shale

Only weathered remnants of the Vilas Shale are found in Neosho County. A few feet of weathered light-gray shale is found on the Plattsburg escarpment in T 28 S, R 17 E. In the NW sec. 2, T 27 S, R 17 E, a thin veneer of weathered gray shale is seen overlying the Spring Hill Limestone Member of the Plattsburg Limestone. Generally, in western Neosho County, the Vilas has been weathered, and all that remains on the Plattsburg escarpment are residual clay deposits which no longer retain the characteristics of the formation.

TERTIARY SYSTEM

Pliocene Series (?)

Pre-Kansan Deposits

Pre-Kansas deposits of angular to subangular, light-brown chert gravel in a matrix of dark reddish-brown silt and clay are found at several sites in the northern half of Neosho County (Pl. 1). These gravel deposits rest on bedrock surfaces which are 100 to 120 feet above the level of the present flood plain, and 70 to 90 feet above the top of terrace deposits of Kansan age. The thickness of the deposits ranges from a few inches to as much as 12 feet. The chert fragments range in diameter from about 0.5 inch to as much as 2 inches, and comprise about 75 percent of the deposits. While the age of these deposits is unknown, they are as old as Nebraskan and may be as old as Pliocene. It is probable that other deposits of the pre-Kansan gravels occur that are too small or inconspicuous to be seen in the field and, thus, are not mapped.

QUATERNARY SYSTEM

Pleistocene Series

Kansan Stage

Material thought to be of Kansan age has been found in only one locality (SW NW sec. 21, T 29 S, R 21 E) in Neosho County (Pl. 1). A deposit of angular to subangular chert pebbles ranging from 1 to 2 inches in diameter in a red clay matrix lies on a bedrock surface about 30 feet above the present flood plain. The thickness of the deposit is about 6 feet, and the areal extent is only a few hundred square yards. Farther north, relatively flat surfaces developed on bedrock immediately adjacent to the Neosho River valley may represent the bedrock floor of a valley cut by the Neosho River during the Kansan glacial Epoch. No deposits have been found on these surfaces which can be identified as Kansan in age.

Illinoisan Stage

The most conspicuous geomorphic feature in the Neosho River valley, exclusive of the present flood plain, is the Illinoisan terrace escarpment. Although the terrace has as much as 15 feet of local relief above the flood plain, it is a discontinuous feature and may be differentiated only in a few areas in the valley (Pl. 1). The pronounced escarpment of the terrace is well seen in section C-C′ in Figure 5.

The deposits are predominantly silt and clay-sized material in the upper portion with some fine to coarse sand at the base. In some areas, small amounts of the fine chert pebbles are found lying on bedrock at the base of the deposits. Average thickness of the terrace deposits is about 25 feet. Logs of test holes drilled in the Neosho River valley in Neosho County and Labette County may be found at the end of this report.

Wisconsinan and Recent Stages

Deposits of Wisconsian and Recent ages comprise the flood plains of the Neosho River valley and its tributaries. Deposits of Wisconsinan age are similar in lithology to the deposits of Illinoisan age. Silt, fine to coarse sand, and very coarse chert pebbles were found in test holes drilled in this material. Generally, the chert pebbles are confined to a 3-foot zone at the base of the deposits. The thickness of the Wisconsinan deposits ranges from 18 feet to 40 feet and averages about 25 feet. These deposits are confined to the Neosho River valley and have an average width of 1.5 miles (Pl. 1). The maximum width of the flood plain is 4 miles in the southeast corner of the County.

In general, material of Recent age is confined to the active channel of the streams. The deposits consist primarily of silt, clay, fine sand, and chert and limestone pebbles. Near the headwaters of some of the smaller streams, pebbles and cobble-sized fragments of shale occur as bar accumulations in the channel. Thickness of the Recent deposits ranges from a few inches to as much as 10 feet.

STRUCTURAL GEOLOGY

A detailed treatment of the structural geology of Neosho County is not within the scope of this report. However, certain gross aspects of the structural setting of the area are evident in the outcropping and near-surface rocks.

The Prairie Plains Monocline is the dominant regional structure that affects the rocks in Neosho County and eastern Kansas. This structure, which is thought to be post-Permian in age, imparts a regional dip to the rocks of about 20 feet per mile to the northwest. Locally, the dip of the strata increases to about 40 feet per mile; in some areas, the rocks are essentially horizontal. This structure is related to the quality of the ground water in consolidated rock aquifers in the County, *i. e.*, the concentration of dissolved solids in water from a given aquifer increases down-dip from the outcrop. The regional structure controls the occurrence of ground water only to the extent that the depth of burial of a given aquifer increases down-dip, and as a result the permeability of the aquifer and the quantity of water available to wells decreases. The apparent domal features southwest of Earlton in T 28 S and T 29 S, R 17 E (Pl. 1) are not structural features, but are sedimentary phenomena which are explained in the section *Stratigraphy of Outcropping Rocks.*

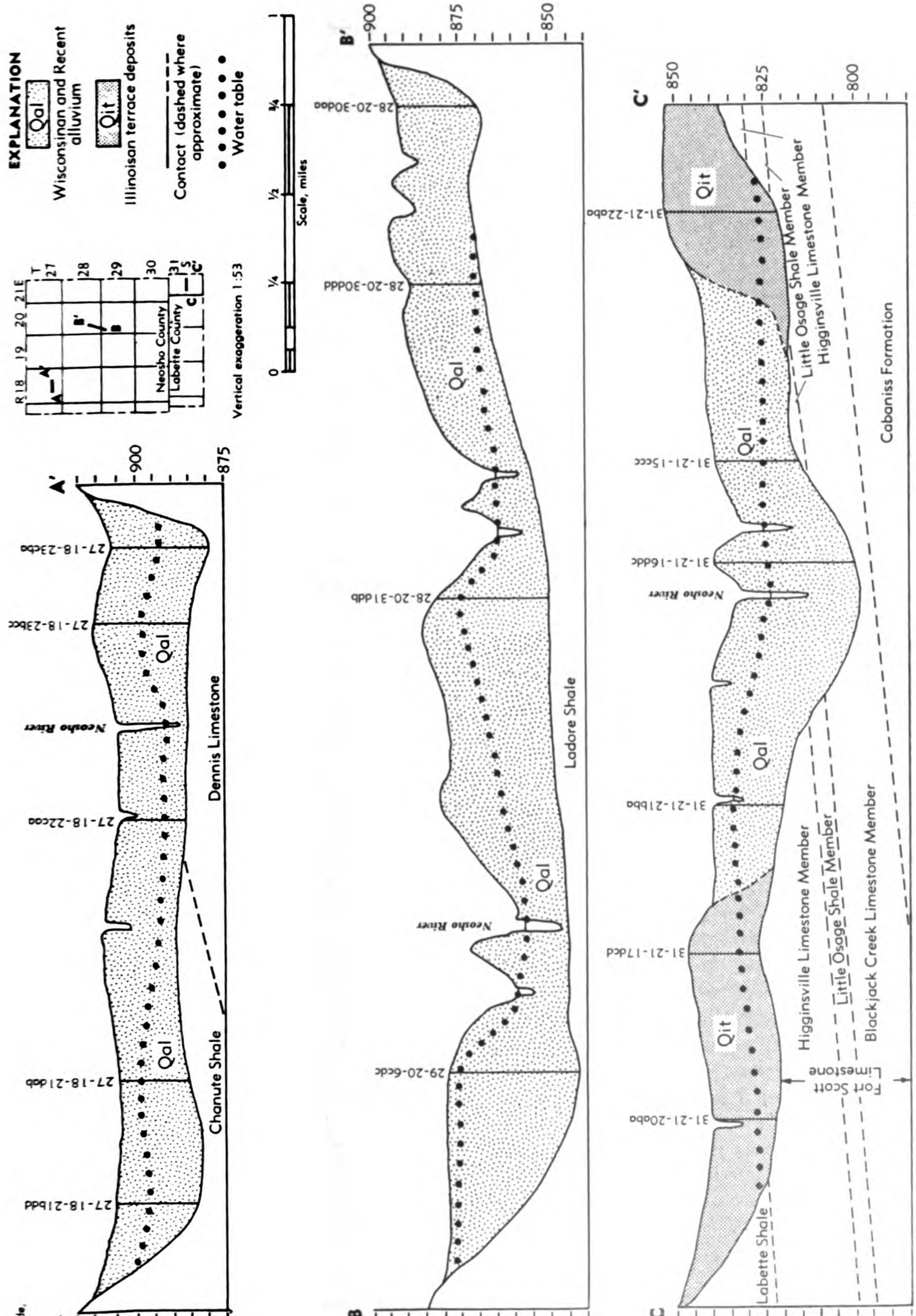

FIGURE 5.—Geologic cross sections of Quaternary deposits in the Neosho River valley, Neosho and Labette counties, Kansas.

GROUND-WATER RESOURCES

SOURCE, OCCURRENCE, AND MOVEMENT OF GROUND WATER

The discussion of the occurrence of ground water in Neosho County is based partly on a detailed treatment by Meinzer (1923, 1923a). A general discussion of the principles of ground-water occurrence with special reference to Kansas has been given by Moore, *et al.* (1940).

Ground water is that water below the surface of the land in the zone of saturation. It is derived mainly from precipitation and reaches the zone of saturation by percolation downward through the soil and subsoil.

The rocks in the outer crust of the earth are not solid but contain many openings, or voids, that hold air, water, or other fluid. Generally, the rock formations below a certain level are saturated with water. The upper surface of the zone of saturation is neither a level surface nor a static surface, but one that has many irregularities, which are generally similar to the irregularities of the surface topography. Under natural conditions, the small part of the precipitation that reaches the zone of saturation moves slowly toward the streams and discharges into them or is lost by transpiration and evaporation in the valley areas.

Water in the zone of saturation, available to wells, may be confined or unconfined. Unconfined or free ground water does not have a confining or impermeable body restricting its upper surface. The upper surface of unconfined ground water is called the water table. The water in weathered limestone, sandstone, and shale, the alluvial deposits in Neosho River valley and other stream valleys, and colluvial slope deposits is unconfined in most localities. Ground water is said to be confined or artesian if it occurs in permeable zones between relatively impermeable beds that confine the water under pressure. Most of the wells constructed in the unweathered Pennsylvanian bedrock of Neosho County tap confined ground water.

GROUND-WATER RECHARGE AND DISCHARGE

The addition of water to natural underground reservoirs is called recharge and may be effected in several ways. The most important source of recharge is local precipitation and this is the major source of recharge for weathered bedrock aquifers in the upland areas of Neosho County. Lesser amounts are contributed to these aquifers by influent seepage from streams and ponds and by subsurface inflow from adjacent areas. Locally, influent seepage from streams may contribute an important amount of recharge to adjacent alluvial deposits and to the bedrock aquifers where streams cut across permeable zones.

However, in the Neosho River valley the gradient of the water table, as indicated by water levels in test holes (Fig. 5), is toward the river. Therefore, it is unlikely that any recharge reaches the Wisconsinan and Recent deposits of the valley from the river except during periods of flooding.

Although no data on amounts are available, some recharge must be taking place in the Chanute Shale from the alluvial deposits or from the Neosho River in the area northeast of Chanute where Wisconsinan alluvium overlies northwestward-dipping sandstone beds in the Chanute Shale.

Recharge is seasonal in the Midwest. Generally the water levels of wells are lowered by natural drainage into streams during the winter, when the soil is frozen and precipitation is slight. During the spring precipitation is relatively abundant, temperature is moderately cool, and transpiration and evaporation are low, which results in the greatest amount of recharge during the year. Recharge may occur during other seasons whenever precipitation is sufficient to overcome the soil-moisture deficiency of a preceding dry period.

Ground water moves downward under the influence of gravity through the permeable rocks, in accordance with their character and structure, to points of lower elevation. It may discharge directly into a stream as a spring or seep or it may be discharged by evaporation or transpiration where the water table is near the surface. A part of the ground water is discharged from wells, but this amount is small in Neosho County compared with that discharged by other means.

Under natural conditions, over a long period of time, approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually.

CHEMICAL CHARACTER OF GROUND WATER

Various gases and minerals are taken into solution by water as it is precipitated and as it percolates through the rocks of the earth's crust. The type and quantity of impurities in ground water may be determined by chemical analysis. The corrosiveness, encrusting tendency, palatability, and other properties can be predicted from the results of a quantitative analysis of the water.

Analyses of 42 water samples from wells in Neosho County are shown in Table 1. Mineral concentrations are given in parts per million (ppm).

The samples of water from wells in Neosho County were analyzed by Howard A. Stoltenberg. Chief Chemist, in the Sanitary Engineering Laboratory of the Kansas State Department of Health. The analyses indicate only the dissolved mineral content of the water and do not indicate the bacteriological content.

Chemical Constituents in Relation to Use

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the U. S. Geological Survey, the State Geological Survey of Kansas, and the U. S. Public Health Service.

Dissolved Solids

When water is evaporated, the residue consists mainly of mineral constituents, but it may also include small quantities of organic matter and some water of crystallization. Water containing less than 500 ppm (parts per million) of dissolved solids is generally suitable for domestic use except for difficulties that may result from hardness or excessive iron or manganese. Water containing more than 1.000 ppm of dissolved solids is likely to have enough of certain constituents to impart a noticeable taste or otherwise render the water unsuitable or undesirable for use.

Hardness

The hardness of water is most commonly recognized by the scum or curd formed when soap is used with the water. Salts of calcium and magnesium cause nearly all the hardness of ordinary water. These salts also cause scale in steam boilers or other containers in which water is heated or evaporated. The total hardness of a water may generally be divided into carbonate hardness and noncarbonate hardness. The carbonate hardness is due to calcium and magnesium carbonates and may be almost completely removed by boiling. This type of hardness is often called temporary hardness. The noncarbonate hardness is caused by the sulfates and chlorides of calcium and magnesium and cannot be removed by boiling. This type of hardness is often referred to as permanent hardness. There is no difference between carbonate and noncarbonate hardness in regard to the reaction with soap.

Water with a hardness of less than 60 ppm is generally considered soft and, ordinarily, treatment for removal of hardness is unnecessary. Hardness ranging from 60 ppm to 150 ppm does not interfere with the use of water in most situations, but it does increase the consumption of soap. Laundries and other industries using large quantities of soap may profitably soften such water. Hardness greater than 150 ppm can be noticed by almost anyone, and if the hardness is 200 ppm or greater, the water is generally softened before use. When municipal supplies are softened. an attempt is usually made to reduce the hardness to about 80 to 100 ppm. Further softening of a public supply is not considered worth the additional expense. For purposes of discussion in this report, water with hardness ranging from 0-60 ppm is considered soft; 61-120 ppm, moderately hard; 121-180, hard; and greater than 180 ppm, very hard.

Nitrate

The use of water containing an excessive amount of nitrate in the preparation of a baby's formula may cause methemoglobinemia in the child, a condition of the blood which results in cyanosis or oxygen starvation. Some authorities specify that water containing greater than 45 ppm of nitrate should not be used in formula preparation for infants under

TABLE 1.—Analyses of water from selected wells in Neosho County, Kansas (in parts per million, except as otherwise indicated*). (Samples analyzed by H. A. Stoltenberg)

Well number	Date of collection	Depth of well, ft.	Geologic source	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$ Carbonate	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)
27-17-1dc	10-9-61	53	Chanute Shale	64	17	0.16	51	18	108	439	36	24	1.1	1.5	473	201	0	820
11ad	10-10-61	46.8	Iola Limestone	....	14	.04	149	29	125	405	98	165	.1	120	900	332	159	1,600
36bb	10-9-61	180	Chanute Shale	....	10	.03	16	8.8	132	381	2.0	31	.7	3.1	391	76	0	690
27-18-21cc	10-9-61	44.1	do	....	28	.02	33	10	22	81	9.1	29	.3	66	237	66	58	400
27-19-6da	8-30-62	18.7	do	68	13	.36	397	248	234	498	1,560	210	.5	235	3,143	408	1,602	3,920
9da	8-29-62	17.7	do	62	13	.58	186	28	135	427	145	169	.2	133	1,019	579	229	1,710
27bb	10-9-61	75.8	Swope Limestone	61.5	10	.62	47	18	444	437	28	540	2.2	1.0	1,305	191	0	2,470
30cd2	12-28-60	105	Galesburg Shale	....	9.0	1.3	72	61	979	464	131	1,440	4.0	.4	2,925	380	50	5,580
27-20-9dc	12-28-60	150.6	Swope Limestone	....	4.5	.07	22	17	821	527	18	1,020	8.0	.9	2,171	125	0	4,130
31ad	10-10-61	125	do	62	11	2.3	50	36	114	407	102	53	2.0	3.1	571	273	0	1,000
27-21-8cc	10-9-61	91.3	Dennis Limestone	61	12	.43	123	31	32	383	102	27	.2	58	574	314	120	970
28-18-4cd	8-29-62	60	do	64	16	.18	184	87	565	334	28	1,250	1.4	4.4	2,300	274	542	4,390
20ad1	12-28-60	145	do	....	12	.10	453	222	260	578	2,000	32	.7	9.3	3,274	474	1,568	3,900
27aa	8-29-62	16.8	Chanute Shale	....	18	.07	36	21	38	149	111	5	.5	6.5	309	122	54	520
28-19-1ba	10-9-61	122.4	Dennis Limestone	63	14	1.3	51	29	55	383	19	18	.5	5.8	381	246	0	680
7cd	12-28-60	106	Swope Limestone	....	12	.03	87	45	78	432	27	62	.5	124	648	354	48	1,090
14cd	10-9-61	48	Wisconsinan alluvium	....	15	.01	125	8.3	17	386	24	14	.1	28	421	316	30	730
28-20-9da	12-23-60	100.0	Tacket Formation	....	8.0	.01	78	25	114	407	116	57	.7	11	610	298	0	1,090
24ad	10-10-61	35	do	59	5.0	.18	237	25	71	429	210	106	.1	159	1,024	352	342	1,730
30ca	8-29-61	20	Wisconsinan alluvium	....	16	.01	175	22	92	403	147	129	.1	71	851	330	197	1,430
28-21-5bb1	10-9-61	27.2	Tacket Formation	60.5	11	.24	78	58	114	498	23	111	.1	115	755	408	25	1,390
29aa	12-28-60	54	Bandera Shale	....	10	.08	148	50	46	400	35	61	0	279	826	328	246	1,270
34dd	10-10-61	23.1	do	65	12	.27	331	92	403	373	860	345	.4	487	2,714	306	898	4,050
29-17-13cc	10-10-61	25.5	Chanute Shale	....	21	1.4	227	83	111	429	748	10	0.3	4.2	1,415	352	556	1,900
29-18-20ac	10-10-61	14.9	do	....	15	3.8	483	265	635	259	1,416	1,115	.5	518	4,575	212	2,082	6,890
35dc	10-10-61	137.5	Galesburg Shale	....	8.5	.02	8	2.0	366	634	57	165	4.0	1.5	924	28	0	1,660
29-19-3ca	8-29-62	104.5	Dennis Limestone	61	13	.13	121	12	16	395	46	12	.1	.4	415	324	28	720
7dc	12-28-60	105	do	....	17	.65	129	102	79	450	502	12	.6	3.8	1,067	369	372	1,560
30bb	10-10-61	81.4	do	....	11	.12	179	61	107	395	325	71	.2	208	1,157	324	373	1,780
29-20-1dd	10-10-61	27.4	Nowata Shale	....	12	.02	82	26	50	459	4.9	25	.2	3.1	429	312	0	780
20cc	12-28-60	20	Hertha Limestone	....	13	.70	182	24	26	210	158	77	.4	204	788	172	380	1,230
29-21-32dd	8-29-62	20	Wisconsinan alluvium	64	16	5.9	89	8.8	20	307	46	7.0	.2	.4	338	252	6	570
30-17-2dd	8-30-62	240	Chanute Shale, Galesburg Shale	....	17	.09	232	102	182	407	875	84	1.1	49	1,742	334	664	2,350
30-18-20ab1	12-28-60	296	Tacket Formation	....	9	.24	70	16	184	233	99	163	1.1	142	799	191	49	1,330
30-19-1da	8-30-62	28.9	Hertha Limestone	60	15	2.3	140	58	75	256	318	50	.4	150	933	210	378	1,410
4bb2	12-28-60	65.0	Swope Limestone	....	9.5	5.6	201	19	93	295	234	89	.3	212	1,003	242	338	1,510
19bb	10-10-61	71.5	Galesburg Shale	61.5	15	.91	636	206	332	266	1,218	430	.5	1,319	4,288	218	2,216	6,040
24bb	8-30-62	100	Tacket Formation	63	13	.70	111	117	785	730	492	910	1.3	89	2,878	598	160	4,390
35bb	8-30-62	66.0	Bandera Shale	63	12	.94	125	50	115	425	360	36	.5	.4	908	348	170	1,390
30-20-13ac	12-28-60	108.6	do	....	6	2.6	250	29	68	278	138	160	.4	363	1,151	228	515	1,920
22dd	8-30-62	21.6	Nowata Shale	63	11	.04	175	43	99	415	237	90	.3	137	997	340	273	1,610
30-21-22cd	12-28-60	60	Bandera Shale	....	9.5	.24	113	12	72	287	48	58	.1	150	604	236	96	960

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

3 months (Metzler and Stoltenberg, 1950). Water containing 90 ppm is generally considered dangerous to infants and water containing as much as 150 ppm may cause severe cyanosis. Cyanosis is not produced in older children and adults by the concentrations of nitrate ordinarily found in drinking water. Boiling of water containing excessive nitrate does not render it safe for use by infants. Rather, boiling reduces the volume of the water by evaporation and increases the concentration of nitrate in the water. Therefore, only water known to be free of excessive nitrate should be used for preparing infant formulas.

The nitrate content of water from some wells is somewhat seasonal, being highest in winter and lowest in summer. In general, water from wells that are susceptible to surface contamination is likely to be high in nitrate concentration.

Nitrate was found in concentrations greater than 45 ppm in 23 of the 42 water samples analyzed for this report.

Fluoride

Fluoride is present in ground water generally in only small quantities. A knowledge of the fluoride concentration is important because use of water containing greater than 1.5 ppm of fluoride by children during the period of formation of permanent teeth may result in mottling of the enamel. If the fluoride concentration is as much as 4.0 ppm, about 90 percent of children using the water may have mottled enamel (Dean, 1936).

Whereas too much fluoride may have a detrimental effect, moderate concentrations of fluoride (1.0-1.5 ppm) help to prevent tooth decay (Dean, *et al.*, 1941). The U. S. Public Health Service has established 1.5 ppm as the maximum concentration of fluoride permissible in drinking water used on interstate carriers.

Chloride

Chloride salts are very abundant in nature. Sea water and oil-field brines contain them in large quantities, and smaller amounts may be dissolved from rock materials by ground water. Water containing less than 250 ppm of chloride is satisfactory for most purposes. Water containing more than 250 ppm usually is objectionable for municipal supplies, while water containing more than 350 ppm can be unfit even for irrigation and industrial use. Water with as much as 500 ppm of chloride has a salty taste. However, cattle will often tolerate concentrations as high as 4,000 or 5,000 ppm. The removal of chloride is too difficult and costly to be economical for most water uses.

Iron

Next to hardness, iron is the constituent of natural waters that is generally most objectionable. The quantity of iron in the water may differ greatly, sometimes even in the same aquifer. If the water contains 0.3 ppm or more of iron in solution, the iron may settle out as a reddish sediment when the water is exposed to air. Iron at concentrations greater than about 0.3 ppm gives a disagreeable taste to water and stains laundry, cooking utensils, and plumbing fixtures. Iron can generally be removed by aeration and filtration, but some waters require chemical treatment for adequate removal of iron.

Manganese has the same effect as iron, except that the stain is black. Iron and manganese are considered together in evaluating the usefulness of water.

Sulfate

Sulfate in ground water is derived principally from gypsum and anhydrite (calcium sulfate), and from the oxidation of pyrite (iron disulfide). Magnesium sulfate (epsom salt) and sodium sulfate (glauber's salt), if present in concentrations greater than about 250 ppm, impart a bitter taste to water and have a laxative effect upon persons not accustomed to drinking it. More than 250 ppm of sulfate is considered undesirable.

Sanitary Considerations

The analyses of water given in Table 1 indicate only the amount of dissolved mineral matter in the water and do not show the bacteriological content of the water. However, high concentrations of certain constituents such as nitrates or chlorides may indicate pollution of the water.

No cities in Neosho County depend upon wells for their water supplies, but much of the rural population of the County rely upon private wells for water for domestic and stock use. Therefore, care should be taken to prevent pollution of these wells. Generally, wells should not be located downhill from such sources of pollution as barnyards, privies, septic tanks, or cesspools. Also, a well should be completely sealed at the top and around the casing to prevent contamination of the ground-water supply by dust, insects, vermin, debris, and surface water. Dug wells are relatively more vulnerable to contamination because the large diameters common among this type of well renders proper sealing more difficult.

AVAILABILITY OF GROUND WATER

In Neosho County fresh ground water is known to occur in consolidated rocks to a depth of nearly 300 feet and in unconsolidated rocks to a depth of 35 feet. The consolidated rock aquifers consist chiefly of limestones, shales, and sandstones of Pennsylvanian age. The sandstones constitute the most permeable consolidated rock aquifers.

The unconsolidated rock aquifers are alluvial deposits of silt, fine sand, and pebble-sized chert fragments of Pleistocene and Recent ages that occur in the stream valleys as valley fill and as low, highly dissected terraces.

Consolidated Rocks

Limestone and Shale Aquifers

The limestone and shale formations in the County possess a well-developed joint pattern which apparently persists at depth. Because of these joints and other fractures, yields of about 1 gpm may be obtained from wells to a depth of about 300 feet. Weathering processes have enlarged openings along the joints, fractures, and bedding planes near the land surface. In these rocks, shallow dug or drilled wells may yield as much as 3 gpm. Dug wells, with a larger storage capacity, are generally more satisfactory than drilled wells in these aquifers.

The Bandera Shale is the oldest formation in the County from which fresh water is obtained. Well drillers report that water in rocks of the Pawnee Limestone and older Pennsylvanian rocks is highly mineralized and unfit for human or animal consumption.

Pre-Pennsylvanian Rocks

A well drilled in 1936 in SE SE sec. 13, T 29 S, R 20 E to a depth of 1,010 feet is reported to have produced highly mineralized, though potable, water from limestone of Mississippian age. The City of St. Paul used this well as a municipal supply for a short time in 1936 and 1937. In 1937, the static water level in this well was reportedly about 35 feet below the land surface. The well has subsequently been plugged, and no recent water-quality or water-level data are available.

The City of Walnut, Crawford County, Kansas, has a well 1,015 feet deep in SW SW sec. 20, T 28 S, R 22 E (about 3 miles east of the Neosho county line) which obtains water from a zone of saccharoidal dolomite and quartz sand informally called the "Swan Creek." The "Swan Creek," which is in the upper part of the Cotter Dolomite of Ordovician age, occurs in the interval between 990-1,010 feet in the well. Water from the overlying Mississippian and Pennsylvanian rocks, which contains high concentrations of chlorides and sulfates, is kept out of the well by steel casing that is cemented in place to a depth of 931 feet. In November 1964, the well was producing approximately 80 gpm. The chloride content of a water sample taken in 1956 soon after completion of the well was 570 ppm. Subsequent analyses performed in 1959 and 1964 have shown chloride concentrations of 640 ppm and 710 ppm, respectively. Although the water contains enough chloride to be objectionable, it is rendered usable by mixing it with water of much lower mineral content from shallow wells.

It is likely that wells penetrating the "Swan Creek" in Neosho County will encounter water with a much higher chloride content.

Tacket Formation

Wells obtaining water from the black shale of the Tacket Formation can generally be expected to yield at least 1 gpm. The highest yield reported from the Tacket is 1.5 gpm in wells 28-20-9da and 30-19-24bb. Water in sufficient quantity for domestic use is available from the Tacket to depths of 200 feet, as in wells 28-19-31cc and 30-17-35ab. In general, water of suitable quality for human consumption in quantities adequate for domestic use may be obtained from the Tacket throughout the County wherever the Formation outcrops (see Pl. 1) or wherever it may be penetrated at a depth of 200 feet or less (usually 5 to 8 miles west or northwest of the outcrop).

All wells except one (28-20-9da) obtaining water from the Formation that are 100 feet or more in depth reportedly yield water containing enough sodium chloride (more than 500 ppm) to have a discernibly salty taste. The quality of water in shallow dug wells penetrating the Tacket is reportedly suitable for human use.

The maximum yield of 1.5 gpm that can be expected from the Tacket indicates that it is not an aquifer that may be developed for irrigation, industrial, or municipal water supplies.

Swope Limestone

The Hushpuckney Shale Member of the Swope is one of the most productive shale aquifers in the County. Yields of 0.5 to 1.5 gpm may be expected from the black shale member in the area bounded on the east by the outcrop of the Swope Limestone and on the west by the west line of R 18 E (Pl. 1). Locally, yields from 2 to 5 gpm are obtainable from the Hushpuckney as indicated by wells 28-21-21bb and 30-19-6cd. Well drillers and well owners report that in most wells water enters the well bore throughout the full thickness of the black shale. However, in wells with relatively high yields such as 30-19-6cd (5 gpm) the water is encountered in the few inches of the shale just below the overlying Bethany Falls Limestone Member.

Water from wells in the Hushpuckney is generally of a quality suitable for domestic use, although very hard water is common. The sulfate concentration in water from this Member is generally low (less than 30 ppm), except for water from well 30-19-4bb2, which has a concentration of 234 ppm. This amount is still below the concentration of 250 ppm that the U. S. Public Health Service considers objectionable. Water slightly salty to the taste is reported in many wells penetrating the Hushpuckney at a depth of 75 feet or more, although water from well 30-18-25da2, which is 100 feet deep, reportedly has no detectable sodium chloride taste.

Dug or drilled wells penetrating the Bethany Falls Limestone Member of the Swope generally will yield 0.5 to 1.5 gpm of very hard water. The area in which these yields may be expected is bounded on the east by the outcrop of the base of the Swope Limestone and approximately on the west by the west line of R 19 E (Pl. 1).

The water from wells in the Bethany Falls is generally free from noticeable chloride concentrations. One well (27-20-7cb) reportedly yields some natural gas. This was the only well in the Bethany Falls found to yield gas and the condition is probably not common in the aquifer. The chemical quality of water from well 28-19-7cd (Table 1), except for the high nitrate concentration (124 ppm), is probably typical of water from the Swope Limestone.

Shallow dug and drilled wells obtaining water from the Bethany Falls and the Hushpuckney where the two members lie at or near the land surface have a tendency to go dry during periods of deficient rainfall. This dependency upon local rainfall for recharge, as well as the low yields common from the Hushpuckney and Bethany Falls, precludes the development of these two aquifers other than for small domestic or stock supplies.

Dennis Limestone

The Stark Shale Member of the Dennis Limestone is probably the most productive shale aquifer in the County. Dug or drilled wells penetrating the Stark generally yield from 0.3 to 4 gpm at or a few inches below the contact of the shale and the overlying Winterset Limestone. The marked variance in yields from wells in the shale is a reflection of local differences in permeability of the aquifer which, in turn, is directly related to the number of joints, cracks, and voids between bedding planes that are present in the shale. There seems to be no pattern to the occurrence of high or low yields throughout the area in which water is available from the Stark except that T 29 S, R 19 E (Centerville Township) appears to be an area in which as much as 4 gpm (well 29-19-1cd) may be generally available. Numerous small springs issue from this horizon at the outcrop of the Stark, which lies near the base of the Dennis Limestone, as shown on Plate 1.

The area in which water of usable quality is available from the Stark is bounded on the east by the base of the Dennis Limestone (Pl. 1) and approximately on the west by U. S. Highway 169. Near the western edge of this area slightly salty water is present locally in the shale as indicated by the analyses of water from well 28-18-4cd (1,250 ppm of chloride) and the report of brackish water in well 28-18-10abl. Hydrogen sulfide is commonly reported to be present in water from the Stark. Concentrations of sulfate greater than 250 ppm were found in 3 out of 5 water samples from the Stark (wells 28-18-20adl, 29-19-7dc, and 29-19-30bb). Indirect evidence of high sulfate concentrations, *i. e.* many reported instances of laxative effects on persons unaccustomed to drinking the water, indicates that excessive sulfate concentrations are common in water from the shale.

The upper, medium-bedded zone in the Winterset Limestone Member of the Dennis is the most productive limestone aquifer in Neosho County. Although most wells in the Winterset will reportedly yield from 0.2 to 1.0 gpm, locally yields as high as 2 or 3 gpm are possible (as in wells 27-19-24ba and 27-18-29cb, respectively). Nearly all wells (11 out of 13) found to be yielding water from the Winterset in usable quantities lie in the northern tier of townships in the County, *i. e.*, T 27 S, R 18, 19, 20, and 21 E. Wells 28-19-1ba and 30-18-20ab2 both have reported yields of less than 1 gpm. Undoubtedly shallow dug or drilled wells located elsewhere in the County where the Winterset crops out or is near the land surface (Pl. 1) may obtain small amounts of water from the limestone especially during periods of ample rainfall.

Water from the Winterset is generally of good quality although reportedly very hard in most wells. Samples from two wells penetrating the Member were higher than 200 ppm total hardness (27-21-8cc and 28-19-1ba, Table 1). The iron concentrations in these samples were 0.43 ppm and 1.3 ppm respectively, both of which are greater than the 0.3 ppm considered objectionable by the U. S. Public Health Service.

The low yields obtainable from the Winterset and the Stark preclude their development as a supply other than for domestic needs.

Sandstone Aquifers

Bandera Shale

The Bandera Shale in Neosho County will yield 0.5 to 5 gpm from wells located in the area bounded on the north by the north line of T 28 S, R 21 E, on the east by the Crawford county line, on the south by the Labette county line, and on the west by the west lines of T 30 S, R 20 E, T 29 S, R 20 E, and T 28 S, R 21 E. Drillers report that water from the Bandera in other parts of the County is generally too highly mineralized to be used. Most wells in the Bandera in this area obtain water from sandstone beds in the middle of the formation. In local areas, some water is available from the sandy shale and clay shale in the upper part of the Bandera, *i. e.*, wells 28-21-29aa and 28-21-29da. As much as 5 gpm is available from wells in T 30 S in the area between Labette Creek and the Crawford county line as indicated by wells 30-19-35bb and 30-21-22cd, which reportedly yield 5 gpm and 4 gpm respectively. The relatively high potential yield in this area is probably a reflection of the greater thickness of the sand bodies in the middle of the Bandera.

The quality of water from the formation is generally good, except that it is commonly very hard. Iron concentrations in 4 out of 5 water samples were greater or only slightly less than the 0.3 ppm considered objectionable. The nitrate content of all the samples except one (from well 30-19-35bb, Table 1) exceeds the limit recommended by the Public Health Service. There are insufficient data to determine if the high nitrate concentration is characteristic of water from the Bandera or merely isolated occurrences caused by local conditions.

The limited yields available from wells in the Bandera indicate that development of the aquifer for other than domestic and stock use is infeasible.

Nowata Shale

In southeastern Neosho County shallow wells dug or drilled into the Nowata Shale may produce as much as 1 gpm, although yields are generally less. In general, the Nowata yields usable quantities of water only from wells near the outcrop in areas where the formation is predominantly a sandy shale, such as south of the central part of T 28 S.

Analyses of samples from wells 29-20-1dd and 30-20-22dd (Table 1) indicate that water from the Nowata is of good quality although very hard. The relatively high concentrations of sulfate (237 ppm) and nitrate (137 ppm) in the sample from well 30-20-22dd may only reflect local conditions, such as contamination by surface water.

The fact that few wells yield water from the Nowata coupled with the reportedly low yields available from the two wells inventoried (0.3 gpm from well 29-20-1dd and 1.0 gpm from well 30-20-22dd) indicate that the formation is not a reliable aquifer for even domestic or stock supplies.

Hepler Sandstone Member

Shallow dug or drilled wells penetrating the Hepler Sandstone Member near its outcrop in the northern part of the County (Pl. 1) may yield 1 gpm or less of potable water. Because of the lateral variations in lithology and thickness of the Member it yields water only locally. Only two wells, 28-21-5bb1 and 28-21-5bb2, were inventoried that are definitely known to obtain water from the Hepler.

The quality of water from well 28-21-5bb1 (Table 1) is probably representative of water from the Hepler. However, the excessive nitrate content (111 ppm) may only reflect local conditions.

The low yields available from the Hepler coupled with the somewhat local occurrence of ground water in the Member makes it unsuitable generally for development of even domestic and stock supplies.

Galesburg Shale

Wells penetrating the sandy shale and sandstone of the Galesburg Shale may be expected to yield from 0.5 to 2 gpm of potable water in the area bounded on the east by the outcrop of the base of the formation (located from a few tens of feet to a few hundred feet west of the outcrop of the Swope Limestone as shown on Pl. 1) and on the west by a line approximately parallel to and about 5 miles west of the outcrop of the overlying Dennis Limestone. A few small springs occur on the outcrop of the formation in the central portion of the County and at least one, 28-20-9da, has been enlarged and developed for a domestic water supply. In general, wells in the northern and southern portions of the County obtain water from the Dodds Creek Sandstone Member at the base of the formation, whereas wells in the central part of the County, especially T 29 S, R 19 E, yield water from sandy shale in the middle and upper part of the Galesburg.

High fluoride concentrations are apparently common in water from the Galesburg—3 out of 4 samples contained greater than 1.0 ppm and 2 of these 3 (27-19-30cd2 and 29-18-35dc) had concentrations of 4.0 ppm fluoride (Table 1). Nitrates in the two wells mentioned above were quite low, 0.4 ppm and 1.5 ppm respectively. However, the concentration in the sample from well 30-17-2dd was 49 ppm which is above that deemed objectionable by the Public Health Service. The nitrate content of the water from well 30-19-19bb was 1.319 ppm, which is more than two and one-half times higher than the nitrate content of any other sample analyzed (Table 1). This extremely high concentration is thought to be the result of some type of contamination by decaying vegetation or animal waste and cannot be considered representative of water from the Galesburg.

The low yields reported from wells penetrating the Galesburg indicate that it is unsuitable for development other than for domestic and stock supplies.

Chanute Shale

The Chanute Shale is the most productive consolidated-rock aquifer in the County. Two sandstone members, the Noxie at the base of the formation and the Cottage Grove at the top, yield 0.5 to 15 gpm of potable water to wells in the western quarter of the County.

East of Chanute, where the Noxie Sandstone Member overlies the Winterset Limestone Member of the Dennis Limestone or, locally, fills a channel eroded into the Dennis, yields up to 4 gpm (as in well 27-18-24cc) may be expected. West and south of Chanute and beneath the city itself, the Cottage Grove and Noxie Sandstone members are in contact or are separated only by a thin clay-shale zone. The sand composing the two members was apparently deposited in the deepest part of the channel described previously (see discussion of the stratigraphy of the Chanute Shale and Fig. 4). Wells penetrating the combined thicknesses of the two members in this area locally encounter as much as 110 feet of saturated, fine-grained sandstone. Some wells, such as 27-18-20ad, that obtain water from this sandstone reportedly yield as much as 10 gpm. In general, yields of 0.5 to 4 gpm may be expected. Permeability tests conducted under laboratory conditions upon core samples of the sandstones indicate that as much as 75 gpm may be obtained locally from properly developed wells (O. S. Fent, Hydraulic Drilling Co., Salina, Kansas, personal communication, 1965). South of the area underlain by the channel sandstone, in T 29 S, R 17 E, and T 30 S. R 17 E, yields as great as 15 gpm, as in well 29-17-24bd2, may be encountered.

The quality of water from wells in the Chanute is generally good, although the water-sample analyses (Table 1) showed very hard water to be common. Chloride content high enough to be objectionable (1,115 ppm) was found only in the sample from well 29-18-20ac. In five out of eight samples analyzed the chloride concentration was less than 40 ppm. Sulfate concentrations in three samples were greater than 700 ppm, but sulfates in the other samples were well below the 250 ppm considered objectionable. No physiological effects attributable to high sulfate concentrations were reported for other wells penetrating the Chanute. Nitrate content of the eight samples ranged from 1.5 to 518 ppm and was greater than 45 ppm in samples from four wells. Hydrogen sulfide gas, common in the bedrock aquifers in the County, was reported present in only one well yielding water from the Chanute. This well (30-17-2dd) penetrates both the Chanute and Galesburg shales. As the hydrogen sulfide is reportedly noticeable only after extended periods of pumping at about 2 gpm, it is probable that the gas is entering the well from the sandstone in the Galesburg.

In general, water from the sandstone beds in the Chanute contains lower concentrations of chlorides, sulfates, and nitrates than does water from sandstone and limestone aquifers stratigraphically lower than the Chanute.

In view of the 75 gpm that may be available, as reported by Fent, and the yields of as much as 15 gpm reported by well owners, it is possible that small industrial or municipal supplies may be developed in the Chanute. Any attempt to develop such supplies should, of course, be preceded by test drilling and pumping tests.

Other Aquifers

In addition to the limestone and shale aquifers discussed above, the well inventories showed that small amounts of water of usable quality are available locally from the Altamont, Lenapah, Hertha, and Iola limestones as well as from the Ladore and Cherryvale shales. These formations generally do not yield water in sufficient quantities for other than domestic and stock supplies.

Unconsolidated Rocks

Neosho River Valley

Although few wells exist in the Neosho River valley, this should not be construed as an indication that little water is available in the valley. Rather, it reflects a cultural adjustment to the danger of flood damage present in the valley, *i. e.*, few landowners or tenants maintain homes in the valley and consequently few water-supply wells exist.

Illinoisan Terrace Deposits

No privately owned wells in the County that yielded water from the terrace deposits of Illinoisan age were inventoried. However, one test well (27-18-9bb), drilled in July of 1964, is probably representative of wells that may be developed in the terrace deposits. This well penetrated 30 feet of unconsolidated material, the lower 10.5 feet of which consisted of fine to coarse, rounded, chert gravel, and fine to coarse sand with about 10 percent of the material composed of silt and clay. The well yielded 20 gpm during a pumping period of 30 minutes with a total drawdown of 11.3 feet. The fact that the drawdown produced by a pumping rate of 20 gpm was more than 60 percent of the saturated thickness of the aquifer may indicate that a reduced pumping rate is necessary to obtain a sustained yield from wells in these deposits. A pumping rate of about 10 gpm is probably the maximum possible over an extended period from single wells in the terrace deposits.

Wisconsinan and Recent Alluvium

Four wells obtaining water from Wisconsinan gravel deposits were inventoried in Neosho County. The minimum yield reported from these wells was 3 gpm (well 28-20-30ca) and the maximum yield was 8 gpm (well 29-20-3ab). Analyses of water samples from two of these wells, 28-20-30ca and 29-21-32dd (Table 1), indicate that water in the Wisconsinan deposits is generally of good quality. The excessive nitrate (71 ppm) in the sample from well 28-20-30ca renders the water dangerous for infants, but the concentrations of other ions in the water are well below those considered objectionable by the Public Health Service.

One test hole (29-20-15ad) drilled in the valley west of St. Paul in July of 1964 contained 4.5 feet of medium to coarse chert gravel in the interval from 20 to 24.5 feet. Total depth of the well was 25 feet with the bottom 0.5 foot penetrating light-gray Holdenville Shale. After installation of torch-perforated steel casing, the well was pumped for one hour at 20 gpm. Total drawdown at the end of the hour was 0.6 foot. In view of the performance of this well, it is likely that other properly developed wells on the flood plain (Pl. 1) penetrating sand and gravel deposits of similar lithology and thickness at the base of the Wisconsinan alluvium would yield comparable quantities of water. It is possible that properly developed wells in deposits of this type may yield as much as 50 gpm in local areas. As the saturated thickness of the material (that part of the deposit that lies below the water table) is generally about 10 feet during periods of normal rainfall, the available drawndown in wells and consequently the yields would vary with time. During periods of deficient rainfall, for example, it is quite likely that the water table would drop and as a result the available drawdown and yields would decrease.

In summary, it seems probable that 10 gpm is the maximum yield that may be expected from the Illinoisan terrace deposits for extended pumping periods. Yields of as much as 30 gpm are probably available for long periods of time from properly constructed and developed wells in the Wisconsinan alluvium. Wells producing as much as 50 gpm may be adversely affected by slight lowering of the water table and can be expected to decrease in yield over an extended pumping period.

Other Stream Valleys

The valleys of the smaller streams that are tributaries to the Neosho or Verdigris rivers contain alluvium of Pleistocene and Recent ages. These deposits are composed predominantly of very fine-grained material, but locally lenses of sand and chert pebbles are present in the basal part. The thickness of the alluvium ranges from 0 to as much as 30 feet.

Few wells obtain water from these deposits, but as much as 1 gpm is probably available everywhere the alluvium is more than 10 feet thick. One well (28-19-14cd) drilled into the alluvium of Canville Creek reportedly yields as much as 30 gpm for extended periods of time. The water from this well is of good quality (Table 1), although very hard (346 ppm total hardness), and is probably representative of water available from the alluvial deposits in the smaller valleys.

UTILIZATION OF GROUND WATER

In Neosho County, the chief use of ground water is for domestic and stock purposes. It is estimated that in 1961 about 300,000 gpd (gallons per day) were obtained from wells and springs. The total 1961 use is estimated at 109 million gallons or about 334 acre-feet.

No cities or towns in Neosho County utilize ground water for their municipal supply. All public supplies in the County are obtained from surface-water sources. However, some residents of the municipalities with public supplies use private wells to supplement their water supply when surface-water sources are deficient.

Use of ground water for industrial purposes is limited to wells used by service stations for car-washing facilities. No irrigation projects that use ground water are known in Neosho County.

SUMMARY

In Neosho County the rocks above the Precambrian basement complex have an average thickness of about 2,100 feet and all are of sedimentary origin. Rocks of Cambrian, Ordovician, Devonian(?), Mississippian, Pennsylvanian, Tertiary, and Quaternary ages are present. The exposed Pennsylvanian, Tertiary, and Quaternary rocks are nearly 700 feet thick.

The dominant regional structure is the Prairie Plains Monocline, chiefly post-Permian in age, which imparts to the outcropping Pennsylvanian rocks a northwestward dip of about 20 feet per mile. Locally, the dip is as much as 40 feet per mile to the northwest.

Fresh water is obtained from wells as deep as 300 feet in consolidated rock aquifers, but most wells in the County are less than 100 feet deep. Most wells in the County are drilled wells, but large-diameter dug wells are common in the low-yielding limestone and shale aquifers; driven wells are the usual type found in the stream valleys.

In general, sandstone aquifers in the Bandera, Galesburg, and Chanute shales are more productive than limestone or shale aquifers. Yields range from less than 30 gallons per hour in some of the limestone and shale aquifers to slightly more than 15 gpm in the sandstone aquifers. The highest reported yields were from wells obtaining water from the Noxie and Cottage Grove sandstone members of the Chanute Shale.

Yields of as much as 30 gpm are reported from unconsolidated rocks of Wisconsinan age in the valley of Canville Creek. Test drilling and a short-term pumping test of a well penetrating Wisconsinan deposits in the Neosho River valley indicate that as much as 50 gpm may be available locally from wells completed in the sand and gravel at the base of the Wisconsinan material.

Water from most wells in the area is highly mineralized. However, water from the sandstone and unconsolidated rock aquifers tends to be softer and generally of better quality than that from limestone and shale aquifers. Nitrate concentration greater than 45 ppm was found in 23 of 42 water samples analyzed for this report. In view of the common occurrence of high-nitrate water and the hazard that such water poses for infants, it is advisable that water for domestic use be analyzed to determine the nitrate content.

RECORDS OF WELLS, TEST HOLES, AND SPRINGS

Information pertaining to 171 water wells, test holes, and springs in Neosho County and northern Labette County is given in Table 2. Measured depths to water are shown to the nearest 0.01 foot, whereas depths reported by the owner, tenant, or driller are given only to the nearest foot. Similarly, measured depths of wells are shown to the nearest 0.1 foot, whereas reported depths are shown only to the nearest foot.

TABLE 2.—Records of wells, test holes, and springs in Neosho County, Kansas. (Locations of wells, test holes, and springs are given on Plate 1.)

* Complete chemical analysis given in Table 1.
† Type of well: *A*, augered; *Dn*, driven; *Dr*, drilled; *Du*, dug; *Du, Dr*, indicates well drilled in bottom of dug well; *S*, spring.
‡ Type of casing: *N*, none; *R*, rock; *S*, steel; *T*, tile.
§ Method of lift: *Ce*, centrifugal; *Cy*, cylinder; *N*, none; *J*, jet; *S*, submersible; *B*, bucket.
Kind of power: *E*, electric; *H*, hand; *W*, wind.
¶ Use: *D*, domestic; *N*, none; *S*, stock; *In*, industrial; *O*, observation.
** Elevations from topographic maps given to nearest 5 feet; leveled elevations given to nearest 0.1 foot.
†† *KGS*, Kansas Geological Survey; *gpm*, gallons per minute; *gpd*, gallons per day (draw-down, in feet); *log*, log given in section *Logs of Test Holes*.

Well number	Owner or tenant	Type of well†	Depth of well, ft.	Diameter of well, inches	Type of casing‡	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift§	Use of water¶	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level feet**	Remarks††
27-17-1dc*	Harvey Clemens	Dr	53.0	8	S	Sandstone	Chanute Shale	J, E	D, S	30.32	8-18-60	980	1.5 gpm reported yield.
11ad*	Gerald Erickson	Dr	46.8	8	S	Limestone	Iola Limestone	J, E	D	12.70	8-19-60	975	Not used for drinking
14bb	Walter Browning	Dr	124	6	S	Sandstone	Chanute Shale	Cy, H	D, S	25	7-11-60	940	Slightly brackish
36bb*	H. L. Johnson	Dr	180	8	S	do	do	Cy, W	D, S	40	7-11-60	1,010	
27-18-9bb		Dr	31.0	8	S	Sand, gravel	Illinoisan terrace deposits	S, E	N	15.20	7-29-64	922	KGS testhole, 20 gpm, 11.30 ft, log.
12bb	Willard Jobe	Du	17.8	60	R	Limestone	Dennis Limestone	Cy, H	D	8.12	7-5-60	970	Less than 1 gpm reported
20ad	W. O. Chandler	Dr	110	6	S	Sandstone	Chanute Shale	S, E	In	40	7-8-60	950	10 gpm reported.
21bdd		A	23.0	1¼	S	Sand, gravel	Wisconsinan alluvium	N	O	10.60	11-4-60	906.2	KGS testhole, log.
21dab		A	18.5	1¼	S	do	do	N	O	5.22	11-4-60	904.2	do
22caa		A	18.5	1¼	S	do	do	N	O	15.67	11-4-60	904.0	do
23ba	Robert Blunk	Dr	123	6	S	Shale (?)	Dennis Limestone	J, E	D	67	7-7-60	950	0.5 gpm reported.
23bcc		A	26.0	1¼	S	Sand, gravel	Wisconsinan alluvium	N	O	14.50	11-3-60	910.9	KGS testhole, log.
23cba		A	28.5	4	N	do	do	N	N	11.00	11-3-60	906.7	do
24cc*	Lew Rush	Dr	44.1	8	S	Sandstone	Chanute Shale	J, E	D	32.72	8-22-60	960	4 gpm reported.
25cd	Pearl Akers	Du	31	48	R	Sandy Shale	do	Ce, E	D	15	8-22-60	935	
29cb	John Niver	Dr	81	6	S	Limestone	Dennis Limestone	J, E	D	20	7-7-60	985	3 gpm reported.
36dd	North Valley School	Dr	22.4	8	T	Sand, gravel	Wisconsinan alluvium	N	N	15.29	7-7-60	910	Abandoned school.
27-19-2dc	Vyrl Roberts	Dr	150	8		Black shale	Swope Limestone	Cy, E	S	55	7-15-60	950	Slightly brackish, 1 gpm reported.
6da	Pearl Brown	Du	18.7	48	R	Sandstone	Chanute Shale	Cy, H	S	12.23	8-23-60	985	Not used for drinking.
9da*	Ralph Baker	Du	17.7	48	R	do	do	Cy, H	S	12.08	8-23-60	965	
11dd	George Greve	Dr	60.4	8	T	Limestone	Dennis Limestone (?)	Cy, H	D	35.40	8-31-60	1,000	
15cd	Verle Dennis	Dr	200	8		do	do	J, E	D, S	25	8-24-60	930	Water level varies with water level in creek east of well.
24ba	Eben Claus	Dr	152	8		Shale	Dennis Limestone and Swope Limestone	J, E	S			1,030	2 gpm reported.
25ba	Ralph Reinhardt	Du	14	144	R	Limestone	Dennis Limestone	Cy, E	S	10	7-6-60	995	
27bb*	Gus Breiner	Dr	75.8	8	S	Black shale	Swope Limestone	Cy, E	S	13.79	8-23-60	920	0.5 gpm reported.
27db	R. I. Friedrich	Dr	60	8	N	do	Dennis Limestone	Cy, H	D	28	8-23-60	930	
28cd	Lyle Meyer	Dr	65	8	N	Limestone	do	N	N			940	15 gpd reported.
30cd1	J. E. Rensing	Du, Dr	73	8	N	Limestone(?)	Dennis Limestone(?)	Cy, H	S	50	8-23-60	950	
30cd2*	do	Dr	105	6	N	Sandy shale and sand-stone	Galesburg Shale	J E	S	50	8-23-60	950	Brackish water.
30dc	H. J. Fisher	Dr	100	6	N	do	do	J, E	D, S	40	8-23-60	945	450 gpd reported.
27-20-3cc	C. O. Drake	Dr	106	6	N	Limestone	Swope Limestone	Cy, E	D, S	70	7-14-60	1,010	1 gpm reported.
6aa	Albert Witt	Du	25.2	36	R	do	Dennis Limestone	Cy, H	S	6.22	8-31-60	1,020	
7cb	Harold Winans	Dr	149.1	9	S	do	Swope Limestone	Cy, H	D	33.55	7-15-60	1,025	Some natural gas dissolved in water
9dc*	R. H. Woodworth	Dr	150.6	8	S	Black shale	do	J, E	S	84.20	7-14-60	1,035	1.5 gpm reported.
11dd	Walter Gericke	Dr	135	8	N	Limestone	do	Cy, E	D, S	35	7-14-60	1,025	
19bb	Glen Winder	Dr	90	8	S	do	Dennis Limestone	J, E	D, S	65	8-31-60	995	

TABLE 2.—Records of wells, test holes, and springs in Neosho County, Kansas (*continued*).

Well number	Owner or tenent	Type of well†	Depth of well, ft.	Diameter of well, inches	Type of casing‡	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift§	Use of water¶	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level feet**	Remarks††
21dd	Elvin Richwine	Dr	96.2	8	T	do	Swope Limestone	Cy, H	S	39.98	9-22-60	1,000	
25cc	Elmer Owen	Dr	55	4	S	do	Swope Limestone(?)	Cy, H	D	45	7-14-60	1,025	
31ad*	Harley Johnson	Dr	125	8	S	Black shale	Swope Limestone	Cy, E	D	85	9-28-60	995	100 gpd reported.
35cc	Don Harding	Du	25	48	R	Sandstone	Galesburg Shale			12	1954	1,025	Well in pond.
27-21-8cc*	Oral Collins	Dr	91.3	8	S	Limestone	Dennis Limestone	Cy, H	S	24.78	9-8-60	1,010	
9dd	Harold Smith	Du	12.2	48	R	do	do	Cy, H	S	5.53	7-14-60	1,025	
10cd	Verdon Sloan	Dr	59	8	N	Limestone(?)	Hertha Limestone	Cy, E	D, S	50	7-14-60	1,010	2 gpm reported.
18ad	L. A. Beggs	Dr	175	8	N	Shale	Pleasanton(?) Group	J, E	S	60	9-8-60	1,050	Slightly brackish water.
20bb	Charles Hill	Dr	147.4	8	S	Limestone	Hertha Limestone	J, E	D	63.62	7-14-60	1,045	Less than 1 gpm reported.
29da	Marion Wright	Dr	70	8	N	Shale	Pleasanton Group	Cy, E	D, S	20	9-27-60	950	Brackish water.
31ab	E. G. Kirkpatrick	Du	30	72	R	Limestone	Dennis Limestone	Ce, E	D	17	9-27-60	1,045	
28-17-1ba	F. A. Prosser	Dr	130			Sandstone	Chanute Shale	J, E	D	12	9-30-60	980	
2bb	R. C. Myers	Dr	175	8	S	do	do	Cy, E	D, S	40	8-19-60	1,015	
11da1	Abbot Arthur	Dr	175	8	N	do	do	J, E	D, S	75	7-19-60	960	100 gpd reported.
11da2	do	Dr	46.6	8	S	do	do	Cy, E	S	6.93	7-19-60	960	Plugged gas well.
14dd	Mrs. Lee Williams	Du, Dr	48.8	48-6	N	Limestone	Iola Limestone	Cy, H	D	13.70	10-5-60	980	1 gpm reported.
36bb	K. W. Brant	Du	26		R	do	do	Cy, W, E	D, S	9	10-5-60	980	1 gpm reported.
28-18-4cd*	George Ricker	Dr	60	8	S	Black shale	Dennis Limestone	J, E	D, S	15	7-8-60	910	
5ad	John Jensen	Dr	220	8	S	do	Swope(?) Limestone	J, E	S	60	7-8-60	940	Reported slightly brackish water.
6bb	Fay Noland	Dr	132	12	S	Sandstone	Chanute Shale	Cy, E	D, S	35	8-19-60	995	1,200 gpd reported, very soft water
8cc	Turkey Creek School	Dr	49.7	8	S	do	do	Cy, H	N	10.14	7-19-60	945	
10ab1	Jay Smith	Dr	70	8	S	Black shale	Dennis(?) Limestone	Cy, E	S	10	8-24-60	915	0.75 gpm reported, brackish water.
10ab2	do	Du	25	36	R	Sandstone	Cherryvale(?) Shale	Ce, E	D, S	19	8-24-60	915	
12cc	E. P. Rustman	Dr	188	8	S	do	do	Cy, E	S			935	Brackish water, gas
15ab	Earnest Flottman	Dr	42.6	6	N	do	Chanute Shale and Cherryvale Shale	J, E	D, S	5.32	8-24-60	935	2 gpm reported
16cc	E. A. Vanhart	Dr	94.4	6	S	Black shale	Dennis Limestone	Cy, E	D, S	11.92	7-8-60	965	1 gpm reported.
20ad1*	R. V. Fickel	Dr	145	6	S	do	do	Cy, E	D	17	7-12-60	955	
20ad2	do	Dr	176	6	N	do	Swope Limestone	Cy, E	S	25	7-12-60	955	Water reported very salty.
20cc	Joseph Allen	Dr	100	8	S	do	Dennis Limestone	Cy, E	D	35	7-12-60	960	
23dd	John Waltermire	Dr	190	8	N	Sandstone	Cherryvale Shale	Cy, E	S	20	8-29-60	950	100 gpd reported.
27aa*	Lewis Taylor	Du	16.8	72	N	do	Chanute Shale	Ce, E	D	6.97	8-29-60	980	
32dd	George Neely	Du	20.2	72	R	do	do	Cy, E	D	7.39	8-29-60	970	
28-19-1ba*	Andy Ashcraft	Dr	122.4	8	S	Limestone	Dennis Limestone	Cy, H	D	35.05	8-31-60	960	
7cd*	Charles Miller	Dr	106			do	Swope Limestone	S, E	D, S	80	8-24-60	915	0.5 gpm reported.
13ab	Warren Hasel	Dr	100	6	S	Black shale	do	S, E	D	25	9-29-60	905	4 gpm reported.
14cd*	Russell Heady	Dr	48	8	S	Gravel	Wisconsinan alluvium	Ce, E	D, S	16	10-19-60	895	30 gpm reported.
21bb	M. C. Mintz	Dr	90	8	N	Limestone	Swope Limestone	Cy, E	D	15	8-24-60	920	2 gpm reported.
24dc	Donald Yarnel	Du	30	36	R	Gravel	Wisconsinan alluvium	Ce, E	D, S	10	9-1-60	890	3 gpm reported.
31cc	R. E. Heilman	Dr	210	8	S	Black shale	Pleasanton(?) Group	Cy, E	S	180	7-12-60	945	500 gpd reported, water slightly brackish.
34cd	Phillip Roth	Dr	192.3	8	S	Black shale(?)	do	B, H	D	38.30	7-12-60	980	
28-20-4cc	Charles Warstler	Dr	178.0	8	S	Black shale	Altamont Limestone	N	N	8.82	7-15-60	990	Water reported brackish.
5cc	Cecil Angleton	Du	20	36	N	Sandstone	Galesburg Shale	N	D		7-15-60	930	Spring enlarged to form well
9da*	Paul Coover	Dr	100.0	8	S	Black shale	Pleasanton Group	J, E	D	69.78	7-15-60	980	1.5 gpm reported.
13bb	Vernon Yoho	Du	15.8	48	R	Limestone	Hertha Limestone	Cy, H	D, S	11.36	9-28-60	950	200 gpd reported.
15bc	Keith Knetzer	Dr	115.4	8	S	Shale	Pleasanton(?) Group	S, E	D, S	20.64	9-22-60	940	Water reported brackish.
19cc	Howard Yarnel	Du, Dr	120	48-8	R, N	Black shale	do	J, E	D, S	30	9-1-60	890	Reported that water causes red iron stain on plumbing fixtures.

28-20-21ab	J. R. Pillot	Du	16	48	R	Shale	Ladore Shale	Ce, E	D, S	10	9-22-60	930	
21ad*	Eugene Smith	Du	35	36	R	Black shale	Pleasanton(?) Group	Cy, H	D	20	10-17-60	970	
26bc	M. W. Wittsell	Du	17	48	R	Gray shale	do	Ce, E	D, S	8	9-22-60	915	10 gpm reported.
30ca*	Melvin Yarnel	Dn	20	1¼	S	Gravel	Wisconsinan alluvium	Ce, E	D, S	10	9-1-60	890	3 gpm reported; reported that water causes iron stain on plumbing fixtures
30daa		A	23.5	4	N	Silt	do	N	N			890.9	KGS testhole, dry hole, log.
30ddd		A	19.5	1¼	S	Sand	do	N	O	17.30	11-3-60	887.3	KGS testhole, log.
31ddb		A	30.0	4	N	Gravel and sand	do	N	N	4.20	11-3-60	880.3	do.
35ad	Earl Hand	Du	29.2	48	R	Shale	Pleasanton(?) Group	Ce, E	D	18.62	10-17-60	925	
28-21-5bb1*	L. O. Fisher	Du	27.2	36	R	Sandy shale	do	Cy, H	D, S	21.55	9-27-60	950	1 gpm reported.
5bb2	do	Du	30	36	R	do	do	Cy, H	S	25	9-27-60	950	
9da	Len Herod	Dr	102	6	S	Shale	do	J, E	D	50	7-6-60	1,000	Less than 0.5 gpm reported.
29aa*	Cyril Madl	Dr	54	8	S	do	Bandera Shale	J, E	D, S	15	9-21-60	890	
29da	John Mitchell	Du	23.9	48	R	do	do	Ce, E	D	11.30	9-21-60	910	1 gpm reported.
34dd*	George Greve	Du	23.1	60	N	Sandstone	do	Cy, H	D	10.65	7-6-60	900	
29-17-2dd	T. J. Van Meter	Dr	85	8	N	Shale	Chanute Shale	J, E	D, S	50	10-5-60	920	H_2S odor, not used for drinking.
13cc*	Frank White	Du, Dr	25.5	72-8	R	Sandstone	do	Ce, E	D, S	2.85	8-17-60	955	0.5 gpm reported.
21bd1	Ellis Holtzman	Dr	262.6	8	S			Cy, E	N	14.51	8-22-60	995	1.5 gpm reported.
21bd2	do	Dr	58	8	S	Sandy shale	Chanute Shale	N	N	10	8-22-60	985	15 gpm reported.
29-18-3aa	Lew Snowden	Du	19.4	48	R	do	do	Ce, E	D, S	5.92	8-30-60	950	1 gpm reported.
3cb	Mrs. Charles Bailey	Du	15	48	R	Sandstone	do	B, H	D	12	7-8-60	1,000	
5dd	Ralph Robertson	Dr	55	10	S	do	do	Cy, E	S	10	8-29-60	975	
20ac*	E. M. Mendenhall	Du	14.9	72	R	do	do	Cy, H	S	7.25	10-19-60	1,010	2 gpm reported.
21dd	Clifford Culbertson	Dr	210	8	N	do	do	S, E	S			1,065	1 gpm reported.
21ba	Opal Ging	Du	22.8	72	N	do	do	B, H	D	9.03	9-29-60	1,000	
27aa	Glen Timmons	Dr	205.7	8	N	do	Galesburg Shale	N	N	10.59	9-30-60	1,010	1 gpm reported.
35dc*	G. S. Gross	Dr	137.5	8	S	do	Galesburg Shale(?)	S, E	D, S	39.32	8-18-60	980	2 gpm reported, H_2S odor.
29-19-1cd	Ronald Thompson	Dr	65	8	N	Black shale	Dennis Limestone	J, E	D	3	10-17-60	965	4 gpm reported.
3ca*	Pauline Shellhorn	Dr	104.5	8	S	do	do	Cy, H	D, S	3.47	7-12-60	990	
7dc*	Darrell Dunivant	Dr	105	8	N	do	do	J, E	D, S	40	8-22-60	990	2 gpm reported.
8ad	J. L. Swank	Dr	103	8	N	do, sandstone	do, Galesburg Shale	Cy, H	D, S	30	9-29-60	910	0.5 gpm reported.
9cd	Verle Winans	Dr	90	8	N	Black shale	Dennis Limestone	Cy, H	D, S	30	8-22-60	950	0.3 gpm reported.
14dc	E. J. Jacquinot	Du	24	72	R	Sandy shale	Galesburg Shale	Ce, E	D	12	9-22-60	915	1 gpm reported.
28ab	William Blair	Dr	90	8	S	do	do	J, E	D			950	1 gpm reported.
30bb*	Gladys Thurman	Dr	81.4	8	S	Black shale	Dennis(?) Limestone	J, E	S	8.09	8-22-60	995	0.3 gpm reported.
33cc1	Forest Newell	Dr	150	6	S	Sandy shale	Galesburg Shale	S, E	D	3.60	7-13-60	995	0.5 gpm reported.
33cc2	do	Dr	161.5	10	T	do	do	Cy, H	S	4.25	7-13-60	995	
29-20-1dd*	William Spielbusch	Du	27.4	36	R	do	Nowata Shale	Ce, E	D, S	21.47	9-21-60	995	0.3 gpm reported.
3ab	T. J. Larue	Du	32	36	R	Gravel	Wisconsinan alluvium	Ce, E	D, S	27	9-22-60	870	8 gpm reported.
6cdc		A	35.0	1¼	S	Sand and gravel	do	N	O	2.30	11-3-60	877.9	KGS testhole, log.
15ad		Dr	25.0	8	S	do	do	S, E	N	15.05	7-28-64	873	KGS testhole, 20 gpm, 0.60 ft., log.
20cc*	Wallace Beard	Du	20	48	R	Limestone	Hertha Limestone	Cy, H	N	12	9-21-60	910	
30da	Grant Beard	Du	16.2	36	R	do	do	Ce, E	S	2.65	9-21-60	935	2 gpm reported.
34bb	Charles Johnson	Dr	69	8	N	Sandstone	Bandera Shale	J, E	D	20	9-21-60	890	1 gpm reported, water reported brackish
29-21-17dd	H. Schettler	Du	21.0	36	R	Limestone	Altamont Limestone	Ce, E	D	15.0	7-6-60	905	
21ab	J. R. Crager	Du	15	96	R	do	do	Cy, H	D	12	7-6-60	890	
27cb	S. A. Westhoff	Du	45	48	R	do	do	Cy, E	D, S	20	9-22-60	900	0.3 gpm reported.
32dd*	Agnes Bergmann	Dn	20	2	S	Gravel	Wisconsinan alluvium	Cy, H	D, S	8	10-14-60	860	5 gpm reported.
30-17-2dd*	Ralph Fortenberry	Dr	210	10	N	Sandstone	Chanute Shale and Galesburg Shale	S, E	D, S	65	8-16-60	980	2 gpm reported, H_2S odor reported after heavy pumping.
23cb	James Parsley	Du	29.6	48	R	do	Chanute Shale	Cy, H	D, S	15.71	8-17-60	980	2 gpm reported.
24ad	Vern Stafford	Dr	228	8	N	Black shale	Dennis Limestone	Cy, E	S	70	10-10-60	985	0.7 gpm reported.
35ab	Jacob Miller	Dr	200	8	S	Shale	Pleasanton Group	J, E	D	Flows	10-10-60	885	1.5 gpm reported, chloride 1,065 ppm, H_2S.

TABLE 2.—Records of wells, test holes, and springs in Neosho County, Kansas (*concluded*).

Well number	Owner or tenant	Type of well†	Depth of well, ft.	Diameter of well, inches	Type of casing‡	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift§	Use of water¶	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level feet**	Remarks††
30-18-2bb	H. L. Bonine	Dr	180	8	S	Sandstone	Chanute Shale	Cy, E	D, S	4	8-18-60	990	1 gpm reported, water reported brackish.
4bb	R. L. Shockley	Du	21.4	48	N	do	do	Cy, H	D	11.32	8-16-60	1,050	
6bc	J. M. Harmon	S				do	do	N	N	Flows		1,020	Water reported very soft.
7cc1	L. D. Dantic	Dr	59	8	N	do	do	J, E	D	30	10-6-60	1,025	1.5 gpm reported.
7cc2	do	Du	30	36	N	do	do	Cy, H	S	20	10-6-60	1,025	Less than 1 gpm reported.
8dd	Marion Mayo	Du	18.1	36	R	Sandy shale	Cherryvale Shale	B, H	D	7.6	9-30-60	985	
11bc	Dale Hughes	Dr	230	8	N	Black shale	Pleasanton Group	S, E	D, S	50	8-18-60	990	2 gpm reported.
20ab1*	George Dougherty	Dr	296	8	S	do	Pleasanton Group(?)	S, E	S	70	7-13-60	980	
20ab2	do	Dr	120	8	N	Limestone	Dennis Limestone(?)	J, E	D	80	7-13-60	980	Less than 1 gpm reported, water reported to have slight H_2S odor
25da1	W. C. Neely	Du, Dr	85	108-8	N	Black shale	do	Ce, E	D, S	16	10-10-60	975	1.5 gpm reported.
25da2	do	Dr	100	8	N	do	Swope Limestone	Cy, E	D, S	20	10-10-60	975	
27bb	K. T. Barsch	Dr	125	8	S	Limestone	do	Cy, E	S	25	8-18-60	965	0.5 gpm reported.
30-19-1da*	A. A. Bennett	Du	28.9	48	R	do	Hertha Limestone	Cy, H	D, S	13.61	10-12-60	1,005	Less than 1 gpm reported.
3dd	Albert Magner	Du	30.6	36	R	do	Swope Limestone	Cy, H	S	8.69	10-11-60	1,010	0.3 gpm reported, water reported very hard
4bb1	R. J. Magner	Dr	55.4	8	N	do	do	Cy, H	S	9.72	7-13-60	975	1 gpm reported.
4bb2*	do	Dr	65.0	8	N	Black shale	do	J, E	D	7.76	7-13-60	975	
6cd	G. M. Reed	Dr	140	12-4	N	do	do	J, E	D, S	26	7-13-60	950	5 gpm reported.
19bb*	Denver Waggoner	Dr	71.5	8	N	Sandstone	Galesburg Shale	Cy, H	D	12.13	10-11-60	970	
24bb*	George Doane	Dr	100	8	N	Sandy shale	Pleasanton Group	Cy, E	S	58	10-12-60	945	1.5 gpm reported, water reported brackish
25dd	Harry Smith	Du	26	36	R	Shale	do	J, E	S	13	10-12-60	925	
29dd	Aaron Drumright	Dr	102	6	N	Limestone	Hertha Limestone	Cy, W	S	40	7-13-60	950	0.3 gpm reported, water reported brackish.
35bb*	J. I. Diediker	Dr	66.0	8	N	Sandstone	Bandera Shale	J, E	D, S	10.90	8-30-62	900	5 gpm reported.
30-20-2cc	Thomas Fish	Du	25.3	48	R	Limestone	Lenapah Limestone	Cy, H	D, S	15.43	10-14-60	935	Greater than 1 gpm reported.
4cc	C. H. Steinbacher	Dr	130	8	N	Sandstone	Bandera Shale	J, E	D, S	45	10-12-60	960	1.5 gpm reported.
13ac*	Ray Carter	Dr	108.6	9	N	do	Bandera Shale(?)	Cy, H	S	30.73	7-6-60	910	0.5 gpm reported.
22dd*	Robert Dyer	Du	21.6	48-36	R	Shale	Nowata Shale	Cy, H	D, S	16.24	7-6-60	945	1 gpm reported during periods of normal precipitation.
28cc	John Owen	Dr	62	8	N	Limestone	Lenapah Limestone	J, E	D, S	27	10-12-60	920	
34dc	Albert Hornback	Dr	75	8	N	Sandstone	Bandera Shale	J, E	D	50	10-12-60	955	1 gpm reported.
36bb	Joseph Heck	Du	27.2	48	R	Limestone	Altamont Limestone	Cy, H	D	13.72	10-12-60	935	0.7 gpm reported.
30-21-4dd	Melvin Holding	Du	36	60	R	Sandstone	Bandera Shale	Cy, H	D	10	10-14-60	890	Reported to yield very little water in dry years.
22cd*	C. H. Wimbish	Dr	60	8	N	do	do	J, E	D	10	7-11-60	880	4 gpm reported.
Labette County 31-21-15cc		A	24.0	1¼	S	Sand and gravel	Illinoisan terrace deposits	N	O	13.67	11-2-60	836.1	KGS testhole, log.
16ddc		A	40.0	4	N	do	Wisconsinan alluvium	N	N	14.50	11-2-60	837.5	do.
17dcd		A	20.0	4	N	Silt and clay	Illinoisan terrace deposits	N	N	14.90	11-2-60	846.7	do.
20aba		A	18.0	4	N	Sand and silt	do	N	N	11.90	11-2-60	839.6	do.
21bba		A	18.5	1¼	S	do	Wisconsinan alluvium	N	O	5.20	11-2-60	838.8	do.
22aba		A	28.0	1¼	N	do	Illinoisan terrace deposits	N	O	21.42	11-2-60	849.3	do.

LOGS OF TEST HOLES

Presented on the following pages are logs of 15 test holes in Neosho County and northern Labette County drilled with a truck-mounted power auger owned by the U. S. Geological Survey. Also included are logs of two test holes drilled with a cable-tool machine.

27-18-9bbb.—Sample log of test hole in NW NW NW sec. 9, T 27 S, R 18 E, at south end of board fence behind building; drilled July 29, 1964. Altitude of land surface 925 feet; depth to water 15.20 feet.

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brown, sandy	2	4
Silt, gray, limonite mottling, clayey	4.5	8.5
Silt, brown, some very fine sand, slightly clayey, much sand at bottom	11	19.5
Gravel, brown, very coarse, much very fine to coarse sand, silt and clay, limestone cobbles at 26 feet	10.5	30
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
CHANUTE SHALE		
Shale, gray	1	31

27-18-21bdd.—Sample log of test hole in SE SE NW sec. 21, T 27 S, R 18 E, between house and south fence of corral about 30 feet north of base of highway fill embankment; augered Nov. 4, 1960. Altitude of land surface 906.2 feet; depth to water 10.60 feet.

	Thickness, feet	Depth, feet
Soil, black, sandy	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Sand, light-brown, fine-grained, silty, yellow clay stringers	5	8.5
Sand, medium-brown, clayey,	5	13.5
Fine chert pebbles, light-brown, silty	6.5	20
Fine chert pebbles, coarse sand, clayey	3	23
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
CHANUTE SHALE		
Shale, bluish-gray		23

27-18-21-dab.—Sample log of test hole in NW NE SE sec. 21, T 27 S, R 18 E, on north shoulder of abandoned highway about 400 yards east of overpass; augered Nov. 4, 1960. Altitude of land surface 904.2 feet; depth to water 5.22 feet.

	Thickness, feet	Depth, feet
Soil, brown	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brown, yellow clay stringers, some coarse sand	5	8.5
Silt, grayish-yellow, clayey	5	13.5
Fine to very coarse brown chert pebbles, brownish-gray silt	5	18.5
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
CHANUTE SHALE		
Shale, light-gray, slightly calcareous		18.5

27-18-22caa.—Sample log of test hole in NE NE SW sec. 22, T 27 S, R 18 E, on west side of driveway 35 feet south of U. S. Highway 59; augered Nov. 4, 1960. Altitude of land surface 904.0 feet; depth to water 15.67 feet.

	Thickness, feet	Depth, feet
Soil, dark-gray, clayey	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brownish-yellow, clayey	10	13.5
Sand, brown, fine-grained, some fine chert pebbles	5	18.5
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
DENNIS LIMESTONE		
Limestone, light-brown, finely crystalline		18.5

27-18-23bcc.—Sample log of test hole in SW SW NW sec. 23, T 27 S, R 18 E, on north side of U. S. Highway 59 inside fence row about 6 feet west of gate; augered Nov. 3, 1960. Altitude of land surface 910.9 feet; depth to water 14.50 feet.

	Thickness, feet	Depth, feet
Soil, light-brown	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, light-brown, clayey	5	8.5
Silt, dark-brown, clayey	5	13.5
Silt, light-brown, clayey	10	23.5
Silt, brown	1.5	25
Sand, dark-gray, few fine chert pebbles	1	26
PENNSYLVANIAN		
UPPER PENNSYLVANIA SERIES		
MISSOURIAN STAGE		
DENNIS LIMESTONE		
Limestone, light-brown		26

27-18-23cba.—Sample log of test hole in NE NW SW sec. 23, T 27 S, R 18 E, on levee 15 feet south of U. S. Highway 59; augered Nov. 3, 1960. Altitude of land surface 906.7 feet; depth to water 11.00 feet.

	Thickness, feet	Depth, feet
Fill material	8.5	8.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brownish-black, some very fine sand, clayey	5	13.5
Silt, light-yellowish-brown, some very fine sand, clayey,	5	18.5
Silt, light-brown, some fine sand, micaceous, clayey	5	23.5
Silt, dark-gray, medium sand	5	28.5
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
DENNIS LIMESTONE		
Limestone, light-gray, finely-crystalline		28.5

28-20-30daa.—Sample log of test hole in NE NE SE sec. 30, T 28 S, R 20 E, 15 feet south of driveway into barnyard on west shoulder of U. S. Highway 59; augered Nov. 3, 1960. Altitude of land surface 890.9 feet; dry hole.

	Thickness, feet	Depth, feet
Soil, black	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN(?) STAGE		
Alluvium		
Silt, yellowish-brown, clayey, slightly calcareous	13.5	17
Silt, brownish-gray, some coarse limestone sand	6.5	23.5
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
HERTHA LIMESTONE		
Limestone, gray		23.5

28-30-30ddd.—Sample log of test hole in SE SE SE sec. 30, T 28 S, R 20 E, about 4 feet west of driveway on north side of road; augered Nov. 3, 1960. Altitude of land surface 887.3 feet; depth to water 17.30 feet.

	Thickness, feet	Depth, feet
Soil, dark-gray, silty	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Silt, light-yellowish-brown, clayey	2	5.5
Silt, yellowish-brown, some very fine sand	3	8.5
Silt, light-yellowish-brown, clayey, slightly calcareous	5	13.5
Silt, yellowish-brown, micaceous, clayey	6	19.5
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
HERTHA LIMESTONE		
Limestone, gray		19.5

28-20-31ddb.—Sample log of test hole in NW SE SE sec. 31, T 28 S, R 20 E, on north side of U. S. Highway 59 at base of highway fill on driveway heading north; augered Nov. 3, 1960. Altitude of land surface 880.3 feet; depth to water 4.20 feet.

	Thickness, feet	Depth, feet
Soil, dark-gray, sandy	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brownish-black, clayey	2	5.5
Silt, brown, clayey	3	8.5
Sand, brownish-black, very fine-grained, clayey	15	23.5
Sand, brown, silty, some coarse chert pebbles	6.5	30
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
LADORE SHALE		
Shale, gray		30

29-20-6cdc.—Sample log of test hole in SW SE SW sec. 6, T 29 S, R 20 E, on east side of abandoned road 5 feet north of east side of concrete culvert; augered Nov. 3, 1960. Altitude of land surface 877.9 feet; depth to water 2.30 feet.

	Thickness, feet	Depth, feet
Soil, black, silty	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brownish-black, clayey	5	8.5
Silt, brownish-black, some coarse to very coarse sand, few fine chert pebbles	5	13.5
Silt, light-brown, some coarse to very coarse sand	5	18.5
Silt, light-brown, some coarse sand	6.5	25
Chert pebbles, fine, some silt and clay	5	30
Sand, medium-gray, fine-grained	5	35
PENNSYLVANIAN		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
LADORE SHALE		
Shale, medium-gray, slightly calcareous		35

29-20-15add.—Sample log of test hole in SE SE NE sec. 15, T 29 S, R 20 E, at north edge of concrete parking apron; drilled July 28, 1964. Altitude of land surface 870 feet; depth to water 15.05 feet.

	Thickness, feet	Depth, feet
Fill	6	6
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, dark-gray, clayey	7.5	13.5
Silt, gray-orange, variegated, clayey; some very fine sand, black ironstone concretions,	4.5	18
Sand, gray, very fine, clayey	2	20

Gravel, brown chert, medium to very coarse, much very fine sand and silt, clayey	4.5	24.5
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
HOLDENVILLE SHALE		
Shale, light-gray	0.5	25

31-21-15ccc.—Sample log of test hole in SW SW SW sec. 15, T 31 S, R 21 E, on north edge of grader ditch on north side of U. S. Highway 160 about 3 feet west of driveway into field; augered Nov. 2, 1960. Altitude of land surface 836.1 feet; depth to water 13.67 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, brown	3.5	3.5
Clay, yellowish-brown, silty	5	8.5
Sand, yellowish-red, very fine-grained, clayey	5	13.5
Sand, yellowish-brown, fine-grained, some coarse chert pebbles, clayey	10	23.5
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE		
LITTLE OSAGE SHALE MEMBER		
Siltstone, light-gray, some very fine sand grains, very hard	0.5	24.

31-21-16ddc.—Sample log of test hole in SW SE SE sec. 16, T 31 S, R 21 E, 6 feet east of driveway and 10 feet north of east-west fence; augered Nov. 2, 1960. Altitude of land surface 837.5 feet; depth to water 14.50 feet.

	Thickness, feet	Depth, feet
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, light-brown, clayey	13.5	13.5
Silt, brownish-black, clayey	5	18.5
No sample	5	23.5
Silt, brownish-black, clayey	5	28.5
Sand, brown, quartzitic, very fine-grained	5	33.5
Coarse chert pebbles	6	39.5
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE	0.5	40

31-21-17dcd.—Sample log of test hole in SE SW SE sec. 17, T 31 S, R 21 E, on west shoulder of north-south road about 100 feet north of U. S. Highway 160; augered Nov. 2, 1960. Altitude of land surface 846.7 feet; depth to water 14.90 feet.

	Thickness, feet	Depth, feet
Road fill	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
ILLINOISAN STAGE		
Terrace deposits		
Silt, yellow, clayey	5	8.5
Silt, yellow, clayey, slightly calcareous	5	13.5
Silt, light-yellow, clayey	6.5	20.0
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE		20.0

31-21-20aba.—Sample log of test hole in NE NW NE sec. 20, T 31 S, R 21 E, in grader ditch on east side of creek about 15 feet south of highway slab; augered Nov. 2, 1960. Altitude of land surface 839.6 feet; depth to water 11.90 feet.

	Thickness, feet	Depth, feet
Soil, black	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
ILLINOISAN STAGE		
Terrace deposits		
Silt, yellow, clayey	6.5	10
Silt, yellow, clayey, some fine chert pebbles	7	17
Shale, weathered, dark-gray, some fine chert pebbles	1	18
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE		18

31-21-21bba.—Sample log of test hole in NE NW NW sec. 21, T 31 S, R 21 E, on west bank of creek about 3 feet south of base of riprap at west end of bridge; augered Nov. 2, 1960. Altitude of land surface 838.8 feet; depth to water 5.20 feet.

	Thickness, feet	Depth, feet
Soil, black	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
WISCONSINAN STAGE		
Alluvium		
Silt, dark-gray, clayey	5	8.5
Silt, yellow, clayey	5	13.5
Sand, light-brown, very fine-grained, clayey	5	18.5
PENNSYLVANIAN		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE		18.5

31-21-22aba.—Sample log of test hole in NW NW NE sec. 22, T 31 S, R 21 E, 50 feet south of junction of railroad and U. S. Highway 160; augered Nov. 2, 1960. Altitude of land surface 849.3 feet; depth to water 21.42 feet.

	Thickness, feet	Depth, feet
Soil, yellowish-brown, clayey,	3.5	3.5
QUATERNARY		
PLEISTOCENE SERIES		
ILLINOISAN STAGE		
Terrace deposits		
Silt, yellowish-brown, clayey,	5	8.5
Sand, yellowish-brown, very fine-grained, blue clay stringers	5	13.5
Sand, light-yellowish-brown, very fine-grained, clayey	5	18.5
Silt, light-yellowish-brown, clayey	9.5	28
PENNSYLVANIAN		
MIDDLE PENSYLVANIAN SERIES		
DESMOINESIAN STAGE		
FORT SCOTT LIMESTONE		28

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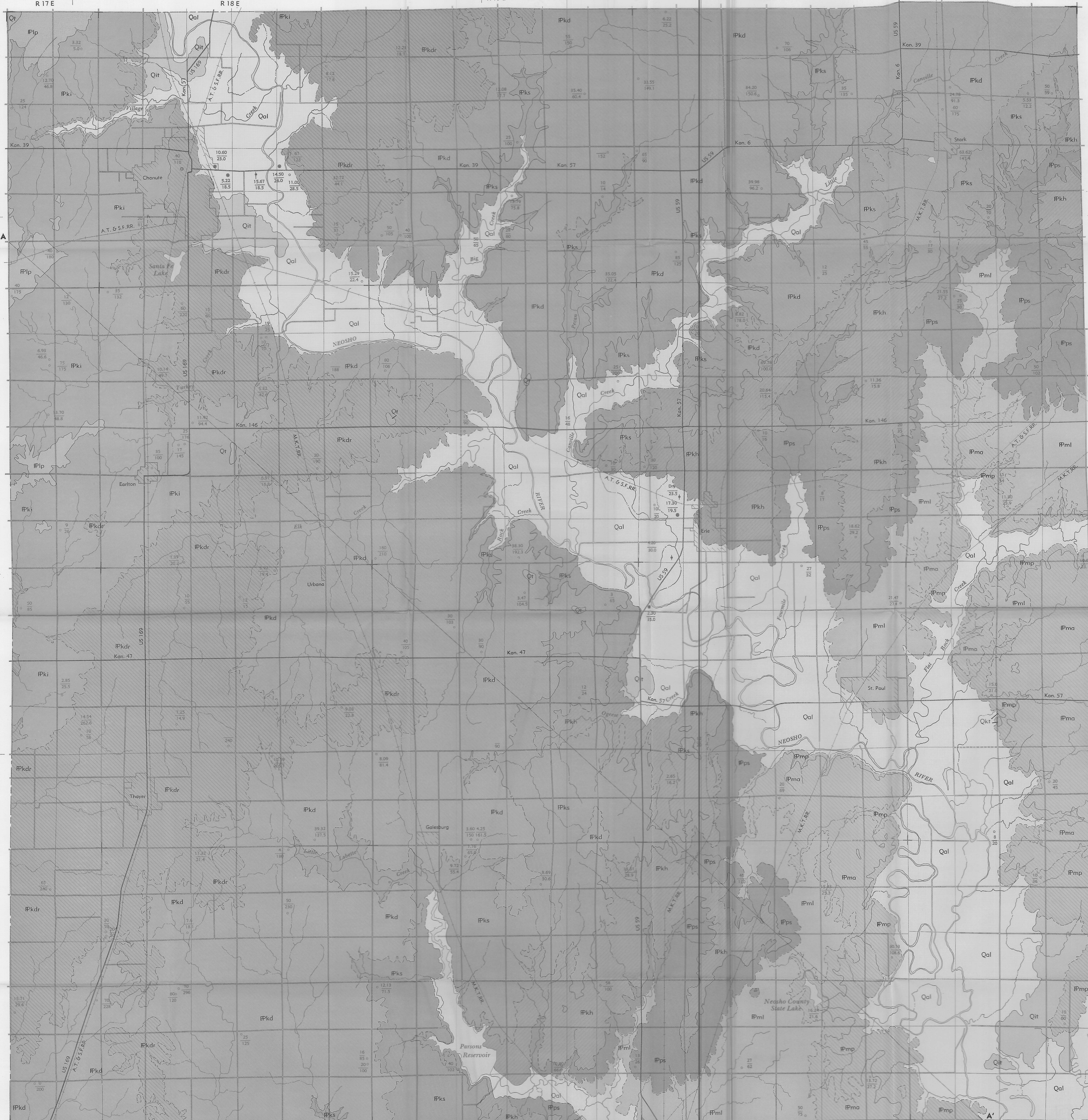
GEOLOGIC MAP OF NEOSHO COUNTY, KANSAS

State Geological Survey of Kansas

Bulletin 183
Plate 1



Base compiled from maps prepared by the Soil Conservation Service.

Prepared by the United States Geological Survey and the State Geological Survey of Kansas, with the cooperation of the Environmental Health Services of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

Areal geology mapped in 1960–61 by William L. Jungmann.

EXPLANATION

QUATERNARY SYSTEM — PLEISTOCENE SERIES

- Qal — Alluvium (Wisconsinan and Recent)
- Qit — Terrace deposits (Illinoisan)
- Qkt — Terrace deposits (Kansan)

TERTIARY SYSTEM — PLIOCENE SERIES

- Qt — High terrace deposits (Nebraskan and/or Pliocene?)

PENNSYLVANIAN SYSTEM — UPPER PENNSYLVANIAN SERIES — MISSOURIAN STAGE

LANSING GROUP

- IPlp — Plattesburg Limestone and Vilas Shale

KANSAS CITY GROUP

- IPki — Iola Limestone, Lane Shale, and Bonner Springs Shale
- IPkdr — Drum Limestone and Chanute Shale
- IPkd — Dennis Limestone and Cherryvale Shale
- IPks — Swope Limestone and Galesburg Shale
- IPkh — Hertha Limestone and Ladore Shale

PLEASANTON GROUP

- IPps — Seminole Formation, Checkerboard Limestone, and Tacket Formation

PENNSYLVANIAN SYSTEM — MIDDLE PENNSYLVANIAN SERIES — DESMOINESIAN STAGE

MARMATON GROUP

- IPml — Lenapah Limestone and Holdenville Shale
- IPma — Altamont Limestone and Nowata Shale
- IPmp — Pawnee Limestone and Bandera Shale

Spring

Domestic or school well

Test hole

Observation well

Industrial well

$\frac{67}{123}$

Upper number, depth to water below land surface, in feet. Reported depth shown to nearest foot; measured depth shown to nearest hundredth foot. (Water levels obtained July 1960–July 1964.)
Lower number, depth of well below land surface, in feet. Reported depth shown to nearest foot; measured depth shown to nearest tenth foot.

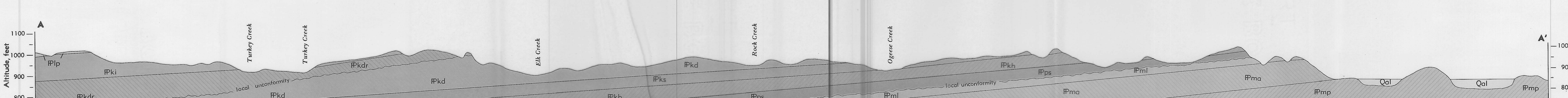
Observable contact

Approximate, inferred, or gradational contact

A — A' Location of cross section

True North
Magnetic North
9°
Approximate mean declination, 1950

0 ¼ ½ 1 2 3 4
Scale, miles
1:63,360



Vertical exaggeration X 21

State Geological Survey of Kansas

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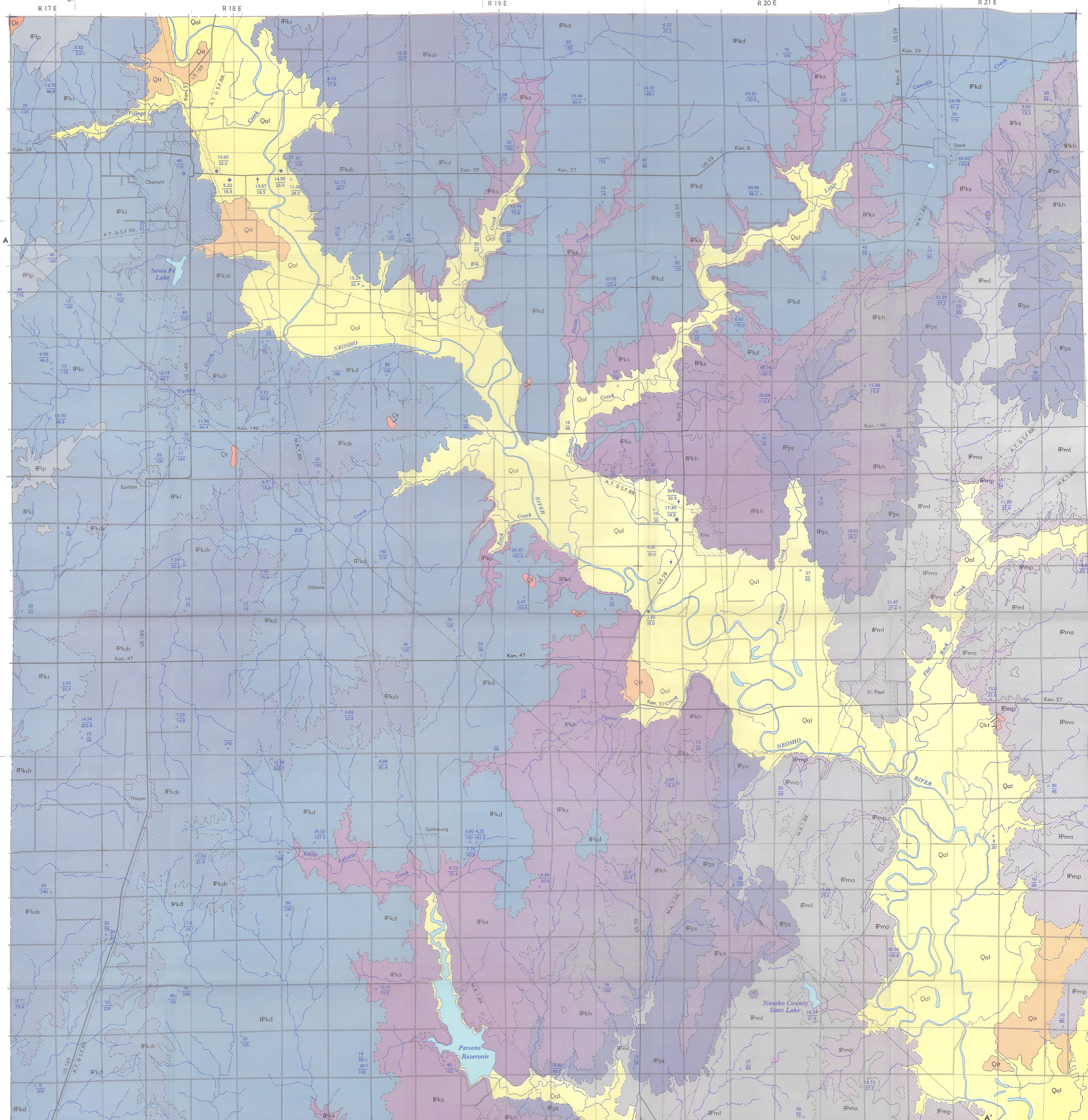

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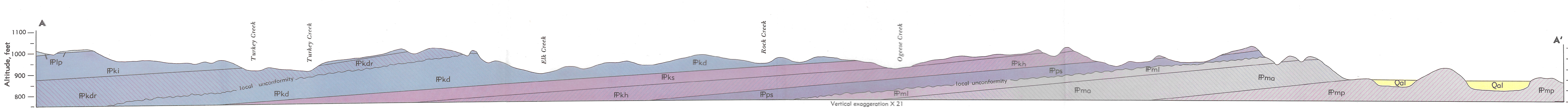

Vertical exaggeration X 21