QUATERNARY HISTORY OF NORTHEAST WASHINGTON COUNTY, KANSAS

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INTRODUCTION

Purpose of Investigation

Pre-glacial buried valleys in northeast Kansas have been of great interest to many people for a considerable number of years due to the potential of these valleys for groundwater supplies. During the Pleistocene Epoch, glaciation extended only as far west in Kansas as eastern Washington County. The glaciated portion of eastern Washington County was the focus of the investigation.

This investigation has developed a geomorphic model of the area to explain the sequence of Quaternary-age sediments. A geologic map of the area, together with cross-sections, have made possible the determination of the pre-Kansan drainage pattern within the area of investigation.

Physiography

The area investigated is located within and on the western boundary of the Dissected Till Plains of the Central Lowlands Province in the northeastern portion of Washington County, Kansas (Schoewe, 1949, p. 280). Present topography has been entirely developed and modified during Pleistocene time. The landscape in the area of investigation was most drastically modified during the Kansan Stage of the Pleistocene Epoch. The continental glacier of Kansan age, which originated in the Keewatin center in Canada, was the only one of the four major glaciers to reach as far south and west as Washington County.

All of the till and glacial outwash occuring in the uplands of the area investigated were deposited in association with this glacier. The only geomorphic effects of glaciers during the Nebraskan, Illinoian, and Wisconsinan Stages in Washington County was deposition of eolian or fluvial sediments, or both.

Area of Investigation

The area of investigation is shown in Figures 1 and 2. The boundaries of the area are delineated by the following legal description: beginning on the Kansas-Nebraska state line at the NW cor., NW¼, sec. 6, T. 1 S., 4 E.; thence east approximately 12 miles to the northeast corner of Washington County at the NE cor., sec. 1, T. 1 S., R. 5 E.; thence south approximately 24 miles to the SE cor., sec. 36, T. 4 S., R. 5 E.; thence west approximately nine miles along the south line of T. 4 S. to the SW cor., sec. 34, T. 4 S., R. 4 E.; thence north approximately four miles to the SW cor., sec. 10, T. 4 S., R. 4 E.; thence west approximately four miles to the SW cor., sec. 12, T. 4 S., R. 3 E.; thence north approximately 15 miles to the NW cor., sec. 36, T. 1 S., R. 3 E.; thence east approximately one mile to the SW cor., sec. 30, T. 1 S., R. 4 E.; thence north approximately five miles to the point of beginning, containing 291 square miles more or less.

Previous Investigations

Currently there is no published U. S. Geological Survey bulletin or Kansas Geological Survey bulletin concerning the geology of

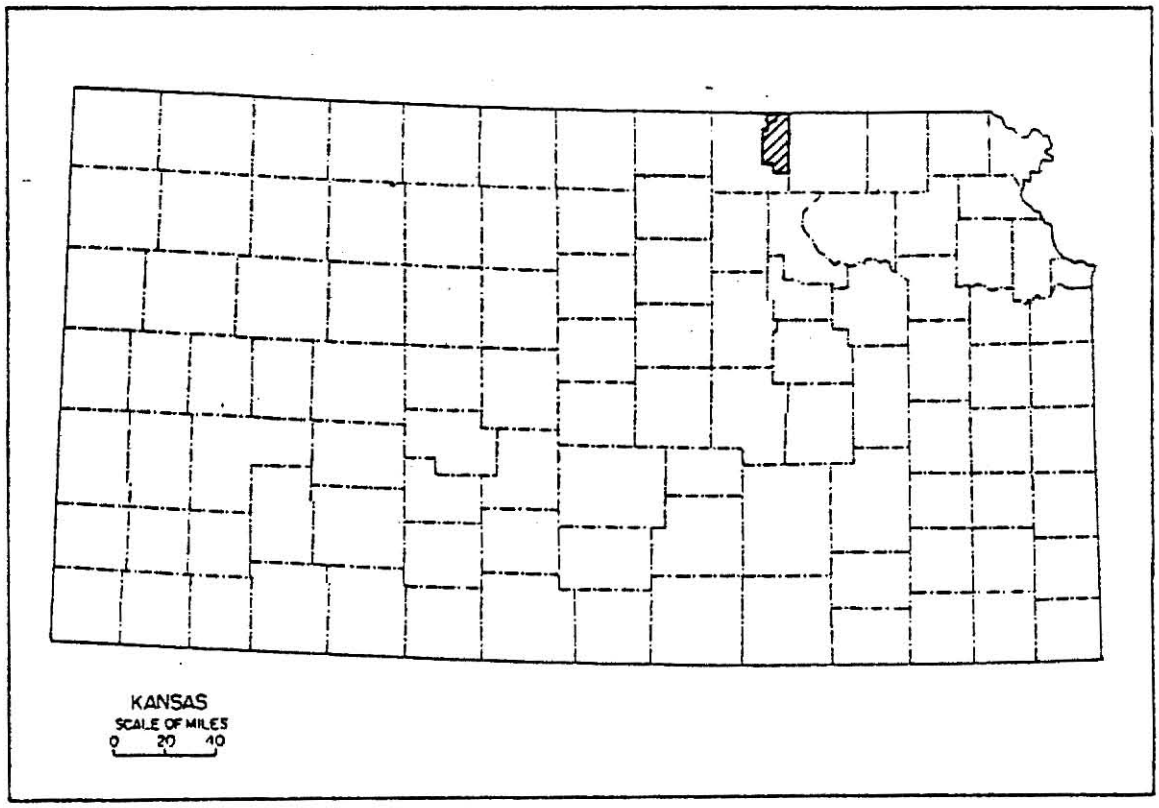


Fig. 1— Map of Kansas showing area of study. (Cross-hatched)

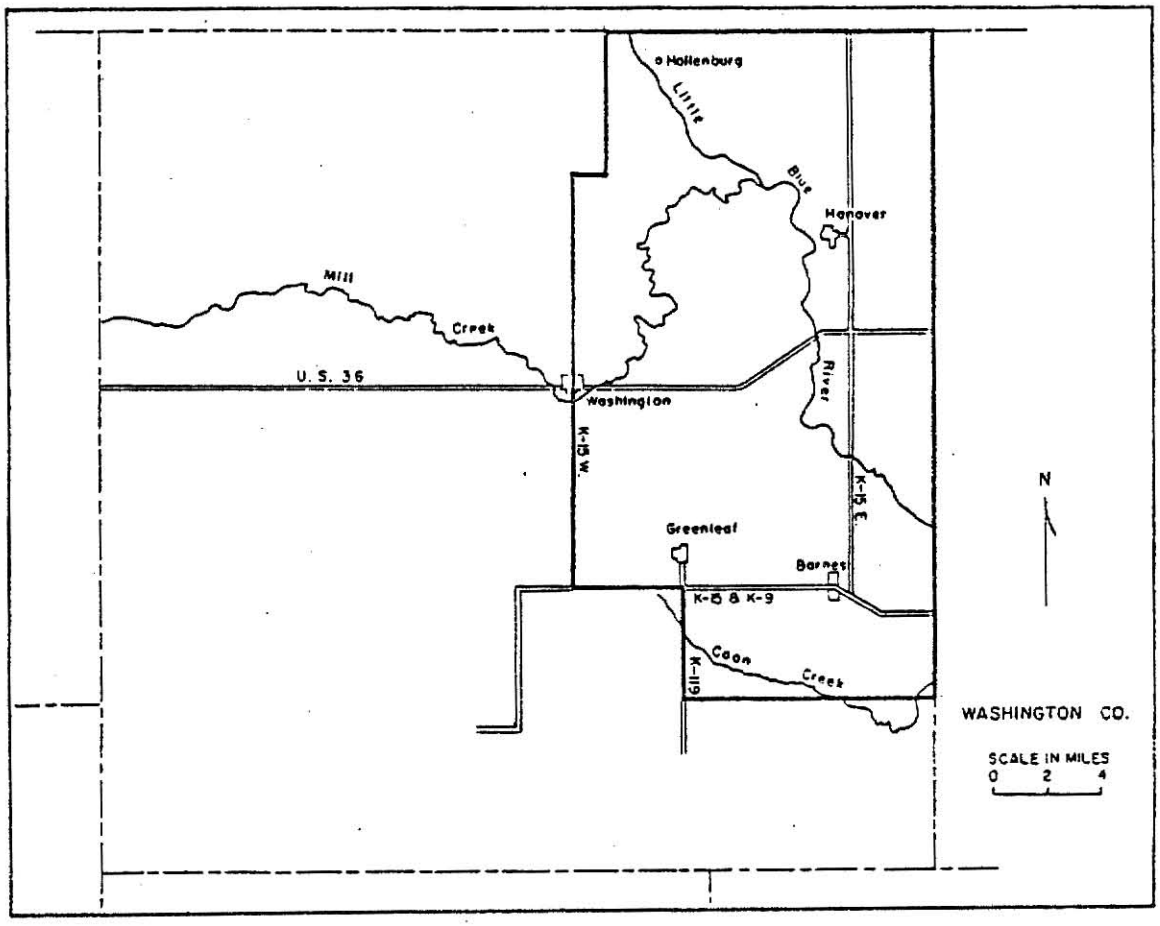


Fig. 2— Map of Washington Co., Kansas. Heavy outline shows area of study.

Washington County. All published geological work concerning Washington County has been restricted to references included in state-wide or regional studies, such as those by Frye and Leonard (1952), Greene (1910), and a guidebook published by Bayne, et. al. (1971). Published information used in the preparation of this report is listed in the references. Unpublished information was provided by Kansas Geological Survey and Layne-Western Company Inc. of Wichita Kansas.

Methods of Investigation

Accumulation of geologic information, pertaining to the area of investigation, was compiled from previous investigations, fieldwork, subsurface drilling, aerial photographs, topographic quadrangle maps, and water-well logs. A brief summary of each method of investigation is listed below.

(1) Published and unpublished information is covered in the preceding section on Previous Investigations.

(2) Fieldwork consisted of geologic mapping and subsurface drilling in the area of investigation.

(3) Subsurface drilling was accomplished through the use of a four-inch diameter Failing rotary drill and a four-inch diameter continuous flight hydraulic auger, both provided by Kansas Geological Survey.

(4) Test holes were drilled in areas where the possibility of a pre-glacial buried channel might exist and along the terraces and floodplains of the Little Blue River and Mill Creek.

(5) Aerial photographs of Washington County were furnished by Kansas Geological Survey and the Agricultural Stabilization and Conservation Service, and were used as a geologic mapping tool. The Kansas

Geological Survey aerial photographs were taken in 1941 at a scale of 1:20,400, and the Agricultural Stabilization and Conservation Service aerial photographs were taken in 1977 and 1978 at a scale of 1:38,500. Also, four band 7, NASA LANDSAT-2 images and one false color composite (bands 4,5 and 7) NASA ERTS-1 image were used as a tool for distinguishing buried pre-glacial valleys. The centerpoint locations for the four NASA LANDSAT-2 images were: Path 30, Rows 32 and 33, both dated May 4, 1976, and Path 31, Rows 32 and 33, both dated October 2, 1975. The NASA ERTS-1 image, dated October 7, 1972, has the approximate centerpoint location as that of the Path 30, Row 32 NASA LANDSAT-2 image.

(6) Topographic maps were used for geologic mapping and as references for test hole locations. Types of topographic maps used are as follows: (1) 1966 and 1968 U.S. Geological Survey 7.5 Minute Series (Topographic) Quadrangle maps; (2) fifty percent reductions of the topographic maps noted in (1) above were used for mapping in the field and as base maps.

(7) Water-well records for Washington County were provided by Kansas State Department of Health (Water Well Contractors), and Kansas Geological Survey.

Well-Numbering System

In this investigation, wells and test holes are numbered according to their location as given by the General Land Office system of land classification. The component parts of the well or test-hole number are the township, range, and section numbers, followed by two lower case letters which indicate, respectively, the quarter section and the quarter-quarter section. The lower case letters of the well number are assigned in a counterclockwise order, beginning with the letter "a" in

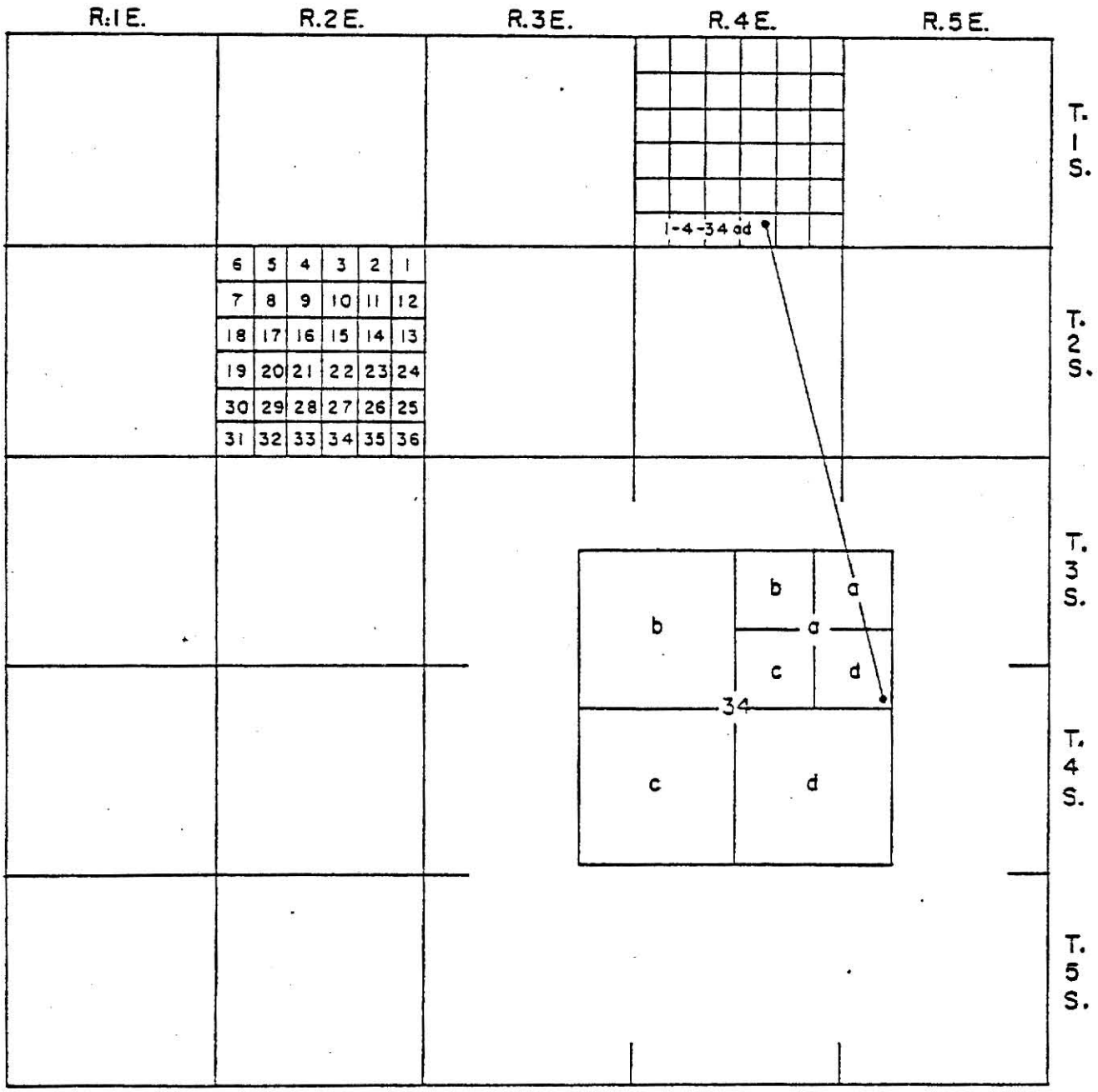


Fig. 3 — Map of Washington County illustrating the well-numbering system used in this investigation.

northeast quarter of the section or quarter-section. An example of this numbering system would be 1-4-34ad (Fig. 3), which is the SE¼, NE¼, sec. 34, T. 1 S., R. 4 E. If two or more wells or test holes occur within the same quarter-quarter section, they will be numbered successively by the order in which they were drilled.

GEOLOGY

Structure

The area of investigation is located within the Salina Basin, just west of the Abilene Anticline (Chelikowsky, 1972, Fig. 4). The structure of the bedrock developed as a result of post-Cretaceous uplift causing rocks of Cretaceous and older age to have a westward regional dip of approximately seven feet per mile in this area (Lee and others, 1948, p. 146). Rocks of Triassic, Jurassic, and Tertiary systems are not present in the area owing to the lack of deposition or erosion, or both, during these intervals of geologic time.

Stratigraphy

Bedrock in the eastern portion of the area is Permian-age limestone and shale, whereas the Cretaceous-age Dakota Formation sandstone and shale occur in the western portion. Rocks of the Lower Permian Series, Gearyan Stage, are the oldest rocks occurring within the area of investigation, with the Florence Limestone Member of the Barneston Limestone in the Chase Group being the oldest rock which crops out. The Wellington Formation of the Sumner Group of the Cimarronian Stage is the youngest of the Permian rocks in the area. The youngest consolidated rock formation definitely

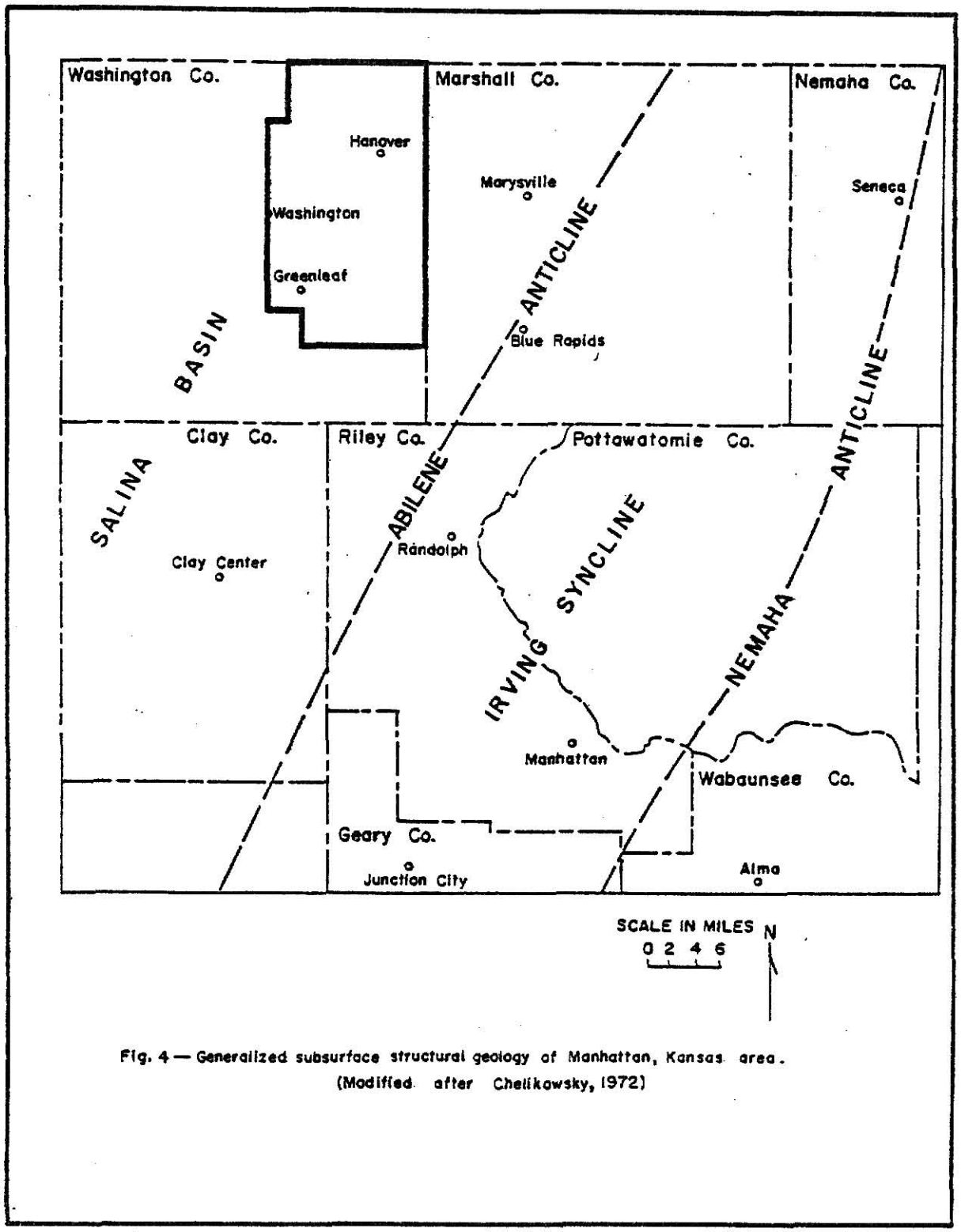


Fig. 4 — Generalized subsurface structural geology of Manhattan, Kansas area. (Modified after Chelikowsky, 1972)

FIG. 5—Stratigraphic section of northeastern Washington County, Kansas

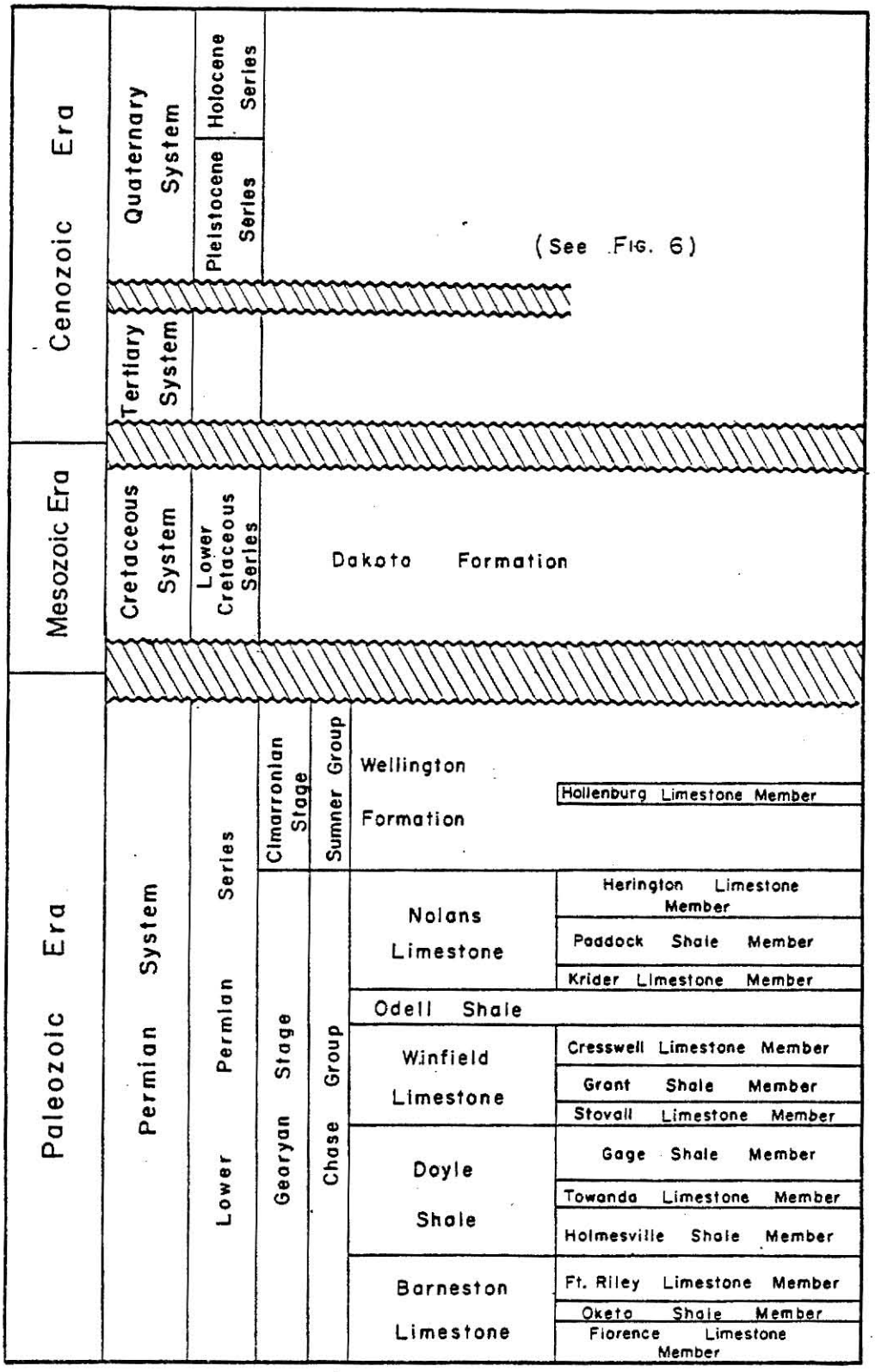
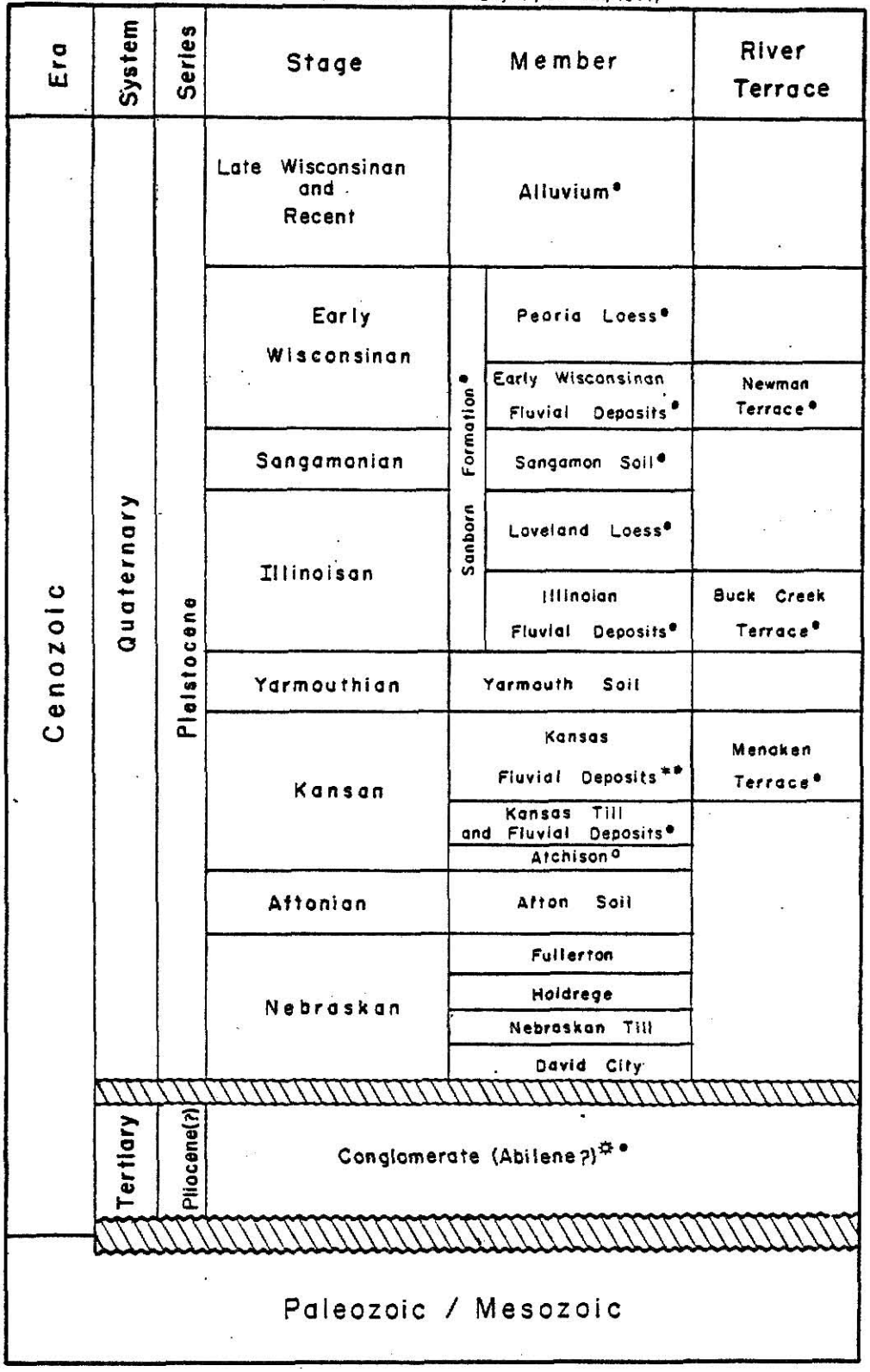


FIG. 6 — Stratigraphic section of Cenozoic deposits in northeastern Kansas (Modified after Bayne, et. al., 1971)

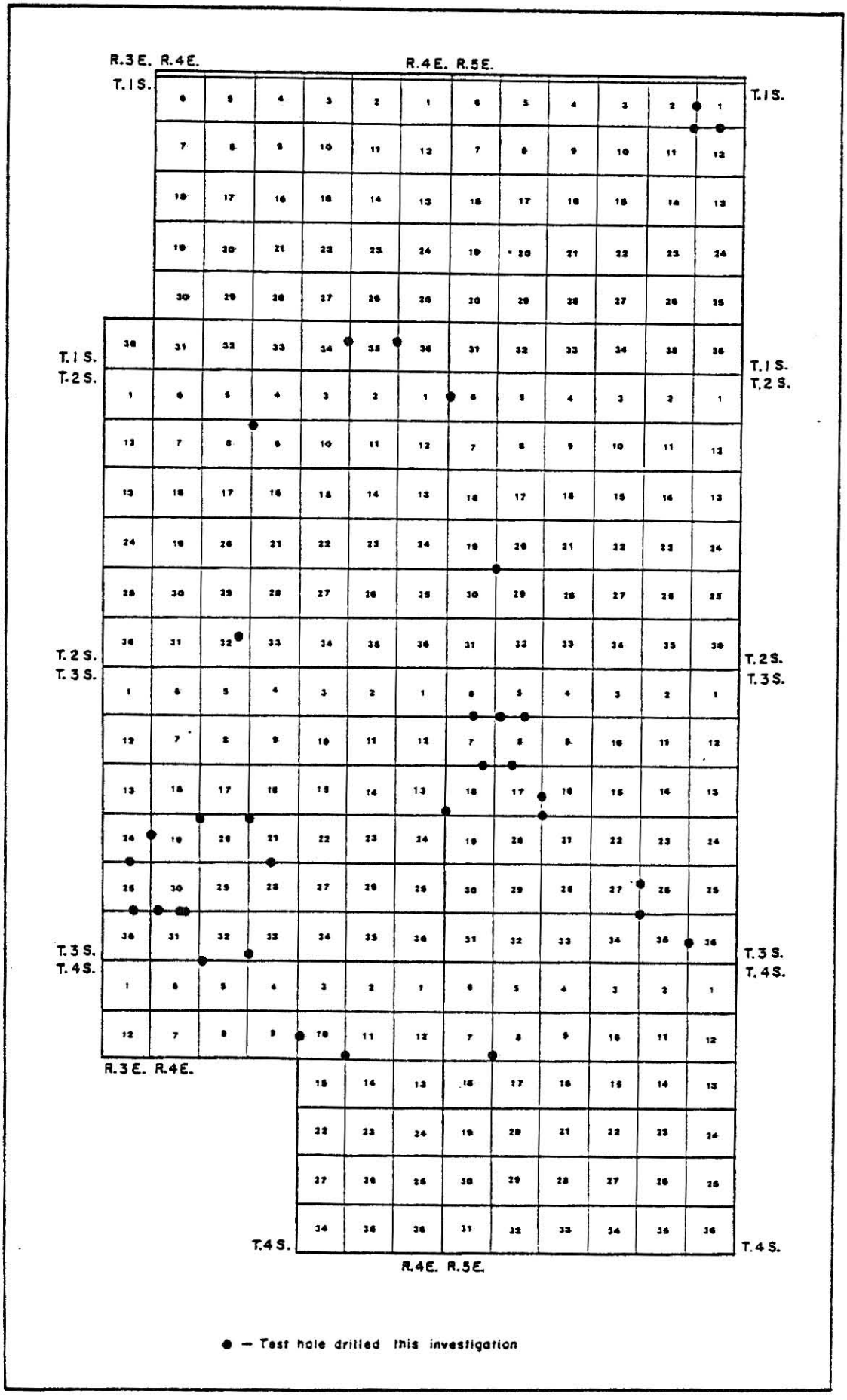


*Locally contains the Pearlette ash bed

✡Conglomerate occurs locally in tributary stream valleys

•Denotes sediments found in area of study.

Fig. 7 — Test hole location map.



identifiable is the Dakota Formation of the Lower Cretaceous Series. Figures 5 and 6 show the stratigraphy of the area of investigation.

PERMIAN SYSTEM

Lower Permian Series -- Chase Group

Barneston Limestone

The Barneston Limestone consists of, in ascending order, the Florence Limestone, Oketo Shale, and Fort Riley Limestone members.

The Florence Limestone Member is almost entirely covered with colluvium, alluvium, or glacial drift in the area of investigation. A small outcrop is exposed in the NW¼, NE¼, sec. 1, T. 4 S., R. 5 E. The Florence Limestone is light gray with chert bands, fossiliferous zones and thin shale beds near the base. The top of the outcrop forms the base of the Menoken Terrace (Kansan age) at this location. Only about 10 to 12 feet of section is exposed.

The Oketo Shale Member was not observed in the area of investigation because it is covered everywhere by Quaternary-age sediment.

The Fort Riley Limestone Member could not be seen throughout its entire section. The only occurence of the Fort Riley is in the southeast corner of the area of investigation where the only observable part of the section is the massive "rimrock" and a few feet of impure thin beds of alternating limestone and shale above and below it. No contacts with the Oketo Shale below, or Holmesville Shale above, were observed because of colluvium or glacial drift. The "rimrock" is about five feet thick and consists of light gray to light brown limestone.

Doyle Shale

The Doyle Shale consists of, in ascending order, the Holmesville Shale, Towanda Limestone, and Gage Shale members. The Doyle shale underlies much of the loess and till in the southeastern portion of the area of investigation. No good exposures were found, therefore thicknesses can only be estimated. Rock descriptions of the Doyle shale are derived from description given in Marshall County by Walters (1954).

The Holmesville shale is approximately 17 to 20 feet thick and consists of green, gray, and red calcareous shale with thin limestone beds occurring in the lower portion.

The Towanda limestone is approximately seven to eight feet in thickness. It consists of platy light gray to yellowish limestone beds with thin, intermittant shale beds occurring throughout.

The Gage shale consists of approximately 25 to 30 feet of red, green, gray, brown and yellow unfossiliferous shale. The upper seven to ten feet of the member consists of gray to black fossiliferous and calcareous shale. A thin limestone bed occurs approximately 10 feet below the base of the overlying Stovall Limestone.

Winfield Limestone

The Winfield Limestone consists of, in ascending order, the Stovall Limestone, Grant Shale, and Cresswell Limestone members. The total thickness is approximately 25 feet (Walters, 1954).

The Stovall limestone is approximately one to one and a half feet thick and consists of gray dense limestone with a very persistent gray to blue-gray chert zone occurring in the middle portion.

The Grant Shale is about eight to ten feet thick and consists of

calcareous gray shale with quartz geodes occurring close to the top of the member at a few localities. A locality where these geodes may be found is in a road cut in the SW¼, SE¼, sec. 5, T. 3 S., R. 5 E.

The Cresswell limestone consists of 12 to 15 feet of alternating limestone and shale beds. The lower two to three feet is a massive light gray limestone whereas the remainder of the member consists of six- to twelve-inch gray limestone beds separated by thin beds of gray to tan shale.

Odell Shale

The Odell Shale, at most exposures, consists of alternating red and light-green shale except for the upper three to four feet which is light-gray shale. An exception to the preceding description can be seen in outcrops along the Union Pacific Railroad tracks in the SW¼, NW¼, sec. 2, T. 1 S., R. 4 E. At this locality the Odell Shale consists almost entirely of a gray shale. The thickness is about 20 feet.

Nolans Limestone

The Nolans Limestone consists of the Krider Limestone Member at the base, the middle Paddock Shale Member, and the overlying Herington Limestone Member. The total thickness is approximately 25 feet.

The Krider Limestone Member consists of two beds of light-gray limestone, each approximately one foot thick and an intermediate light-gray shale bed about two feet thick. The thickness of the member is from three to four feet.

The Paddock Shale Member is light-gray calcareous shale about 12 feet thick. There are numerous fossil pelecypods in the upper part of the member (Walters 1954, p. 57).

The Herington Limestone Member consists of yellowish to tan dolomitic limestone with thin shale partings throughout. Numerous quartz geodes were found at most of the outcrops. The total thickness of the member is about eight feet.

Lower Permian Series--Sumner Group

Wellington Formation

The Wellington Formation is the youngest formation of Permian age to crop out in the area of investigation. The Wellington Formation consists mainly of gray, red, and green shale. The Hollenburg Limestone Member, which is approximately 20 feet above the Herington Limestone Member, is fairly consistent throughout the area of investigation except where post Wellington-pre Cretaceous erosion has occurred. The Hollenburg Limestone Member is an argillaceous dolomitic limestone which usually forms a scarp within the Wellington Formation where it occurs. A major erosional episode began sometime after the deposition of the Wellington Formation and spanned Triassic, Jurassic, and a portion of Early-Cretaceous time, and ended with the deposition of the Lower Cretaceous Dakota Formation. The unconformity was described by Bayne, Walters and Plummer (1959, p. 57) as occurring at the base of a persistant cobble zone as much as three feet thick in Cloud County, Kansas, which is southwest of the area under investigation in this report. This cobble zone was not detected in the area of investigation, probably owing to the amount of till and loess covering the area. Therefore, a definite contact between the shale of the Wellington Formation and the shale of the Dakota Formation was difficult and sometimes impossible to determine.

CRETACEOUS SYSTEM

Lower Cretaceous Series

Dakota Formation

The Dakota Formation is the youngest consolidated rock, other than the few scattered occurrences of a conglomerate of probable Tertiary age, in the area of investigation. The Dakota Formation consists mostly of white, gray, red, tan and brown claystone, shale, and siltstone which contain many iron oxide concretions. In the central and northwest portions of the area of investigation, red, brown, and tan crossbedded sandstone of the Dakota Formation crops out and forms numerous bluffs.

TERTIARY SYSTEM

Post-Lower Cretaceous--Pre-Quaternary (?) Conglomerate

A pre-Quaternary conglomerate of probable Tertiary age crops out at a few scattered localities in the area of investigation. Some well-exposed outcrops of this conglomerate are in the SE¼, SW¼, sec. 9, T. 3 S., R. 5 E., NE¼, NE¼, sec. 28, T. 2 S., R. 5 E., and just to the south of the area of investigation under the bridge in the SW¼, SE¼, SW¼, sec. 3, T. 5 S., R. 5 E. Prior to deposition of the conglomerate, the Permian rock had been deeply eroded. The conglomerate in the SE¼, SW¼, sec. 9, T. 3 S., R. 5 E. crops out at approximately the same elevation as the Newman Terrace (Wisconsinan age) in the Little Blue River valley. The conglomerate consists of sand-size to pebble-size ironstone and sand-size to boulder-size limestone, claystone and siltstone in a light-brown calcareous silty matrix.

Evidence of the post-lower Cretaceous age of the conglomerate is its occurrence below the base of Cretaceous sediments wherever it crops out, which reflects deep erosion in the area during Tertiary time. The conglomerate also has ironstone, derived from the Dakota Formation, incorporated into its matrix. The conglomerate is pre-Quaternary because it lacks erratic particles.

QUATERNARY SYSTEM

Pleistocene Series

The Pleistocene stratigraphy and terminology used during this investigation is shown in Figure 6, which gives a comprehensive view of the sequence of Pleistocene sediments in northeast Kansas. The terminology used for these sediments is adapted from the publication by Bayne, et. al. (1971) but includes modifications from Zeller (1968) and Frye and Leonard (1952). These modifications were made so that the mapping units would correspond more closely with terminology used in previously published Kansas Geological Survey bulletins of adjoining counties in Kansas and to facilitate mapping in the area of investigation. All modifications to terminology used by Bayne, et. al. (1971) are widely accepted in Kansas. The area investigated in this report does not contain each of the units of the Pleistocene (shown in Figure 6), however, it does contain sediments from each of the stages in the Pleistocene except the Nebraskan and Aftonian. All sediments in the Quaternary System are unconsolidated except for a few loosely cemented high-level gravels of Kansan age.

Kansas Stage

The Kansas Stage, named after the State of Kansas (Frye and Leonard, 1952, p. 34), is composed of, in ascending order, the Atchison Formation, Kansas Till and fluvial deposits (Menoken Terrace along the Little Blue River).

The Atchison Formation, named in 1951 from exposures in the vicinity of Atchison, Kansas, by Moore and others (Frye and Leonard, 1952, p. 70), was deposited as outwash and lacustrine deposits in pro-glacial lakes produced by the advancing Kansas glacier (Frye and Leonard, 1952, p. 71). In Kansas, the Atchison Formation forms the oldest deposits of the Kansan Stage. In the area of investigation, these deposits consist of as much as 37 feet of fine to very-fine quartz sand which overlies bedrock and is overlain by Kansas Till. The Atchison Formation was penetrated in test holes located in the west-central part of the area of investigation, such as the test hole drilled 150 feet north of the SW cor., SW¼, SW¼, sec. 33, T. 3 S., R. 4 E., on the east shoulder of the road in the vicinity of the city of Greenleaf.

Kansas Till derives its name from Chamberlin (1896), who initially applied the name Kansan Drift to till occurring in the vicinity of Afton Junction, Union County, Iowa (Frye and Leonard, 1952). Frye and Leonard (1952) refer to the Iowa Point section in Doniphan County, Kansas as one of two type localities for Kansas Till in Kansas. Kansas Till occurs throughout most of the area of investigation, but varies greatly in eastern Washington County. In some areas it is not present, whereas in other areas it is as much as 40 feet thick. The thicker, more persistent deposits are located in the north central portion of the area, possibly because the glacier covered this area for a longer period of time. The east central and southeastern parts of the area contain a relatively thin

cover of till, whereas the till thickness of the area west and south of the Little Blue River is considerably different from one area to the next. Much of the till throughout the area is hidden under a thin but persistant cover of loess, the Sanborn Formation (see p. 23).

The Kansas Till was deposited unconformably on both Permian and Cretaceous rocks. Locally the till was deposited conformably on the Atchison Formation. The clay till varies from reddish-brown to brown to gray with approximately five percent of the volume consisting of sand-size to boulder-size material. The reddish-brown clay occurs in the upper 10 to 12 feet of the till, which is the zone of highest weathering and oxidation. The zone of brown clay shows effects of minor weathering and oxidation and is usually located 10 to 20 feet below the surface. The unweathered gray clay of the till is seldom encountered in the subsurface because the till thickness rarely exceeds 20 feet. Where gray till is present, it is usually mottled with brown clay and specks of oxidized iron. The sand- to boulder-sized material in the Kansas Till typically composes less than five percent of the total volume of the till; the material consists of fragments of the country rock from around and within the area of investigation plus various erratic sand and gravel particles. The country rock that occurs in the till includes sand-size to pebble-size ironstone nodules from the Dakota Formation. The erratic particles within the till consist of sand-size to boulder-size, rounded granite and metamorphic rocks; the most distinctive metamorphic rocks occurring in the area are sub-rounded blocks of pink quartzite.

The Kansan-age fluvial deposits in northeast Washington County are represented by outwash deposits derived from the Kansan-age glacier. These deposits are situated in scattered upland locations and along the

valley walls of the Little Blue River. The deposits along the Little Blue River will be classified as the Menoken Terrace in this report to comply with terminology that was previously proposed by Davis and Carlson (1952, p. 212-213). In their publication, Davis and Carlson proposed the names Menoken, Buck Creek, and Newman for terraces occuring along the Kansas River corresponding to deposits of Kansas, Illinoisan, and Wisconsinan age, respectively. A cross-section (from Plate 1) and an idealized cross-section, showing relative positions of these terraces, are shown in Figures 8 and 9, respectively.

The Kansan-age fluvial deposits represented in this area are not contemporaneous and occur at different altitudes. This report will refer to the sand and gravel units either as fluvial deposits for upland, or high-level deposits, or as the Menoken Terrace for deposits along the Little Blue River and not differentiate between in as much as both are deposits derived from the Kansas glacier.

The upland fluvial deposits, because of their extremely restricted areal distribution, are not shown on Plate 1. Some exposures of fluvial deposits, however, may be observed in a gravel pit south-southeast of the city of Washington in the NW¼, SW¼, sec. 8, T. 3 S., R. 4 E. Remnants of the upland fluvial deposits are also exposed in a road cut in the SW¼, SE¼, sec. 25, T. 3 S., R. 4 E., where it is partially cemented by iron. Fluvial deposits occur at other sidely scattered locations on the uplands west of the Little Blue River within the area of investigation. The upland fluvial deposits are composed predominantly of sand and rounded granitic gravel up to cobble size, together with some rounded to sub-rounded metamorphic rocks (such as pink quartzite)

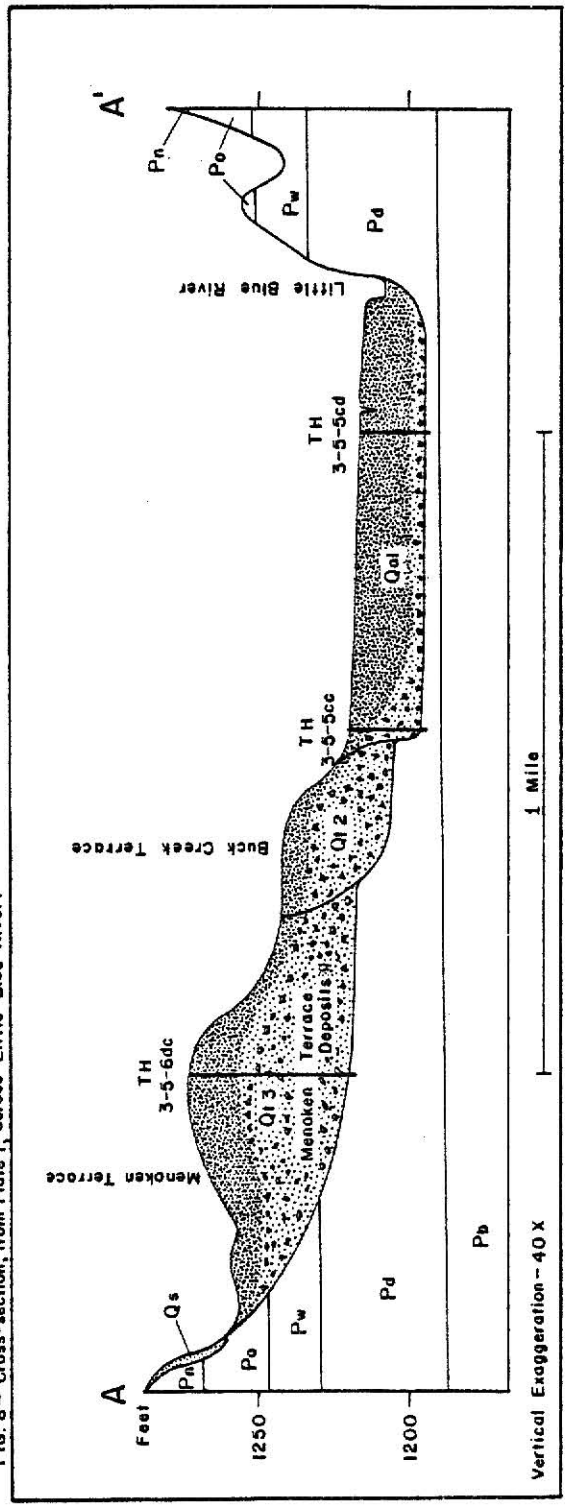


FIG. 8 — Cross-section, from Plate I, across Little Blue River.

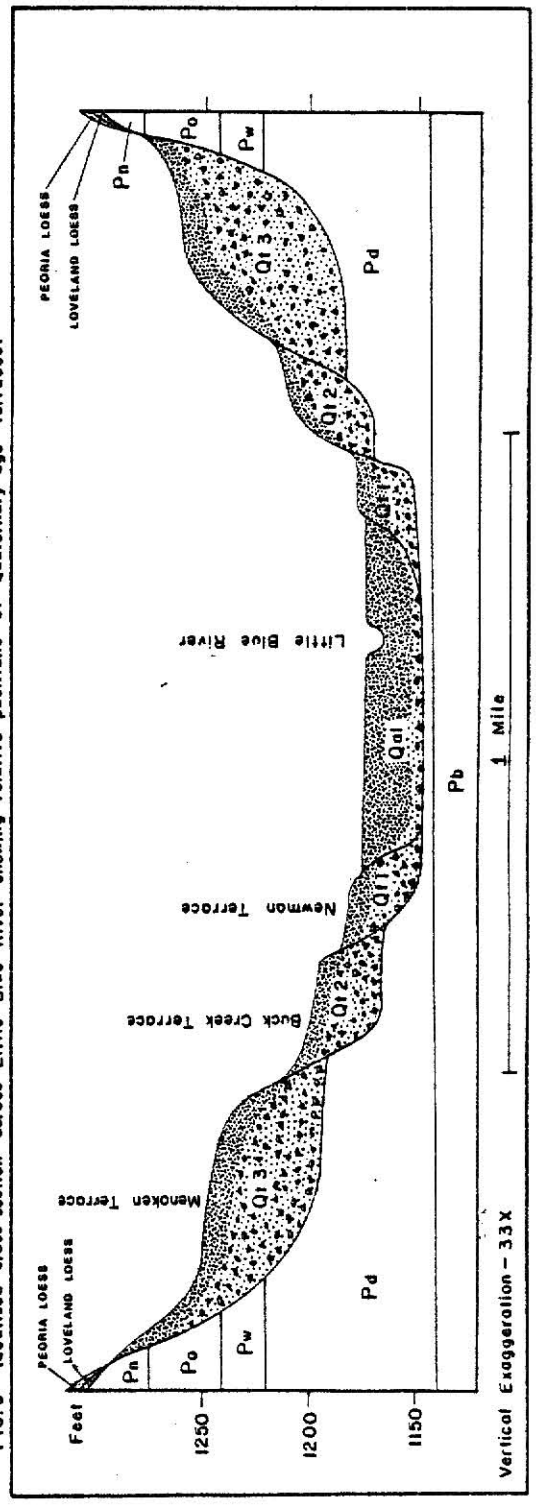


FIG. 9 — Idealized cross-section across Little Blue River showing relative positions of Quaternary-age terraces.

up to cobble size. There are also minor amounts of ironstone that ranges from fine sand to pebble size, probably from the Dakota Formation. The sand and gravel is stained red and reddish-brown and cross beds occur throughout the unit in the gravel pit. The upland fluvial deposits were deposited approximately fifty feet higher than the sand and gravels of the Menoken Terrace along the Little Blue River. These upland fluvial deposits represent an earlier higher deposit of outwash laid down prior to retreat of the Kansan glacier from its maximum extent (Frye and Leonard, 1952, p. 90) during which the Menoken Terrace deposits accumulated.

The Menoken Terrace was previously classified by Lill (1946, p. 80) as a glacial outwash terrace. It is located discontinuously on both sides of the Little Blue River valley. The thickness of the Menoken Terrace varies, however, the thickest section drilled was 75 feet thick and is located at the SW cor., SW¼, sec. 6, T. 3 S., R. 5 E., on the north shoulder of the road. This places the base of the Menoken Terrace approximately five to ten feet above the present flood plain. The sand and gravels are predominantly fine to coarse quartz sand and fine to course granitic granules. The size ranges from coarse silt to pebbles.

Illinoisan Stage

The Illinoisan Stage in the area of investigation is represented by the Buck Creek Terrace and the Loveland Loess of the Sanborn Formation.

The Buck Creek Terrace represents a discontinuous Illinoisan-age alluvial terrace that occurs along the valley walls of the Little Blue River. Its upper surface is approximately 40 feet lower than the top of the Menoken Terrace. The Buck Creek Terrace deposits, as referred

to in this investigation, are considered to be the terrace equivalent of the Illinoisan-age fluvial deposits. A test hole was drilled in the Buck Creek Terrace, 300 feet north of the SE cor., SE¼, NE¼, sec. 27, T. 3 S., R. 5 E., on the west shoulder of the road. This test hole contained a predominance of quartz sand with minor amounts of granitic coarse sand and fine to medium granitic gravel of granule size, underlying 24 feet of brown clay and silt. In the sand and gravel zone, the sediments ranged in size from silt to pebble. The base of the Buck Creek Terrace at this test hole was approximately ten feet lower in altitude than the present flood plain of the Little Blue River. The Loveland Loess, in this investigation, will be considered to be part of the Sanborn Formation.

Sanborn Formation

The term Sanborn Formation was first proposed by Elias in 1931; the type locality is in the northwest corner of Cheyenne County, Kansas, near Sanborn, Nebraska (Frye and Leonard, 1952, p. 108). Using the description given by Elias, Frye and Leonard (1952, p. 106) defined the Sanborn Formation to include deposits both of the Illinoisan and the Wisconsinan stages and further stated:

> In the official classificaiton of the Kansas Geological Survey the Sanborn Formation includes, in ascending order, the following members: (1) Crete Sand and Gravel Member; (2) Loveland Silt Member, commonly containing within its top the Sangamon buried soil; (3) unnamed early Wisconsinan alluvial deposits; (4) Peoria Silt Member, commonly containing within its top the Brady buried soil; (5) unnamed late Wisconsinan alluvial deposits; (6) Bignell Silt Member.

The Illinoisan-age Loveland Silt Member, as described by Frye and Leonard (1952, p. 116), is water-laid valley silt and on the uplands, loess. Metz (1954, p. 19), however, noted that the Loveland Silt Member occupied three physiographic positions. These include an upland

loess, valley silt and clay, and a colluvial deposit located along valley slopes. As classified and mapped in this report, the Illinoisan-age Loveland Loess and Wisconsinan-age Peoria Loess of the Sanborn Formation will only include what Metz previously described as upland loess and colluvial deposits along valley slopes. The Sanborn Formation mantles much of the area of investigation with a thin layer of loess usually less than three feet thick. The water-deposited silt and clay deposited in the valleys was mapped as part of the valley terraces and floodplains. With the exception of some unnamed early and late Wisconsinan deposits, the remaining units classified previously as part of the Sanborn Formation, were not observed in the area of investigation. The unnamed early Wisconsinan alluvial deposits will be discussed later in the report and will be classified as the Newman Terrace, whereas the unnamed late Wisconsinan alluvial deposits will be discussed in the section titled late Wisconsinan and Recent alluvium.

The Loveland Loess is characteristically yellowish- to reddish-brown, non-calcareous in its upper part, and has been leached throughout much of its thickness. Where the Loveland occurs between 26 and 36 feet in a test hole drilled 15 feet south of the NE cor., NE¼, NW¼, sec. 12, T. 1 S., R. 5 E., on the south shoulder of the road, it is a yellowish-brown silty clay and contains numerous calcareous concretions that resemble weathered limestone granules. The zone between 14 and 26 feet in the same test hole contains the leached portion of the Loveland, with the Sangamon soil occurring in the upper portion of the zone where most of the carbonaceous material is located. Where the Loveland Silt Member can be observed on the surface, it is reddish-brown and non-calcareous.

The Peoria Loess contains lighter-colored silt and clay than the

Loveland Silt Member. The loess is usually a brown to light-tan calcareous silt and clay. In the test hole discussed in the previous paragraph, the Peoria Loess is 14 feet thick. The first three feet contains the A and B horizons of the soil, and the C horizon occurs from three to nine feet. The zone from nine to fourteen feet probably was what Frye and Leonard (1952, p. 129) referred to as the "inverted A horizon" that is found just above the Sangamon soil. At this location, the lower portion of the B horizon and all the C horizon contain limonitic stain; the zone between six and nine feet is very highly stained.

Wisconsinan Stage

Wisconsinan-age deposits in the area of investigation, consist of Peoria Loess and early Wisconsinan alluvial terrace deposits (Newman Terrace). The Peoria Silt Member was discussed in the preceding section as part of the Sanborn Formation.

The Newman Terrace, as described by Beck (1959, p. 37), consists of alluvial deposits that were laid down during the Wisconsinan Stage and that form a broad level surface a few feet higher than the present flood-plain. Prior to the formation of early Wisconsinan terrace deposits, there occurred an episode of valley deepening throughout most of Kansas (Frye and Leonard, 1952, p. 125). This valley deepening was apparently the last cycle in the sequence of active erosion in the Little Blue River valley. The valley floor was deepened by approximately 20 to 25 feet below that underlying the Buck Creek Terrace. In a test hole drilled in the Newman Terrace 300 feet east of the SW cor., SW¼, SW¼, sec. 5, T. 3 S., R. 5 E., on the north shoulder of the road, the upper seven to eight feet is a brown silty clay which grades downward for approximately five feet into a light-brown to tan silt and very fine sand.

Both the silty clay and the silt and sand are the water-laid deposits of the Peoria Silt Member of the Sanborn Formation, as described by Frye and Leonard (1952, p. 106). Below the silt and very fine sand, there was no recover until reaching bedrock at 33 feet. The zone of no recovery was completely water-saturated sand and gravel. The groundwater in this test hole is under low artesian pressure because the water level was measured at four and a half feet below the surface, which is approximately 10 feet above the normal water table in this area.

Lat Wisconsinan and Recent Alluvium

The late Wisconsinan and Recent alluvium form the present flood plains of the river valleys in the area of investigation. There is no indication of valley deepening since early Wisconsinan time in any of the test holes drilled. There are indications that during the late Wisconsinan and Recent, the rivers eroded the Newman Terrace down to, or just above, bedrock level. This assumption was made because no deeper channels were encountered during test drilling along the flood plain and there was no gravel encountered in the test holes except just above the bedrock, such as in the test hole drilled 15 feet north of fence line and 800 feet west of the SE cor., SE¼, SW¼, sec. 8, T. 3 S., R. 5 E. In the test holes drilled through the late Wisconsinan and Recent alluvium, the upper 15 to 17 feet is either a clay, silt, very fine sand, or combinations of these sediments. Underlying these sediments, down to bedrock, there occur zones of predominantly fine sand with some medium to coarse sand and granule- to pebble-size gravel just above bedrock.

Geomorphic History of Drainage

The drainage in the area of investigation underwent drastic changes during the Quaternary. These changes were caused by alternating glacial advances and retreats that occurred during this time. The four major glacial stages were periods of active deposition and erosion whereas the interglacial stages were periods of relative stability.

Nebraskan and Aftonian deposits are not represented. The Nebraskan glacier, which did not cross west of the axis of the Nemaha anticline to any great extent, probably had no great effect upon drainage development within the area. Because the area of investigation lies on the west flank of the Nemaha and Abilene anticlines, drainage in the area was probably westward toward the Republican River, however, no evidence of this westward drainage pattern during these stages was found.

The Kansan Stage had the greatest impact upon the development of the present-day topography in the area of investigation. This was the stage during which the Kansas Till and the Menoken Terrace deposits were formed (denoted as Qkt and Qt3, respectively, on Plate 1) and during which the framework for present-day drainage pattern in the area was created. The location of the till and gravel deposits indicates that the Kansas-age glacier did not extend beyond the Little Blue River in the northern portion of the area, extended approximately two miles east of the city of Washington in the central portion, and followed the line of Coon Creek in the southern portion of the area of investigation. The western margin of the glacier apparently was located only a short time at this position before retreating to the eastern edge of the Little Blue River valley. This is suggested by the thicker and more widespread

till deposits to the east of the Little Blue River and by the lack of a recognizable glacier-margin stream channel developed along the western-most terminus of the glacier. Greene (1910, p. 4) suggested the possible existence of a buried glacier-margin stream channel between the cities of Washington and Greenleaf.

Following the retreat of the glacier-margin to the east edge of the Little Blue River valley, the regimen of the glacier was apparently maintained at equilibrium for a long enough period of time to develop an ancestral Little Blue River valley. Evidence for the longer period of equilibrium at this location is supported by the previously mentioned thicker and more widespread till sequences located to the east of the Little Blue River valley at most locations, and the existence of the Little Blue River itself which probably originated as a glacier-margin stream. In the vicinity of the juncture of Mill Creek and the present day Little Blue River, the ancestral Little Blue River channel apparently curved approximately four miles westward and then curved back northward. This course is evident from the existence of the Menoken Terrace deposits located in the SW¼, sec. 28, T. 1 S., R. 4 E., and the fact that the base of the Menoken Terrace deposits on the west side of the Little Blue River valley, south of Mill Creek, are slightly lower than the base of the Menoken Terrace deposits and other Quaternary-age sediments to the north of Mill Creek and substantially farther west of the present day Little Blue River channel. The infrequent and thin Menoken Terrace deposits in this vicinity are probably the result of partial removal by Mill Creek. This period of erosion could have occurred contemporaneously with or sometime following their deposition but prior to deposition of the Sanborn Formation, which now overlies Permian sediments. The

approximate location of the western and southern edge of the ancestral Little Blue River channel in this vicinity is shown of Plate 1 by elongated dashed lines cutting across Mill Creek Valley. The absence of most of the Menoken Terrace deposits along the east side of the Little Blue River valley in the central portion of the area, where Permian sediments are exposed, cannot be explained as an erosional feature according to Ferrel's Law. The explanation for the absence of these deposits is probably that after retreat of the Kansan-age glacier, the river entrenched itself along fractures where the glacier-marginal stream closely aligned itself with the regional joint patterns of the area. The joint patterns in this area trend approximately N. 75 E. and N. 15 W. (Chelikowsky, 1972, p. 6). The Mill Creek valley configuration has been established subsequent to the formation of the ancestral Little Blue River, since the Little Blue River forms the outlet for Mill Creek.

During the Illinoisan Stage, the present day configuration of the Little Blue River valley was probably established, because in the area of investigation, remnants of the Buck Creek Terrace deposits (denoted as Qt2 in Plate 1) tend to line both sides of the lower valley walls throughout most of its length.

The Newman Terrace deposits (denoted on Plate 1 as Qt1) form a substantial portion of the existing valley floor along the Little Blue River; late Wisconsinan and Recent alluvium compose the remaining sediments. The Newman Terrace is identified by its undissected surface and by a distinct scarp that rises three to five feet above the alluvial floodplain.

Terrace Development Along Little Blue River

During the Kansan Stage the ancestral Little Blue River was being developed along the glacier-margin of the Kansan glacier. Subsequently, increased load and discharge in the river was produced by wastage of the glacier. The increased discharge and load deepened the bedrock floor of the valley 65 to 75 feet below its former level. As dissipation of the Kansan glacier continued, the decrease in river discharge also produced deposition of its load of fluvial sediments. By the end of the Kansan Stage, the surface of the fluvial desposits was at least 80 feet above the present flood plain, as shown by the Menoken Terrace.

During the Illinoisan Stage, continental glaciation reached the northern border of Nebraska, which resulted in a more moist climate for Kansas. Apparently the discharge during the Illinoisan Stage increased in Kansas sufficiently to erode through the Kansan-age fluvial deposits forming the Menoken Terrace and deepened the bedrock in the valley an additional 15 to 20 feet. Illinoisan fluvial deposits (Buck Creek Terrace deposits) then filled the valley to approximately 35 feet above the present flood plain, as stream discharge decreased.

The Wisconsinan-age continental glacier, like the Illinoisan-age glacier, reached the northern border of Nebraska. Again, the increased discharge due to a wetter climate was sufficient to erode the Illinoisan fluvial deposits to bedrock and incised an additional 12 to 15 feet into the bedrock floor of the valley. Early Wisconsinan fluvial deposits, the Newman Terrace deposits, were deposited to a level between three and five feet above the present flood plain as stream discharge diminished in the later part of early Wisconsinan. The surface of the Illinoisan fluvial deposits that remain form the Buck Creek Terrace.

During early late-Wisconsinan there was a re-advance of the Wisconsinan glacier (Flint, 1971, p. 564). With this re-advance came a wetter climate which increased the discharge and erosion. The bedrock floor beneath the Newman Terrace indicates that entrenchment was down to, or just above, the bedrock valley floor that occurs beneath the Newman Terrace deposits. Following this entrenchment, the discharge of the river was reduced due to the retreat of the glacier and a return to a drier climate, which resulted in deposition of late Wisconsinan to Recent alluvium. Deposits of this alluvium reached a level between three to five feet below the surface of the Newman Terrace. The upper surface of late-Wisconsinan and Recent alluvium forms the present flood plain of the Little Blue River.

Five criteria were used in recognizing and mapping the various terraces. These are:

(1) The degree of weathering and dissection of the terrace surfaces. The Menoken Terrace has the greatest degree of surface modification because of erosion, whereas the Newman Terrace is virtually undissected.

(2) The bedrock levels beneath each of the terraces occur at different heights above or below the present flood plain, with the highest beneath the Menoken and the lowest beneath the Newman.

(3) Each terrace surface occurs at different heights above the present flood plain; the highest surface is the Menoken, the lowest is the Newman.

(4) Scarps resulting from erosion were used to delineate approximate boundaries between the various terraces.

(5) Composition of the terrace deposits was used to a limited degree in distinguishing them. It was discovered that the Menoken Terrace deposits can easily be distinguished from the other two terrace deposits by larger and more abundant gravel in the Menoken. Distinguishing between the Buck Creek and Newman Terrace deposits by lithology was not reliable.

Climate Relationships During the Quaternary

The relationship between climate and stream regimen has never been successfully resolved. Flint (1971, p. 306) gave three possible relationships. First, wetter climates result in stream trenching, whereas drier climates result in deposition. Second, wetter climates result in filling, whereas drier climates result in trenching. Finally, dry climates result in trenching in upstream valley segemnts, and filling occurs in segments farther downstream; whereas during transition to wetter climates, upstream segments become filled and downstream segments begin to be trenched. The first relationship that Flint stated best accounts for fluvial erosion and deposition in northeast Washington County.

During the Quaternary, the climates in Kansas varied from cooler and wetter conditions during glacial stages, to warmer and drier conditions during the interglacial stages (Flint, 1971, pp. 541-572). Climate variations played an important role in determining the regimen of streams in the central Great Plains, where erosion and valley deepening is associated with the glacial stages and alluviation is associated with the waning glacial to intergalcial stages.

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APPENDIX I

Drilling logs of test holes were drilled in the area of investigation by a four-inch diameter Failing rotary drill and a four-inch diameter continuous flight hydraulic auger and were described in the field and later by examination of samples collected.

1-4-34ad. Sample log of test hole 100 feet west of the SE cor., SE¼, NE¼, sec. 34, T. 1 S., R. 4 E., on the north shoulder of the road, drilled October 1, 1979. Surface elevation, 1,226 feet.

	Thickness Feet	Depth Feet
Quaternary - Pleistocene, late Wisconsinan to Recent		
Alluvium - Mill Creek		
Topsoil, dark-brown to black	3	3
Clay, brown, contains much silt.	10	13
Clay, yellowish-brown, contains much silt.	9	22
Sand, very fine to fine grained, sub-angular to sub-rounded quartz, both clear and frosted grains, tan to light-brown	20	42
Permian-Chase, Odell Shale		
Shale, green, gray and red	5	47
	Total Depth	47

1-4-35ad. Sample log of test hole 100 feet east of the SW cor., SE¼, NE¼, sec. 35, T. 1 S., R. 4 E., on the north shoulder of the road, drilled October 3, 1979. Surface elevation, 1,250 feet.

	Thickness Feet	Depth Feet
Quaternary - Pleistocene, late Wisconsinan to Recent		
Alluvium		
Topsoil, brown	2	2
Silt, brown to light-brown, contains clay.	10	12
Silt, reddish-brown to red, contains clay.	6	18
Sand, quartz, very fine to fine grained, reddish-tan to red	14	32
Sand and gravel, very fine to coarse, sub-angular to rounded granitic sand, granule- to pebble-size, sub-angular to sub-rounded granitic gravel, reddish-tan, contains some thin seams of brown silty clay.	10	42
Permian-Chase, Odell Shale		
Shale, gray.	8	50
Shale, red	2	52
	Total Depth	52

1-5-1cb. Sample log of test hole 10 feet east of the NW cor., NW¼, SW¼, sec. 1, T. 1 S., R. 5 E., on the east shoulder of the road, drilled November 15, 1979. Surface elevation, 1,375 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Illinoisan-Wisconsinan		
Peoria Loess		
Topsoil, brown	1	1
Clay, greenish-gray, silty, contains iron staining and fine to course grain-size iron concretions.	2	3
Loveland Loess		
Silt, brown, clayey, contains iron stains and black carbonaceous banding	6	9
Silt, reddish-brown, clayey, contains iron stains.	4	13
Silt, yellowish-brown, calcareous, clayey, contains some coarse grained to granule-size, sub-rounded limestone particles, contains iron stains	14.5	27.5
Permian-Sumner, Wellington Formation		
Limestone, brown to gray, weathered.	3	30.5
Shale, yellowish-brown	1.5	32
	Total Depth	32

1-5-2dd. Sample log of test hole 300 feet west of the SE cor., SE¼, SE¼, sec. 2, T. 1 S., R. 5 E., on the north shoulder of the road, drilled November 14, 1979. Surface elevation, 1,370 feet.

	Thickness Feet	Depth Feet
Quaternary - Pleistocene, Illinoisan-Wisconsinan		
Peoria Loess		
Topsoil, brown	1	1
Silt, light-brown to brown, contains clay.	2	3
Silt, brown to reddish-brown, contains clay iron stains.	3	6
Silt, light-brown, weak calcareous reaction, contains medium to coarse sand-size iron concretions.	2	8
Silt, light-brown, strong calcareous reaction white carbonate throughout, contains from medium grained-size to pebble-size concretions of carbonate, contains iron stains and some clay.	5	13
Loveland Loess		
Silt, brown to reddish-brown, clean, contains some iron stains	6	19
Silt, red-brown, calcareous, contains numerous granule-size to pebble-size calcareous concretions	2	21

	Thickness Feet	Depth Feet
Permian-Sumner, Wellington Formation		
Shale, yellow, clayey, calcareous.	9	30
Shale, greenish-gray, clayey, calcareous, contains thin lenses of limestone	5	35
Shale, yellow to red, clayey	1	36
Total Depth		36

1-5-12ba. Sample log of test hole 15 feet south of the NE cor., NE¼, NW¼, sec. 12, T. 1 S., R. 5 E., on the south shoulder of the road, drilled November 15, 1979. Surface elevation, 1,373 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Illinoisan-Wisconsinan		
Peoria Loess		
Topsoil, brown	1	1
Silt, tan to light-brown, clayey, contains iron stains throughout, very weak calcareous reaction	2	3
Silt, light-brown to brown, clayey, contains small patches of iron stains	3	6
Silt, brown to reddish-brown, banded with irregular iron stains and brown carbonaceous material	3	9
Silt, brown to reddish-brown, clayey, contains small patches of iron stains	5	14
Loveland Loess		
Silt, brown, clayey, weak calcareous reaction, contains small amounts of black carbonaceous material and iron stains	12	26
Silt, yellowish-brown to reddish-brown, contains black carbonaceous material and medium sand-size to pebble-size calcareous concretions, calcareous	10	36
Silt, greenish-yellow, calcareous, clayey, contains medium sand-size to pebble-size calcareous concretions	2	38
Silt, brown to yellowish brown, strong calcareous reaction, contains iron stains and medium sand-size to pebble-size calcareous concretions.	7	45
Permian-Sumner, Wellington Formation		
Shale, yellowish-brown, contains thin beds of limestone.	6	51
Total Depth		51

2-4-9bb. Sample log of test hole 50 feet south of the NW cor., NW¼, NW¼, sec. 9, T. 2 S., R. 4 E., on the east shoulder of the road, drilled October 8, 1979. Surface elevation, 1,238 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, late Wisconsinan and Recent		
Alluvium-Mill Creek		
Topsoil, brown	3	3
Clay, light-brown, clayey	13.5	16.5
Clay, brown, clayey	5	21.5
Sand and gravel (?), no sample recovered	11.5	33
Permian-Chase, Odell Shale		
Shale, gray	1	34
	Total Depth	34

2-4-32ac. Sample log of test hole 200 feet east of the SW cor., SW¼, NE¼, sec. 32, T. 2 S., R. 4 E., on the north shoulder of the road, drilled October 8, 1979. Surface elevation, 1,282 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, late Wisconsinan and Recent		
Alluvium-Mill Creek		
Topsoil, brown	3	3
Silt, light-brown, clayey	3.5	6.5
Silt, brown to reddish-brown, contains minor amount of very fine to medium-size, sub-angular to rounded quartz grains	2.5	9
Sand, brown to reddish-brown, very fine to medium-size, sub-rounded to rounded quartz grains, contains large amount of clay and silt	3	12
Silt, brown to reddish-brown, clayey, contains minor amount of very fine to medium-size, sub-rounded to rounded quartz grains	5	17
Sand, reddish-brown, very fine to medium-size, sub-angular to rounded quartz grains, grains are both clear and frosted, contains approximately four percent coarse to very coarse sub-angular to rounded quartz sand and ironstone	13	30
Permian-Chase, Odell Shale		
Shale, light-brown to dark-gray	2	32
	Total Depth	32

2-5-6cb. Sample log of test hole 100 feet west of the NE cor., NW¼, SW¼, sec. 6, T. 2 S., R. 5 E., on the south shoulder of the road, drilled October 3, 1979. Surface elevation, 1,268 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansas		
Menoken Terrace		
Topsoil, brown	3	3

	Thickness Feet	Depth Feet
Silt, brown to reddish-brown, clayey, contains minor amount of very fine to medium-size, sub-angular to sub-rounded, quartz grains	6	9
Silt, reddish-brown, clayey, calcareous, contains small amount of black carbonaceous material	6	15
Sand and gravel, very fine to coarse-size, sub-angular to sub-rounded granitic sand and granule-to pebble-size, sub-angular to rounded granitic gravel, reddish-brown, contains less than five percent silt-size material	4	19
Sand and gravel, very fine to coarse-size, sub-angular to sub-rounded granitic sand and granule-to pebble-size, sub-angular to rounded granitic gravel, dark-brown, contains less than five percent silt-size material, contains thin seams of gray to brown clay and silt.	11	30
Permian-Chase, Odell Shale		
Shale, yellowish-gray, clayey.	3	33
Shale, gray, firm.	9	42
	Total Depth	42

2-5-30aa. Sample log of test hole at the NW cor., NE¼, NE¼, NE¼, sec. 30, T. 2 S., R.5 E., drilled October 10, 1979. Surface elevation, 1,250 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Topsoil, brown	3	3
Silt, light-brown.	5	8
Silt, reddish-brown, contains some very fine to very coarse, sub-angular to rounded granitic material	5	13
Sand and gravel, very fine to very coarse, sub-rounded to rounded granitic sand, granule-to pebble-size, sub-angular to sub-rounded granitic gravel, reddish-brown to brown, contains approximately five percent silt-size material	17	30
Sand and gravel, very fine to very coarse, sub-angular to sub-rounded granitic sand, granule-to pebble-size, sub-rounded to rounded granitic gravel, light-brown to brown, contains a higher percentage of gravel than in previous sand and gravel sequence	29	59

	Thickness Feet	Depth Feet
Permian-Chase, Doyle Shale		
Gage Shale member		
Shale, gray, yellowish-brown, brown, chocolate.	6	65
	Total Depth	65

3-3-25ab. Sample log of test hole at the NW cor., NW¼, NE¼, sec. 25, T. 3 S., R. 3 E., on the south shoulder of the road, drilled June 20, 1979. Surface elevation, 1,390 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	1	1
Silt, brown, clayey.	4	5
Kansas fluvial deposits		
Sand and gravel, very fine to very coarse, sub-angular to rounded granitic sand, granule-to pebble-size, sub-angular to rounded granitic gravel and ironstone, reddish-brown, contains very high percentage of silt-and clay-size material	2	7
Sand, very fine to coarse, sub-angular to rounded granitic sand, reddish-brown	5	12
Sand, granitic, very fine to medium, sub-angular to sub-rounded, brown to reddish-brown, contains minor amount of granule-to pebble-size, sub-angular to sub-rounded granitic gravel and ironstone.	5	17
Cretaceous-Dakota Formation		
Shale, red, clayey	5	22
Shale, reddish-brown, clayey	4.5	26.5
Shale, dark-green to black, clayey	.5	27
	Total Depth	27

3-3-36ab. Sample log of test hole 50 feet east of the NW cor., NW¼, NE¼, sec. 36, T. 3 S., R. 3 E., on the south shoulder of the road, drilled July 3, 1979. Surface elevation, 1,407 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	1	1
Silt, light-brown, contains iron stains throughout.	5	6
Silt, brown, clayey, contains iron stains. . . .	7.5	13.5

	Thickness Feet	Depth Feet
Cretaceous-Dakota Formation		
Sandstone, red-brown, contains much ironstone	2	15.5
Shale, gray	1.5	17
Sandstone, red-brown, contains ironstone	0.5	17.5
Shale, gray	3.5	21
Total Depth		21

3-4-19aa. Sample log of test hole 75 feet south of the NE cor., NE¼, NE¼, sec. 19, T. 3 S., R. 4 E., on the west shoulder of the road, drilled June 21, 1979. Surface elevation, 1,378 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Kansas fluvial deposits		
Topsoil, brown	1	1
Sand, granitic, very fine to very coarse, sub-angular to sub-rounded, reddish-brown, contains much clay- and silt-size material and some sub-rounded granule-size ironstone	8	9
Sand, granitic, very fine to very coarse, sub-angular to rounded, red, contains much clay and silt-size material	6	15
Sand, granitic, very fine to very coarse, sub-angular to sub-rounded, red, contains clay and silt size material	1	16
Sand, granitic, very fine to coarse, sub-angular to rounded, reddish-brown, contains some sand-size to granule-size, sub-angular to sub-rounded ironstone	8	24
Sand and gravel, granitic, very fine to very coarse, sub-angular to rounded sand, granule- to pebble-size, sub-angular to rounded gravel, reddish-brown, contains some granule-to pebble-size, sub-angular to sub-rounded limestone and ironstone	8	32
Atchison Formation		
Silt, gray to reddish-brown	4	36
Cretaceous-Dakota Formation		
Shale, clayey, gray	.17	53
Shale, clayey, gray, contains some thin beds of brown sandstone	3	56
Total Depth		56

3-4-19bb. Sample log of test hole 30 feet south of the NW cor., NW¼, NW¼, sec. 19, T. 3 S., R. 4 E., on the east shoulder of the road, drilled June 26, 1979. Surface elevation, 1,355 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	3	3
Silt, light-brown, clayey	8	11
Atchison Formation		
Silt, tan, coarse, contains some very fine sand, becomes moist at 21 feet	18	29
Cretaceous-Dakota Formation		
Shale, clayey, gray, clean	12	41
	Total Depth	41

3-4-19bc. Sample log of test hole 200 feet north of the SW cor., SW¼, NW¼, sec. 19, T. 3 S., R. 4 E., on the east shoulder of the road, drilled July 3, 1979. Surface elevation, 1,375 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	2	2
Kansas fluvial deposits		
Sand, granitic, very fine to coarse, sub-angular to sub-rounded, reddish-brown, contains much clay-and silt-size material	5	7
Sand, granitic, very fine to very coarse, sub-angular to rounded, red-brown, contains clay- and silt-size material	5	12
Atchison Formation		
Silt, tan, coarse, contains some very fine sand, contains iron stains	8	20
Cretaceous-Dakota Formation		
Shale, clayey, blue-gray, clean	12	32
	Total Depth	32

3-4-20aa. Sample log of test hole 50 feet south of the NE cor., NE¼, NE¼, sec. 20, T. 3 S., R. 4 E., on the west shoulder of the road, drilled June 21, 1979. Surface elevation, 1,402 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown to brownish-black	3	3
Silt, light-brown to brown, clayey	3.5	6.5
Kansas fluvial deposits		
Sand, granitic, very fine to very coarse, sub-angular to rounded, reddish-brown, contains much clay-and silt-size material, contains minor amount of granule-size, angular to sub-rounded granitic gravel	2	8.5

	Thickness Feet	Depth Feet
Sand, granitic, very fine to medium, sub-angular to sub-rounded, light-brown to brown, contains some clay-to silt-size material, contains minor amounts of coarse to very coarse sand-size to granule-size, angular to sub-angular granitic gravel and ironstone.	3.5	12
Sand, granitic, very fine to very coarse, sub-angular to sub-rounded, tan to reddish-tan . . .	8	20
Atchison Formation		
Silt, gray to brownish-gray, contains much very fine sand-size material	.16	36
Silt, gray to tan, contains very fine sand . . .	.15	51
Cretaceous-Dakota Formation		
Shale, clayey, gray, green, brown (vari-colored)	4	55
Shale, clayey, gray, clean, becomes sandy with increased depth	.19	74
	Total Depth	74

3-4-28ba. Sample log of test hole 300 feet west of the NE cor., NW¼, sec. 28, T. 3 S., R. 4 E., on the south shoulder of the road, drilled June 20, 1979. Surface elevation, 1,365 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Kansas Till		
Topsoil, brown	2	2
Clay, brown.	2	4
Kansas fluvial deposits		
Sand, granitic, very fine to very coarse, sub-angular to rounded, brown to reddish-brown, contains much clay-and silt-size material. .	.22.5	26.5
Cretaceous-Dakota Formation		
Shale, clayey, gray, clean	.30.5	57
	Total Depth	57

3-4-31ab. Sample log of test hole 200 feet east of the NW cor., NE¼, NE¼, sec. 31, T. 3 S., R. 4 E., on the south shoulder of the road, drilled July, 1979. Surface elevation, 1,423 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, light-brown	1	1
Silt, light-brown, some clay-size material, rust colored stain, clayey.	4	5
Silt, light-brown to light-gray, clayey.	2	7

	Thickness Feet	Depth Feet
Silt, reddish-brown to brown, contains very fine to medium, sub-angular to rounded quartz sand and ironstone, contains iron stains	6.5	13.5
Silt, reddish-brown with black mottling, contains very fine to medium, sub-angular to sub-rounded quartz sand	5.5	19
Silt, light-brown to gray, clayey, contains minor amount of very fine to medium, sub-angular to sub-rounded quartz sand, contains small amount of iron stains	8	27
Silt, light-brown to brown, clayey, calcareous, contains very fine to medium, sub-angular to sub-rounded quartz sand, contains medium sand-size to pebble-size calcareous concretions contains bands of black carbonaceous material and iron stains	16	43
Atchison Formation		
Sand, granitic, very fine to coarse, sub-rounded to rounded, contains some clay-and silt-size material	2	45
Sand, granitic, very fine to very coarse, sub-angular to rounded, reddish-brown, contains some granule-size, sub-angular to sub-rounded granitic gravel, contains clay-and silt-size material	12	57
	Total Depth	57

Note: A second hole was drilled 100 feet east of this location; the same sequence of sediments was encountered at approximately the same depths. Bedrock was encountered after drilling through the reddish-brown sand at 66 feet in this hole.

3-4-33cc. Sample log of test hole 150 feet north of SW cor., SW¼, sec. 33, T. 3 S., R. 4 E., on the east shoulder of the road, drilled June 19, 1979. Surface elevation, 1,404 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	2	2
Silt, gray to reddish-brown, clayey, contains iron stains	7	9
Silt, brown to light-brown, calcareous, clayey, contains medium to coarse sand-size calcareous concretions	17	26
Kansas fluvial deposits		
Sand, granitic, very fine to very coarse, sub-angular to rounded, reddish-brown, calcareous, contains much clay-and silt-size material, contains medium to very coarse sand-size to pebble-size calcareous concretions	12.5	38.5

	Thickness Feet	Depth Feet
Atchison Formation		
Sand, granitic, very fine to coarse, sub-rounded, calcareous, contains some clay- and silt-size material	36.5	75
Cretaceous-Dakota Formation		
Shale, clayey, gray, clean	18	93
Sandstone (?), no sample recovered	4	97
	Total Depth	97

3-5-5cc. Sample log of test hole 300 feet east of the SW cor., SW¼, SW¼, sec. 5, T. 3 S., R. 5 E., on the north shoulder of the road, drilled October 26, 1979. Surface elevation, 1,178 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, late Wisconsinan and Recent		
Alluvium - Little Blue River		
Topsoil, brown	3	3
Clay, brown, silty	4	7
Sand, granitic, very fine to medium, sub-angular to angular, light-brown to tan	5	12
Sand and gravel, granitic, sand is very fine to coarse, sub-angular to rounded, gravel is granule- to pebble-size, sub-rounded to rounded, tan to light-brown, contains some clay- and silt-size material, bottom five feet has green tint	21	33
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, gray and red, clayey	4	37
Shale, gray, hard	5	42
	Total Depth	42

3-5-5cd. Sample log of test hole 100 feet west of the SE cor., SE¼, SW¼, sec. 5, T. 3 S., R. 5 E., on the north shoulder of the road, drilled September 26, 1979. Surface elevation, 1,175 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, late Wisconsinan and Recent		
Alluvium-Little Blue River		
Topsoil, dark-brown	2	2
Clay, light-brown to brown, silty	6	8
Sand, granitic, very fine to medium, sub-angular to rounded, light-brown to tan, very weak calcareous reaction, contains much clay- and silt-size material, contains minor amount of coarse- to very coarse-grained granitic sand	3	11

	Thickness Feet	Depth Feet
Sand, granitic, very fine to coarse, angular to sub-rounded, brown to reddish-brown, very weak calcareous reaction, contains clay-and silt-size material.	2	13
Sand, granitic, very fine to coarse, sub-angular to sub-rounded, light-brown to brown, contains about ten percent granular- to pebble-size, sub-rounded granitic gravel, contains clay-and silt-size material	16	29
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, brownish-gray	8	37
	Total Depth	37

3-5-6dc. Sample log of test hole at the SW cor., SW¼, SE¼, sec. 6, T. 3 S., R. 5 E., on the north shoulder of the road, drilled September 26, 1979. Surface elevation, 1,255 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Topsoil, dark-brown.	2	2
Clay, light-brown to brown, silty, contains trace very fine to medium, sub-angular to sub-rounded granitic sand.	6	8
Silt, brown, clayey, contains very fine to very coarse, sub-angular to rounded granitic sand, and granule-size to pebble-size, sub-rounded to rounded granitic gravel.	5	13
Sand and gravel, granitic, sand is fine to very coarse, sub-angular to rounded gravel is granule-to pebble-size, sub-rounded to rounded, brown, contains a trace of clay-, silt-and very fine sand-size material, pebble-size gravel more abundant after 20 feet	13	26
Sand, granitic, fine to coarse, sub-angular to rounded, light-brown, contains trace of clay, silt and very fine, sand-size particles, contains minor amount of granule-to pebble-size, angular to rounded granitic gravel	5	31
Sand and gravel, granitic, sand is fine to very coarse, sub-angular to rounded, gravel granule-to pebble-size, sub-angular to rounded, brown, gravel becomes coarser between 43 and 48 feet, trace clay, silt, and very fine sand-size particles	33	64

	Thickness Feet	Depth Feet
Sand, granitic, very fine to very coarse, sub-angular to rounded, brown, contains some granule-to pebble-size, sub-angular to rounded granitic gravel	4	68
Sand and gravel, granitic, sand is fine to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to rounded, brown, trace clay, silt and very fine sand particles.	7	75
Permian-Chase, Doyle Shale		
Gage Shale member		
Shale, gray.	6	81
	Total Depth	81

3-5-8cd. Sample log of test hole 15 feet north of fence line and 800 feet west of the SE cor., SE¼, SW¼, sec. 8, T. 3 S., R. 5 E., drilled November 16, 1979. Surface elevation, 1,180 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, late Wisconsinan and Recent		
Alluvium-Little Blue River		
Topsoil, dark brown.	2	2
Sand, granitic, very fine to medium, sub-angular to rounded, light-brown to brown, contains much clay-and silt-size material, contains minor amount of coarse to very coarse, sub-angular to rounded granitic sand	15	17
Sand, granitic, very fine to fine, brown, very silty and clayey, contains minor amounts of medium to very coarse granitic sand, contains up to pebble-size, sub-angular to rounded granitic gravel within bottom few feet.	17	34
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, yellowish-brown	3	37
	Total Depth	37

3-5-16cb. Sample log of test hole 300 feet south of NW cor., NW¼, SW¼, sec. 16, T. 3 S., R. 5 E., on floodplain south of Beaver Creek, drilled July, 1979. Surface elevation, 1,180 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Illinoisan		
Buck Creek Terrace		
Topsoil, brown.	1	1

	Thickness Feet	Depth Feet
Silt, clayey, dark-brown, contains some very fine sand size material	2	3
Sand, granitic, very fine to medium, sub-angular to rounded, brown to dark-brown, contains much clay- and silt-size material.	5	8
Sand, granitic, very fine to fine, sub-angular to rounded, gray to light-brown, contains a minor amount of medium to very coarse granitic sand and up to pebble-size, sub-angular to rounded granitic gravel in bottom five feet.	.15	23
Permian-Chase, Doyle Shale		
Towanda Limestone member		
Limestone, weathered, brown.	1	24
Limestone, hard, gray.	0.5	24.5
Holmesville Shale member		
Shale, light-gray.	3.5	28
Shale, gray-green.	2	30
	Total Depth	30

3-5-18ab. Sample log test hole 1,000 feet east of NW cor., NE¼, sec. 18, T. 3 S., R. 5 E., on south road shoulder, drilled July, 1979. Surface elevation, 1,235 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Silt, clayey, tan.	5	5
Silt, clayey, dark-brown, contains minor amount of very fine to very coarse, sub-angular to rounded granitic sand and granule-to pebble-size, sub-rounded to rounded granitic gravel between seven and nine feet.	4	9
Sand and gravel, granitic with trace limestone, sand is coarse to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to rounded, brown, trace clay, silt and very fine to medium sand-size material	.14	23
Clay, light-gray	0.5	23.5
Sand and gravel, granitic with trace limestone, sand is very coarse, sub-angular to rounded, gravel is granule-to pebble-size, angular to rounded, brown, contains minor amount of coarse granitic sand and a trace of clay, silt and very fine to medium granitic sand	3.5	27
Sand, granitic, very fine to very coarse, sub-angular to rounded, brown, contains minor amount of clay- and silt-size particles	4	31

	Thickness Feet	Depth Feet
Sand and gravel, granitic with trace limestone, sand is fine to very coarse, angular to rounded, gravel is granule-to pebble-size, angular to sub-rounded, brown, contains trace amounts of clay, silt and very fine sand particles	15	46
Sand and gravel, granitic with trace limestone, sand is medium to very coarse, sub-angular to rounded, gravel is angular to sub-rounded, brown, contains trace of clay, silt and very fine to fine particles.	14	60
Permian-Chase, Doyle Shale		
Gage Shale member		
Shale, gray to dark-gray, to green-gray	5	65
Limestone, no sample recovered, lost circulation at 65 feet	2	67
Shale, gray to green-gray	3	70
	Total Depth	70

3-5-20aa. Sample log of test hole at the NE cor., NE¼, sec. 20, T. 3 S., R. 5 E., in island at curve in road, drilled July, 1979. Surface elevation, 1,208 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Topsoil, black.	3	3
Clay, reddish-brown, no sample collected.	3	6
Clay, light-brown, no sample collected.	1	7
Clay, silty, reddish-brown, no sample collected	5	12
Sand and gravel, granitic, sand is coarse to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to sub-rounded, brown, contains trace amounts of clay, silt and very fine to medium sand-size particles	8	20
Sand and gravel, granitic, sand is coarse to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to sub-rounded, reddish-brown, contains lower percentage gravel than 15 to 20 feet, contains minor amount of clay, silt and very fine to medium sand-size material	8	28
Clay, light-brown, no sample collected.	0.5	28.5
Sand and gravel, granitic, sand is coarse to very coarse, sub-angular to angular to rounded, gravel is granule-to pebble-size, sub-angular to sub-rounded, brown, contains minor amount of clay, silt, and very fine to medium sand-size particles.	1.5	30
Clay, silty and sandy, reddish-brown, no sample collected.	0.5	30.5

	Thickness Feet	Depth Feet
Sand and gravel, granitic, sand is medium to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to rounded, reddish-brown, contains minor amount of clay, silt and very fine to fine sand particles.	4.5	35
Permian-Chase, Doyle Shale		
Towanda Limestone member		
Shale, gray	9.5	44.5
Limestone, soft, brown to gray.	1.5	46
Shale, gray to dark-gray, contains gypsum	4	50
Limestone, gray, hard	1	51
Shale, light-gray, hard	2	53
Shale, gray	1.5	54.5
Limestone, gray, hard	0.5	55
	Total Depth	55

3-5-27ad. Sample log of test hole 300 feet north of the SE cor., SE¼, NE¼, sec. 27, T. 3 S., R. 5 E., on the west shoulder of the road, drilled September 24, 1979. Surface elevation, 1,185 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Illinoisan		
Buck Creek Terrace		
Topsoil, brown.	2	2
Silt, brown, clayey, contains iron stains	8	10
Silt, brown to light-brown, contains minor amounts of very fine to medium, sub-rounded to rounded granitic sand.	14	24
Sand, granitic, fine to very coarse, sub-rounded to rounded, reddish-brown, sand becomes coarser with depth, contains minor amount of granule-size, sub-rounded, granitic gravel, contains minor amount of clay, silt, and very fine sand particles, contains some thin clay seams containing up to pebble-size granitic gravel at 33 feet.	16	40
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, clayey, yellowish-brown.	2	42
Shale, gray	5	47
	Total Depth	47

3-5-34aa. Sample log of test hole 30 feet south of the NE cor., NE¼, NE¼, sec. 34, T. 3 S., R. 5 E., on the west shoulder of the road, drilled September 21, 1979. Surface elevation, 1,230 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Topsoil, brown	1	1
Silt, light-brown to brown, contains minor amount of very fine sand-size particles.	6	7
Silt, brown, contains some very fine to medium, sub-rounded to rounded granitic sand	5	12
Silt, reddish-brown, contains granitic sand, very fine to very coarse, sub-rounded to rounded.	5	17
Sand and gravel, granitic, sand is very fine to very coarse, sub-rounded to rounded, gravel is granule to pebble, sub-rounded to rounded, brown, contains much silt-and clay-size particles, percentage of gravel increases to 35 feet	18	35
Sand and gravel, granitic, sand is coarse to very coarse, sub-angular to rounded, gravel is granule to pebble, sub-angular to sub-rounded, contains some thin seams of gray and brown clay	14	49
Sand and gravel, granitic, sand is very fine to coarse, sub-angular to rounded, gravel is granule to pebble, sub-angular to rounded, light-brown, contains some clay-and silt-size particles.	19	68
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, light-gray.	5	73
	Total Depth	73

3-5-35da. Sample log of test hole 300 feet south of the NE cor., NE¼, SE¼, sec. 35, T. 3 S., R. 5 E., on the west shoulder of the road, drilled September 24, 1979.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Menoken Terrace		
Topsoil, light-brown	2	2
Clay, light reddish-brown, no sample collected	5	7
Clay, reddish-brown, no sample collected	5	12
Clay, reddish-brown, contains some sand and gravel, no sample collected.	5	17
Silt, tan to reddish-brown, contains some very fine to medium, sub-rounded to rounded granitic sand.	5	22
Sand and gravel, granitic, sand is very fine to very coarse, sub-angular to rounded, gravel is granule-to pebble-size, sub-angular to sub-rounded, tan to light-brown, contains much clay-to silt-size material	2	24

	Thickness Feet	Depth Feet
Sand and gravel, granitic with trace limestone, sand is very fine to very coarse, sub-angular to sub-rounded, gravel is granule- to pebble-size, sub-angular to sub-rounded, light-brown to brown, contains much clay- to silt-size material.	9	33
Permian-Chase, Doyle Shale		
Holmesville Shale member		
Shale, gray.	4	37
Total Depth		37

4-4-5bb. Sample log of test hole 50 feet east of the NW cor., NW¼, sec. 5, T. 4 S., R. 4 E., on the south shoulder of the road, drilled June 20, 1979. Surface elevation, 1,400 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Sanborn Formation		
Topsoil, brown	0.5	0.5
Silt, brown and gray	6.5	7
Silt, reddish-brown, clayey.	5	12
Silt, light reddish-brown, clayey, contains trace of very fine to medium, sub-rounded to rounded, granitic sand, which is mostly quartz sand.	5	17
Silt, light-brown to reddish-brown, contains minor amount of very fine to medium, sub-rounded to rounded granitic sand that is mostly quartz.	5	22
Atchison Formation		
Sand, granitic, fine to medium, sub-angular to rounded, light-brown, contains trace amount of clay, silt and very fine sand particles, contains trace of coarse to very coarse sand-size to granule-size material	5	27
Sand, granitic, fine to coarse, sub-angular to rounded, brown to reddish-brown, contains minor amount of clay, silt and very fine sand particles, contains very minor amount of granule-size particles	.25	52
Cretaceous-Dakota Formation		
Shale, clayey, gray, clean	5	57
Total Depth		57

4-4-10cb. Sample log of test hole 75 feet east of the NW cor., NW¼, SW¼, sec. 10, T. 4 S., R. 4 E., in the east ditch of highway 119, drilled June 19, 1979. Surface elevation, 1,398 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Kansas Till		
Topsoil, brown	3	3
Clay, brown	4	7
Atchison Formation		
Sand, quartz, very fine to medium, sub-angular to sub-rounded, gray, both clear and frosted grains	1.5	8.5
Sand, same as above but tan	8.5	17
Sand, same description as above, but reddish-tan	5	22
Clay, grayish-brown, contains from very fine to very coarse grained, angular to sub-rounded, granitic material, quartz grains are both clear and frosted, contains from medium-to very coarse-grained, angular to sub-angular ironstone, contains minor amount of coarse, platy and angular, gray limestone. Probably Kansas Till	1.5	23.5
Sand, same description as from 17 to 22 feet	18.5	42
Cretaceous-Dakota Formation		
Clay, gray, very clean	20	62
	Total Depth	62

4-4-11cc. Sample log of test hole 150 feet north of the SW cor., SW¼, SW¼, sec. 11, T. 4 S., R. 4 E., on the east shoulder of the road, drilled June 18, 1979. Surface elevation, 1,398 feet.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene		
Peoria Loess		
Topsoil, dark brown	2	2
Silt, tan	4	6
Loveland Loess		
Silt, reddish-tan	4	10
Silt, red	3	13
Silt, yellowish-brown, water level at 23.5 feet	12.5	25.5
Kansas Till		
Erratic (?)	1.3	26.8
Clay, gray to tan, contains fine to coarse, angular to sub-rounded, granitic sand and sub-angular to sub-rounded granitic granule-size gravel, contains some medium to coarse sand-size and granule-size sub-rounded ironstone	3.2	30

	Thickness Feet	Depth Feet
Clay, calcareous, light-brown to light-gray, contains fine to coarse, angular to sub-rounded granitic sand, and sub-angular to rounded granitic granule-to pebble-size gravel, contains medium to coarse sand-size and granule-size sub-rounded ironstone.	8	38
Permian-Sumner, Wellington Formation		
Shale, calcareous, gray.	14	52
	Total Depth	52

4-5-8cc. Sample log of test hole 200 feet north of the SW cor., SW¼, SW¼, sec. 8, T. 4 S., R. 5 E., on the east shoulder of the road, drilled on June 21, 1979. Surface elevation, 1,332 feet. No samples available for laboratory examination of this test hole.

	Thickness Feet	Depth Feet
Quaternary-Pleistocene, Kansan		
Kansas Till (?)		
Topsoil.	1	1
Clay, brown.	7	8
Clay, reddish-brown.	5	13
Atchison Formation (?)		
Sand, fine to coarse, brown, moist	5	18
Permian-Chase, Odell Shale		
Shale, clayey, red and green	9	27
	Total Depth	27

QUATERNARY HISTORY OF NORTHEAST WASHINGTON COUNTY, KANSAS

by

MARK ALLEN CARL

B. S., Southwest Missouri State University, 1971

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

The glaciated portion of northeastern Washington County, Kansas, was the focus of this investigation into the geomorphic relationship between the unconsolidated Quaternary sediments and the Permian and Cretaceous bedrock. A geologic map and cross-section of the area of investigation were constructed to graphically explain the relationship between the Quaternary-age sediments and the Permian and Cretaceous bedrock. Logs of test holes drilled are included as an appendix.

Bedrock within the area consists of Lower Permian (Gearyan and Cimarronian Stage) limestone and shale, and the sandstone and shale of the Cretaceous-age Dakota Formation. A conglomerate of possible Tertiary age occurs locally at several scattered locations.

No evidence of Nebraskan-age sediments was found in the area of study. Subsequently, any geomorphic effects that might have occurred during this stage are not distinguishable from the pre-Quaternary geomorphic history. Therefore, any possible effects that might have occurred during this stage will not be discussed because of the lack of any reliable evidence.

Although each of the four major glacial stages during the Quaternary effected the geomorphic history of northeast Washington County, evidence indicates the topography and sequence of Quaternary sediments that exist today were established primarily during the Kansan Stage. The most profound effects that occurred during the Kansan Stage were directly related to the Kansan-age glacier and the location of its western edge. The important geomorphic developments that occurred during this stage were the formation of the glacio-lacustrine Atchison Formation, the deposition of Kansas Till, upland fluvial deposits, and the formation of an ancestral, glacier-marginal, Little Blue River

Subsequent to the development of the ancestral Little Blue River, probably towards the end of the Kansan Stage, there occurred erosion of bedrock followed by deposition of fluvial sediments.

During the Illinoisan Stage, a second episode of erosion by the Little Blue River began. This episode eroded through the Kansan-age fluvial deposits leaving the Menoken Terrace where not eroded. After erosion through these deposits, the river incised deeper into bedrock than it had in Kansan time. Evidence indicates that the river entrenched itself along fractures wherever the ancestral Little Blue River closely aligned itself with the regional fracture pattern of the area. Following erosion of the bedrock, Illinoisan-age fluvial deposits were deposited to the level of the Buck Creek Terrace. The present day configuration of the Little Blue River was probably established during this stage. The upland areas during this stage, were being covered by the Loveland Loess, probably derived from the Illinoisan-age flood plain.

The Peoria Loess was deposited on top of the Loveland Loess during the Wisconsinan Stage. The last episode of valley deepening probably occurred during early Wisconsinan time, and eroded the bedrock to a depth of 15 feet below that of the Illinoisan erosion. Early Wisconsinan fluvial deposits were deposited following erosion through Illinoisan fluvial deposits leaving the Buck Creek Terrace as remnants of Illinoisan fluvial deposits above bedrock.

The early Wisconsinan fluvial deposits were subsequently eroded during late Wisconsinan and Recent. Erosion was down to, or just above, bedrock beneath early Wisconsinan fluvial deposits. Following

erosion of these sediments, the present day flood plain of late Wisconsinan and Recent alluvium developed to a level approximately three to five feet below the surface of the early Wisconsinan deposits. The Newman Terrace is the surface on the early Wisconsinan fluvial deposits that remains where not eroded by post early Wisconsinan erosion.

GEOLOGIC MAP OF NORTHEAST WASHINGTON COUNTY, KANSAS

July, 1980

EXPLANATION

QUATERNARY

Holocene
- Qal — Alluvium

Pleistocene
- Qt 1 — Newman Terrace
- Qs — Sanborn Formation
- Qt 2 — Buck Creek Terrace
- Qt 3 — Menoken Terrace
- Qkt — Kansas Till

TERTIARY(?)

Pliocene(?)
- Conglomerate

CRETACEOUS

Lower Cretaceous Series
- Kd — Dakota Formation

PERMIAN

Lower Permian Series

Sumner Group
- Pwe — Wellington Formation

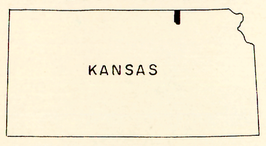
Chase Group
- Pn — Nolans Limestone
- Po — Odell Shale
- Pw — Winfield Limestone
- Pd — Doyle Shale
- Pb — Barneston Limestone

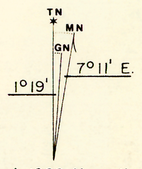
- Contact – 0' to 3' of cover
- Inferred contact – > 3' cover
- Gravel or sand pit
- Quarry
- Edge of ancestral Little Blue River

1 1/2 0 1 2 3 4 Miles

1 1/2 0 1 2 3 4 Kilometers

LOCATION MAP





UTM Grid and 1980 Magnetic North Declination at Center of Sheet (9.2' W. Annual Change)

Base from 50 percent reductions of U.S. Geological Survey, 1:24,000 7.5 Minute Quadrangles of Washington NE, Hanover West, Hanover East, Hanover SE, Hanover SW, 1966; Greenleaf, Barnes, and Linn, 1968

Geology by Mark A. Carl
Masters Thesis, July, 1980