

SURFACE EXPRESSION OF THE NEMAHA ANTICLINE IN SOUTHEASTERN
RILEY COUNTY AND NORTHWESTERN WABAUNSEE COUNTY, KANSAS

by

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INTRODUCTION

Location of the Area

The area of investigation covers 40 square miles in parts of townships 11 and 12 south and ranges 9 and 10 east (Plate 1). The area constitutes a rectangle that is 8 miles east-west and 5 miles north-south that is bisected by U. S. Highway 40 in an east-west direction. It lies along the boundary between southeastern Riley county and northwestern Wabaunsee county, Kansas, with the majority being in Wabaunsee county. Kansas state highway 99 trends north-south along the eastern edge of the area.

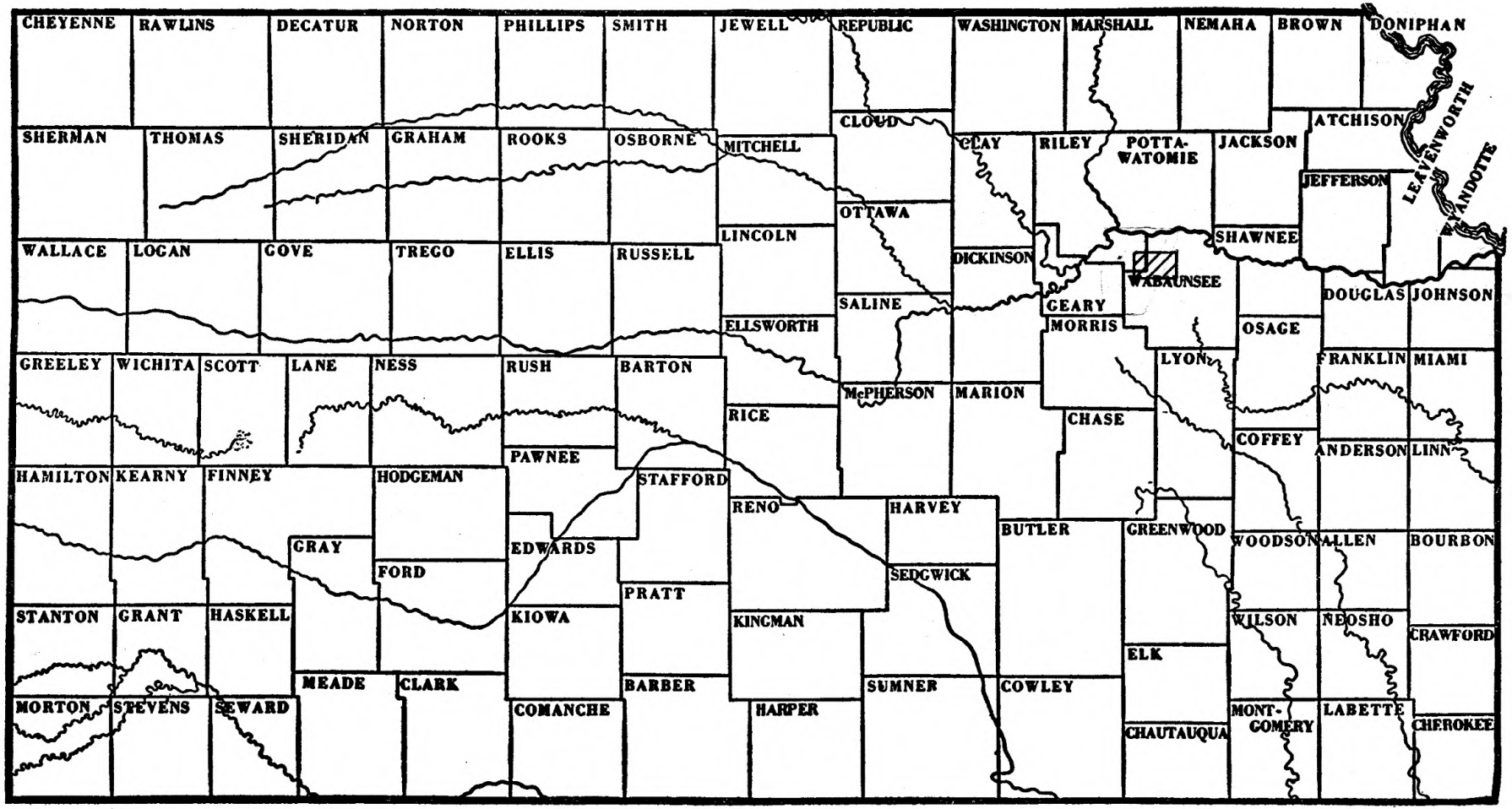
Physiographic Description


The area of investigation is in the Flint Hills section near the western edge of the Central Lowlands physiographic province. The Central Lowlands is an area bordered by the High Plains on the west and by the Ozark and Appalachian plateaus on the east. The typical Flint Hills topography that exists in this area is a series of prominent scarps facing eastward with dip slopes developed on weathered resistant, cherty, lower Permian limestones. The Flint Hills are nearly coincidental in position with the gentle arch of strata above the Nemaha anticline and a small part of the ruggedness of the hills is a result of that arching (Jewett, 1941). The topographic relief in the area of investigation approaches 450 feet with the highest points lying in the northwest corner and the lowest points in the east-central section.

EXPLANATION OF PLATE I

**A map of Kansas showing the area
covered by this investigation.**

PLATE I



 Area of Investigation

Drainage is well developed throughout the area and dendritic drainage pattern indicates the nearly horizontal, thick sedimentary rocks that are present (Smith, 1943). The Sanborn formation of Quaternary age covers much of the interstream areas thus effectively concealing the Paleozoic bedrock in many instances. Terrace deposits blanket some of the larger creek valleys, but because of the size of the creeks flowing through this area no alluvium has been deposited. A majority of the stratigraphic section of this area is exposed in the road cuts made for U. S. 40 and numerous outcrops in the form of hillside benches are made by the resistant limestones. No glacial materials were deposited in this area although some have been reported immediately north of this area.

The area of investigation lies somewhat to the east of the axis of the Nemaha anticline. The Nemaha anticline trends north-northeast across the area and separates the Salina Basin on the west from the Forest City Basin on the east. The surface expression of the southern flank of the Zeandale dome that lies along the anticlinal axis (Swett, 1959) is seen in the northwestern corner of the area and the surface expression of the fault which has long been thought to be present on the eastern flank of the Nemaha anticline (Ratcliff, 1957; Lee, 1956; Kotoyantz, 1956; Koons, 1955; and Rieb, 1954) is seen as a reversal of dip striking north-northeast through the center of the area parallel to the Nemaha anticline.

Review of the Literature

Little geologic work has been done on the surface expression of the Nemaha anticline in this area. Recently a number of investigations have been conducted into the subsurface geology of this general area and specifically into the possible faulting on the eastern flank of the Nemaha anticline.

Jewett (1941) worked on the geology of Riley county but concentrated mainly on stratigraphy rather than structural geology. However, he did mention that the valley of Deep creek (a few miles to the west of the writer's area) is superposed upon a structural dome or anticline in southeastern Riley county. The upwarping of the strata in the area of Deep Creek was supposedly in superposition upon the buried Nemaha Mountains. Jewett also thought the crest of the fold in Deep Creek valley to be a few miles southeast of Zeandale, although the alluvium of Deep Creek valley actually obscured the bed rock over an extensive area; because exposures in the Flint Hills west of Zeandale show a steep westward dip and the rocks there lie upon the west limb of the Deep Creek fold.

Beck (1949) and Mudge (1949) mapped the geology of Riley county, the former mapping the Quaternary geology and the latter mapping the pre-Quaternary rocks. Here, as with Jewett, the emphasis was on the stratigraphy of the formations, although Mudge mentioned a "Salina" dome some $1\frac{1}{2}$ miles south of Zeandale. Also mentioned was a steep southward dip that could be seen in the strata south of Zeandale in Sections 15, 16, 17 and 18, T. 11 S.,

R. 9E. and a steep southeasterly dip that was evident in the Grenola and Beattie limestones along the east side of Section 22, T. 11 S., R. 9 E (sections 15, 16 and 22 being in the writer's area).

Mudge and Burton (1950) made a preliminary report of geologic construction material resources in Wabaunsee county which included the stratigraphy and geologic mapping of the area but no structure.

Swett (1959) mapped the surface expression of the Zeandale dome (Jewett's Salina dome) and pinpointed the apex of the dome as lying in the southern half of Section 34, T. 10 S., R. 9 E. with a closure of some 40 feet in just the small area mapped, but believed that a somewhat greater closure was present over the entire structure.

The presence of the Nemaha anticline in the subsurface of this area was unknown in 1915 except for some core samples of "granite". The anticline was first recognized as an uplift of great length and the name Nemaha first used as a structural term by Moore and Haynes (1917).

Lee (1943) discussed in detail the structural history of the Nemaha anticline and the geology concerning its development. This was in connection with the stratigraphy and structural development of the Forest City basin.

Jewett (1951) discussed the Nemaha anticline along with the Salina and Forest City basins in his "Geologic Structures of Kansas".

Nelson (1952), Rieb (1954), Koona (1955) and Kotoyantz (1956) all make mention of the proposed faulting in the subsurface and the general consensus of opinion seems to be that there is a fault in the pre-Cambrian granite on the eastern flank of the Nemaha anticline in this area. The fault is believed to be a high angle, normal fault (approaching vertical) that has a displacement of some 1500 feet in this area.

Lee (1956) while working on the stratigraphy and structural development of the Salina basin mentioned the development of the Nemaha anticline, but expressed some doubt as to whether the east flank was actually faulted. This possible faulting will be discussed later and in greater detail.

Purpose of the Investigation

The purpose of this investigation is (1) to describe the surface expression of the fault line in the pre-Cambrian granite on the eastern flank of the Nemaha anticline, (2) to describe the surface expression of the southern end of the Zeandale dome lying along the axis of the Nemaha anticline, and (3) to determine, if possible, the origin of the surface expressions of the Nemaha anticline in the area of investigation.

The Nemaha anticline is the most striking of the structural features produced in eastern Kansas by post-Mississippian folding. It extends, with varying structural relief, from a point near Omaha, Nebraska, southwestward beyond Oklahoma City, Oklahoma, and passes through the vicinity of this investigation area

trending north-northeast. In the area it is essentially an asymmetrical anticline plunging southward. The depth to the pre-Cambrian granite in the southern part of the area of investigation is some 1500 feet (Lee, 1956) as compared to some 950 feet in the vicinity of the Zeandale dome (Swett, 1959) which is 6 miles to the north.

Numerous investigations have indicated the presence of an anomaly on the pre-Cambrian surface along the axis of the Nemaha anticline underlying southeast Riley county and northwest Wabaunsee county. The anomaly has been interpreted as a granite dome. Approximately four miles east of the Zeandale dome, still lying on the Nemaha anticline, is a possible fault line in its eastern flank or just the line where the eastern limb is notably steeper than that of the western limb. This line, fault or otherwise, strikes parallel to the axis of the Nemaha anticline and passes through the center of the area of investigation.

MAPPING PROCEDURE

Field work was conducted in the spring and summer of 1959. An extensive reconnaissance of the problem area was made to determine if any surface expression of the Nemaha anticline was to be found. Upon discovery of that expression (a decided reversal of dip) an exact area was selected to be studied and mapped in detail. Because of the numerous road cuts made by U. S. Highway 40, it was decided to use this line (east-west) as the structural

profile of the area of investigation. Formations in and around this line were identified, sections were measured, and dips and strikes of the formations were taken with a Bruton compass.

United States Geological Survey topographic quadrangles (scale 1:24,000) helped serve with the aid of aerial photographs as the base map. Since it was decided to also map the area geology from the aerial photographs, the scale of 1:19,800 (that of the photograph) was used instead. The geologic map (Plate V) was then completed using previous geologic maps of Riley county by Mudge (1949) and Beck (1949), and of Wabaunsee county by Mudge (1950) and Burton (1950) as an aid in correlation.

By the measurement of the stratigraphic sections and determination of their strikes and dips, a structural cross-section was drawn along U. S. 40 with the aid of a State Highway Commission of Kansas profile. The cross section shows in detail the surface expression of the Nemaha anticline which causes a steepening of the dip immediately over the anticlinal crest on the eastern side (Plate V).

Upon further research it was decided that the reversal of dip was caused specifically by the fault in the pre-Cambrian granite of the eastern flank of the Nemaha anticline. The next logical step was to attempt to determine whether the steepening of dip on the eastern side was because of compaction of the overlying sediments or movement along the fault zone in a vertical direction. The sections in the immediate area of dip reversal were measured so as to determine any thinning of the beds over the fault line.

While the field investigations were continuing, another reversal of dip (from regional dip) was discovered in the northwest corner of the area of investigation. This reversal was attributed to the surface expression of the Zeandale dome on its southern flank. It was then decided that a structure contour map on one of the formations in the area would be extremely useful in interpreting the surface expression caused by the Nemaha anticline in this area. The top of the Americus limestone member of the Foraker limestone formation was selected because (1) it was easily recognized, (2) it was very resistant to weathering and made an excellent hillside bench, (3) it cropped out more abundantly than the others, and (4) most important it cropped out both in the northwest corner and in the center of the area where the surface expression of the fault occurred.

The structure contour map (Plate VI) was completed with the aid of a plane table and alidade. The stadia rod was used to mark and measure the elevations. Bench marks and section elevations were obtained from a U. S. G. S. topographic map of the area. All elevations on the structure contour map are referred to them. It was decided a 10 foot interval would be the most logical. Because the formational dips tended to level in the eastern and southern part of the area, outcrops of the Americus limestone were few and control was generally inadequate as indicated by the dashed contour lines on the structural contour map. However, because of the knowledge of the regional dip, a fairly accurate estimate of its structure was made in this area.

Formational outcrops, except along U. S. 40, were sparse in some areas because of the deposition of the Sanborn formation on most of the interstream areas and deposition of terrace deposits in the larger creeks.

STRATIGRAPHY

Introduction

The outcropping stratigraphic units of the area of investigation will be discussed in terms of their areal distribution, general description and facies changes in the formations. These are supplemented by the geologic map of the area (Plate V) and the measured sections of the stratigraphy under discussion.

① Stratigraphic units of sedimentary origin ranging in age from Permian to Quaternary crops out in the area (Plate II). The oldest rock unit represented is the Aspinwall limestone and the youngest is the Wreford limestone (both of the lower Permian system). Some of the higher hills, slopes and valleys are covered with the Sanborn formation (Pleistocene Series) while terrace deposits are found in the larger stream valleys.

Quaternary System

Pleistocene Series. The Pleistocene series is represented in this area by terrace deposits and the Sanborn formation. These sediments are unconsolidated, non-marine in origin, and were deposited by wind, streams or mantle creep. The Sanborn formation formed by the wind occurs on the tops of most of the

EXPLANATION OF PLATE II

**Generalized stratigraphic column of
southeast Riley County and northwest
Wabaunsee County, Kansas.**

Plate II

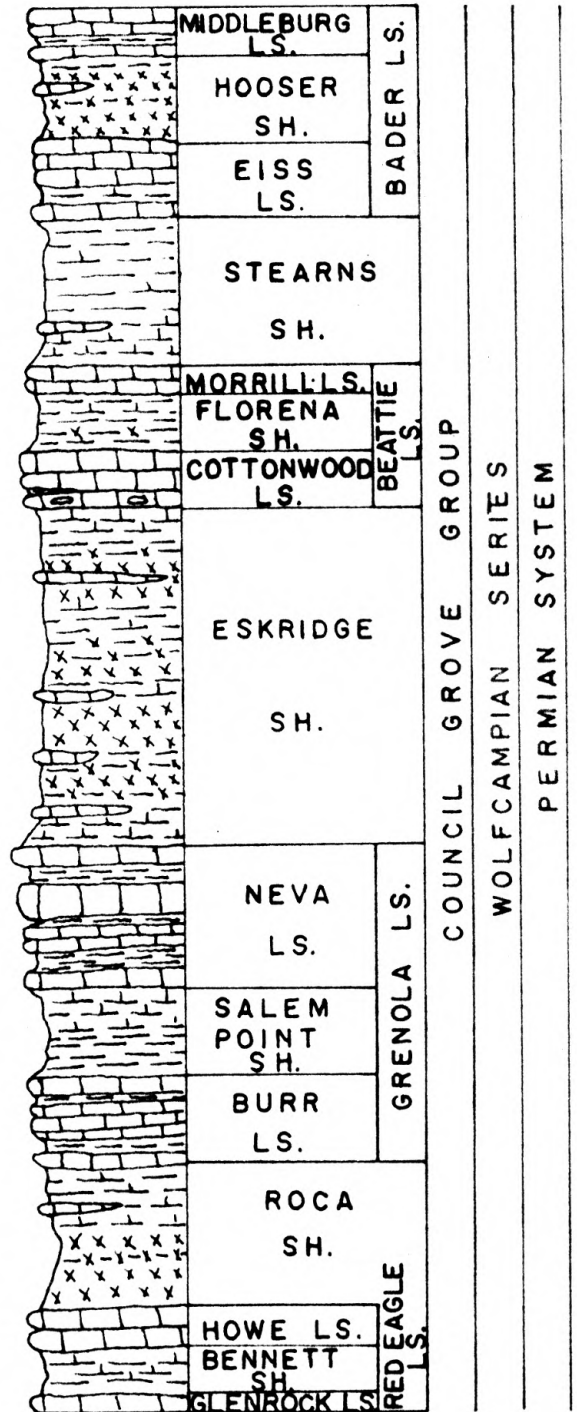
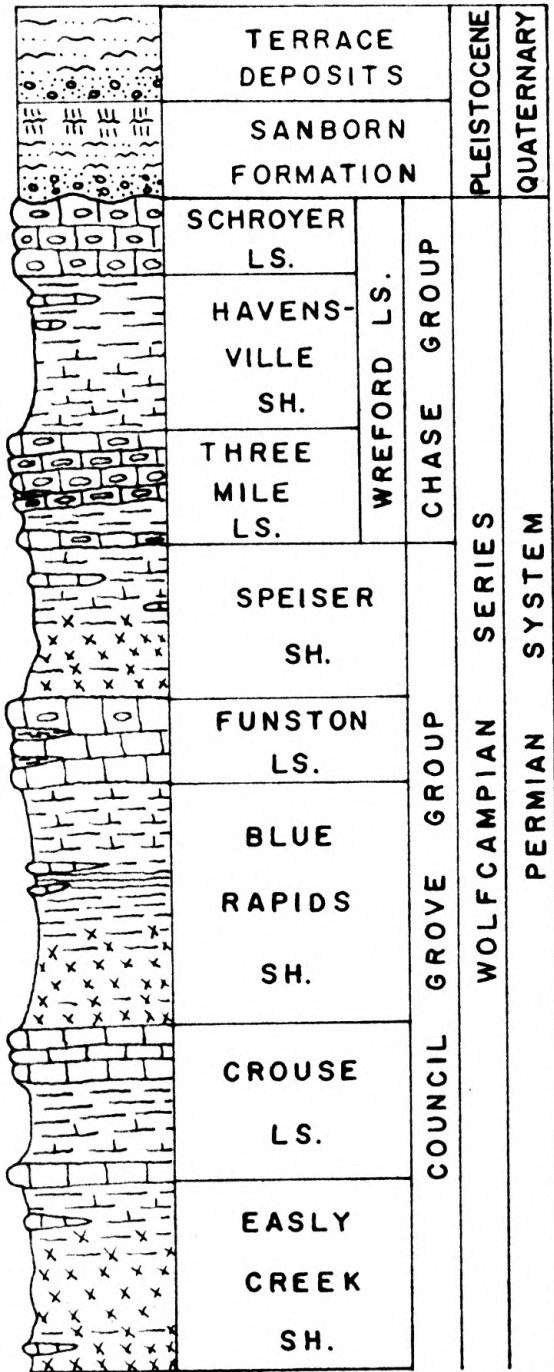
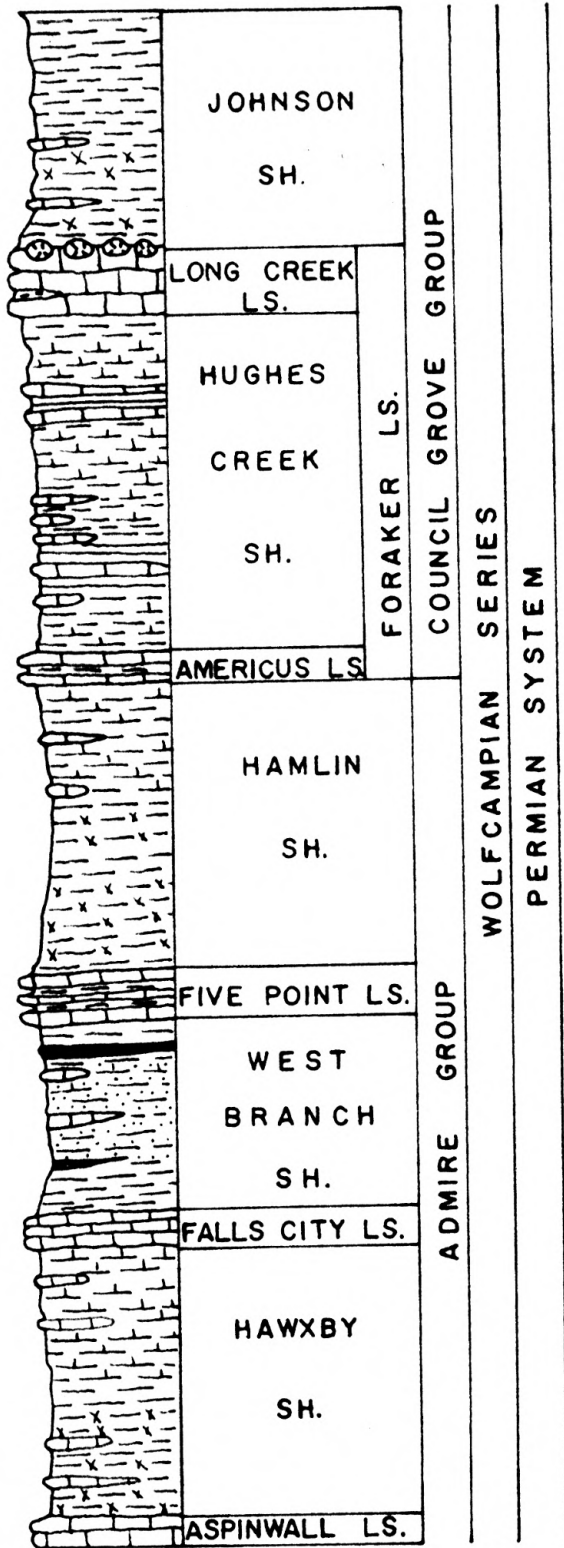
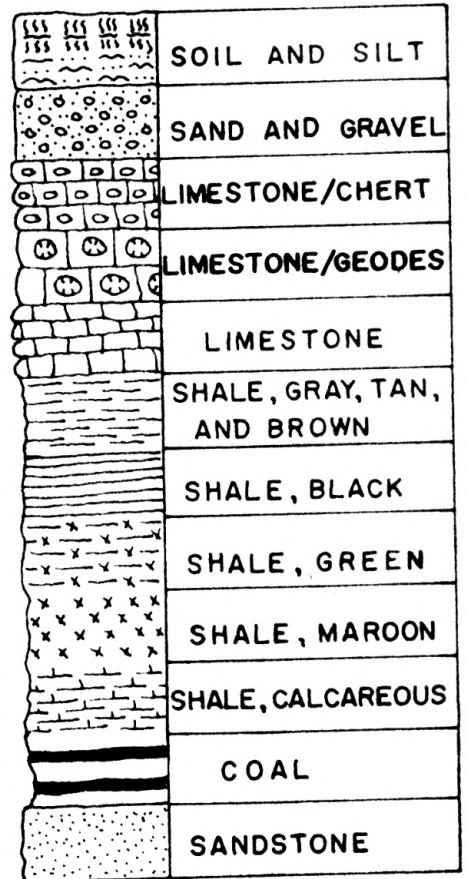


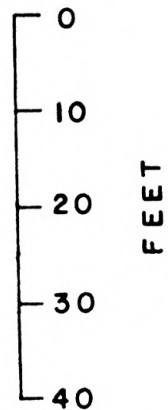
Plate II (cont.)



KEY



SCALE



interstream areas and along some of the valley sides. The stream-deposited terrace sediments are present along all of the major streams and some of their tributaries and are usually restricted to the stream valley. There was no evidence of glacial deposits in the area. Because all the major streams are relatively small, no alluvium deposits were mapped.

Terrace Deposits. Terrace deposits of Quaternary age are mapped in the valleys of Pretty, Hendricks and Antelope Creeks and some of their tributaries. The terrace deposits are composed of materials laid down by present-day streams in earlier cycles of deposition. These deposits are predominantly red-brown to dark-gray silt and clay that tend to be sandy in some areas. Some chert and limestone gravels occur in the basal part of the deposit. The terrace materials tend to stand in vertical banks. The thickness of these deposits average about 10 feet in this area.

Sanborn formation. The Sanborn formation is the most widely distributed stratigraphic unit that crops out in the area of investigation. Although the formation has been divided into four members (Frye and Fent, 1947), the Sanborn formation is treated as an undivided unit by the author. This formation occurs on the crests of interstream areas, along the margins of the terraces of the larger streams, in the valleys of their tributaries and also on the limestone benches at various levels above the streams.

The Sanborn formation consists of materials deposited by wind, sloopwash, streams and through the action of soil or mantle creep. This formation is predominantly gray-brown to red-brown silt (loess) and clay with some chert and limestone gravels in the basal part. The formation, especially above the Wreford limestone, has many fragments of weathered chert. Although it is generally unconsolidated as the terrace deposits the Sanborn formation has some cemented zones where the clay and fine sand are intermixed with gravel. The thickness of the formation ranges from 2 feet on the crest of the interstream areas to some 20 feet in the larger valleys and averages about 10 feet.

Permian System

The only Paleozoic rock units that crop out in the area of investigation are those of the Permian System which consist of, in descending order, the Guadalupian, the Leonardian and the Wolfcampian series. Only those rock units of the Wolfcampian series crop out. The Wolfcampian series is divided into three groups which are, in descending order, the Chase, Council Grove and Admire (Moore and others, 1951).

Chase Group. The Chase group is the uppermost group of formations in the Wolfcampian series. However, only the lowest formation, the Wreford limestone, of the Chase group crops out in the area of investigation.

Wreford Limestone Formation. The Wreford limestone is composed of the Schroyer limestone member in the upper part, the Havensville shale member in the middle, and the Threemile limestone member in the basal part. The average thickness of this formation is about 36 feet.

(1) Schroyer Limestone Member. The Schroyer limestone crops out on the crest of the interstream areas in the two higher topographic areas and tends to trend north-south. These two general outcrop areas extend from the southern border to just short of the northern border of the area of investigation where the generally southern dip of the rock units causes even lower Permian units to crop out.

The Schroyer limestone consists of thick beds of limestone with thin bands or lenses of chert, or scattered chert nodules. The limestone is hard, light-gray to tan-gray, massive and weathers blocky and irregular. The chert is usually dark-gray to gray, hard and dense. The weathered surface of the Schroyer limestone is mantled by numerous small fragments of chert. The Schroyer limestone contains echinoid spines and brachiopod fragments and forms a less prominent bench than the Threemile limestone below. The average thickness of this limestone is about 8 feet. (For detailed description, see measured section 3.) The thickness of the Schroyer limestone remains fairly constant in this area.

(2) Havensville Shale Member. The Havensville shale is closely associated with the outcropping of the Schroyer

limestone member. The Havensville shale is composed predominantly of shale, but does include a few limestone lenses. The shales are silty near the top, but become progressively more clayey near the base. The shales are gray to dark gray, generally calcareous and thin-bedded. The shale itself is generally unfossiliferous, but some brachiopods, Polypora sp., crinoid columnals and Myalina sp. are found in the several limestone lens. The Havensville shale is easily recognized by its position between the two chert-bearing limestone members of the formation. The average thickness of the member is about 16 feet. (For detailed description, see measured section 3.) The total thickness of the Havensville shale varies but little over the area of investigation.

(3) Threemile Limestone Member. Outcrops of the Threemile limestone are also closely associated with those of the Schroyer limestone and Havensville shale. However, the Threemile limestone tends to make a more prominent hillside bench than the other two members.

The Threemile limestone consists of a thick cherty bed in the upper part with a thin shale parting separating it from thick, massive, cherty beds in the lower part. A thick, dark shale parting in the lower part separates a somewhat less cherty limestone bed from the remainder of the member. The limestones are hard, dense, and massive with a light-gray to tan-gray color and weather blocky. The chert is in the forms of bands and nodules that are present throughout the thickness of the

limestone. The shale parting near the base is silty, calcareous thin-bedded and fossiliferous. Fossil fragments of brachiopods are present in the limestones. The member is easily recognized in the field. The average thickness of the formation is about 12 feet. (For detailed description, see measured section 3.) The Threemile limestone tends to thicken somewhat toward the south in this area.

Council Grove Group. The Council Grove Group is the middle group of formations in the Wolfcampian series. This group is composed of the Speiser shale down to the Foraker limestone, inclusive (Plate II). Every formation of this group crops out in the area of investigation.

Speiser Shale Formation. Speiser shale outcrops are invariably associated with those of the Threemile limestone. This shale forms the nearly vertical slope between the limestone benches formed by the Threemile limestone above and the Funston limestone below.

The Speiser formation is a silty, calcareous and varicolored shale, although in some places the formation is entirely tan, gray and olive-drab zones. Two beds of thin, hard, massive limestone are present near the top in more complete sections. The tan-gray shale zone directly below the Threemile limestone has brachiopods, echinoid spines and crinoid columnals. The average thickness of the Speiser shale is about 16 feet. (For detailed description, see measured section 3 and 4.) The

Speiser shale locally thins to the west and thickens gradually toward the north.

Funston Limestone Formation. Outcrops of Funston limestone are associated with those of the Speiser shale and forms a hillside bench just below the prominent terrace formed by the Threemile limestone bench.

The Funston limestone consists of one or two limestones with some shale partings. The limestone is generally soft, massive, argillaceous and weathers blocky to porous. The limestone is gray to light gray and weathers tan-gray. The average thickness of the formation is about 9 feet. (For detailed description, see measured section 4.) The Funstone limestone tends to thicken and become more massive toward the south and southwest.

Blue Rapids Shale Formation. Although the outcrops of the Blue Rapids shale tend to be associated with those of the Speiser shale and Funston limestone, it is found to crop out on top of some of the lower interstream areas. In general the Blue Rapids shale tends to crop out more toward the center of the area.

The Blue Rapids shale is a silty, calcareous and thin-bedded shale that is light gray to gray-brown to tan with a vari-colored zone (gray, gray-green, green and maroon to red) at the base. Two limestone lens are present in the middle part. The limestone is hard, massive, arenaceous, lenticular and tan-gray. The average thickness of the shale is about 25 feet.

(For detailed description, see measured section 4.) The thickness of the Blue Rapids shale is nearly constant in this area.

Crouse Limestone Formation. Outcrops of the Crouse limestone are generally associated with those of the Blue Rapids shale. The upper unit of the Crouse limestone forms a broad, flat, hillside bench.

The Crouse formation consists of two limestones, the upper being very thin-bedded, platy limestones with numerous thin shale partings, whereas the lower limestone is massive. The limestone in general is hard, dense, weathers blocky to platy, and is gray to brown and weathers tan-gray. There are a few brachiopod fragments present in the limestones. Small plates weathered from the upper limestone are numerous on the weathered surface of the prominent bench formed by the formation. The average thickness of the Crouse limestone is about 16 feet. (For detailed descriptions, see measured sections 4 and 5.) The thickness of the Crouse limestone remains fairly constant over the area of investigation.

Easly Creek Shale Formation. The Easly Creek shale is almost invariably associated with the Crouse limestone but does crop out with the Bader limestone on some of the lower valley slopes.

The Easly Creek formation is predominantly a silty, calcareous shale that is tan to gray in the upper part while the middle is gray-green to gray and maroon at the base. The shale is thin-bedded to blocky. A thick, hard, massive, tan-gray limestone

occurs in the upper part of the Easley Creek formation. The shale is unfossiliferous while some brachiopod fragments occur in the limestone. The average thickness is about 20 feet. (For detailed descriptions, see measured sections 2 and 5.) The limestone bed varies in its vertical position in the Easley Creek and tends to thicken somewhat toward the north while the overall thickness of the shale thickens toward the south.

Bader Limestone Formation. The Bader limestone is composed of the Middleburg limestone member in the upper part, the Hooser shale member in the middle, and the Eiss limestone member in the lower part. The average thickness of this formation is about 22 feet.

(1) **Middleburg Limestone Member.** The Middleburg limestone is associated with the Easley Creek shale above and Eiss limestone below. It crops out as a small but fairly prominent bench between the Crouse and Eiss limestone.

The Middleburg limestone is composed of a massive limestone with a shale parting. The limestone is hard, dense, light gray that weathers to tan-gray. Polypora sp. and crinoid columnals are present. The weathered surface is stained maroon and it weathers blocky. The average thickness is about 5 feet. (For detailed descriptions, see measured sections 2 and 5.) The thickness of the Middleburg limestone remains constant in this area.

(2) Hooser Shale Member. The Hooser shale is usually associated with the Eiss limestone below and the Middleburg limestone above. The Hooser shale member is a silty, calcareous, and varicolored shale (tan-gray, gray-green, maroon and purple). It weathers thin-bedded and a few thin lenticular limestone are present in some places. The average thickness is about 9 feet. (For detailed descriptions, see measured sections 2 and 5.) The Hooser shale thickens slightly toward the southeast.

(3) Eiss Limestone Member. The Eiss limestone is generally associated with the Middleburg limestone and Hooser shale above and sometimes the Stearns shale below. The Eiss limestone forms the first prominent hillside bench above the Cottonwood limestone.

The Eiss limestone consists of two limestones and a thin intervening layer of shale. The upper limestone is medium-hard, massive, argillaceous, gray to light gray and weathers blocky to platy and porous. It forms a prominent bench. The lower limestone is hard, light gray to gray, shaly and weathers in chips. There are fossil fragments in the limestones. The shale is olive to black, silty, calcareous and thin-bedded. (For detailed descriptions, see measured sections 2 and 5.) The Eiss limestone tends to thicken somewhat in a southward direction.

Stearns Shale Formation. The Stearns shale crops out generally on the valley slopes of the interstream areas and usually strikes north-south. It is generally associated with the Cottonwood limestone below.

The Stearns formation is mostly a silty, calcareous, gray to olive-drab shale that weathers light gray to tan. It is thin-bedded to blocky and thin beds of shaly limestone occur in the middle part. The Stearns shale is unfossiliferous and its average thickness is about 15 feet. (For detailed description, see measured section 5.) The thickness of the Stearns shale remains fairly constant in the area of investigation.

Beattie Limestone Formation. The Beattie limestone is composed of the Morrill limestone member in the upper part, the Florena shale member in the middle, and the Cottonwood limestone member in the lower part. The average thickness of the formation is about 15 feet.

(1) **Morrill Limestone Member.** The Morrill limestone crops out in approximately the same pattern as the Cottonwood limestone and similar to the Stearns shale in certain areas. The Morrill limestone usually consists of two thin limestones and an intervening shale. The limestone is medium-hard, slightly argillaceous, tan-gray to gray-orange and weathers tan, and is massive but weathers irregular and porous. The shale is calcareous, silty, tan-gray and thin-bedded. The Morrill limestone is unfossiliferous and its average thickness is about 3 feet. The Morrill limestone tends to thicken slightly toward the south.

(2) **Florena Shale Member.** The Florena shale almost always is exposed above outcrops of the Cottonwood limestone except in one or two isolated places. The Florena member is a silty, calcareous, tan-gray to gray-green, thin-bedded and very

fossiliferous. Chonetes granulifera is exceptionally abundant in the lower part of the shale. The average thickness of the Florena shale is about 6 feet. The thickness of the Florena shale is fairly constant over the area of investigation.

(3) Cottonwood Limestone Member. The Cottonwood limestone crops out over the general area except for the western edge and extends from the northern to the southern border. The limestone crops out on the valley slopes and tends to crop out more continuously on the eastern side of the area than on the western side.

The Cottonwood limestone is a massive limestone that forms a very conspicuous hillside bench characterized by massive limestone blocks and a fairly persistent growth of bushes at the base of the outcrop. The limestone is hard, massive, blue-gray, fossiliferous and has some chert nodules and lenses. The limestone weathers blocky and small tear-shaped fusulinids are numerous on the weather surface of the upper part. The Cottonwood limestone thickness averages about 6 feet. (For detailed description, see measured section 1.) The lithology and thickness of the Cottonwood limestone is very constant over the area of investigation.

Eskridge Shale Formation. The Eskridge shale crops out beneath the Cottonwood limestone in some places but also crops out on valley slopes above the Neva limestone where the Cottonwood limestone is absent. The outcrops tend to be in the center of the area except where it crops out in the northwestern corner.

The Eskridge formation is predominantly a calcareous shale, silty in some zones and clayey in others, and vari-colored. The upper part is tan, gray and green with maroon, purple, green and tan-gray zones constituting the lower three-fourths of the formation. There is a persistent, thin bed of hard, massive, argillaceous and tan limestone in the upper part of the formation. The average thickness is about 35 feet. (For detailed description, see measured section 1.) The Eskridge shale tends to thicken toward the north and northwest. The position of the limestone in the Eskridge shale is extremely variable.

Grenola Limestone Formation. The Grenola limestone is composed of the Neva limestone member in the upper part, the Salem Point shale member in the middle, and the Burr limestone member in the lower part. The average thickness of the formation is about 33 feet.

(1) Neva Limestone Member. The Neva limestone forms the first prominent hillside bench below the Cottonwood limestone. It is closely associated with both the Cottonwood limestone and the Eskridge shale.

The Neva limestone is composed of thick limestones separated by beds of shale in the upper and lower part. The hardness of the limestone decreases toward the center and the middle is soft, massive and becomes porous when weathered. The limestone is light gray and weathers the same color or even lighter. The shales are generally silty, calcareous, dark in color and fossiliferous. The uppermost ledge of limestone weathers into thin

slabs in most exposures. The average thickness is 15 feet. (For detailed description, see measured section 8.) The Neva limestone tends to thin toward the south.

(2) Salem Point Shale Member. The Salem Point shale is closely associated with the Neva limestone. The Salem Point shale member is a calcareous, silty, and clayey shale. It is gray that weathers tan and is blocky to thin-bedded. Numerous calcareous plates appear on the weathered surfaces. The Salem Point shale is unfossiliferous. The average thickness is about 9 feet. (For detailed description, see measured section 8.) The Salem Point shale tends to thicken toward the south.

(3) Burr Limestone Member. The Burr limestone crops out almost continuously with the Neva limestone and Salem Point shale above. The Burr limestone crops out on the valley slopes nearer the bottom than the top.

The Burr limestone is essentially a thick limestone interrupted by shale partings. Some of the beds of limestone are hard, dense, massive, and others are soft porous. Their color is tan-gray that weathers tan and contains brachiopod fragments. The shale is usually clayey, non-calcareous to silty and calcareous, and is light gray to tan in color. Its average thickness is about 9 feet. (For detailed description, see measured section 6.) The thickness of the Burr limestone remains fairly constant in the area of investigation.

Roca Shale Formation. The Roca shale tends to crop out on the lower valley slopes in the north and central part of the

area, except where it crops out extensively in the northwest corner. It is sometimes associated with the Burr limestone.

The Roca shale formation is a silty and clayey, calcareous and vari-colored (tan, gray, green and maroon) shale. A persistent bed of thin, hard limestone occurs near the top. The Roca shale is the lowermost of the vari-colored Permian shales. Its average thickness is about 15 feet. (For detailed description, see measured section 6.) The thickness of the Roca shale remains fairly constant over the area.

Red Eagle Limestone Formation. The Red Eagle limestone is composed of the Howe limestone member in the upper part, the Bennett shale member in the middle, and the Glenrock limestone in the lower part. The average thickness of the formation is about 11 feet.

(1) Howe Limestone Member. The Howe limestone crops out in a belt similar to the Roca shale above and to the Glenrock limestone below, although it is not as resistant as the Glenrock limestone which is the benchformer of the formation.

The Howe limestone is soft, massive, gray-orange and weathers tan, with a rotten, porous, maroon stained surface. This member makes no more than a minor hillside bench. Its average thickness is about 4 feet. (For detailed description, see measured section 9.) The Howe limestone shows a slight thickening toward the south.

(2) Bennett Shale Member. The Bennett shale is usually associated with the Glenrock limestone above and Howe limestone

below. The Bennett shale is clayey, with some silt, calcareous, thin-bedded to fissile, and dark gray to black. It is very fossiliferous. The average thickness of the member is about 5 feet. (For detailed description, see measured section 9.) There are no significant changes in the Bennett shale in the area of investigation.

(3) Glenrock Limestone Member. The Glenrock limestone crops out on valley slopes mostly in the center part of the area except for a few outcrops in the northcentral and some extensive outcrops in the northwest corner. It is usually associated with the Howe limestone and the Bennett shale.

The Glenrock limestone is hard, dense, massive, tan-gray that weathers to tan limestone that is blocky with some maroon stains on the weathered surface. Fusulinids are present throughout the bed and it has an average thickness of about 2 feet. (For detailed description, see measured section 9.) The Glenrock limestone is very persistent and no changes were found in the area of investigation.

Johnson Shale Formation. The Johnson shale is associated with the Foraker limestone below and crops out mostly on the northern side of U. S. 40. Most of the outcrops appear in the central or western parts of this specific area.

The Johnson formation is a thick, silty, calcareous, gray-green to olive drab shale that contains numerous thin calcareous lenses and limestones. It is thin-bedded to blocky and unfossiliferous. The average thickness of the formation is about 25

feet. (For detailed description, see measured section 9.) The thickness of the Johnson shale as a whole remains fairly constant over the area.

Foraker Limestone Formation. The Foraker limestone is composed of the Long Creek limestone member in the upper part, the Hughes Creek shale member in the middle, and Americus limestone member in the lower part. The average thickness of the Foraker formation is about 45 feet.

(1) Long Creek Limestone Member. The Long Creek limestone is closely associated with the Hughes Creek shale and Americus limestone below. The Long Creek limestone crops out mostly north of U. S. 40 and in the central and western parts of this area.

The Long Creek limestone member is soft, fine-grained, massive and slightly dolomitic. It is usually tan to gray-orange and weathers tan. The bedding weathers irregular, platy to porous. Celestite nodules and geodes are present in the upper part of the limestone in the weathered sections. Its average thickness is about 7 feet. (For detailed description, see measured section 7.) No facies changes were observed in the Long Creek limestone in this area.

(2) Hughes Creek Shale Member. The Hughes Creek shale is closely associated with the Long Creek limestone above and the Americus limestone below. The Hughes Creek shale member is silty, calcareous, and gray to dark gray that varies from fissile to blocky. Lenses of soft, clayey, fusulinid-bearing limestone

occur in the upper and middle parts of this member and fossils are very abundant in most of the beds of shale. Fusulinids are very abundant, especially in the shales of the upper part. The average thickness of the member is about 35 feet. (For detailed description, see measured section 7.) The Hughes Creek shale is fairly consistent in thickness and lithology in the area of investigation.

(3) Americus Limestone Member. The Americus limestone is associated closely with the other members of the Foraker limestone formation. It forms the prominent hillside bench of this formation. The Americus limestone consists of two limestones separated by a shale. Both limestones are hard, dense, massive, and dark gray to blue-gray and weathers light gray. The limestones weather blocky and usually in rhombohedral blocks which make a very conspicuous bench. The shale is unfossiliferous, but the limestones are very fossiliferous and are characterized by numerous crinoid columnals showing on weathered surfaces. Its total thickness is about 3 feet. (For detailed description, see measured section 7.) The lithology and thickness of the Americus limestone remains very consistent over the entire area of investigation.

Admire Group. The Admire group is the lower group of formations in the Wolfcampian series. All the formations of the Admire group, except the basal one, crop out in the area of investigation. These formations are composed of the Hamlin shale down to the Aspinwall limestone, inclusive.

Hamlin Shale Formation. The Hamlin shale crops out only occasionally in the center and northcentral area and a little more extensively in the northwest corner. In the center area it tends to crop out in the valley bottoms while in the northwest corner it crops out on the valley slopes.

The Hamlin shale is actually composed of three members; the Oaks shale, the Houchens Creek limestone and the Stine shale. However, the Houchens Creek limestone is absent in this area and the contact between the Oaks and Stine shales is indistinguishable. The Hamlin formation is a silty with some clay, calcareous, gray to gray-green shale. The middle part of this shale is arenaceous. The Hamlin shale is blocky, but becomes thin-bedded toward the base. Some calcareous lenses are present in the upper part. The average thickness of the Hamlin shale is 30 feet. (For detailed description, see measured section 7.) The thickness of the Hamlin shale stays fairly constant over the area and the only difference is the absence of the Houchens Creek limestone.

Five Point Limestone Formation. The Five Point limestone crops out only in the northwestern corner and along the northern border of the area of investigation. The outcrops were usually on the lower hill slopes in this area and form prominent hillside benches.

The Five Point limestone is hard, massive, gray that weathers tan-gray, and contains brachiopod fragments in the lower part while it is platy and somewhat argillaceous in the upper part.

The massive upper part forms the lowest recognizable bench in the Permian rocks in this area. The average thickness in this area is about 5 feet. Because of the absence of a number of outcrops, it is not possible to determine if any significant changes took place in the immediate area.

West Branch Shale Formation. The West Branch shale is closely associated with the Five Point limestone outcrops and is usually covered along the base of the escarpment in the northwest corner of the area. This area is the only area where it crops out extensively.

The West Branch formation is a clayey, somewhat silty, gray to green shale. It contains a zone of sandy shale near the middle, a thin massive limestone lens in the upper part and a thin sandstone lens in the middle part. The formation is thin-bedded and unfossiliferous. Its average thickness is 20 feet. Because of the lack of suitable outcrops in the area, it was not possible to determine if there were any facies changes.

Falls City Limestone Formation. The Falls City limestone makes only a very indistinctive outcrop in the northwest corner right at the borders of the area. It forms only a small and poorly developed hillside bench when it crops out at all.

The Falls City limestone is soft, porous, tan-gray that weathers to tan. It does have some shale partings and is platy near the base in some outcrops. It is somewhat fossiliferous and has an average thickness of about 4 feet. It was not possible to determine any facies changes because of lack of outcrops.

Hawxby Shale Formation. The Hawxby shale crops out in the extreme northwest corner of the area on a hill slope near the bottom of the valley. The Hawxby shale is composed of a thick shale containing numerous thin limestone lenses. The shale is clayey, calcareous, thin-bedded and fossiliferous in some zones. The limestones are hard, massive, clayey, gray to gray-brown, and very fossiliferous. The color of the shale ranges from gray to gray-green to tan. The average thickness of the Hawxby shale is about 28 feet. Because of the small area of outcrop of the Hawxby shale, it was not possible to determine the changes, if any, that occurred.

Aspinwall Limestone Formation. The Aspinwall limestone is closely associated with Hawxby shale in the extreme northwest corner of the area of investigation. The Aspinwall limestone is hard, massive, tan-brown and contains crinoid columnals. The limestone weathers blocky to platy and exhibits a brecciated appearance. It does not make a prominent outcrop in this area. Its average thickness is about 3 feet. Because of the lack of exposure, it is difficult to determine facies changes in the Aspinwall limestone.

STRUCTURE

The general structure of the area has been divided, for convenience, into two parts; the regional structures and the local structures. The regional structures include the Nemaha anticline, the Salina basin and the Forest City basin. Included in the local structures are the surface fault zone in

southeastern Riley county, the Zeandale dome and the subsurface fault in the pre-Cambrian granite on the eastern flank of the Nemaha anticline.

Regional Structure

Nemaha Anticline. The Nemaha anticline is a regional structure that strikes approximately N 20°E through the area of investigation. It is one of the major positive areas in Kansas, extending from Omaha, Nebraska through Kansas (Nemaha county in the north to Sumner county in the south) and terminating at Oklahoma City, Oklahoma (Plate III). The Nemaha is a truncated anticline, plunging southward and is asymmetrical with the steeper dips on the eastern flank. The Salina basin parallels it on the west and the Forest City basin to the east. It is discernable in surface rocks along most of its length but is much more pronounced in the subsurface and is believed to be faulted in many places along its eastern flank (Ratcliff, 1957; Lee, 1956; Kotoyantz, 1956; Koons, 1955; and Rieb, 1954). A fault flanking the northern part of the Nemaha anticline is called the Humboldt fault.

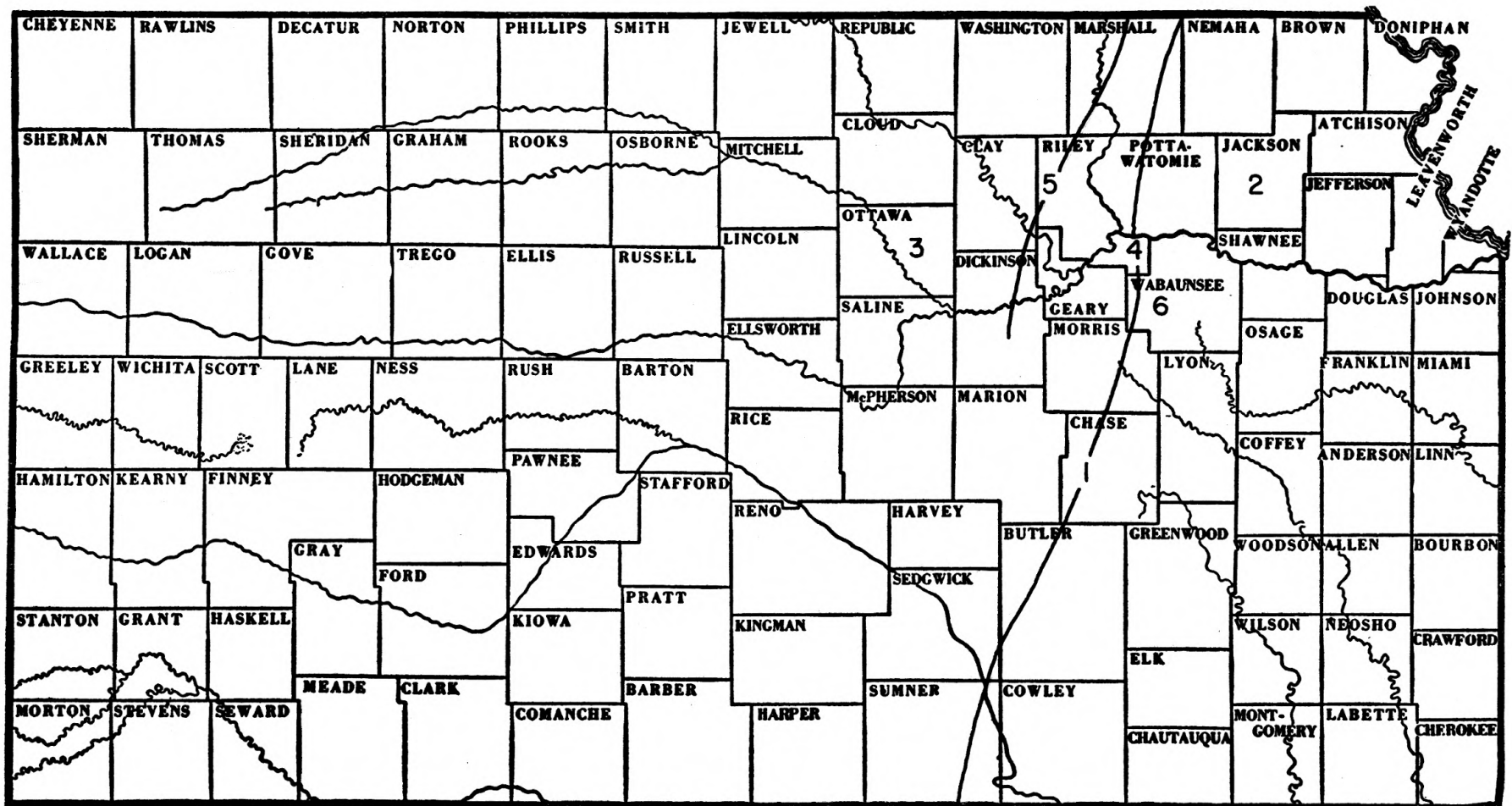
The Nemaha anticline is a post-Mississippian structure whose crest was peneplained after initial folding and then followed by faulting along the eastern flank. The Burns dome, Elmdale anticline, Diamond Creek province, Cottonwood province and the Zeandale dome are some of the local anticlinal structures along the axis of the larger Nemaha anticline. The depth to the granite ranges from some 950 feet (Swett, 1959) in the

EXPLANATION OF PLATE III

Regional and local structures.

1. Nemaha Anticline
2. Forest City Basin
3. Salina Basin
4. Zeandale Dome
5. Abilene Anticline
6. Alma Anticline

PLATE III



area of Zeandale to more than 1500 feet (Lee, 1956) in the area of investigation.

Salina Basin. The Salina basin occupies an area in north-central Kansas between the northern end of the Nemaha anticline and the central Kansas uplift (Plate III). The axis of the southern part of the Salina basin is roughly parallel to the northeastern flank of the Central Kansas uplift, but its northeastern limb swings north around the broad northern end of the Nemaha anticline. The Salina basin is an area of depressed Mississippian and older rocks between the two anticlinal areas and is bounded on the south by an arch-like structure which separates it from the Sedgewick basin. Its age is post-Mississippian. Middle Pennsylvanian sediments were deposited on the peneplained Mississippian rocks and at the end of post-Mississippian beveling 350 feet of Mississippian limestone remained in the deepest part of the basin. Lee (1956) describes the five principal periods during which folding took place within the area: (1) late Cambrian to early Ordovician, (2) St. Peter to Mississippian, (3) Mississippian to Permian, (4) post-Permian and pre-Cretaceous, and (5) post-Cretaceous. During the post-Mississippian deformation several northeast trending structures were formed in the basin with their strike parallel to the Nemaha anticline. These structures included the Voshell, Abilene and Barneston anticlines.

Forest City Basin. The Forest City basin is essentially described as a low broad structural feature whose central area

lies in northeastern Kansas (east of the Nemaha anticline and the area of investigation) and extends into the adjoining parts of Nebraska, Missouri and Iowa (Plate III). The basin was originally a topographic and structural feature in which the earliest Pennsylvanian rocks of this part of Kansas were deposited before it was actually formed by regional warping of the pre-Pennsylvanian rocks (Lee and Payne, 1944). As shown the Forest City basin had a relatively brief existence. As in the Salina basin, another northeast trending structure (the Alma anticline) striking parallel to the Nemaha anticline was formed during post-Mississippian deformation.

Local Structure

Fault Zone in Southeastern Riley County. Mudge (1949) and Bruton (1958) have mapped seven normal faults located approximately 3 to 4 miles west of the writer's area of investigation. The faults strike northeast and have a maximum displacement of 25 feet. The influence of the faulting must be only local as there are no surface faults in the area of investigation.

Zeandale Dome. The Zeandale dome is a local name given to a structural anomaly on the pre-Cambrian surface of the Nemaha anticline. Its surface expression is located in the vicinity of Zeandale, Kansas. Nelson (1952) appears to have been the first to apply the name. Rieb (1954), Koons (1955) and Bruton (1958) also mentioned the dome specifically in their theses while Lee (1956) and Farquhar (1957) only mentioned a structural and

stratigraphic anomaly in that area. Sweet (1959) pinpointed the surface apex of the Zeandale dome as being near the center of his area of investigation in the southern half of Sec. 34, T. 10 S., R. 9 E. (some $2\frac{1}{2}$ miles north of the northwest corner of the area of this investigation). His area only covered the structurally higher portion of the dome. Within the area mapped pronounced elongation was not apparent, but the west flank was noticeable steeper than the east and the dome was nearly symmetrical along a north-south axis but slightly asymmetrical along its east-west axis. Closure in this area was only some 40 feet but maximum closure on the Zeandale dome is thought by Koons (1955) to be some 600 feet in the subsurface. Koons stated that the dome, as a whole, appeared to be elongated in a north-southeast direction and that it originally was elongated parallel to the Nemaha fault (discussed below), but that a short fault had cut the northern half giving an appearance of elongation in a northwest-southeast direction.

Sweet (1959) came to the conclusion that the Zeandale dome is a local "high" on the axis of the regional Nemaha anticline and although the surface data did not reveal the precise age and origin it is the result of differential compaction of sediments over an anomaly in the granite surface emphasized by post-Mississippian pre-Cretaceous (?) uplift associated with the Nemaha anticline.

Faulting on the Eastern Flank of the Nemaha Anticline. It is the general consensus of opinion that the Nemaha anticline is

faulted on its eastern flank in the area of investigation and also north and south of it. Koons (1955) described the fault as a high angle, nearly vertical fault. It is classified as a normal fault although no wells have reportedly penetrated the fault zone, so no definite descriptive geology can be given. The strike of the fault is approximately N. 20° E. or parallel to the Nemaha anticline itself. It extends for some 150 miles from a point in Nemaha county to as far south as Chase county where it appears to die out. The largest displacement is approximately 3,100 feet in Nemaha county and the smallest displacement is about 850 feet in Chase county. The average displacement of the fault in the area of investigation appears to be approximately 1,500 feet (Rieb, 1954 and Lee, 1956). There seems to be no pronounced strike-slip movement, as highs on the east side (downthrow) appear to correspond to highs on the west side (upthrow). It is suggested that the fault is a continuation of the stress that originally produced the Nemaha anticline in post-Mississippian time. Farquhar (1957) goes so far as to say that the Nemaha anticline is still tectonically active, and uplift evidently has not been completed.

GEOLOGIC HISTORY

The discussion of the geologic history of the area of investigation is based primarily upon the investigations and interpretations of Lee (1943, 1948 and 1956) in his stratigraphy and structural development of the Salina and Forest City basins

and the formation of the Nemaha anticline. This is further supplemented by the available subsurface and surface data (Barrett, 1958; Merryman, 1957; and Swett, 1959). Although the area's surface geology was studied in detail and the structural interpretation presented, it only contained a brief portion of the actual geologic history of the area because of the nearly horizontal strata and low topographic relief.

Paleozoic Era

The Paleozoic was an era of deposition, folding and warping, erosion, and faulting in this area. Rocks of the Cambrian to Permian systems were deposited. Between the deposition of sediments by the intervening Paleozoic seas were three major periods of warping that occurred and each was followed by erosion to a relatively flat surface. The principal periods were: (1) deformation of the Arbuckle dolomite group which was leveled by erosion before the deposition of the overlying St. Peter sandstone of early Ordovician age; (2) the deformation that occurred during the deposition of the rocks between the St. Peter sandstone and the base of the Mississippian; and (3) the deformation that began in early Mississippian time, culminated at the end of the period and continued with decreasing emphasis until middle Permian time. It was during this last period of deformation that the Nemaha anticline was developed and eventually caused the formation of the Salina basin and even later, the Forest City basin. Subsequent erosion after the formation of the Nemaha

anticline caused granite to be exposed in the area of investigation during part of the Missourian time. However, by the end of the Missourian time this area was submerged by Pennsylvanian seas encroaching upon the Nemaha anticline and marine sediments covered the pre-Cambrian granite. The rocks of the Pennsylvanian age consist of numerous cyclothems, alternating sequences of limestones, marine and non-marine shales, and sandstone. Each sequence was developed during a depositional cycle that included an advance and retreat of the sea whose depth was never very great in this area. Some evidence even points to a brief emergence of this area in the Missourian or Virgilian time. As the Pennsylvanian seas retreated, this area became part of an extensive land area. The retreating seas cut valleys 60 feet or more deep in the relatively flat surface. When the early Permian sea advanced these valleys were filled with basal marine sands (Indian Cave sandstone in this area). The area was again submerged by early Wolfcampian time and remained covered by shallow water that was constantly oscillating and causing cyclic sedimentation similar to that in the Pennsylvanian period (Hattin, 1957). The area probably spent the remainder of the Paleozoic era covered by shallow seas.

Mesozoic Era

The Mesozoic era was predominantly an era of erosion and regional tilting to the west, although the events of this era are, for the most part, unknown in eastern Kansas because no

Mesozoic rocks are present east of the extreme western part of Riley county (some 30 miles west of this area). With the retreat of the Paleozoic seas this area was exposed to erosion which removed the upper and middle Permian sediments leaving only the majority of the Wolfcampian series. The Paleozoic rocks developed a slight westward dip because of regional tilting during the Cretaceous period.

Cenozoic Era

The Cenozoic era in this region was predominantly a period of erosion. All the sedimentary rocks in the area of investigation younger than the Permian system were eroded during the Tertiary period and deposition occurred only in the Quaternary period. Two ice sheets extended into Kansas during the Pleistocene epoch, but neither sheet moved as far south as this area, although the Kansas glacier extended south of the Kansas River. Deposits of the Sanborn formation were laid down during the latter part of this epoch. In recent times creeks have somewhat eroded their valleys and are now flanked by deposits of terrace materials (Beck, 1949), but because of their size there is no alluvium (Mudge, 1950).

DISCUSSION

The surface geology of the area of investigation is influenced greatly by the presence of the Nemaha anticline and Zeandale dome. The surface expression of the sedimentary rocks results from the Zeandale dome in the granite and the steepness of the east flank of the anticline.

The Nemaha anticline is considered to be the most prominent tectonic feature in Kansas and strikes approximately N.20'E. through the area of investigation. The actual axis of the Nemaha anticline lies to the west of the area of investigation in the vicinity of Deep Creek (Jewett, 1941). The Nemaha is described as a truncated anticline, plunging southward and is asymmetrical with the steeper dips on the eastern flank. Although discernable in surface rocks along most of its length, it is much more pronounced in the subsurface. Ratcliff (1957), Kotoyantz (1956), Koons (1955), and Rieb (1954) believed that the eastern flank is faulted in many places, while Lee (1956) suggested that although displacement in several places is produced by faulting, in many places it is the result of sharp monoclinial dip.

No attempt to determine whether the east flank is faulted or not was made, but only the fact is recognized that the east flank of the Nemaha anticline is noticeably steeper than the western flank and its surface expression is present in the area of investigation. After the first stage of folding of the Nemaha anticline was completed the region was peneplained. At the close of the peneplanation the area west of the Nemaha anticline was raised above the area on the east, with some faulting occurring at this time. The result was the formation of an eastward-facing escarpment rising several hundred feet high above a basin (Forest City basin) formed by the subsidence of the peneplain east of the anticline (Lee, 1943). As has been pointed out the nature of the escarpment formed on the east side of the

Nemaha anticline has long been a subject of debate. After the initial formation of the escarpment, renewed activity during early Pennsylvanian time increased the structural displacement on the east flank and tilted the upraised block slightly toward the west. The uplifting of the Nemaha anticline continued into the Permian Period although it was not as extensive as that of the late Mississippian Period.

Lee in "The Stratigraphy and Structural Development of the Salina Basin" shows a structural cross section through the area of investigation (Plate IV). Maximum displacement of the pre-Cambrian approaches 1300 feet as compared to the 1400 feet mentioned by Kotoyantz (1956) who believed it was caused by faulting rather than a steepening of the dip. The surface expression of this part of the eastern flank of the Nemaha anticline can be clearly seen in the structure contour map made on top of the Americus limestone member of the Foraker limestone formation (Plate VI) and in the geologic cross section running east-west through the area of investigation (Plate V).

Although there is a slight reversal of dip from east to west in the eastern part of the area of investigation, the dip never exceeds 40 feet per mile until the center section of the area is approached. Here, the surface expression, because of the steepening of the east flank of the Nemaha anticline, is immediately noticed as the dip increases to approximately 200 feet per mile to the east-southeast. The trend of the structure in this part of the area of investigation strikes N. 20° E.,

EXPLANATION OF PLATE IV

Cross section showing the substructure
underlying an east-west line in the
southern part of the area of investigation.

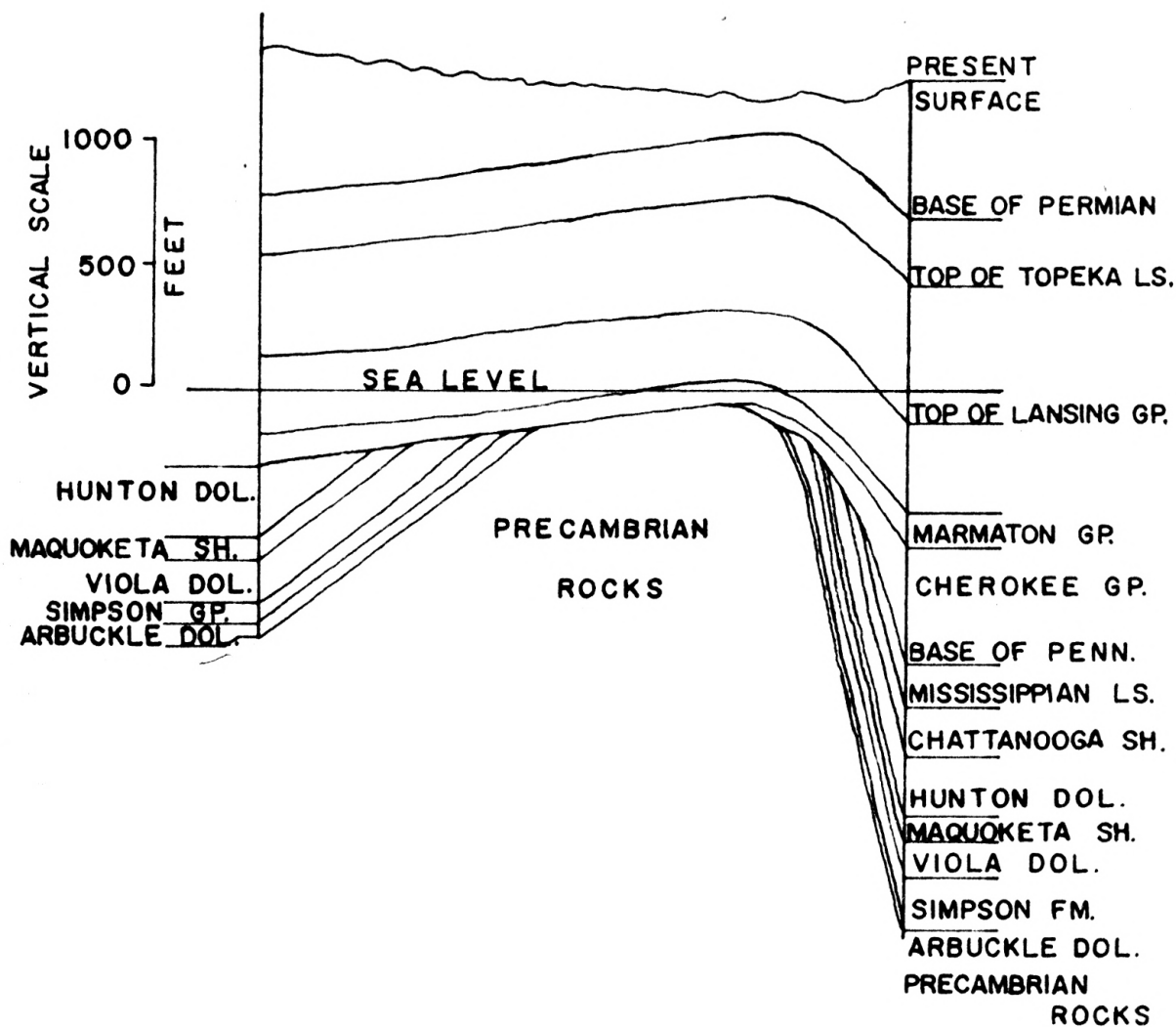
Plate IV

WABAUNSEE COUNTY

	R. 8 E.				R. 9 E.				R. 10 E.						
T	5	4	3	2	1	6	5	4	3	2	1	6	5	4	3
S	8	9	10	11	12	7	8	9	10	11	12	7	8	9	10

MAP OF CROSS SECTIONAL AREA

CROSS SECTION



parallel to the axis of the Nemaha anticline. It was noticed that the geology of this area (Plate V) strikes in approximately the same direction.

Immediately upon crossing over the axis of this anticline the dip should be reversed to the west but at a much gentler rate than on the eastern side. This reversal of dip can be seen in the south-central part of the area of investigation (Plate VI). However, north of this section of the area of investigation the reversal of dip is obscured by the surface expression of the Zeandale dome.

The Zeandale dome is a structural anomaly on the pre-Cambrian surface of the Nemaha anticline lying along the axis of the structure. Swett (1959) pinpointed the surface apex of the dome as being near the center of his area of investigation in the southern half of Sec. 34, T. 10 S., R. 9 E. Although Swett only mapped some 40 feet of closure in this area, it was thought by Koons to approach some 600 feet of closure in the subsurface. An additional 80 feet more of closure over the Zeandale dome was mapped in the area of this investigation. The surface expression of the Zeandale dome can be seen in the northwest, north-central and west-central parts of the area of investigation. Swett also thought that the east dip away from the crest of the Zeandale dome was probably continuous down the east limb of the Nemaha anticline. The structural interpretation of this thesis agrees with Swett that the east dip continues down the east limb of the Nemaha anticline. A relatively steep dip was observed affecting

lower Permian sediments in the center of Sec. 33, T. 10 S., R. 10 E. by Swett, who assumed that it represented the sharp increase in dip normally found on the east limb of the Nemaha anticline. When a line from this area was projected southward at N. 20° E., it coincided with the anticlinal axis in the area of this investigation.

Bruton (1958) mapped the structure of the Cottonwood limestone in southeast Riley county just a few miles west of the area of investigation. He noted a dip of some 200 feet per mile to the south in SW $\frac{1}{4}$ Sec. 18, T. 11 S., R. 9 E. which was thought to represent the southern flank of the Zeandale dome. The Americus limestone dips some 100 feet per mile to the south in Sec. 16, T. 11 S., R. 9 E. which is part of the southern flank of the Zeandale dome in the area of investigation.

Mudge (1949) also mentioned the southward dip found in the strata south of Zeandale in Sec. 15, 16, 17 and 18, T. 11 S., R. 9 E. which lies partly in the area of investigation.

Another purpose, besides describing the surface expression of the fault (?) line in the pre-Cambrian granite on the eastern flank of the Nemaha anticline and the southern flank of the Zeandale dome lying along the axis of the Nemaha anticline, was to determine, if possible the origin of the surface expressions in the area of investigation.

From the previous information reviewed it can be seen that the Nemaha anticline was formed by a combination of uplifts and deformations caused by vertical and horizontal forces. These

periods of uplift and deformation were interrupted by periods of erosion causing peneplanation of the area.

The Nemaha anticline resulted from uplift in post-Mississippian time and is probably a result of vertical uplift that was differential in character and occurred along an extended zone of weakness. This zone of weakness controlled the post-Mississippian uplift although the zone of weakness was probably first manifested in the uplift that took place at the close of Lower Ordovician times (Rieb, 1954). The Zeandale dome is one of the many knobs and saddles that marked the pre-Cambrian surface of the Nemaha anticline that were later concealed by Pennsylvanian and younger rocks (Farquhar, 1957).

An attempt was made to discover if any thinning of the sediments occurred over the area where a reversal of dip was caused by the steepness of the east limb of the anticline. With the aid of the State Highway Commission of Kansas profile along U. S. Highway 40, a portion of the stratigraphic column from the top of the Cottonwood limestone to the top of the Americus limestone was measured. No appreciable thinning of the section was discovered, although the western side measured some 139 feet to some 132 feet on the eastern side. No surface faulting of the sediments was discovered in the area of investigation.

The surface expression of the Zeandale dome and the steepness of the east flank of the Nemaha anticline is believed to be the result of differential compaction of the sediments over the granite dome and steep eastern limb of the anticline. The

compaction of the overlying sediments has been further emphasized by the uplift that was contemporaneous with deposition and post depositional deformation and uplift (Lee, 1956 and Swett, 1958).

This type of anticlinal and domal folding in the surface sediments is a typical mid-continent feature. These flexures in the rock layers above the basement complex are also formed because of differential compaction and settling of the younger rock layers above the rigid crystalline rocks forming the uneven surface below (Jewett, 1941; Lee and Payne, 1944 and Farquhar, 1957).

CONCLUSION

The surface expression of the Nemaha anticline was mapped in the area of investigation. A slight reversal of dip was found in the eastern part of this area, but a noticeable steepening of the sediments was discovered in the central part of the area. The steepening of the strata is the surface expression of the east flank of the Nemaha anticline and strikes parallel to the axis of the anticline. The dip over the east flank increases to 200 feet per mile as compared to less than 40 feet per mile average in the general area.

The surface expression of the Zeandale dome was mapped in the northwest, north-central and west-central part of the area of investigation. Approximately 80 feet of closure is present in this area. The dip increases to some 100 feet per mile to the south on the southern flank of the Zeandale dome.

The surface expression of the Zeandale dome and steepening of the east flank of the Nemaha anticline is believed to be the result of differential compaction of the younger sediments over the pre-Cambrian granite of the basement complex. The compaction is probably further emphasized by the initial uplift of the Nemaha anticline and other post depositional deformation and uplift.

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APPENDIX

APPENDIX

Section 1

This section from the Cottonwood limestone of the Beattie limestone to the Eskridge shale, inclusive, is exposed in a road cut on U. S. 40 some 1900 feet east from the center of section 27, T. 11 S., R. 10 E.

Feet

Beattie limestone formation. (4.5 feet exposed.)

Cottonwood limestone member (4.5 feet)

Limestone, hard, dense; bluish-gray, weathers tan-gray; massive, weathers blocky; some chert in forms of nodules. Fusulinids very abundant in upper half, other fossil fragments (brachiopods, crinoid columnals and echinoid spines) are common near the base. Face of formation is fractured, but formation as a whole makes a prominent hillside bench.

4.5

Eskridge shale formation. (24 feet exposed.)

Shale, clayey, some silty with clay, mostly non-calcareous; a vari-colored sequence in the following order: tan, maroon, green, maroon, green and maroon; predominantly non-fossiliferous.

8.8

Limestone, argillaceous; light gray, weathers tan; massive; hard, dense; contains pelecypods.

.7

Shale, clayey slightly silty, calcareous; predominantly maroon except for .5 foot of green at top; thin-bedded to blocky.	10.0
Shale, silty, calcareous; dense; platy; hard, breaks with subconchoidal fracture; gray-green, weathers light gray.	1.5
Shale, clayey, slightly silty, calcareous; maroon; thin-bedded to blocky.	3.0
Base covered.	

Section 2

This section from the Easley Creek shale to the Eiss limestone of the Bader limestone, inclusive, is exposed in a road cut on U. S. 40 some 900 feet east from the center of section 28, T. 11 S., R. 10 E.

	Feet
Loess, gray-brown to red-brown clayey silt with rock fragments.	1 ₂ ⁺
Easley Creek shale formation. (4.5 feet exposed.)	
Shale, clayey with some silt, calcareous; dark red to maroon, weathers to brown or tan; thin-bedded; unfossiliferous.	4.5
Bader limestone formation (12.5 feet exposed.)	
Middleburg limestone member (2 feet exposed)	
Limestone, dense; massive; light gray, weathers to tan; some chert nodules; maroon stains on the	

weathered surface; some algae in upper part; crinoid columnals and <u>Polypora</u> sp.	2.0
Hooser shale member (8 feet)	
Shale, clayey with some silt, slightly calcareous; olive-drab, weathers tan; blocky in top and platy near bottom.	1.4
Shale, clayey to silty, calcareous, maroon to purple; blocky to thin-bedded.	1.0
Limestone, argillaceous; gray, weathers light gray; massive.	.3
Shale, silty, calcareous; light gray-green, weathers light gray; thin-bedded.	.3
Shale, clayey with some silt, calcareous; maroon; blocky to thin-bedded.	5.0
Eiss limestone member (2.5 feet exposed)	
Limestone, argillaceous; gray weathers light gray; massive; hard; echinoids, crinoids and brachiopods.	2.5
Base covered.	

Section 3

This section from the Schroyer limestone member of the Wreford limestone to the Speiser shale, inclusive, is exposed in a road cut on U. S. 40 some 1600 feet east of the center of section 29, T. 11 S., R. 10 E.

	Feet
Weathered limestone and flint	1±

Wreford limestone formation. (33 feet exposed)

Schroyer limestone member. (5 feet exposed)

Limestone, hard; light gray to gray-orange, weathers tan-gray; massive; weathers blocky and irregular; weathered-out flint nodules (rust colored) common; echinoid spines and brachiopod fragments.

5.0

Havensville shale member (16 feet)

Shale, clayey with some silt; gray to dark gray; calcareous; thin-bedded; several thin limestone lens; brachiopods, Polypora sp. crinoid columnals and Myalina sp.

16.0

Threemile limestone member (12 feet)

Limestone, hard, dense; light gray to gray-orange weathers tan-gray; massive; several chert bands and chert nodules are common; weathers irregular; brachiopod fragments.

6.0

Shale, silty, calcareous; black, weathers dark gray; thin-bedded.

.5

Limestone, hard, dense; tan-gray; cherty; weathers irregular; brachiopod fragments common.

2.0

Shale, silty, calcareous; black; thin-bedded; brachiopods and fossil fragments common.

3.0

Limestone, hard; light gray, weathers tan-gray; massive; some chert nodules.

1.5

Speiser shale formation (3 feet exposed)

Shale, silty with some clay, calcareous; tan-gray, weathers light gray, thin-bedded; crinoid columnals, brachiopod fragments and Chonetes granulifera.

3.0

Base covered.

Section 4

This section from the Speiser shale to the Crouse limestone, inclusive, is exposed in a road out on U. S. 40 some 1100 feet west of the center of section 29, T. 11 S., R. 10 E.

Feet

Speiser shale formation (5.5 feet exposed)

Shale, silty with some clay, calcareous; tan-gray weathers tan; thin-bedded to blocky; brachiopods, crinoid columnals and echinoid spines.

5.5

Funston limestone formation (3.5 feet)

Limestone, soft dense, argillaceous; gray, weathers tan-gray; massive, weathers rotten and blocky; some chert nodules; a few thin shale partings.

3.5

Blue Rapids shale formation (33 feet)

Shale, silty with some clay, calcareous; tan at top to light gray at bottom; thin-bedded to blocky; unfossiliferous.

12.5

Limestone, arenaceous; dense; lenticular and nodular.

1.0

Shale, silty; calcareous; black; thin-bedded.	1.5
Limestone, arenaceous; dense; cherty.	.8
Shale, silty; calcareous; tan-gray, weathers tan; thin-bedded to blocky.	3.2
Shale, silty with some clay; calcareous; vari- colored (gray, green and red); contains two local limestone members.	14.0
Crouse limestone formation. (12 feet exposed)	
Limestone, hard, fine-grained; tan-gray, weathers tan; massive, weathers platy; numerous thin shale partings.	8.0
Limestone, hard, dense; tan-gray; massive, weathers blocky and porous; brachiopod fragments in top part.	4.0
Base covered.	

Section 5

This section from the Crouse limestone to the Stearns shale is exposed in a road cut on U. S. 40 some 1300 feet west of the center of section 30, T. 11 S., R. 10 E.

	Feet
Crouse limestone formation (1 foot exposed)	
Limestone, hard; tan-gray weathers tan; weathers very platy.	1.0
Easly Creek shale formation (23 feet)	
Shale, silty, calcareous; tan to gray, weathers tan; thin-bedded.	5.5

Limestone, hard; tan-gray, weathers tan; massive, weathers blocky to platy; brachiopod fragments, <u>Polypora sp.</u> and crinoid columnals.	1.5
Shale, clayey with some silt, calcareous; vary col- ored (tan to gray-green at top and predominantly maroon at bottom); blocky; unfossiliferous.	14.5
Limestone, hard; tan; massive; blocky; cherty.	.3
Shale, maroon.	1.2
Bader limestone formation (16.8 feet exposed)	
Middleburg limestone member (2.3 feet)	
Limestone, hard; dense; massive; light-gray weathers to tan; weathers blocky; brachiopod fragments.	2.3
Hooser shale member (10.0 feet)	
Shale, silty with some clay; calcareous; vari- colored (tan-gray to gray green to maroon and purple); thin-bedded.	10.0
Eiss limestone member (4.5 feet exposed)	
Limestone, medium-hard, argillaceous; gray, weathers light gray; massive, weathers blocky to platy, porous; black algae on weathered surface; some brachiopod fragments.	2.0
Shale, silty, calcareous; olive to black; thin- bedded.	.5
Limestone, hard; gray, weathers light gray; massive weathers in small chips; some brachiopod fragments.	2.0

Stearns shale formation (1 foot exposed)

Shale, silty with some clay, calcareous; olive-drab to gray, weathers light gray; thin-bedded to blocky; unfossiliferous. 1.0

Section 6

This section from the Burr limestone of the Grenola limestone formation to the Roca shale, inclusive, is exposed in a road cut on U. S. 40 at the center of section 30, T. 11 S., R. 10 E.

Feet

Grenola limestone formation (12.1 feet exposed)

Burr limestone member (7.3 feet exposed)

Shale, clayey, non-calcareous; light-gray, weathers to tan; thin-bedded. 1.5

Limestone, hard, dense, massive; tan-gray, weathers blocky and irregular; some fossil fragments. 1.0

Shale, clayey, non-calcareous; dark gray, weathers to light-gray; thin-bedded. 2.3

Limestone, hard, dense, massive; tan; weathers blocky, platy near base; crinoid columnals, Chonetes granulifera, and brachiopod fragments. 2.5

Legion shale member (1 foot)

Shale, clayey, non-calcareous; olive-drab to black; fissile. 1.0

Sallyards limestone member (.8 feet)

Limestone, hard, dense; light gray, weathers tan;
lenticular; cherty. .3

Shale, clayey, non-calcareous; light gray, weathers
tan; thin-bedded. .25

Limestone, hard, dense; light gray, weathers tan;
lenticular. .25

Roca shale formation (3 feet exposed)

Shale, clayey, calcareous; olive to dark gray to
green (vari-colored); thin-bedded. 3.0

Section 7

This section from the Long Creek limestone of the
Foraker limestone formation to the Stine shale of the
Hamlin shale formation, inclusive, is exposed in a
road cut some 1100 feet south of U. S. 40 on the east-
west boundary of section 30, T. 11 S., R. 10 E. and
section 25, T. 11 S., R. 9 E.

Feet

Foraker limestone formation (40 feet exposed)

Long Creek limestone member (5.5 feet exposed)

Limestone, soft, fine-grained; gray-orange, weathers
tan; massive, weathers platy and irregular; porous,
celestite nodules in top; unfossiliferous; dark gray
shale partings that are thin-bedded, blocky and
slightly calcareous. 5.5

Hughes Creek shale member (31.5 feet)

Shale, silty; calcareous; olive-drab, blue-gray to black; weathers tan; thin-bedded to blocky; fusulinids are very abundant along with crinoid columnals and brachiopods.	7.0
Limestone, argillaceous; gray-orange weathers tan; massive; weathers blocky; fusulinids and crinoids present.	.8
Shale, clayey, non-calcareous; dark gray to black, weathers gray; fissile; fusulinids and crinoid columnals present.	1.7
Limestone, argillaceous; gray-orange, weathers tan; massive; weathers blocky; fusulinids.	1.0
Shale, silty with clay, calcareous to non-calcareous; dark gray to black, weathers to gray; fissile to thin-bedded; fusulinids, crinoid columnals and brachiopods present.	8.5
Limestone, argillaceous.	.5
Shale, black.	.3
Limestone, argillaceous.	.5
Shale, brown.	.4
Limestone, argillaceous; weathers blocky.	.8
Shale, clayey with silt; brown to black, weathers tan; fossiliferous.	3.0
Limestone, argillaceous; weathers platy; thin-bedded.	2.0

Shale, brown.	5.0
Americus limestone member (3 feet)	
Limestone, hard, dense; blue-gray to dark gray, weathers tan; massive; weathers in rhombohedral blocks; many crinoid columnals on weather surface, also echinoid spines, fusulinids and brachiopods present.	1.2
Shale, clayey, non-calcareous; black to dark gray; thin-bedded; non-fossiliferous.	.8
Limestone, dense, hard; argillaceous in lower part; dark gray, weathers tan-gray; massive; algae, crinoid columnals and brachiopods fragments present.	1.0
Hamlin shale formation (10.8 feet exposed)	
Shale, silty with some clay, calcareous; gray to gray-green, weathers light gray; arenaceous near bottom; weathers blocky to thin-bedded near base.	10.8
Base covered.	

Section 8

This section from the Neva limestone to the Salem Point shale of the Grenola limestone formation, inclusive, is exposed in a road out on U. S. 40 in the center of section 26, T. 11 S., R. 9 E.

Feet

Grenola limestone formation (6.75 feet exposed)

Neva limestone member (3.25 feet exposed)

Limestone, hard, massive; light gray, weathers light gray; weathers blocky; conchoidal fracture; crinoid columnals and echinoid spines. 1.0

Shale, silty, calcareous; dark gray to bluish-gray, weathers light gray; thin-bedded; fossiliferous. .75

Limestone, hard, dense; light gray, weather gray-white; massive, weathers blocky; crinoid columnals, echinoid spines and brachiopod fragments. 1.5

Salem Point shale member (3.5 feet exposed.)

Shale, silty with some clay, calcareous; gray to light gray; weathers light gray with calcareous plates on weathered surfaces; blocky to thin-bedded. 3.5

Covered interval.

Section 9

This section from the Howe limestone of the Red Eagle limestone formation to the Johnson shale, inclusive, is exposed is a road cut on U. S. 40 some 500 feet east of the center of section 26, T. 11 S., R. 9 E.

Feet

Red Eagle limestone formation (9.5 feet exposed)

Howe limestone member (2.5 feet exposed)

Limestone, soft; gray-orange, weathers tan-orange;

- massive; maroon stains on weather surfaces;
weathers porous and irregular. 2.5
- Bennett shale member (5.5 feet)
- Shale, silty with some clay, calcareous; dark
gray to black, weathers dark gray; thin-
bedded to fissile; brachiopods fragments. 5.5
- Glenrock limestone member (1.5 feet)
- Limestone, hard, dense, tan-gray, weathers tan;
massive, weathers blocky; some maroon stains;
fusulinids and brachiopods fragments. 1.5
- Johnson shale formation (3.5 feet exposed)
- Shale, silty with clay, calcareous; olive drab to
dark gray, weathers gray-green; thin-bedded to
blocky; unfossiliferous. 3.5



PLATE V

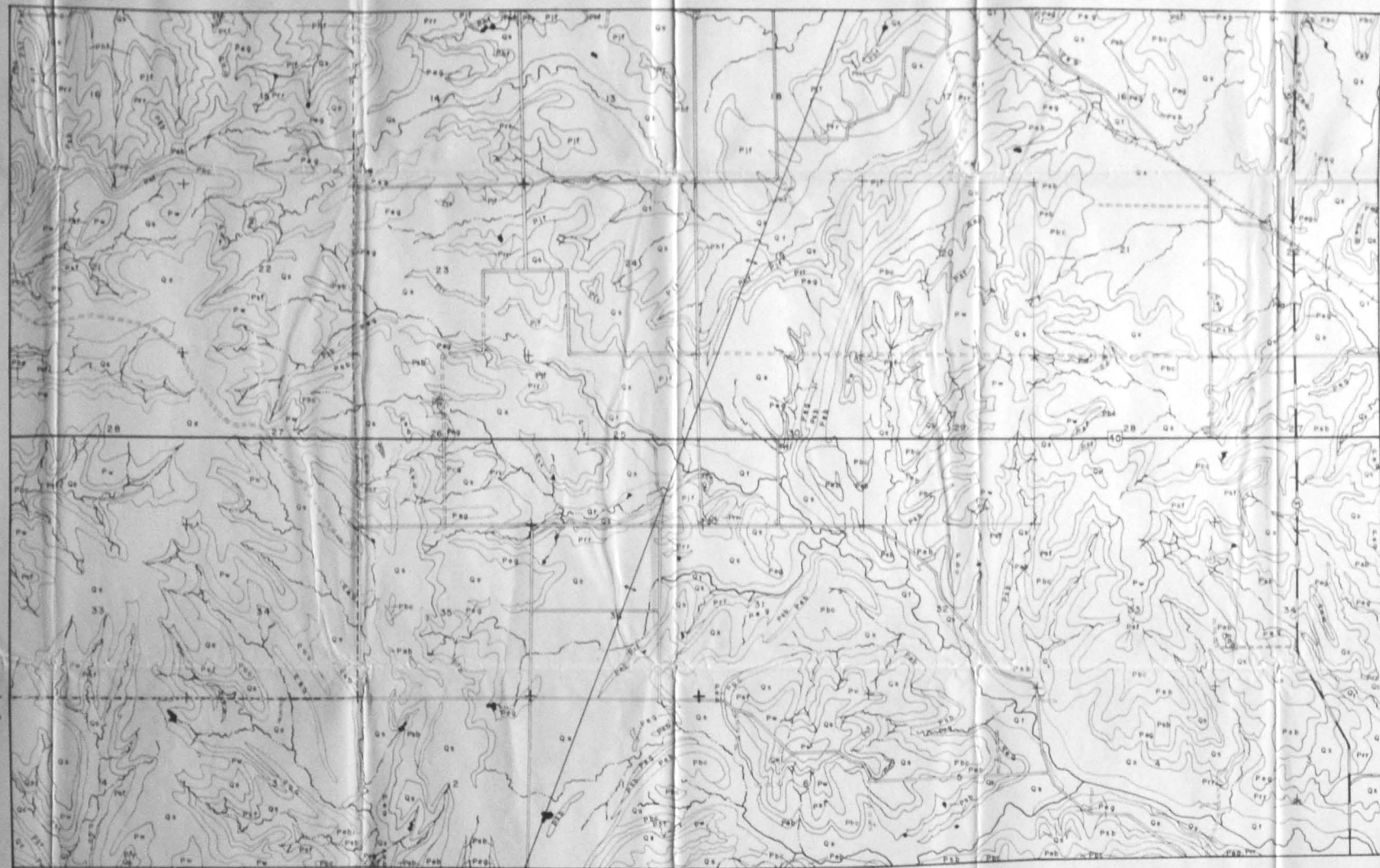
Geologic map and cross section of an area in southeast Riley county and northwest Wabaunsee county, Kansas.

(In Pocket)



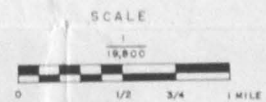
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GEOLOGIC MAP OF AN AREA IN SOUTHEAST RILEY COUNTY AND NORTHWEST WABAUNSEE COUNTY, KANSAS



EXPLANATION

FORMATIONS		SYMBOLS	
Q1	TERRACE DEPOSITS		U.S. HIGHWAY
Qk	DISCONFORMITY		STATE HIGHWAY
Pw	WRETFORD LIMESTONE		ALL WEATHER ROAD
Pst	SPEISER SHALE		ACCESS ROAD
Psk	FUNSTON LIMESTONE		BRIDGE
Psb	BLUE RAPIDS SHALE		RAILROAD
Psc	CROUSE LIMESTONE		TOWNSHIP CORNER
Psd	EASLY CREEK SHALE		SECTION CORNER
Pse	BADER LIMESTONE		COUNTY BOUNDARY
Psf	STEARNS SHALE		PERENNIAL STREAM
Psg	BEATTIE LIMESTONE		INTERMITTENT STREAM
Psh	ESKRIDGE SHALE		POND
Psi	GRENOLA LIMESTONE		GEOLOGIC CONTACT LINE
Psl	ROCA SHALE		ARTICLINAL AXIS
Psm	RED EAGLE LIMESTONE		CROSS SECTION
Psn	JOHNSON SHALE		
Pso	FORAKER LIMESTONE		
Psp	HAMLIN SHALE		
Pst	FIVE POINT LIMESTONE		
Psw	WEST BRANCH SHALE		
Psx	FALLS CITY LIMESTONE		
Psy	HAWKBY SHALE		
Psz	ASPINWALL LIMESTONE		



APPROXIMATE MEAN DECLINATION, 1959

MACK A. GASAWAY III
SUMMER, 1959

BASE FROM U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS
RANGE 9 EAST | RANGE 10 EAST
GEOLOGY AND DRAINAGE FROM AERIAL PHOTOGRAPHS AND MODIFIED AFTER BECK (1949) AND MUDGE (1949 AND 1950)

CROSS SECTION ALONG LINE X-X'

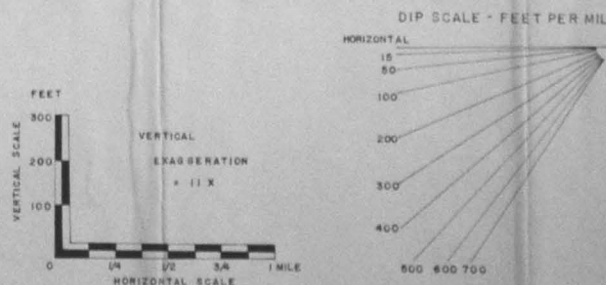
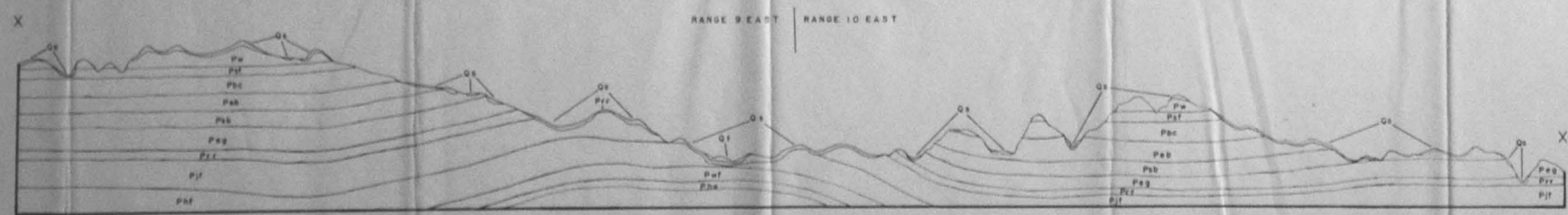


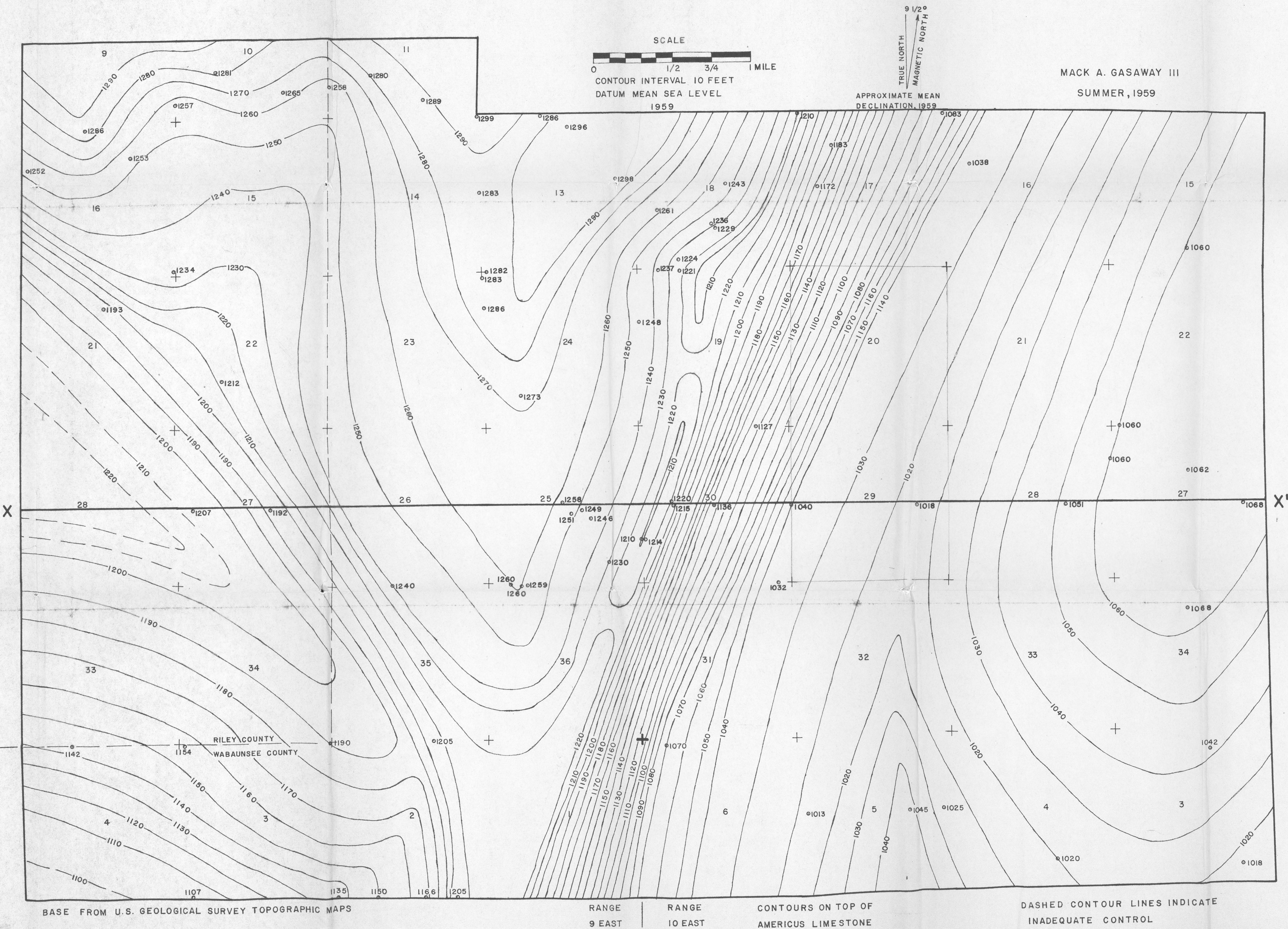
PLATE VI

Structure contour map of
an area in southeast Riley
county and northwest
Wabaunsee county, Kansas.
(In Pocket)



CHAMPION NO. 63
CLASP $6\frac{1}{2} \times 9\frac{1}{2}$

STRUCTURE CONTOUR MAP OF AN AREA IN SOUTHEAST RILEY COUNTY AND NORTHWEST WABAUNSEE COUNTY, KANSAS



**SURFACE EXPRESSION OF THE NEMAHA ANTICLINE IN SOUTHEASTERN
RILEY COUNTY AND NORTHWESTERN WABAUNSEE COUNTY, KANSAS**

by

MACK AMERICUS GASAWAY III

B. A., University of Colorado, 1956

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

**KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE**

1959

The area of investigation covers 40 square miles in southeast Riley county and northwest Wabaunsee county, Kansas and is bisected by U. S. Highway 40 in an east-west direction. The Nemaha anticline strikes through the general area although the actual axis of the anticline is to the west of the area of investigation. The purpose of this investigation is to map and describe the surface expression of the steepness of the east flank of the Nemaha anticline and the Zeandale dome and to determine, if possible, the origin of these surface expressions.

A general reconnaissance of the area was made and a reversal of dip because of the steepness of the east flank of the Nemaha anticline was discovered. A specific area was selected and upon detailed investigation it was found that there was surface expression of the Zeandale dome in the northwest corner. The area of investigation was found to be covered by thick, horizontal sedimentary rocks of lower Permian age.

In the investigation of the area these sedimentary outcrops were identified and measured in detail. The geology was mapped from aerial photographs and correlation checked by field surveys. Dips and strikes were recorded and with the accumulated data and the aid of a State Highway Commission of Kansas profile, a geologic cross section was prepared. A structure contour map on the top of the Americus limestone was constructed to help clarify the structural interpretation of the area.

The surface expression of the steepness of the east flank of the Nemaha anticline strikes N.20'E. through the center of the

area of investigation. The dip of the strata in this area increases to 200 feet per mile to the east as compared with an average of 40 feet per mile in the area. The reversal of dip is seen in the south-central part of the area but is obscured farther north by the surface expression of the Zeandale dome. The surface expression of the Zeandale dome is seen in the northwest, north-central and west-central parts of the area of investigation. Approximately 80 feet of closure appears to be present. More closure is present in the area of the surface apex of the dome. The dome is apparently located on the axis of the Nemaha anticline. The steep dips on the eastern flank of the Zeandale dome continue down the east flank of the Nemaha anticline. The sedimentary formations over the east flank of the Nemaha anticline show no evidence of thinning and no surface faults were found in the area of investigation.

The surface expression of the Zeandale dome and the east flank of the Nemaha anticline is believed to be the result of differential compaction of the younger sedimentary rocks over the uneven surface of the pre-Cambrian basement complex. The compaction of the sediments being further emphasized by the initial uplift of the Nemaha anticline that was contemporaneous with deposition, and post depositional deformation and uplift.