GEOLOGY OF AN AREA IN SOUTHWESTERN RILEY COUNTY, KANSAS

by

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INTRODUCTION

Location of the Area

The area covered by this investigation is located in the southwestern corner of Riley County, Kansas (Plate I). The Clay-Riley county line forms the western boundary and the Geary-Riley county line forms the southern boundary. The area is approximately six miles long and four miles wide, with the long direction east-west.

Geologic Setting

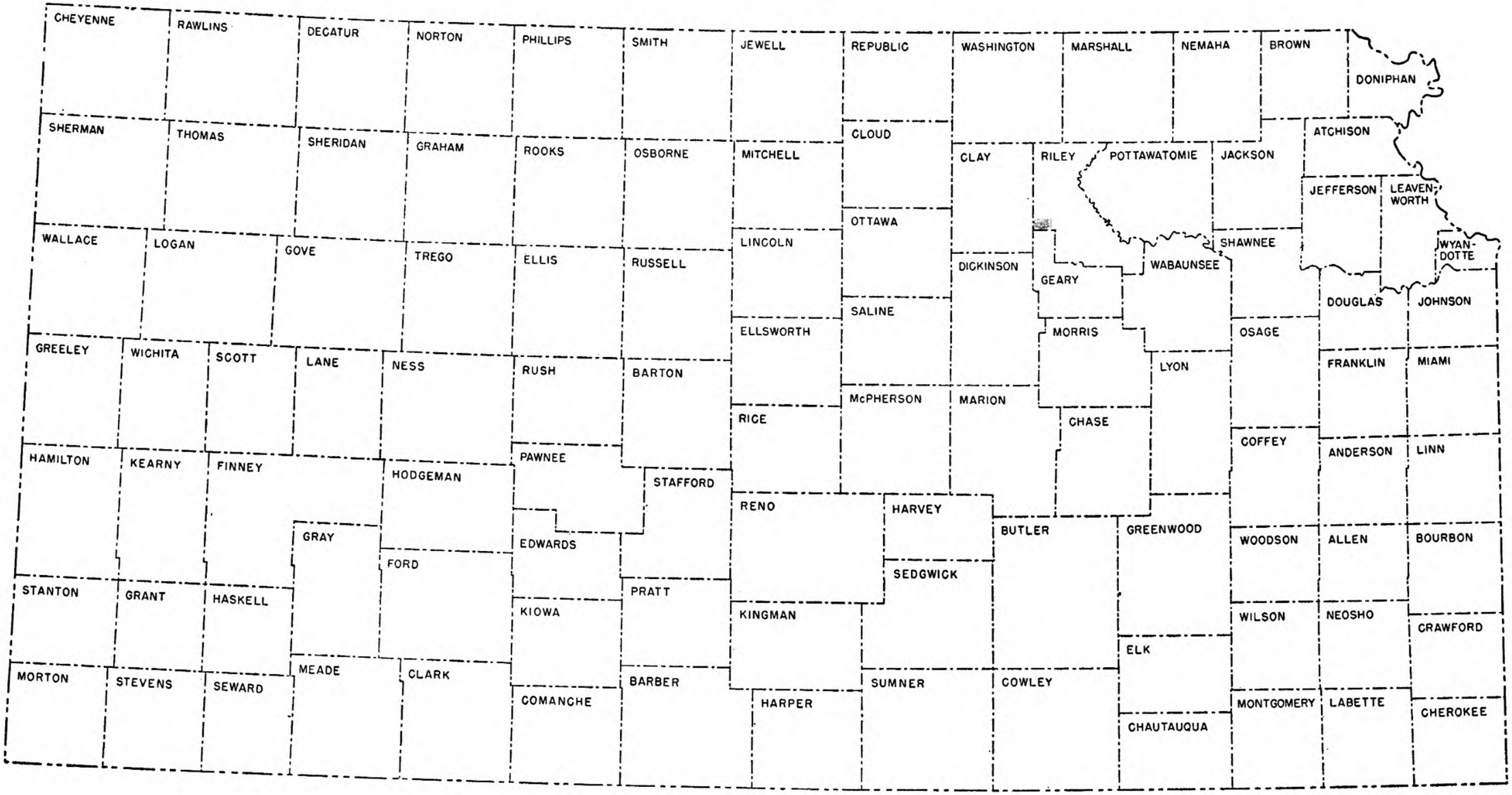
Southwestern Riley county lies within the Central Lowlands physiographic province in a subdivision called the Flint Hills uplands. The typical Flint Hills topography, a series of prominent scarps and dip slopes developed on weather resistant cherty or flinty Permian limestones, is located to the east and southeast of the problem area. Less typical of the Flint Hills region, the topography of the problem area can be divided into two minor types: The upland areas, which are cuesta uplands or the "dip-slopes" of resistant limestone layers; and the broken, hills country extending from the borders of the uplands downward to the valley floors or terraces where present.

The upland area which covers the larger part of the region generally lies at an altitude of 1200-1350 feet above sea level and is located stratigraphically above the Fort Riley limestone. The Towanda, Cresswell and Herington limestones, resistant strata

EXPLANATION OF PLATE I

Map of Kansas showing the area covered by this investigation.

PLATE I



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above the Fort Riley limestone, form small buttes and sinuous escarpments over the entire area. Although the upland areas are described as dip slopes of the limestone strata, they are almost everywhere covered by part of the shale unit overlying the scarp-making limestone.

The second type of topography is represented between the stream valleys and the upland area. It is limited in the problem area to outcrops of Fort Riley limestone, which forms a fence-like wall along Timber creek near the Clay county line.

Drainage in the area is well developed and forms a semi-rugged topography. The creek valleys are filled with Recent alluvium and terrace deposits. The uplands are covered over wide areas by unconsolidated Quaternary sediments of the Sanborn formation.

The main structural features in the area are the Irving syncline and the Abilene anticline. To the east is the Nemaha anticline and to the west is the Salina basin.

Statement of the Problem

The Abilene anticline is a pronounced anticlinal fold west of and nearly parallel to the Nemaha anticline. It runs through Clay, Riley and Marshall counties in Kansas. The Abilene anticline is along the same trend as the Voshell anticline farther south and the Barneston anticline to the north in Nebraska. A Synclinal fold east of the Abilene anticline and west of the

Nemaha anticline, and paralleling these features, is called the Irving syncline. The Irving syncline was named and described by Condra and Upp (1931) p. 10. Lee (1956), Nelson (1952), Neff (1949), Jewett (1951) and others have briefly described the surface expressions of the Abilene anticline and Irving syncline in Riley county and surrounding area. The purpose of this paper is to describe the surface expression of the Abilene anticline and any related structure in the area.

MAPPING PROCEDURE

Field work was started in the summer of 1957 and finished in the late fall of 1957. An extensive reconnaisance was made of the problem area and surrounding areas to obtain information concerning the stratigraphy and structural expression of the anticline. Formations were identified, sections were measured, and strikes and dips of the formations were measured with a plane table and alidade. The geology of Riley county had previously been mapped by Beck (1949) and Mudge (1949) and their map supplemented by aerial photographs served as a base map. The geologic map in this thesis was traced from the base map and aerial photographs (Fig. 2, Appendix). The base map was enlarged from two inches to the mile to four inches to the mile with a sketchmaster.

The structural map of the area was made by using a plane table and alidade in conjunction with aerial photographs (Fig. 2, Appendix). Bench marks were obtained from the United States

Geologic Survey and all elevations are referred to them. A base line was run through the center of the problem area. Elevations taken on other formations were projected up or down to the base of the Cresswell limestone.

The structural profile section was made across the area with a plane table and alidade. The section shows the surface expression of the anticline and syncline and steepening of the dip on the west side (Fig. 3, Appendix).

GEOLOGIC HISTORY

The geologic history of the problem area has been discussed by Koons (1955), Nelson (1952), and Lee (1956). Lee's report on the "Stratigraphy and Structural Development of the Salina Basin Area" is the most recent and complete of these reports and a major portion of the material was derived from it. The interpretations of structural movements is based on the following concept: if a sequence of rocks is deposited on an originally flat surface, and if this sequence of rocks is warped and folded before the later development of a second flat horizontal surface, the variation in thickness of the rocks between the two surfaces will reveal the amount and place of the deformation (Lee, 1956) that had taken place when the second surface was still undisturbed.

Paleozoic Era

This was an era of deposition, folding, erosion and faulting in Riley county. Rocks of Cambrian to Permian age were deposited. There were three principal periods of deformation during this era.

(1) The Arbuckle dolomites (Lamotte sandstone, Bonneterre dolomite, Roubidoux dolomite, Jefferson City and Cotter dolomite) were deformed and leveled by erosion before the deposition of the overlying St. Peter sandstone of early Ordovician age.

(2) The second period of deformation occurred during the deposition of the rocks between the St. Peter sandstone and the base of the Mississippian.

(3) The third period of deformation began in early Mississippian time, culminating at the end of Mississippian time and continued with decreasing emphasis until middle Permian time. It was during this period of deformation that the Nemaha anticline, Abilene anticline, Irving syncline and the Salina basin were formed. There were at least two types of deformations going on contemporaneously during Mississippian time. The first were the initial movements along the Nemaha and Abilene anticlines, whose maximum development occurred at the end of Mississippian deposition, and the second was progressive tilting of the region from south to north during Kinderhookian time, and later tilting in the opposite direction. The lack of subsurface data on the Abilene anticline restricts accurate determination of the structure forming sequence but it is believed to be contemporaneous with the Nemaha anticline.

Erosional surfaces are numerous all through the Paleozoic, the most prominent is the Mississippian "chat" below the

Pennsylvanian rocks. The "chat" is a residual chert derived from the weathering of Mississippian chert bearing limestones.

Mesozoic Era

The Mesozoic was predominantly an era of erosion and regional tilting to the west. There are no Mesozoic rocks present in the area but remnants of the Cretaceous Dakota formation outcrop in northwestern Riley county. It was shown by Lee (1956) that in the western part of the Salina basin pre-Dakota warping was downward to the southwest and post-Dakota warping was downward to the northwest.

Cenozoic Era

The Cenozoic era in this region was predominantly a period of erosion. Deposition occurred only in the Quaternary period. All the sediments in the area younger than Permian were completely stripped away by erosion during the Tertiary period.

The Pleistocene epoch of the Quaternary is known as the ice age. Two ice sheets extended into Kansas, but only the Kansan glacier penetrated as far south as the Kansas River and as far west as the Big Blue River. Glacio-fluvial sediments were deposited extensively in Riley County from the melt waters draining from the glaciers. Deposits of the Sanborn formation were formed during the Pleistocene epoch and are widely distributed on the divides. In Recent times streams have eroded their valleys and are now flanked by deposits of terrace materials and alluvium (Beck, 1949).

STRATIGRAPHY[1]

The stratigraphic units that outcrop in southwestern Riley county are all of sedimentary origin and range in age from Permian to Quaternary. The Florence limestone member, outcropping along the banks of Timber Creek near the Clay county line, is the oldest outcropping Permian rock in the area. The Herington limestone member, Permian age, is the youngest outcropping rock in this region. Much of the Paleozoic bedrock is covered by deposits of the Sanborn formation and recent alluvium.

Permian System

The Permian system in descending order consists of the Guadalupian, Leonardian, and the Wolfcampian series. The Wolfcampian series, in descending order, consists of the Chase, Council Grove and Admire groups. The Chase group is the only one represented in the problem area.

The Chase group was named from a type exposute in Chase county by Prosser (1902). Prosser included it in all the units from the Winfield limestone down to the Wreford limestone. Moore, et al. (1936) placed the top of the Chase group to include the Luta limestone. Later, Moore, et al. (1951) defined the Chase group to include the (in descending order) Nolans limestone, Odell shale, Winfield limestone, Doyle shale, Barneston

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1 Moore and Mudge's new stratigraphic classification is used.

limestone, Matfield shale, and the Wreford limestone. The formations of the Chase group outcropping in the problem area are from the Nolans limestone down to the Barneston limestone. A geologic column of these formations is shown in Plate II.

Barneston Limestone Formation: The Barneston limestone was named by Condra and Upp (1931). It consists of the Fort Riley limestone member in the upper part, the Oketo shale member in the middle part, and the Florence limestone member in the lower part.

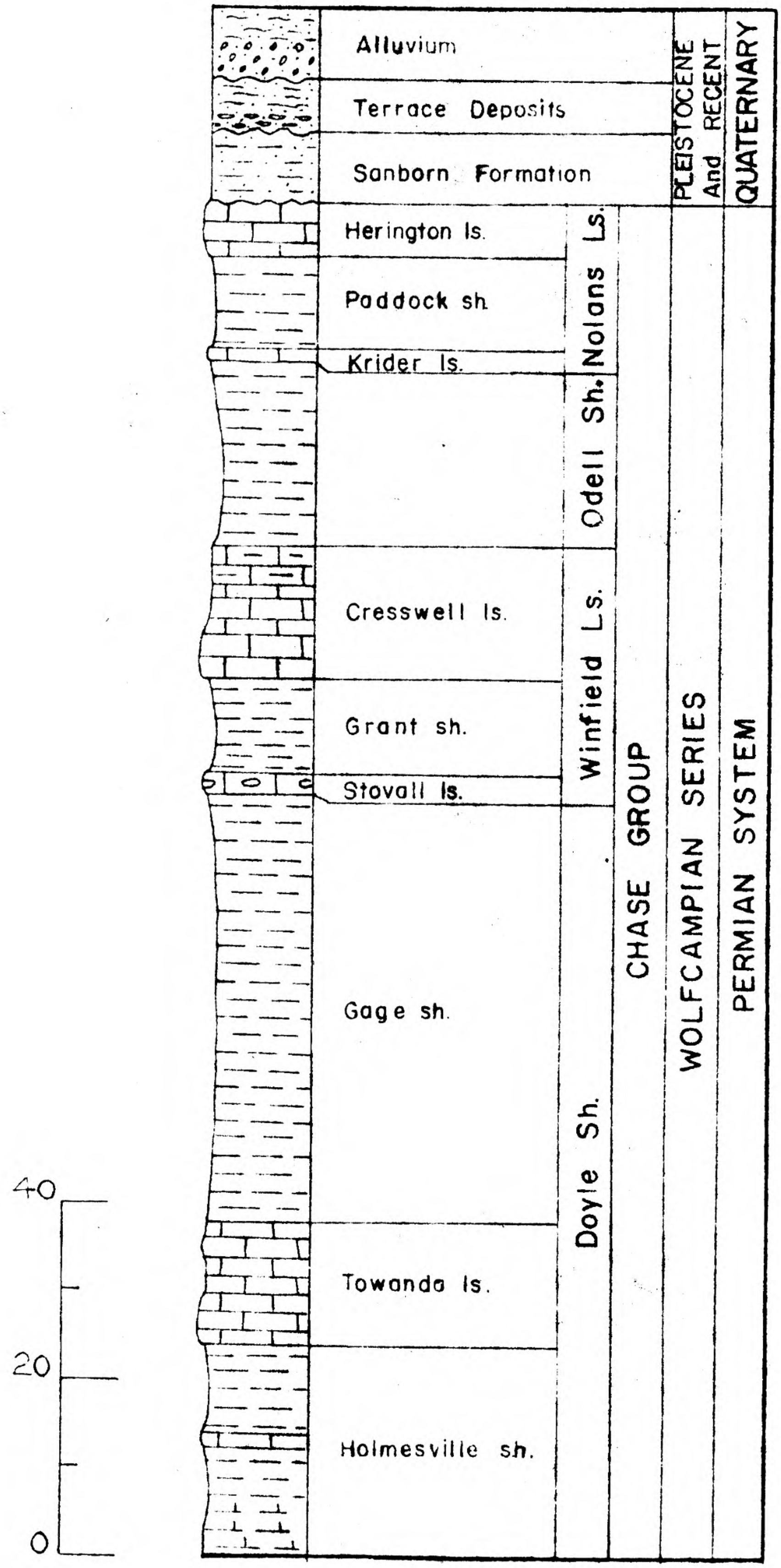
Florence limestone member. The Florence limestone is defined as overlying the Blue Springs shale and underlying the Oketo shale (Moore, 1932). Only the top few feet of the Florence is present in the problem area. This is along the banks of Timber Creek near the Clay county line. The Florence is composed of massive beds of limestone containing numerous bands and nodules of chert with a thin shale parting near the top. The limestone is usually light gray to gray and weathers gray to tan-gray. It is usually fossiliferous.

Oketo Shale Member. The Oketo shale was named by Moore, et al. (1936) from exposures found near Oketo in Marshall county, Kansas. The Oketo shale is easily recognized in the field by its stratigraphic position between the Fort Riley and the Florence limestone and the abundance of its fossils. The shales are bluish-gray to tan, silty, clayey, calcareous and thin-bedded. Locally thin beds of limestone are present in the upper part of

EXPLANATION OF PLATE II

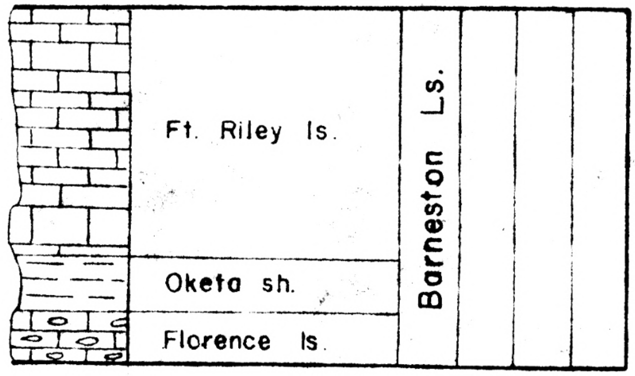
Generalized stratigraphic column of southwest Riley county, Kansas.

PLATE II



Alluvium
Terrace Deposits
Sanborn Formation
PLEISTOCENE And RECENT
QUATERNARY
Herington ls.
Paddock sh.
Krider ls.
Nolans Ls.
Odell Sh.
Cresswell ls.
Grant sh.
Stovall ls.
Winfield Ls.
Gage sh.
Towanda ls.
Holmesville sh.
Doyle Sh.
CHASE GROUP
WOLFCAMPIAN SERIES
PERMIAN SYSTEM
40
20
0

PLATE II (Cont.)



the shale. The fossils observed in the Oketo shale are: Dictyoclostus americanus, Composita ovata, Derbyia crassa, Hustedia mormoni, Polypora sp., crinoid columnals and Aviculopecten occidentalis. The average thickness of this shale is about 6 feet.

Fort Riley Limestone Member. The Fort Riley limestone was first named by Swallow (1866). The type locality is Fort Riley, Geary county, Kansas. Prosser (1895) described the Fort Riley as including the Florence limestone. Prosser and Beede (1904) later redefined the Fort Riley to include the thinner bedded limestone both above and below the massive Fort Riley main ledge. Moore, et al. (1936) revised the terminology of the unit and included the Fort Riley limestone as the upper member of the Barneston limestone. The Fort Riley limestone overlies the Oketo shale and underlies the Holmesville shale.

The Fort Riley limestone crops out in the problem area along Timber Creek near the Clay-Riley county line. The Fort Riley is easily recognized by its thickness, "rim rock" exposure, and stratigraphic position above the Florence limestone. The lower beds of this limestone are so constant in their wall-like outcrop that they look artificial in places.

The Fort Riley limestone consists of massive limestone in the lower part with a less massive zone near the top. Thinner limestones in which there are many shale partings make up the rest of the member. The lower portion of the Fort Riley limestone which outcrops so conspicuously and so consistently is called the "Fort Riley rim rock." This massive ledge of limestone attains a thickness up to eight feet and is very resistant to weathering and erosion. Some of the limestone ledges weather to form blocks, others weather to form plates. The limestones range from fairly hard to soft and are somewhat dolomitic. They are usually tan to gray and weather tan-gray. A shaly-lime parting is usually present near the base of this limestone member. The upper contact of the Fort Riley and the overlying shale seems to be characteristically blue-gray poorly resistant massive limestone. It is difficult to define this contact in most places. Fossils are not common in the Fort Riley limestone as a whole, but common lower Permian brachiopods and pelecypods are to be seen at various exposures. Fossils identified in the Fort Riley limestones are: Derbyia crassa, Dictyoclostus sp., Meekela striatocostata, echinoid spines, crinoid columnals, Rhombopora sp., and brachiopod fragments. The average thickness of the Fort Riley limestone is about 26 feet.

Doyle Shale Formation: The Doyle shale was named from exposures on Doyle Creek, southwest of Florence, Marion county, Kansas. The name was given by Prosser (1902). The Doyle shale overlies the Barneston limestone and underlies the Winfield limestone. Condra and Upp (1931) divided the Doyle shale into three members, in descending order: Gage shale, Towanda limestone, and Holmesville shale. Moore, et al. (1936) dropped the name Doyle shale and raised the members to formation rank. Moore's redefinition was not accepted and the tendency is to retain the name in its original sense and to classify the three parts of the formation as members.

Holmesville Shale Member. The Holmesville shale was named by Condra and Upp (1931) from exposures near the town of Holmesville, Gage county, Nebraska. It overlies the Fort Riley limestone and underlies the Towanda limestone.

The Holmesville outcrops along the western row of sections in the problem area. Outcrops of the Holmesville shale are almost always associated with those of the Towanda limestone. The shale is readily identified by its stratigraphic position.

The Holmesville consists predominantly of shales but contains thin limestones in the middle and lower part of the member. The upper half of the Holmesville is an argillaceous shale and is gray, yellow, green and maroon in color. The maroon zone is in the upper middle part while the uppermost few feet, exposed in many places, is everywhere green. The lower half of the Holmesville is a tan to gray, silty, calcareous shale that is covered by a mantle of soil in most places, making it hard to recognize. The middle limestone is soft, usually argillaceous, and weathers to a honey combed appearance. The basal limes are platy, silty and calcareous. The Holmesville shale is noted for being non-fossiliferous. The average thickness of the shale in the problem area is about 24 feet.

Towanda Limestone Member. The Towanda limestone was named by Fath (1921) from exposures near Towanda, Butler county, Kansas. The Towanda limestone overlies the Holmesville shale and underlies the Gage shale. It is easily recognized by its thickness, color, absence of fossils, small blocks and plates found on the weathered surface and its position above the Fort Riley Limestone.

The Towanda limestone crops out along the western row of sections in the problem area. It forms the first prominent bench above the Fort Riley and is readily traceable on the landscape.

The Towanda varies from a soft yellow limestone to a gray lithographic limestone. It is hard, dense in some zones, massive, and weathers to small blocks and plates. The color is gray-orange to tan-brown and limonite stains and nodules appear abundantly on the surface. Thin shale partings are present throughout the area. The Towanda limestone is characterized by an absence of fossils. The average thickness of the Towanda limestone in the problem area is about 14 feet.

Gage Shale Member. The Gage shale was named by Condra and Upp (1931) from type exposures in Gage county, Nebraska. It overlies the Towanda limestone and underlies the Stovall limestone. The Gage shale is recognized in the field by its position beneath the easily recognized Winfield limestone.

The Gage shale outcrops throughout the problem area. The upper part of the Gage, in most outcrops, is exposed beneath the Stovall limestone.

The Gage shale member is divisible into three parts: The lower and greater part which is predominantly maroon, mottled with green, and contains some well defined thin green lenses; the upper two-thirds which contains thin limestone lenses; and an upper part less than 10 to 15 feet thick, consisting of yellowish-gray to gray-green shale containing abundant fossils. Locally the upper shale can almost be considered a coquinoid shale. The shale is composed of silt with some clay and is thin bedded to blocky. The maroon zones are non-calcareous, but the others are at least slightly calcareous. The following fossils are generally present in the upper shales: Derbyia crassa (very abundant), Dictyoclostus americanus, crinoid columnals, Stenopora sp., Polypora sp., Rhombopora, echinoid spines, Aviculopecten occidentalis. The average thickness of the shale in the problem area is 49 feet.

Winfield Limestone Formation: Prosser (1897) introduced the term Winfield as a stratigraphic name. He (Prosser, 1895), had formerly called the same strata the "Marion chert and concretionary limestone." Although the name Winfield was applied because of exposures near Winfield in Cowley county, Kansas, Prosser's original type exposure near Marion in Marion county, Kansas should be regarded as typical for the formation. The Winfield limes were divided into three members by Condra and Upp (1931): the Cresswell limestone in the upper part; the Grant shale in the middle part; and the Stovall limestone in the basal part. Moore (1936) gave the name Luta limestone member to the uppermost beds of the Winfield limestone. Moore, et al. (1951)

accepted the definition of the Winfield limestone made by Condra and Upp and in so doing, dropped the name Luta as a separate stratigraphic unit. This later designation will be used in this report.

Stovall Limestone Member. The Stovall limestone was named by Condra and Upp (1931) from type exposures situated on the Stovall farm seven miles southwest of Florence, Marion county, Kansas. The Stovall overlies the Gage shale and underlies the Grant shale. It is easily recognized in the field by the presence of nodular chert bands, relative thinness, and its stratigraphic position (Plate 5, Fig. 1).

Outcrops of the Stovall limestone are almost invariably associated with those of the Cresswell limestone. It outcrops throughout the problem area.

The Stovall in the area of investigation is hard, dense, massive and weathers down until in some places, only the nodular chert is left (Plate V, Fig. 1). It is gray to tan-gray in fresh exposures and weathers light gray to tan. Chert nodules are abundant in this limestone. Silicified fossils of Dictyoclostus americanus are very abundant throughout this area. Other fossils found in the Stovall are: crinoid columnals, echinoid spines, Polypora sp., and brachiopod fragments. The average thickness of this member, in the problem area, is from 1.5 feet in the north to 2.4 feet in the south.

Grant Shale Member. Condra and Upp (1931) gave the name

Grant shale to the middle member of the Winfield formation. The type locality for this member is between five and six miles north of Florence, Kansas. This unit overlies the Stovall limestone and underlies Cresswell limestone. This shale is easily recognized by its stratigraphic position in the Winfield limestone.

The Grant shale crops out throughout the problem area and is always associated with the Cresswell limestone.

The Grant shale is silty, thin-bedded and calcareous. It is tan-gray and weathers tan. The upper contact of the Grant shale and the Cresswell limestone is noted for structures that resemble organic burrows. These have been replaced by calcite, are approximately one inch wide by one-half inch high and are all connected in a random pattern. They are noted throughout the problem area. Fossils vary in abundance from one exposure to the next but are usually abundant. The fossils observed in this shale are: Composita ovata, Derbyia crassas, Dictyoclostus americanus, Chonetes granulifera, echinoid spines, Polypora sp., Rhombopora sp., and Aviculopecten occidentalis. The average thickness of the Grant shale is about 10.5 feet.

Cresswell Limestone Member. The name Cresswell was given by Condra and Upp (1931) to the third member of the Winfield formation from exposures in Cresswell township in Cowley county, Kansas. The Cresswell limestone overlies the Grant shale and underlies the Odell shale.

The Cresswell limestone is the most persistent outcropping rock in the problem area. It is easily recognized by its massive light gray limestone, abundance of echinoid spines in the basal part, and its position above the easily identified Stovall limestone.

The base of the Cresswell limestone consists of a unit bedded persistent limestone generally less than three feet thick (Plate VI, Fig. 2). The basal "unit" is persistent, resistant to weathering, contains abundant fossil fragments, and chert nodules are present locally. The abundance of echinoid spines and numerous crinoid columnals is a diagnostic feature but the fossils may be absent locally. Hooker (1956) attributes the absence of fossils in the Cresswell to the high magnesium content of the limestone at that particular locale. Test plates and brachiopod fragments are also common. The lower part of the Cresswell is tan-brown to light gray and usually weathers tan-gray.

The basal unit of the Cresswell is overlain by thinner bedded limestones that grade into the platy beds of the Luta limestone (Plate IV, Fig. 2). The Luta beds are composed predominantly of light grayish-white platy limestones, but locally may be a shale containing abundant geodes and concretions. The geodes range from a few inches up to one foot in diameter. These geodes are numerous in the northern part of the problem area. In the southern part of the problem area the Luta beds range from a white powdery calcareous marl used by farmers for agricultural lime, to a thin, platy, marly limestone up to ten feet thick. The Luta beds are characteristically nonfossiliferous. The Cresswell limestone within this area ranges from fourteen to eighteen feet in thickness.

Odell Shale Formation: The Odell shale was named by Condra and Upp (1931) from exposures east of Odell, Gage county, Nebraska. The Odell shale member comprises the lower part of the old Enterprise shale and lies between the top of the Winfield formation and the base of the Krider limestone. Moore (1936) elevated the Odell shale to the rank of formation, which assignment will be accepted here.

The Odell shale crops out over the problem area, usually in close association with the Herington limestone.

The Odell is a non-calcareous silt with some clay. It is gray-green to maroon, often mottled with green, in the upper part, and yellow to gray green in the lower part. The shale is noted as being non-fossiliferous. The average thickness of the Odell in the problem area is about 21 feet.

Nolans Limestone Formation: The Nolans limestone was named from the type locality near Emmons, Washington county, Kansas. Moore (1936) defined this formation as overlying the Odell shale and underlying the Pearl shale. The Nolans limestone consists of the following members in ascending order: 1. Krider limestone, 2. Paddock shale, and 3. Herington limestone.

Krider Limestone Member. The Krider was named by Condra and Upp (1931) from type exposures near Krider in Gage county, Nebraska. The Krider overlies the Odell shale and underlies the Paddock shale.

The limestone is easily recognized in the problem area by its stratigraphic position below the Herington limestone. It outcrops throughout the problem area and is invariably associated with the Herington Limestone and Paddock shale.

The Krider is a single massive bed of limestone. It is a soft, tan-gray, dolomitic limestone that has sugary texture. Fossils found in this unit are Myalina sp., and Aviculopecten occidentalis. The average thickness of the limestone, in the problem area, is about 1.5 feet.

Paddock Shale Member. The Paddock shale was named by Condra and Upp (1931) from outcrops 1/4 mile south of Krider, Paddock Township, Gage county, Nebraska. Moore (1936) designated the Paddock shale as the middle member of the Nolans formation. The Paddock shale overlies the Krider limestone and underlies the Herington limestone.

The Paddock shale outcrops throughout the problem area and is invariably associated with the Herington limestone. It is easily recognized by the nearly constant thickness, general olive-gray color, and the stratigraphic position within the Nolans limestone.

The Paddock is a thin-bedded, gray to olive-drab shale that weathers tan. It is composed of non-calcareous clay in the upper half and grades into calcareous silt in the lower half. Molds of _Aviculopecten occidentalis_ occur in some of the bedding planes. The average thickness of this unit throughout the problem area is about 12 feet.

Herington Limestone Member. The Herington limestone was named by Beede (1908) and was included as a part of the Marion stage. Moore (1936) defined the Herington as the top member of the Nolans limestone. The Herington overlies the Paddock shale and underlies the Wellington formation.

The Herington limestone caps many of the hills throughout the problem area. Only the lower few feet of limestone is present in any of the outcrops. It is easily recognized by its thickness, color, soft dolomitic texture, molluscan fauna, and by the prominent hillside bench it forms.

The Herington is a medium hard dolomitic limestone in which there are thin shale partings. The limestone is massive, porous, weathers blocky to platy, and has a sugary texture. It is yellowish to sandy-appearing. The limestone contains abundant molluscan fauna. The average thickness of the Herington around the problem area is about seven feet.

Quaternary System

Pliestocene Series: Glacio-Fluvial outwash material, deposited by the Kansan glacier, is prominent in some of the higher reaches of the stream valleys to the north and east of the problem area. There is evidently some outwash material in the problem area but it was not recognized in any of the immediate outcrops. The Glacio-Fluviatile outwash deposits consist of clay, sand and gravels. Chert and limestone make up the larger particles.

Sanborn Formation. The Sanborn formation blankets most of the divide areas in the problem area. It consists of materials deposited by wind, slope-wash and the process of soil creep. Soils on the upland and valley slopes have developed on materials called the Sanborn formation.

Terrace Deposits. Gravel and sand laid down by present day streams in earlier cycles of deposition are called Terrace deposits. These Terrace deposits are found along Timber, Madison and Dry Creeks in the problem area.

STRUCTURE

Regional Structures

Nemaha Anticline. The Nemaha anticline is one of Kansas' major positive areas, extending from Omaha, Nebraska to Oklahoma City, Oklahoma (Plate III). The anticline lies to the east of the problem area and strikes approximately N 18 E. In the northern portion of Nemaha county, Kansas, Pre-Cambrian rocks of the Nemaha anticline are encountered 500 feet below the surface and in the southern portion in Sumner county, Kansas they are encountered at 3000 feet. The Nemaha is a truncated anticline, plunges toward the south, and is asymmetrical with the steeper dips on the east flank. It parallels the Forest City Basin on the east and the Abilene anticline on the west. Maximum relief on the east side of the Anticline occurs in Nemaha county where the crest is 3200 feet above the floor of the Forest City Basin. The relief decreases to a minimum in the southwest part of Butler county.

The Nemaha anticline is a post-Mississippian structure. After the initial folding the crest of the anticline was peneplained, followed by faulting along the east side. This fault has been mapped in the subsurface by Lee (1956), Koons (1955) and Rieb (1954). Permian deformation is visible at the surface in some places. Ratcliff (1957) mapped the surface expression of the fault in northeast Pottawatomie county, Kansas. The Nemaha anticline has been known by the following names (Jewett 1941): Nemaha Mountains, Table Rock anticline, Nemaha ridge, Granite ridge, Nemaha Granite ridge and Nemaha-Oklahoma City uplift.

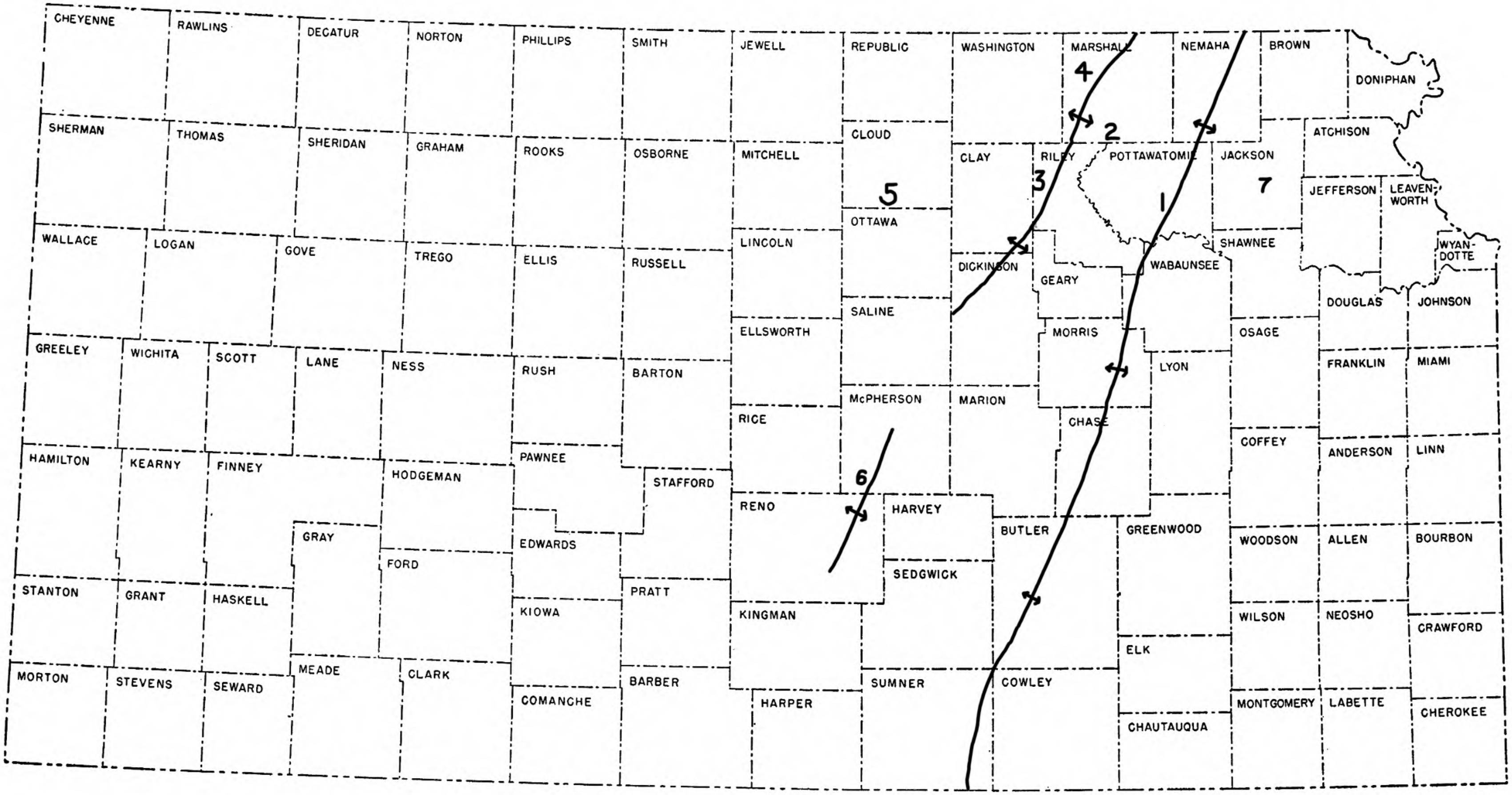
Salina Basin: The Salina Basin is a post-Mississippian structure to the west of the problem area (Plate III). It occupies an area in north-central Kansas between the northern end of the Nemaha anticline on the east and the Central Kansas Uplift on the west. It is bounded on the south by an unnamed arch like structure, which separates it from the Sedgwick Basin, and extends into Nebraska on the North. The basin lies on the

EXPLANATION OF PLATE III

Regional and local Structures

1. Nemaha anticline
2. Irving syncline
3. Abilene anticline
4. Barneston anticline
5. Salina basin
6. Voshell anticline
7. Forest City basin

PLATE III



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margin of an earlier structural basin referred to as the North Kansas Basin. The Salina Basin had no separate existence until the uplifting of the Nemaha anticline divided the North Kansas Basin and developed the Salina basin on the west and the Forest City Basin on the east. The Salina Basin was at first a structural basin revealed by leveling of Pre-Pennsylvanian rocks (Lee, 1956) while during Pennsylvanian time it was a subsiding area in which thick Pennsylvanian sediments accumulated. During post-Mississippian deformation several northeast trending structures were formed in the basin with their strike parallel to the Nemaha anticline. The structures are the Voshell anticline, Abilene anticline, and the Barneston anticline (Lee, 1956).

<u>Barneston Anticline</u>. This is a post-Mississippian anticline present in outcropping rocks in southern Nebraska and Northern Kansas. It is considered to be the northern extension of the Abilene anticline (Plate III). This anticline is separated from the Nemaha anticline by the Irving syncline.

<u>Voshell Anticline</u>. The Voshell is an anticline in McPherson and Harvey counties that is approximately parallel to the Nemaha anticline which lies about 50 miles to the east (Plate III). It is approximately in line with the Abilene anticline farther north. According to Bunte and Fortier (1941): "The Voshell trend consists of an anticlinal fold extending in a northeasterly direction and plunging southwest. A reverse fault with a throw of about 400 feet is present on the west side of this anticlinal

structure. The strike of the fault is almost parallel with the axis of the Voshell anticline and it is situated approximately 1/4 mile west of the axis. It appears that no structural movement had taken place here before Kinderhookian deposition. In all probability the Voshell anticline was formed contemporaneously with the forming of the Nemaha Granite Ridge of east-central Kansas."

Local Structures

Abilene Anticline. The dominant structural feature in this area is the Abilene anticline (Plate III). It was named by Barwick (1928). He described it as a fold of considerable size paralleling the larger Nemaha anticline to the east and bordering the Salina Basin to the west. The Abilene anticline trends north northeast through Riley county and is recognized in the surface rocks of this area. The Abilene anticline extends into west central Dickinson county, on the south, terminating in the Salina Basin syncline. It extends into northern Kansas and Nebraska on the north, where it is called the Barneston anticline.

The Abilene anticline was formed in post-Mississippian time contemporaneously with the surrounding regional structures. The period of deformation began in Mississippian time reaching its peak at the end of Mississippian and continued diminishingly into Permian time.

The Abilene anticline is an asymmetrical plunging anticlinal fold. In Riley county the anticline dips two to four degrees to the southeast on its southeastern flank and zero to one degree to the northwest on its west flank. Some of the steepest dips to be found in surface rocks in Riley county are found along this structure. The crest of the anticline plunges to the southwest 22 feet per mile (Nelson, 1952).

The Abilene anticline is believed by many to be the surface expression of a fault in the Pre-Cambrian basement complex. Sub-surface maps made with the scanty data available seemed to indicate a fault of some magnitude is present along the eastern flank of the anticline. Koons (1955), Rieb (1954), Nelson (1952) and Lee (1956) have all done subsurface work on this structure. Koons (1955) called the fault a hinge fault having 400 feet of displacement upward to the west in Marshall county and disappearing completely in Clay county. The younger beds were draped over the escarpment to produce a supratenuous fold. Rieb (1954) called it a rotational fault, the west side being elevated to the north and depressed to the south. Nelson (1952) described it as a normal fault with an oblique slip movement that affected the clockwise rotation of the joint pattern in the area. Lee also calls attention to the probable existance of a reverse fault along the Voshell anticline to the south. Four hundred feet of downward displacement may exist on the west side of this structure. Lee also points out that the Voshell anticline farther south is approximately in the same trend with the Abilene anticline, but the two probably are not connected. Neff (1949) described the causal stresses of the Abilene and Nemaha faults to be the result of tension resulting from the subsidence of the basins to either side of the two structures.

Irving Syncline. The Irving syncline is a fold east of the Barneston or Abilene anticline and west of the Nemaha anticline (Plate III). The Irving syncline was named by Condra and Upp (1931): "The narrow trough between the Barneston arch and the Table Rock arch is herein named the Irving syncline from Irving, Kansas." Irving is in southern Marshall county.

The Irving syncline is an asymmetrical syncline with its axis paralleling the east flank of the Abilene anticline. In Riley county the syncline dips two to four degrees to the southeast on its west limb and very gently to the west on its east limb. The syncline plunges to the south at approximately the same rate as the Abilene anticline. The Irving syncline, or what is believed to be an extension of the Irving syncline crosses the problem area in a north north-easterly direction (Fig. 2, Appendix).

The Irving syncline is believed to be post-Mississippian in age. It was formed contemporaneously with the uplifting of the Abilene and Nemaha anticlines. It is believed to be a structural syncline, due to the uplifts on either side of it, and not a subsiding basin.

Surface Structural Geology. The axis of the Abilene anticline strikes approximately N 50 E through Sec. 13 and 14, T 9 S, R 4 E, in the northwest corner of the problem area. To the east a synclinal axis parallels the anticlinal axis, passing through Sec. 25, 26, and 35, T 9 S, R 4 E and Sec. 17, 18 and 19, T 9 S, R 5 E (Fig. 2, Appendix).

The majority of the rocks in the problem area strike approximately N 40 E, with local variations from this amount. The surface rocks on the northwest flank of the anticline dip zero degrees to 30 minutes to the northwest. On the southeast flank of the anticline or the northwest limb of the syncline the surface rocks dip from one to two degrees to the southeast. On the southeast limb of the syncline the dips flatten out and dip from zero degrees to 30 minutes to the northwest (Fig. 1, Appendix). The strikes and dips of the surface rocks are probably due to the drape effect of the sediments over the Abilene anticline and their return to the regional dip of the area (Fig. 3, Appendix).

The anticlinal structure is responsible for the older rocks of the Barneston limestone and Doyle shale formations, outcropping in the northwest corner of the problem area (Fig. 1, Appendix). The synclinal axis can be traces by following the western edge of the Nolans limestone formation across the problem area. Merryman (1957) found the shale sections thinning over the Abilene anticline in the Winkler area. There probably is a tendency towards the same thinning effect in this area but it was not immediately recognizable.

Faulting. The Stovall and Cresswell limestones are locally faulted throughout the area (Plate IV, Fig. 1, Plate V, Fig. 2).

EXPLANATION OF PLATE IV

Fig. 1. Normal fault of the Cresswell limestone member. SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 31, T 9 S, R 5 E.

Fig. 2. Luta limes of the Cresswell limestone member. SW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 30, T 9 S, R 5 E.

PLATE IV

Fig. 1

Fig. 2

EXPLANATION OF PLATE V

Fig. 1. Typical outcrop of the Stovall limestone showing nodular chert. SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 31, T 9 S, R 5 E.

Fig. 2. Series of small normal faults in the Stovall limestone. NW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 30, T 9 S, R 5 E.

PLATE V

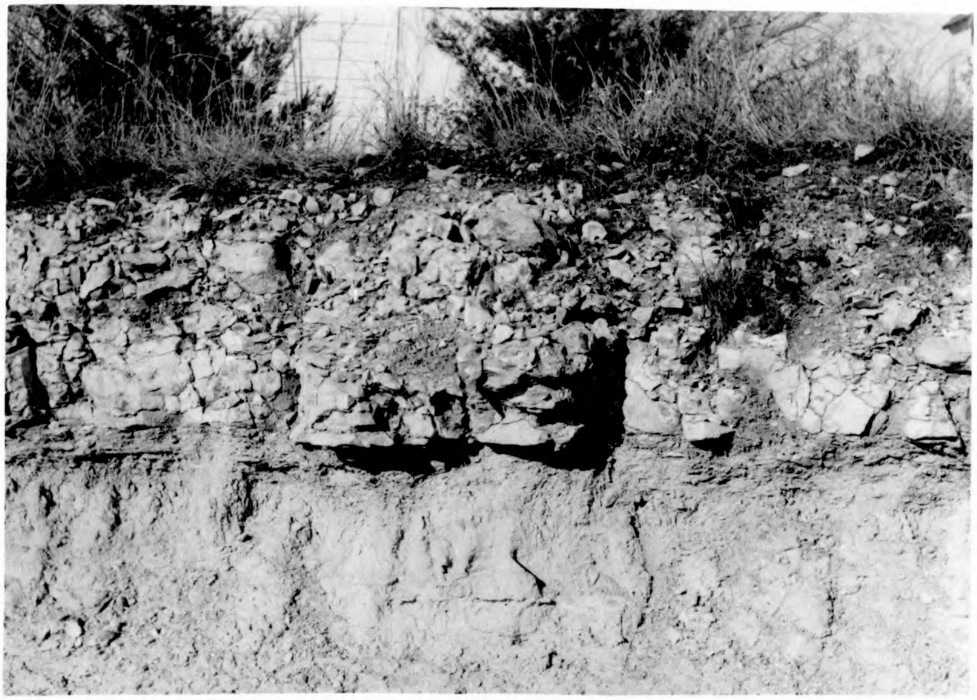

Fig. 1

Fig. 2

Fault displacement is small ranging from a few inches up to five feet. There are both normal and reverse faults present in and around the problem area with no apparent obvious cause.

High angle normal faults are numerous in the Cresswell and Stovall limestones, with displacements from a few inches to five feet. A typical normal fault in the Cresswell limestone can be found in Sec. 31, T 9 S, R 5 E (Plate IV, Fig. 1). The Grant shale has a general thickness of 10.5 feet and separates the Cresswell limestone from the Stovall limestone. At the faulted structure the displacement of the fault is absorbed in the shale causing irregularities in the shale thickness. There are thick shale sections above and below the two limestones and these are believed to absorb the displacing forces, thus keeping the limestone units above and below from being faulted.

The faults in NE$\frac{1}{4}$, Sec. 31, T 9 S, R 5 E rupture both the Stovall and the Cresswell limestones. Shale has been forced into the space opened by the break in the strata. It was also noted that the downthrown side was nearest the valley.

Thrust and low angle reverse faults are numerous in the Stovall limestone in and around the problem area. Reverse faulting is noted on both sides of the anticlinal and synclinal axis with the upper bed projecting away from the crest or structural high. The Stovall limestone does not yield plastically to deforming forces because the abundance of chert present makes it an extremely brittle unit. The faults in and around the problem area display a heave of two to four feet and a throw of one to two feet. The reverse faults in this area tend to have a heave twice that of the throw (Nelson, 1952).

Neff (1949) pointed out that the uniformity and small throw of the displacements in the Stovall suggest that they are the result of compaction rather than a more active stress such as lateral compression. The thrusts seem to be towards the valleys and away from the structural highs. Some lateral movement in the Gage shale, caused by easy lateral relief due to erosion of the valleys, might be augmented by seepage of water into clay zones of the shale. Because movement of the Gage shale is downward from the crest of the anticline it would create lateral forces in that direction. Such action would cause the Stovall to become bent and warped and at places where the forces become too great, small thrust faults would develop. Irregularities in the Stovall would not be reflected in the thicker Cresswell limestone except where causal stresses were exceptionally great.

The flexure in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 8, T 9 S, R 5 E and the fault in the NE$\frac{1}{4}$, Sec. 1, T 9 S, R 4 E are both in the Stovall and both have the lower side facing the valley. There are undoubtedly more thrust faults present in the problem area, but they are concealed by a thick mantle. As Neff (1949) pointed out in his thesis, most of the surface faulting in the problem area is due to relief by erosion of stresses resulting from differential compaction and down dip plastic flow of the enclosed thick shales. Relief of the stored stresses are in the direction of the strike and the thrust of the faults.

Neff (1949) showed that there are two major sets of joints in the area. One set strikes approximately north northeast and the other set is approximately at right angles to it. In each instance the strike of the fault appears to parallel one of the joint sets and/or a major subsurface structure (Nelson, 1952). Nelson also pointed out that most of the thrust-faults in Riley county are in the general vicinity of an intrusive and believes that some of the stresses causing the thrust faulting were created by these intrusions.

Other Intraformational Structures. One of the most unusual intraformational structures in the area of investigation is the brecciation displayed by the Cresswell limestone, Stovall limestone and the Gage shale. Hooker (1956) says that brecciation is predominant in the Towanda with almost comparable amounts in the Cresswell. The Towanda was not present at the surface in most of the problem area. The zone of greatest brecciation is located in SW$\frac{1}{4}$, Sec. 31, T 9 S, R 5 E. The Cresswell limestone, Stovall limestone and Gage shale are all severely brecciated throughout. The unusual feature about this zone is the red shale inclusions incorporated in the brecciated zone of the limestone. These inclusions must have come from the red basal portions of the shales overlying the Cresswell. The breccia and red shale inclusions are cemented with calcite. The brecciation consists of angular fragments of limestone surrounded by a matrix of cemented red shale. Hooker (1956) worked on this problem of brecciation and found in many localities the exact opposite where the angular fragments are found to be red shale inclusions with a matrix of limestone. This latter case was not as prevalent as the first and the fragments are more or less isolated and less abundant. This occurrence is most often found in the Cresswell limestone. The limestone fragments within the brecciated zones are approximately two and one-half to one-tenth of an inch measured the long dimension. Hooker (1956) observed some of the red shale inclusions as long as three feet.

Intraformational brecciation in places shows distinct evidence of soft or a partly lithified condition of the rock during induration (Hooker, 1956). The limestone fragments are angular to subangular. The emplacement of the red shale fragments into a matrix of limestone had to be accomplished during the soft rock stage.

Hooker (1956) attributed the deforming or distorting forces to earthquakes or some similar agent capable of shaking the limestone in the soft rock state. Some agent of this type would be needed to form the severe brecciation and incorporate the shales from overlying units into the limestone to a maximum of 25 feet.

Sink holes are a common feature in the Cresswell limestone. These sink holes have originated from recent erosion of the Grant shale at the surface (Plate VI, Fig. 1). Hooker (1956) showed the sink holes were formed in the Grant shale and the overlying Cresswell had collapsed into the cavities.

The presence of both soft and hard rock deformation in the problem area suggests at least two periods of deformation must have taken place.

There is some topographic expression of the joint systems in the area. The streams and creeks have a dendritic pattern but in some places they seem to parallel one an other in almost a trellis-like arrangement. Madison and Timber Creeks drain the area, flowing south southeast toward the Republican River. Several small creeks drain into Timber and Madison Creeks. Timber and Madison Creeks have a parallel arrangement in their direction of flow. The most noticeable topographic expression of joint sets are some of the rock ledges of the Fort Riley rim rock along Timber Creek. These ledges have broken off along one set of joints causing the formation of a very straight valley wall. Most of the streams that have cut down into limestone bed rock are to some extent controlled in their direction of movement by the joint patterns in the limestones. Timber creek seems to parallel and almost coincide with the axis of the Abilene anticline along the Clay-Riley county lines (Fig. 2, Appendix).

<u>Subsurface Structural Geology</u>. Koons (1955), Rieb (1954), Nelson (1952) and Lee (1956) have all done work on the subsurface rocks along the Abilene anticline. There is very little well data available over most of the area in Riley county, hence it is very difficult to get a clear picture of the actual

EXPLANATION OF PLATE VI

Fig. 1. Cross sectional view of a sink hole in the Grant shale and Cresswell limestone. SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 2, T 9 S, R 4 E.

Fig. 2. Typical outcrop of the Grant shale and Cresswell limestone located across the road from Fig. 1.

PLATE VI

Fig. 1

Fig. 2

topographic and structural expression of the basement complex in this area. As determined from well cuttings the basement complex is far from homogeneous in composition. It is made up of a mottled mass of granite and gneiss with patches of schist, quartz, porphyry and quartzite. The basement complex is an ancient buried plain that has been subjected to weathering and erosion and has been repeatedly wrinkled, warped, folded, intruded by magmas and faulted. It is these processes that have influenced the localization and orientation of subsequent anticlines, synclines and fracture patterns in the problem area.

The Riley county area of the basement complex belongs to a southwestern extension of the Canadian shield and is called the Central North American stable region by Eardley (1951). The North American stable region is surrounded by the Paleozoic Colorado and Meso-Cenozoic Rocky mountains to the west, Oklahoma mountains to the south, Paleozoic Appalachian mountains to the east and the pre-Paleozoic Algoman and Laurentian mountains to the northeast. With all this mountain building going on around the margins of the stable region, it seems likely that these forces would affect the rocks in the mid-continent area, at least to a limited degree.

Faults. Faults are usually produced from simple tension or compression acting in a horizontal plane. The most common type of fault is probably the strike-slip fault. In a strike-slip fault there is no force needed to overcome gravity and the majority of the stresses are horizontal due to lateral displacement of eroded material causing shifts in the rock at depth to compensate in isostatic adjustment. Strike-slip faults create little or no escarpments and are frequently buried under sediments which take up the differential movement plastically, thus making them difficult to recognize at the surface. Nelson (1952) mapped a major subsurface fault along the Abilene anticline, in north central Riley county and Western Marshall county. He points out that southeast of Blue Rapids, in Marshall county the pre-Cambrian surface is displaced nearly 400 feet by this fault, causing obvious dips in the surface formations of nearly 200 feet per mile to the southeast. The fault was classified as an oblique-slip fault with a steep normal dip-slip element as indicated at the surface by the dipping formations and at depth by the displacement of the pre-Cambrian surface. The strike-slip movement is believed to be responsible for the emplacement of igneous intrusions in joints opened by the strike-slip friction. Nelson (1952) proposed the name "Big Blue Fault" for this fault along the Abilene anticline.

Koons (1955) called the fault a hinge fault that dies out in Clay county. Rieb (1954) called it a rotational fault, the west side being elevated to the north and depressed to the south. Neff (1949) described the causal stresses for the Abilene and Nemaha faults to be the result of tension resulting from the subsidence of the basins on either side of the anticline.

__Age of Folding.__ The Abilene anticline resulted from an uplift in post-Mississippian time. The initial movement of the anticlinal ridge began, along an extended zone of weakness in the basement complex, during Mississippian time and was followed by a major uplift at the close of Mississippian time. Movements continued intermittently along fault zones until the end of the Paleozoic era. The Irving syncline was formed contemporaneously with the Abilene anticline. It is a distinct structural feature as indicated by the dips of the surface formations and was brought into existence by the uplifts on either side of it and not by subsidence. Folding later than Permian is not recognizable due to the erosion of the Cenozoic and Tertiary sediments and the unconsolidated character of the Quaternary sediments.

CONCLUSION

The surface investigation of the problem area has revealed the existence of a low asymmetrical anticlinal structure, considered to be the Abilene anticline. To the east of the Abilene anticline and paralleling it is an asymmetrical syncline believed to be the southern extension of the Irving syncline.

The youngest folded rocks in the problem area are the Nolans formation of the Wolfcampian series, Permian period. There is no recognizable evidence of movement in Quaternary and Recent sediments.

The Abilene anticline is responsible for the outcrop of the Barneston formation in the northwest corner of the problem area, instead of the younger sediments that ordinarily would be expected to be in this vicinity. In this area, Timber creek approximately parallels the axis of the Abilene anticline. The Abilene anticline and Irving syncline strike approximately N 50 E through the problem area, swinging more towards the north as they leave the area on the north. Both of these features parallel the Nemaha ridge to the east.

The Abilene anticline was probably the result of vertical uplift that was differentiated in character and occurred along an extended zone of weakness in the basement complex. This uplift began in Mississippian time and was followed by the major uplift at the close of Mississippian time. After the major uplift, movements continued intermittently along fault zones until the end of Paleozoic time. Later faulting was produced by the combined forces of differential compaction and differential uplift.

The Irving syncline was formed contemporaneously with the Abilene anticline. It is a structural syncline brought into existence by uplifts of the anticlinal ridges on either side of it.

The reversal of regional dip in the area is caused by a drape effect of the sediments over a fault scarp and periodic movement along a zone of weakness in the basement complex. The surface rocks show no indication of having been faulted, except for the small local faults in the area due to minor stresses.

It is believed that there is a good chance of a subsurface fault along the Abilene anticline. There is a rotation of the two major joint systems in Riley county (Neff, 1949), igneous plugs in the general area of the anticline have been intruded into the sediments above the basement complex, and a fault with 400 feet displacement has been mapped along the Barneston-Winkler anticline in Marshall county, Kansas (Nelson, 1952). Faulting is the best possible explanation for the rotation of these joint systems and the intrusion of the igneous plugs into the country rock. With the well data that was available, Nelson (1952) showed that the basement complex can be best contoured with a fault present. The exact type of fault that is present is difficult to determine and until more subsurface information is available in this area, it will be impossible to get a clear picture of the subsurface structure and topography. At the present time Nelson's oblique-slip fault with a steep normal dip-slip element seems the most logical. This type of fault accounts for the rotation of the joint systems, the emplacement of the igneous intrusions and the apparent fault scarp along the anticline.

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APPENDIX

MEASURED SECTIONS

(1) $SE\frac{1}{4}$, $NE\frac{1}{4}$, Sec. 11, T 9 S, R 4 E.

Doyle shale formation

Towanda limestone member

9 feet	limestone, hard, dense in part; massive, weathers platy to blocky; gray-orange to gray, weathers gray-orange; limonite stains abundant; non-fossiliferous.
5 feet	limestone, medium hard; impure; somewhat brecciated; light tan to orange, weathers tan; limonite stains abundant; pitted in middle part; non-fossiliferous.
10 feet	limestone, arenaceous, laminated; yellow tan; non-fossiliferous.

Holmesville shale member

13 feet	shale, non-calcareous; thin-bedded; tan, green, yellow and red; non-fossiliferous; partly covered.
1.0 feet	limestone, soft; massive; badly weathered, honey-comb effect; non-fossiliferous.
24 feet	shale, calcareous; thin-bedded to platy; calcareous lenses in lower part; yellow to tan; non-fossiliferous; partly covered.

Barneston limestone formation

Fort Riley limestone member (incomplete)

3.3 feet	limestone; medium hard, dolomitic; massive, weathers blocky; gray, weathers gray; porous, bed rock in stream.

(2) SW Sec. 12, T 9 S, R 4 E

Doyle shale formation

Towanda limestone member (incomplete)

6 feet	limestone, hard, dense in part; massive, weathers platy to blocky; yellow-tan to tan, weathers yellow-tan; limonite stains abundant; non-fossiliferous.

Holmesville shale member

11 feet	shale, non-calcareous; thin-bedded; tan, green, yellow and red; non-fossiliferous.
1.0 feet	limestone, soft, impure; massive; badly weathered, honey-comb effect; yellow to gray.
11.1 feet	shale, calcareous; thin-bedded to platy; yellow to tan; basal part covered.

Barneston limestone formation

Fort Riley limestone member

3 feet	limestone, crystalline; platy to blocky; gray, weathers tan-gray; fossils as fragments.
2 feet	limestone, crystalline; massive; gray, weathers light yellow; non-fossiliferous.
1.7 feet	limestone, dense; thin bedded and blocky; gray, weathers tan to gray; many pelecypods as cast.
4.7 feet	limestone, argillaceous, platy; light gray, weathers tan to gray, partly covered.
6 feet	limestone; covered interval.
5 feet	limestone, dense; massive "rim rock"; gray, weathers light gray; pitted; partly covered.

(3) SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 27, T 9 S, R 4 E.

Doyle shale formation

Towanda limestone member (incomplete)

4.3 feet	limestone, hard, dense in part; massive, weathers platy to blocky; yellow-tan to tan, weathers yellow-tan; non-fossiliferous.

Holmesville shale member

8.2 feet	shale, non-calcareous; thin-bedded; vari-colored; non-fossiliferous.
1.0 feet	limestone, dense; massive; gray weathers tan to gray.
16 feet	shale, calcareous; thin bedded and platy; calcareous lenses in lower part; tan weathers buff; non-fossiliferous.

Barneston limestone formation

Fort Riley limestone member

17 feet	limestone, finely crystalline, dense; platy to blocky; tan to gray; weathers gray; partly covered.
7 feet	limestone, dense; massive; "rim rock"; gray, weathers light gray; some fossil fragments.

Oketo shale member

7.1 feet	shale, calcareous; thin-bedded to platy; fossiliferous; most of outcrop covered.

Florence limestone member

1.0 feet	limestone, cherty; massive; only small amount exposed.

(4) NE¼, NW¼, NW¼, Sec. 24 T. 9 S, R 4 E.

Doyle shale formation

Towanda limestone member (incomplete)

7.7 feet	limestone, hard, dense in part; massive, weathers blocky to platy; gray-orange to gray, weathers gray-orange; limonite stains; porous in part; non-fossiliferous;
3.6 feet	shale, silty, non-calcareous; thin-bedded; tan to green; partly covered.

(5) SW¼, NE¼, SE¼, Sec. 35, T 9 S, R 4 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

2.5 feet	limestone, finely crystalline; massive, weathers blocky, gray, weathers buff to tan; echinoid spines and plate numerous, brachiopod fragments.

Grant shale member

10.1 feet	shale, calcareous; platy to blocky; gray; weathers buff; Composita Ovata, Derbyia crassa, crinoid columnals, Polypora sp., and Rhombopora sp.

Stovall limestone

2.2 feet	limestone, hard, dense; numerous chert nodules; massive, weathers blocky; gray, weathers buff to gray. Dictyoclostus americanus, echinoid spines, Polypora sp. and crinoid columnals.

(6) SW¼, SE¼, Sec. 31, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

3 feet	limestone, finely crystalline; thin bedded, weathers buff to gray; badly weathered; brecciated with red shale inclusions, non-fossiliferous.
4 feet	limestone, finely crystalline; massive, weathers blocky; gray to buff, weathers buff; echinoid spines, test plates and numerous brachiopod fragments; brecciated with red shale inclusions. Small normal fault present, some folding.
Grant shale member	
10.8 feet	shale, calcareous; platy to blocky; gray, weathers buff; calcite geodes present. Composita ovata, Derbyia crassa, Chonetes granulifera, crinoid columnals, Polypora sp., Rhombopora sp. and organic burrows (?).
Stovall limestone member	
2.2 feet	limestone, cherty; unit bedded; red shale inclusions in fractured zone; light gray, weathers buff; highly weathered. Dictyoclostus americanus, Polypora sp., echinoid spines and crinoid columnals.

Doyle shale formation

Gage shale member	
49 feet	shale, calcareous in upper part; platy to fissle; upper part gray, weathers tan to buff; lower part vari-colored, tan green, and red with red calcareous lenses; highly fractured and brecciated. Highly fossiliferous in upper part. Derbyia cymbula, Derbyia crassa, crinoid columnals, Polypora sp., Rhombopora sp., echinoic spines, Aviculopecten occidentalis.

Towanda limestone member (top exposed in creek bed)

(7) SW¼, SW¼, Sec. 33, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

3.7 feet	limestone, finely crystalline, dense; massive, weathers blocky; gray, weathers gray to buff; honeycombed weathering in parts; echinoid spines and plates are numerous, brachiopod fragments present; chert in basal part.

Grant shale member

9.5 feet	shale, calcareous; platy to blocky; grayish to buff, weathers tan to buff. Composita ovata, Derbyia crassa, Rhombopora sp., crinoid columnals, test plates and organic burrows (?)

Stovall limestone member

2 plus feet	limestone, cherty; unit bedded; light gray, weathers buff, badly weathered; Dictyoclostus americanus, Polypora sp., and crinoid columnals.

Doyle shale formation

Gage shale (incomplete)

6 feet	shale, calcareous; platy to fissle; gray, weathers buff; Derbyia crassa; crinoid columnals, Aviculopectin occidentalis and echinoid spines.

(8) NE¼, SW¼, Sec. 31, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

3.2 feet	limestone, soft; massive, weathers platy and cavernous; tan, weathers tan-gray; becomes shaly in middle part.

1.0 feet — limestone, hard, dense; massive, weathers blocky; gray, weathers tan-gray; red shale inclusion in fractures; echinoid spines.

3.1 feet — limestone, hard, dense; massive, weathers blocky; tan to gray, weathers tan; maroon shale inclusions on fracture planes. Echinoid spines, crinoid columnals and some brachiopod fragments.

Grant shale member

11.5 feet — shale, silty, calcareous; thin-bedded to blocky; tan-gray, weathers tan. Composita ovata, Derbyia crassa, Dictyoclostus americanus, crinoid columnals, Polypora sp., Polypora sp., Rhombopora sp., and organic burrows (?).

Stovall limestone member

2.8 feet — limestone, hard, dense; massive, weathers blocky; numerous chert nodules. Dictyoclostus americanus, Polypora sp., echinoid spines and crinoid columnals; extremely faulted and folded.

Doyle shale formation

Gage shale (incomplete)

10.5 feet — shale, silty, calcareous; thin-bedded; tan to gray, weathers tan; some limonite stains in bedding planes. Derbyia crassa, Derbyia cymbula, crinoid columnals, Stenopora sp., Rhombopora sp., Aviculopecten occidentalis, and echinoid spines.

(9) SW¼, SE¼, Sec. 30, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member

15 feet	limestone, marly to finely crystalline; platy in upper part to blocky in lower part; gray, weathers buff; non-fossiliferous.
3 feet	limestone, finely crystalline, dense; massive, weathers blocky; gray to tan, weathers tan; echinoid spines and crinoid columnals.

Grant shale member

1.0 feet	shale, only top exposed; organic burrows (?).

(10) SE$\frac{1}{4}$, SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 30, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

3 feet	limestone, finely crystalline; blocky to platy; gray, weathers gray to buff; non-fossiliferous.
5.2 feet	limestone, finely crystalline, dense; massive, weathers blocky; gray, weathers buff; sparse echinoid spine and test plates.

(11) CW line, Sec. 1, T 9 S, R 4 E.

Winfield limestone formation

Cresswell limestone member (sinkholes present) (incomplete)

5 feet	limestone, finely crystalline, dense; massive, weathering blocky; tan to gray, weathers tan; echinoid spines.

Grant shale member

12 feet	shale calcareous; thin bedded; light gray, weathered tan to gray; very fossiliferous.

Stovall limestone member

1.4 feet	limestone, very cherty; massive, weathers blocky; gray to tan, weathers tan; *Dictyoclostus americanus*, crinoid columnals.

(12) NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 28, T 9 S, R 5 E.

Winfield limestone formation

Cresswell limestone member (incomplete)

5 feet	limestone, finely crystalline, dense; massive, weathers blocky in low part; platy in upper part; gray to tan, weathers tan; non-fossiliferous.

Grant shale member

10.3 feet	shale, calcareous; thin-bedded; gray to tan, weathers tan; non-fossiliferous.

Stovall limestone member

2 feet	limestone, cherty; massive, weathers blocky; very badly weathered; gray, weathers tan; *Dictyoclostus americanus*.

(13) NW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 17, T 9 S, R 4 E.

Winfield limestone formation

Cresswell limestone formation

15 feet	limestone, soft, marly to shaly in the upper two-thirds with many calcite geodes, thin bedded and platy; dense crystalline limestone in lower part; massive, weathers blocky; few shale partings; gray to buff, weathers light buff; non-fossiliferous throughout. Partly covered.

(14) NE$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 35, T 9 S, R 4 E.

Nolans limestone formation

Herington limestone member (incomplete)

2.6 feet	limestone, hard; slightly dolomitic; massive; weathered badly; yellow to tan, weathers tan, limonite stains; small geodes.

Paddock shale member

11.1 feet	shale, argillaceous; thin-bedded to blocky; gray-brown, weathers tan; partly covered.

Krider limestone member

1.1 feet	limestone, hard, dolomitic; massive, weathers blocky; gray to tan, weathers tan; iron stains.

Odell shale member (covered)

(15) NW$\frac{1}{4}$, NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 8, T 9 S, R 5 E.

Nolans limestone formation

Herington limestone member

0.4 feet	limestone, hard; massive, weathers blocky; limonite stained. Pelecypods abundant in certain zones.
0.9 feet	shale, silty, calcareous; thin bedded to blocky; tan; calcareous nodules; iron stained.
0.7 feet	limestone, soft, argillaceous; massive, weathers blocky, tan-gray; some iron staining.
0.8 feet	limestone, hard, slightly dolomitic, dense in part; massive, weathers blocky; tan-gray, weathers tan; two thin shale partings; limonite staining; small geodes present. Fossiliferous.

Paddock shale member

12.2 feet	shale, argillaceous; thin bedded to blocky; some calcareous lenses; iron stained. <u>Aviculopecten occidentalis</u>.

Krider limestone member

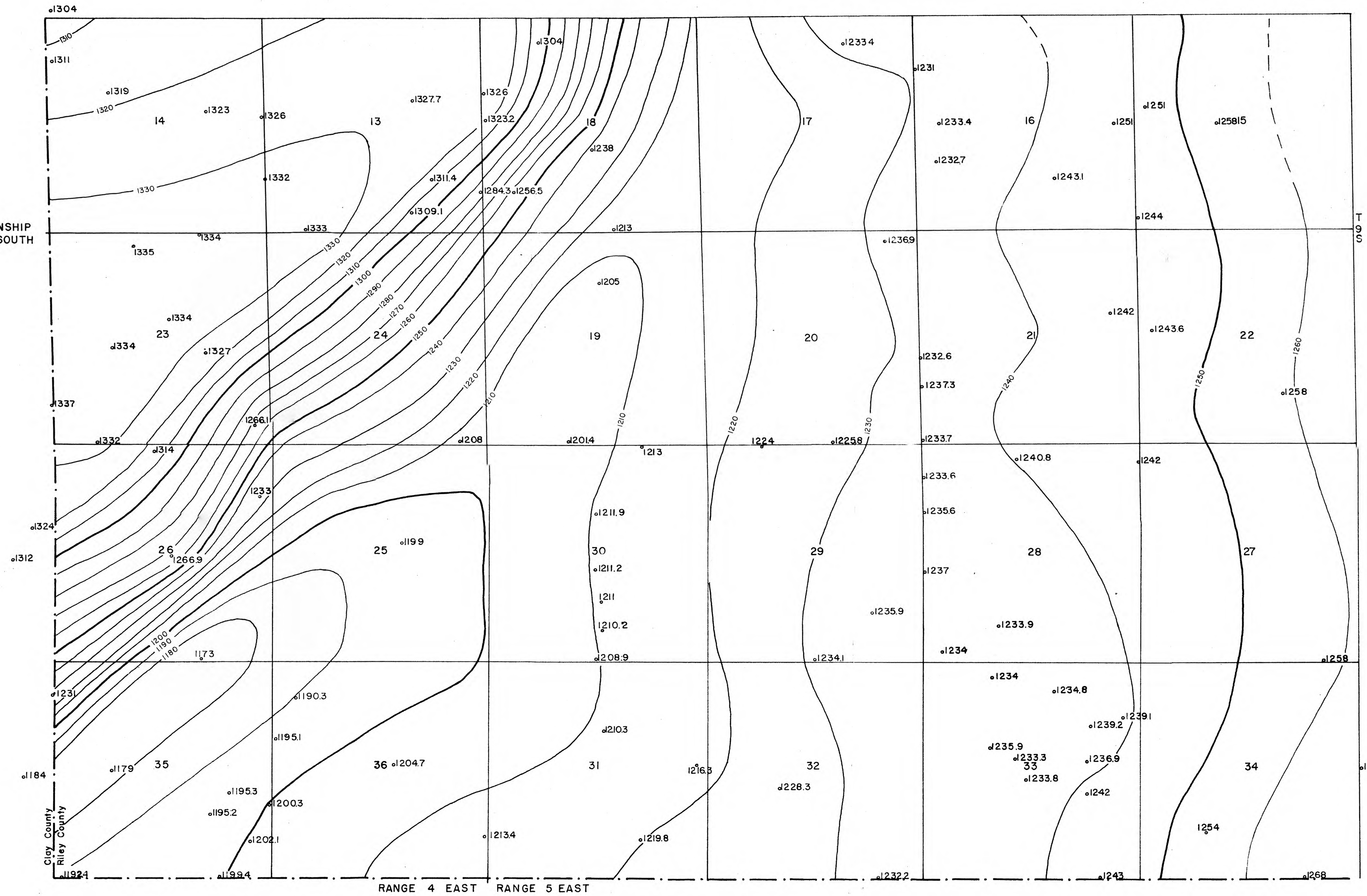
0.9 feet	limestone, soft, dolomitic; massive, weathers blocky and in chips; iron stained; fossiliferous.

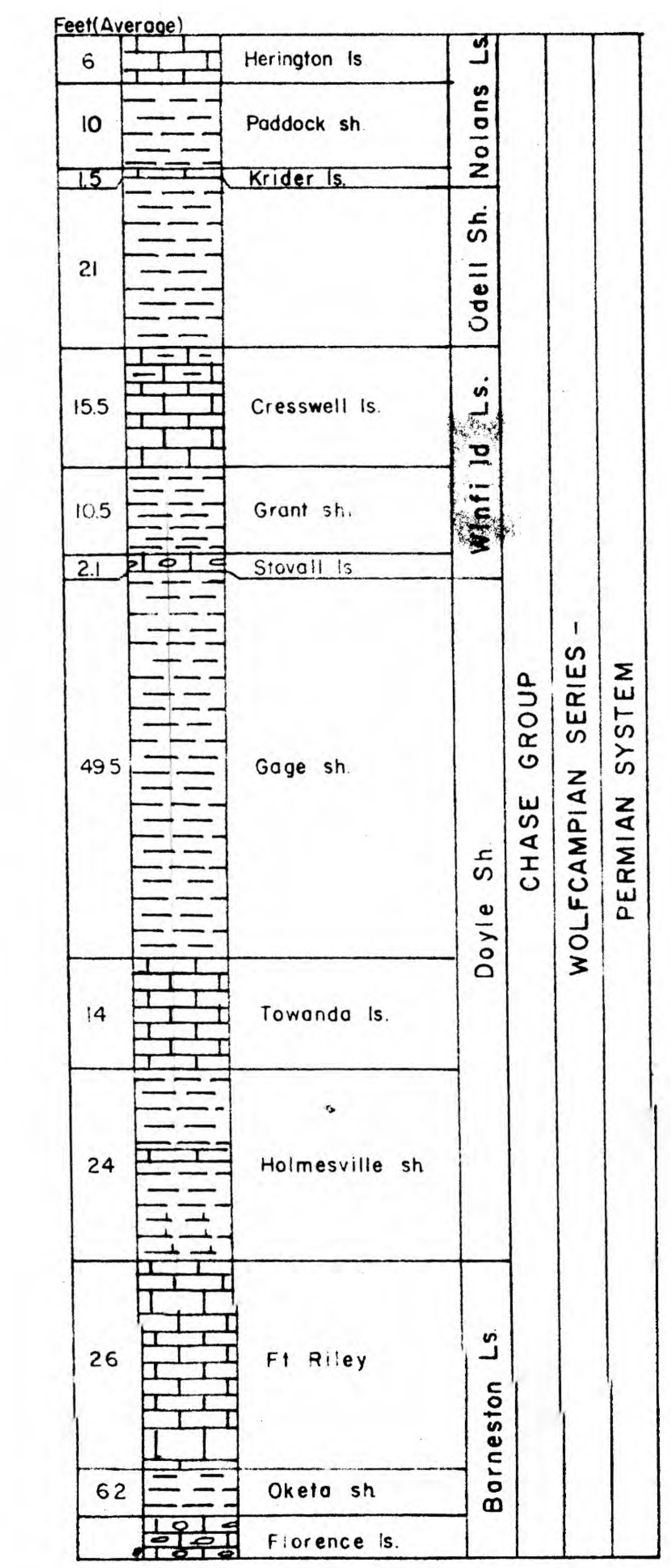
Odell shale formation (incomplete)

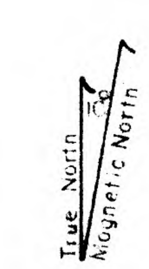
1.5 feet	shale, silty, calcareous; tan-gray, weathers tan; iron stained.

GEOLOGIC MAP OF AN AREA IN SOUTHWEST RILEY COUNTY, KANSAS

STRUCTURE CONTOUR MAP OF AN AREA IN RILEY COUNTY, KANSAS







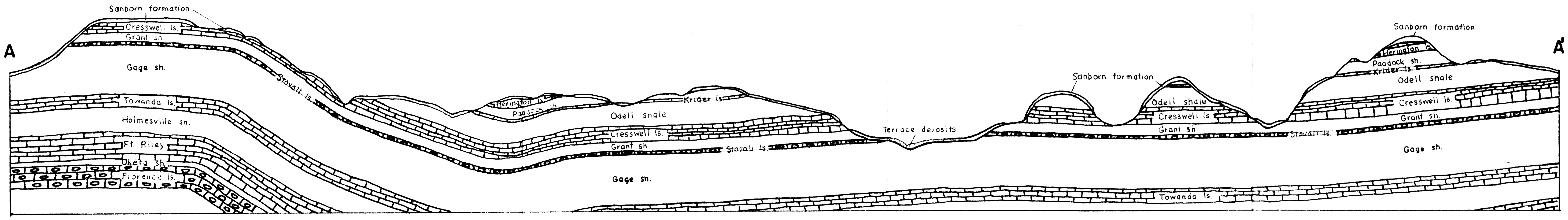
Scale- 4 inches = 1 mile

Contours on the base of the Cresswell limestone. Sea level datum

Contour interval = 10 feet

W.J. BARRETT 1958

STRUCTURE CROSS-SECTION



Horizontal Scale 1" = 1320'
Vertical Scale 1" = 66'
Vertical exaggeration = 20X

GEOLOGY OF AN AREA IN SOUTHWESTERN RILEY COUNTY, KANSAS

by

WILLIAM J. BARRETT

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1958

The area covered by this investigation consists of 24 square miles in the extreme southwest corner of Riley county, Kansas. A low asymmetrical anticlinal structure crossing the area, trending northeast, is thought to be the subsurface Abilene anticline. To the east of the Abilene anticline and paralleling it is an asymmetrical syncline believed to be the southern extension of the Irving syncline.

The purpose of this thesis is to describe the surface geology of the Abilene anticline and any related structure in the problem area. The Abilene anticline is described in much of Kansas Geologic literature as a subsurface ridge that parallels the larger Nemaha anticline to the east through the counties of Clay, Riley and Marshall in Kansas. The surface expression of this structure has been noted and briefly described by numerous geologists.

A geologic map of the problem area was made from a base map and aerial photographs. The surface structure was located by use of the plane table and alidade in the construction of a structural map and a structural profile section. An anticline with low dips on the west and steeper dips on the east, trending N 50 E through the problem area, was established. To the east of the anticline and paralleling it, a synclinal structure with low dips on the east and steeper dips on the west was also established. It is believed that there is a good chance of a subsurface fault along the Abilene anticline. The reversal of the regional dip in the area is thus believed caused by the drape effect of the sediments over a fault scarp and periodic movement along a zone of weakness in the basement complex. The surface rocks show no indication of having been faulted, except for the small local faults in the area due to minor stresses.

The rock outcrops of the area are of lower Permian in age and are covered by unconsolidated Quaternary sediments. The anticlinal structure is responsible for the older rocks of the Barneston limestone and the Doyle shale formations outcropping in the northwest corner of the problem area. The synclinal axis can be traced by following the western edge of the Nolans limestone formation across the problem area.

The Stovall and Cresswell limestone are locally faulted throughout the problem area. There are both normal and reverse faulting and the fault displacement is small ranging from a few inches up to five feet. Surface faulting in the problem area is due to relief by erosion of stresses resulting from differential compaction and down dip plastic flow of the enclosed thick shales.

In some areas the Cresswell limestone, the Stovall limestone and the Gage shale are severely brecciated throughout with red shale inclusions incorporated in the brecciated zone. These inclusions must have come from the red basal portions of the red shale overlying the Cresswell. The deforming or distorting forces are attributed to earthquakes or some similar agent capable of shaking the limestone in the soft rock state and incorporating shales from overlying units to a maximum of 25 feet.

The Abilene anticline was probably the result of vertical uplift that was differential in character and occurred along an extended zone of weakness in the basement. This uplift began in Mississippian time and was followed by the major uplift at the close of Mississippian time. After the major uplift movements continued intermittently along fault zones until the end of Paleozoic time. Later faulting was produced by the combined forces of differential compaction and differential uplift.

The Irving syncline was formed contemporaneously with the Abilene anticline. It is a structural syncline brought into existence by uplifts of the anticlinal ridge on either side of it.

There is a rotation of the two major sets of joints in Riley county, igneous plugs in the general area of the anticline have intruded into the sediments above the basement complex, and a fault with 400 feet displacement has been mapped along the Barneston-Winkler anticline in Marshall county, Kansas (Nelson, 1952). Nelson's oblique-slip fault with a steep normal dip-slip element seems the most logical type of fault to account for the above features.