SURFACE GEOLOGY OF BALA, RILEY COUNTY, KANSAS

by

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TABLE OF CONTENTS

INTRODUCTION

Location of the Area

This investigation covers an area of 24 square miles in the vicinity of Bala, Riley County, Kansas. The Riley-Clay county line is the western boundary and U. S. Highway 24 is the northern boundary. The area is six miles north-south and four miles east-west being rectangular in shape. It extends into both townships eight and nine south and ranges four and five east (Plate I).

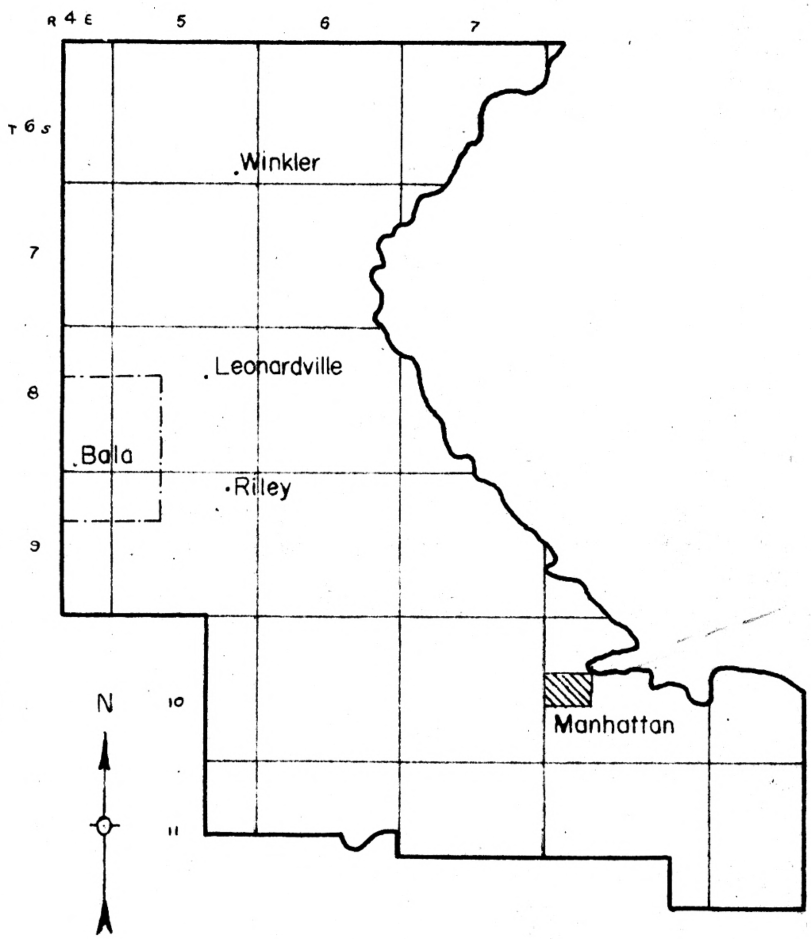
Geologic Setting

The area of interest lies within a subdivision of the Central Lowlands physiographic province named the Flint Hills Upland, located on the crest of the Abilene anticline. In general the Flint Hills are best described as "series of prominent cuesta scarps and dip slopes developed on resistant cherty limestone of early Permian age", primarily Wreford, Florence, Fort Riley, and Herington (Frye and Leonard, 1952). The east face of the upland consists of a series of stratigraphically controlled benches, and the western edge of the upland in most places is a relatively smooth series of dip slopes. The topography constitutes semi-rounded hills, well developed drainage and stream valleys which are filled with recent alluvium and terrace deposits. Quaternary sediments cover much of the upland

EXPLANATION OF PLATE I

A map of Riley County, Kansas, showing the area covered by this investigation.

PLATE I.


R 4 E
5
6
7
T 6 S
Winkler
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Leonardville
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Bala
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areas. The main structural feature in the problem area is the Abilene anticline. To the west of the area is the Salina basin and to the east of the area are the Irving syncline and the Nemaha anticline (Jewett, 1951).

Purpose of the Investigation

Much of the Kansas geological literature has described the Abilene anticline as a subsurface ridge paralleling the Nemaha anticline. The Abilene anticline trends northeasterly through Clay, Riley and Marshall counties in Kansas. The northern extension of the Abilene anticline is referred to as the Barneston anticline beginning in central Marshall county and extending across the Kansas-Nebraska line. The possible subsurface reflection of the Abilene anticline on the surface has been inferred and described briefly by Jewett (1951), Lee (1956), Merryman (1957), Nelson (1952), Neff (1949), and others. The purpose of this investigation is to determine if the surface expression of the Abilene anticline is evident in the problem area.

MAPPING PROCEDURE

Field work was started in the summer of 1957 and was completed in the late fall of 1957. A thorough investigation was made of the problem area and adjacent areas to obtain information concerning the surface expression of the anticline. Formations were identified, sections measured.

Dip and strikes of the formations were taken with the plane table and alidade and supplemented by the Brunton Compass. Elevations and the structural profile of the area were made with the plane table and alidade and checked with the altimeter. A base line between U.S.G.S. bench marks on the northern and southern boundaries was established through the central part of the area. All elevations were accurately made in reference to the base line and bench marks. Beck (1949) and Mudge (1949) mapped the geology of Riley County. Their (Beck and Mudge) map supplemented by aerial photographs served as a base map to determine the geology of the area in question. The map compiled for this thesis has a smaller area, more detail and a larger scale than that compiled by Beck and Mudge.

The stratigraphic formations, as identified in the field, were traced on the thesis map from the aerial photographs. The scale of the aerial photographs was enlarged, from three and two-tenths inches to the mile to four inches to the mile, with a sketchmaster. This scale was considered sufficiently large to depict adequately the local structure of the area, yet small enough to make the map easy to handle. The contour interval of ten feet was selected to show adequately the local structure of the formations within the area. The geologic cross-section was constructed with a vertical exaggeration of 66.

GEOLOGIC HISTORY

The geologic history of Riley County has been taken from the papers by Jewett (1951), Lee (1956), Lee, et al. (1948), and Nelson (1952) with the larger part from Lee's investigations. By the use of isopachous maps, Lee determined the structural deformation of Kansas. From this work he has developed an idea that:

> If a formation of uniform character were deposited upon a perfectly flat surface and subsequently folded and exposed to erosion for a period long enough to be reduced to a perfect peneplain, the rocks would be thin on anticlines and thick in the synclines, and the thickness of the formation as expressed by an isopachous map would reflect clearly the amount and location of all structural movements.

Deformational forces have affected the rocks in the problem area and ajacent areas in different ways. These forces have greatly modified the original attitude of all the rocks and have expressed themselves from time to time in structural domes and basins, in synclines and anticlines, and in faults and regional tilting. At times, the strata were deformed almost as soon as deposited.

Paleozoic Era

The Paleozoic was an era of deposition, folding, and faulting in Riley County. Periods of erosion occurred throughout the Paleozoic era, with major intervals occurring during Early Cambrian, Late Ordovician and Late Mississippian time. The most prominent erosional breaks in the Paleozoic are revealed in the Arbuckle limestone and the Mississippian "chat". Three major periods of folding occurred during the Paleozoic era. The first period of folding occurred between Upper Cambrian and Lower Ordovician just before the deposition of the St. Peter sandstone. Another period of folding extended from Lower Ordovician to the base of the Mississippian limestone and possibly continued through Kinderhookian time. The third period began in early Mississippian and continued through Pennsylvanian and Permian time. The greatest amount of folding and faulting occurred during post-Mississippian and pre-Desmoinesian time. Subsurface faulting of the Nemaha anticline has been mapped by Koons (1955). The complete determination of the structural forming element of the Abilene anticline is restricted by inadequate subsurface information.

Mesozoic Era

The Mesozoic was an era of erosion and regional tilting. The Mesozoic rocks are unknown in northeastern Kansas, although there could have been a time of deposition and later removal by erosion. In the extreme northwestern portion of Riley County, rocks belonging to the Dakota (Cretaceous) formation outcrop locally.

Cenozoic Era

Erosion and deposition occurred in Riley County during the Cenozoic. The sediments younger than Permian were stripped away by the Tertiary erosion except for a few outliers of Dakota formation in the northwestern part of Riley County. The Quaternary is known as the period of glaciation and deposition. The two stages of Pleistocene glaciation to reach Kansas were the Nebraskan and the Kansan. The Kansan extended south to the Kansas River and west to the Big Blue River. The Sanborn formation, which is widely distributed on the divides, was laid down during the latter part of the Pleistocene epoch (Frye and Leonard, 1952). The glacial sediments in Riley County were deposited by the melt-waters draining from the glaciers. The terrace and alluvium deposits flanking the valley floors are the result of extensive stream activity since the close of the Pleistocene epoch.

STRATIGRAPHY

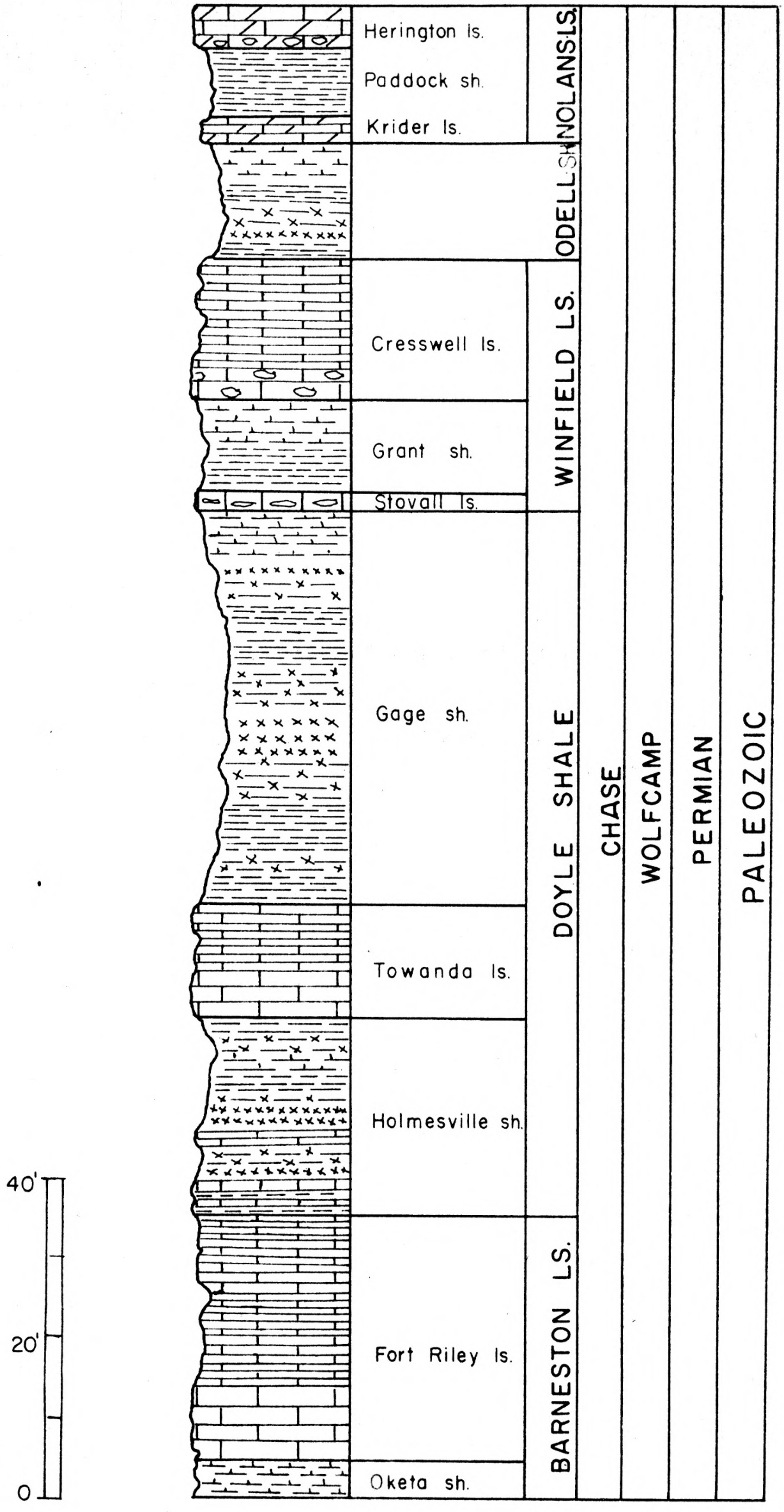
The stratigraphic units that outcrop in the area of investigation are of sedimentary and igneous origin and range in age from Permian to Quaternary (Plate II). The Barneston limestone, outcropping along the southwestern edge of the problem area, represents the oldest Paleozoic formation while the upland divides are covered with Quaternary sediments consisting of glacial materials and recent alluvium. The igneous intrusion, locally outcropping in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 6, T. 9 S., R. 5 E., is believed to be of late Cretaceous age.

EXPLANATION OF PLATE II

Generalized stratigraphic column of southwest Riley County, Kansas.

PLATE II

Exposed Sedimentary Rocks



Permian System

The Permian system includes, in ascending order, the Wolfcampian, Leonardian, and Guadalupian series. Only the upper part of the Wolfcampian series is represented in the problem area. The Wolfcampian series includes, in ascending order, the Admire, Council Grove, and Chase groups.

Chase Group. The Chase group, the upper group of the Wolfcampian series, was named from exposures in Chase County by Prosser (1902). Flint bearing limestones are characteristic of the lower and middle portions of this group. The lower boundary of the Chase group is the Threemile limestone member of the Wreford limestone formation. The upper boundary is the Herington limestone member of the Nolans limestone formation. Moore, et al. (1944) defined the Chase group to include the Wreford limestone, Matfield shale, Barneston limestone, Doyle shale, Winfield limestone, Odell shale, and the Nolans limestone formations. The formations of the Chase group investigated for this report are the Barneston limestone through the Nolans limestone.

Barneston Limestone Formation. The Barneston limestone was named by Condra and Upp (1931) from exposures outcropping in the bluffs, west and southwest of Barneston, Gage County, Kansas. The Barneston limestone includes the following members in ascending order: the Florence limestone, the Oketo shale and the Fort Riley limestone. The Florence did not outcrop and only a portion of the Oketo shale outcropped in the area under investigation.

Oketo Shale Member. The Oketo shale was named by Moore, et al. (1936) from exposures near Oketo, Marshall County, Kansas. Prosser (1902) included this shale as part of the Fort Riley limestone. The Oketo is composed of two shales which are separated by a layer of limestone. The shales are tan to blue-gray, silty, clayey-calcareous and are thin bedded in structure. The calcareous zones are in the upper area directly under the overlying Fort Riley limestone. Lateral variations could not be determined since the shale was observed in only one area. Fossils identified in the Oketo shale are the following: Brachiopods, *Dictyoclostus*, *Composita*, *Meekella*, *Derbyia*; Bryozoans, *Fenestrellina*, *Polypora*, *Rhombopora*; crinoid columnals; Gastropods, *Bellerophon*; Pelecypods, *Aviculopecten*, *Myalina*. The thickness of the Oketo shale is five to seven feet.

Fort Riley Limestone Member. The Fort Riley limestone was named by Swallow (1866) from the exposures near Fort Riley, Geary County, Kansas. The Fort Riley limestone overlies the Oketo shale and underlies the Holmesville shale. The principal outcrops in the problem area are located in sections 11 and 12 of T. 9 S., R. 5 E. along stream cuts. The limestone consists of thin bedded to blocky limestone in the upper part with thin shale partings. A massive ledge of limestone known as the "rim rock" is present near the base. This limestone ledge is very resistant to weathering and erosion. The Fort Riley limestone ranges from fairly hard to soft in hardness; the unweathered color varies from tan to gray and weathers tan-gray. Fossils identified in the limestone are: Brachiopods, Derbyia, Dictyoclostus, Meekella; Bryozoans, Fenestrellina, Rhombopora; crinoid columnals and other unidentifiable fragments. It is difficult to determine the lateral variation of the Fort Riley limestone within the problem area since the limestone outcrops were only exposed in the southern edge of the area. The thickness of the limestone ranges from 27 to 34 feet.

Doyle Shale Formation. The Doyle shale was named by Prosser (1902) from exposures along Doyle Creek southwest of Florence, Marion County, Kansas. The Doyle shale was divided into three members by Condra and Upp (1931). The three members are, in ascending order, Holmesville shale, Towanda limestone and the Gage shale.

Holmesville Shale Member. Condra and Upp (1931) gave the Holmesville shale its name from a type locality northwest of Holmesville, Gage County, Nebraska. The outcrops of the Holmesville shale are generally associated with those of the overlying Towanda limestone. Good exposures of the Holmesville shale were observed in stream cuts, quarry cuts and road cuts in the southwestern one-fourth of the problem area. The Holmesville shale is predominantly shale with lenses of limestone in the middle and lower parts with the middle limestone being characterized by "box work". The "box work" is the result of differential weathering of the limestone and shales, Moore, et al. (1951). The shale is readily identified by the vari-colored gray-green and maroon zones. The unfossiliferous shale's thickness is between 21 and 24 feet, with a thinning of the shale towards the north.

Towanda Limestone Member. The Towanda limestone was named by Moore (1920) from exposures near Towanda, Butler County, Kansas. The Towanda limestone is the first hard, dense limestone to outcrop above the Fort Riley limestone. The limestone benches cap many of the hills in the southwestern portion of the problem area. The Towanda limestone is a hard, dense, limestone that weathers to form blocks in the lower part and plates in the upper part with thin shale partings. The Towanda limestone is easily recognized by its thickness, orange to tan color, and outcrops. The nonfossiliferous Towanda increases in thickness to the south. The thickness for the Towanda limestone is between 14 and 17 feet.

Gage Shale Member. The Gage shale was named by Condra and Upp (1931) from exposures south of Wymore, Gage County, Nebraska. Exposures of this shale are seen along road cuts immediately below the outcropping Stovall limestone. The Gage shale is vari-colored with maroon in the lower two-thirds and tan-gray to gray-green in the upper one-third. The fossils found in the Gage shale are present in the upper parts and are the following: Brachiopods, Derbyia, Dictyoclostus, Meekella; Bryozoans, Polypora, Rhombopora, Stenopora; Pelecypods, Aviculopecten; and numerous fragments of crinoid columnals and echinoid spines. The thickness of the Gage is between 47 and 57 feet with a thickening to the northwest.

Winfield Limestone Formation. The Winfield limestone was named by Prosser (1897) for its exposures near Winfield, Cowley County, Kansas. Condra and Upp (1931) divided the Winfield limestone into the following three ascending members: the Stovall limestone, the Grant shale and the Cresswell limestone. Moore, et al. (1936) gave the name of Luta limestone to the uppermost bed of the Winfield limestone. Later Moore, et al. (1944) dropped the Luta as a separate stratigraphic unit and accepted the original definition by Condra and Upp. The Winfield limestone covers the larger portion of the mapped area.

Stovall Limestone Member. Condra and Upp (1931) named the Stovall limestone from its exposures southeast of the Stovall elevator and seven miles southwest of Florence, Marion County, Kansas. The Stovall limestone outcrops are generally associated with those of the Cresswell limestone. The Stovall limestone is a dense, resistant limestone that weathers blocky. The gray to tan-gray limestone contains abundant chert nodules, usually iron stained. Fossils found in the Stovall limestone are: Brachiopods, Composita, Dictyoclostus; Bryozoans, Polypora; crinoid columnals and echinoid spines. The thickness is between 1.7 and 2 feet and increases toward the south.

Grant Shale Member. The Grant shale was named by Condra and Upp (1931) for its exposures in Grant Township, Marion County, Kansas. The outcrops of the Grant shale are invariably associated with those of the Cresswell limestone. The Grant shale is silty and calcareous, thin bedded to blocky, weathering tan-gray to tan. Fossils vary in abundance from one exposure to the next but generally it contains more fossils than any other shale in the area. The fossils found are: Brachiopods, Chonetes, Composita, Derbyia, Dictyoclostus; Bryozoans, Polypora, Rhombopora; Pelecypods, Aviculopecten, Allorisma; crinoid columnals and echinoid spines. Thickness is 11 to 12 feet with local thinning and thickening.

Cresswell Limestone Member. Condra and Upp (1931) gave the Cresswell limestone its name from an outcrop on the east side of the Arkansas City golf course in Cresswell Township, Cowley County, Kansas. The Cresswell limestone is characterized by the persistent basal massive limestone generally three feet in thickness. It is resistant to weathering and contains an abundance of fossil fragments, usually crinoid columnals and echinoid spines. The Cresswell limestone is massive, hard, and weathers blocky in the lower part and blocky to platy in the upper part. Numerous sink holes occur in the Cresswell limestone when the upper part becomes porous and cavernous from percolating waters and the underlying Grant shale has been dissolved and carried away. Calcite-filled geodes are generally found associated with the porous zones. The thickness measured was between 15 and 17 feet with local variations due to slumping around sink holes.

Odell Shale Formation. The Odell shale overlies the Cresswell limestone and underlies the Krider limestone. Condra and Upp (1931) gave the name of Odell shale to an outcrop southeast of Odell, Gage County, Nebraska. They (Condra and Upp) designated the Odell shale as the basal member of the Enterprise formation but later Moore, et al. (1936) raised the Odell shale to the rank of a formation and this is now accepted. Odell outcrops in the mapped area are generally associated with those of the Nolans limestone formation. The shale is a vari-colored green to maroon in the lower part and gray to green in the upper part. The unfossiliferous shale shows no lateral change in the problem area. The thickness varies between 15 and 21 feet.

Nolans Limestone Formation. The Nolans limestone was named for its exposure near the Nolans railway siding at Emmons, Washington County, Kansas, by Moore, et al. (1936). The Nolans limestone formation is composed of three members which are, in ascending order; the Krider limestone, the Paddock shale and the Herington limestone.

Krider Limestone Member. The Krider limestone member was named by Condra and Upp (1931) from the type locality south of Krider, Gage County, Nebraska. Condra and Upp included the Krider limestone as the middle member of the Enterprise formation. Moore, et al. (1936) included the Krider as the lower member of the Nolans limestone, which is now accepted. The outcrops of the Krider are generally associated with those of the Herington limestone. The Krider limestone is a soft, sugary, gray to tan dolomitic limestone composed of two thin limestones generally one foot thick which are separated by a thin shale parting. Fossils found in the Krider limestone are: Pelecypods, Aviculopecten, Myalina, Pleurophorus and Pseudomonotis. The thickness measured in the mapped area varied between 1.4 and 2.6 feet.

Paddock Shale Member. Condra and Upp (1931) named the Paddock shale from exposures south of Krider, Paddock Township, Gage County, Nebraska. They (Condra and Upp) named the Paddock shale as the top member of the Enterprise formation, which was later changed by Moore, et al. (1936) to the middle member of the Nolans formation. The Paddock is a thin bedded to blocky, gray to olive drab shale that weathers to tan-gray and contains thin veins of calcite. The fossils present in this shale are: Pelecypods, Aviculopecten, Mytilarca; Bryozoans, Crassimarginatella and Fenestrellina. The measured thickness varied between nine and eleven feet, and thickened slightly to the north.

Herington Limestone Member. Beede (1909) named the Herington limestone for its exposures near Herington, Dickinson County, Kansas, and included it as a part of the Marion stage. Bass (1929) elevated the Herington limestone to the rank of a formation in the Sumner group and discarded the Marion stage. Later Moore, et al. (1936) defined the Herington limestone as the top member of the Nolans limestone. Good outcrops of the Herington were observed along road cuts in the mapped area. The Herington limestone is a soft, sugary, yellowish to tan dolomitic limestone that weathers from blocky to platy. Fossils found in the Herington limestone are: Gastropods, Leptoptygma, Pelecypods, Aviculopecten, Myalina, Mytilarca and Pseudomonotis. It was difficult to determine the lateral variation within the mapped area as incomplete outcrops were measured. The thickness varied between three and six feet.

Quaternary System

Pleistocene. The Pleistocene Epoch is largely responsible for the present day landscape. It is likely that only the Sanborn formation that covers the divides can be considered Pleistocene in age. The alluvium of the valley slopes and bottoms were largely, if not wholly, redeposited from the divides during late Pleistocene and Recent times. The redeposition of the topographically higher Sanborn formations to the lower areas is still going on, the wind and surface waters being the chief agents of transportation.

Sanborn Formation. The Sanborn formation is named for the loess in northwestern Cheyenne County, Kansas. The name is derived from Sanborn, Nebraska, a town adjacent to Cheyenne County, Kansas. The Sanborn formation is a reddish-gray to black silt and contains some clay. The basal part contains, usually, fragments of the local underlying rocks. The local thickness ranges from a few feet on some of the divides to 18 feet in SW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 23, T. 8 S., R. 4 E.

Terrace Deposits. The terrace deposits are predominantly silt and fine sand-size particles. The terrace deposits are mapped along all major streams and tributaries throughout the problem area. The terrace deposits show good sorting and stratification and are believed to be stream deposited.

IGNEOUS INTRUSIVES

The exposure located in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 6, T. 9 S., R. 5 E., represents the only igneous rock in the mapped area. This igneous rock is known locally as the Bala Plug. This exposure is situated near the northwest corner of the section between a railroad and highway one and one-quarter miles east of Bala, Riley County, Kansas. The physiographic expression of this intrusion is a small rounded knoll about 20 feet in height and 200 feet in diameter. A magnetic survey of the Bala intrusive with a vertical magnetometer indicates that the intrusive is an eastwardly-plunging vertical dike (Dreyer, 1947). The intrusive cuts the Permian shales and limestones of the Winfield formation (Jewett, 1941). The contact between the igneous intrusion and the surrounding country rock is not exposed. The rock was described by Moore and Haynes (1920) as a serpentinized, carbonized, porphyritic, peridotite breccia containing numerous shale xenoliths, and phenocrysts of altered olivine with some altered augite and biotite.

STRUCTURE

Regional Structures

Two major regional structures that have affected the area of investigation are the Nemaha Anticline to the east and the Salina Basin to the west (Plate III).

Nemaha Anticline. The Nemaha anticline, or uplift, was first recognized as an uplift of great length and the name Nemaha was first used as a structural term by Moore and Haynes (1917). The Nemaha anticline (a truncated anticline that plunges to the south), is a major post-Mississippian element that extends from a point near Omaha, Nebraska, southward beyond Oklahoma City, Oklahoma. The subsurface structure has been investigated by Lee (1956), Koons (1955) and Rieb (1954). The surface expression has been mapped by Ratcliff (1957).

Salina Basin. The Nemaha anticline developed and divided the North Kansas Basin into the Salina Basin to the west and the Forest City Basin to the east during the Mississippian period. During post-Mississippian deformation several northeast trending structures were formed in the basin with the strikes approximately parallel to the Nemaha anticline. These structures are the Voshell anticline, the Abilene anticline and the Barneston anticline (Lee, 1956). The Salina Basin was formed both as a structural and topographic basin bordered on the west by the Central Kansas Uplift.

Local Structures

The local structures that have affected the area of investigation are the Voshell Anticline, Abilene Anticline, Barneston Anticline and the Irving Syncline (Plate III).

Voshell Anticline. The Voshell anticline is located in McPherson and Harvey counties. It is approximately parallel to the Nemaha anticline to the east and nearly in line with the Abilene anticline to the north. A reverse fault with a throw of 400 feet has been mapped by Bunte and Fortier (1941) on the west side of the anticlinal fold. It appears that the major structural uplift took place in post-Mississippian time and minor movements followed until late or post-Permian time. It is believed that the Voshell anticline was formed contemporaneously with the forming of the Nemaha anticline.

Barneston Anticline. The term Barneston anticline is applied to the northern extension of the Abilene anticline. It enters central Marshall County, Kansas, at the Kansas-Nebraska state line and extends on into southern Nebraska.

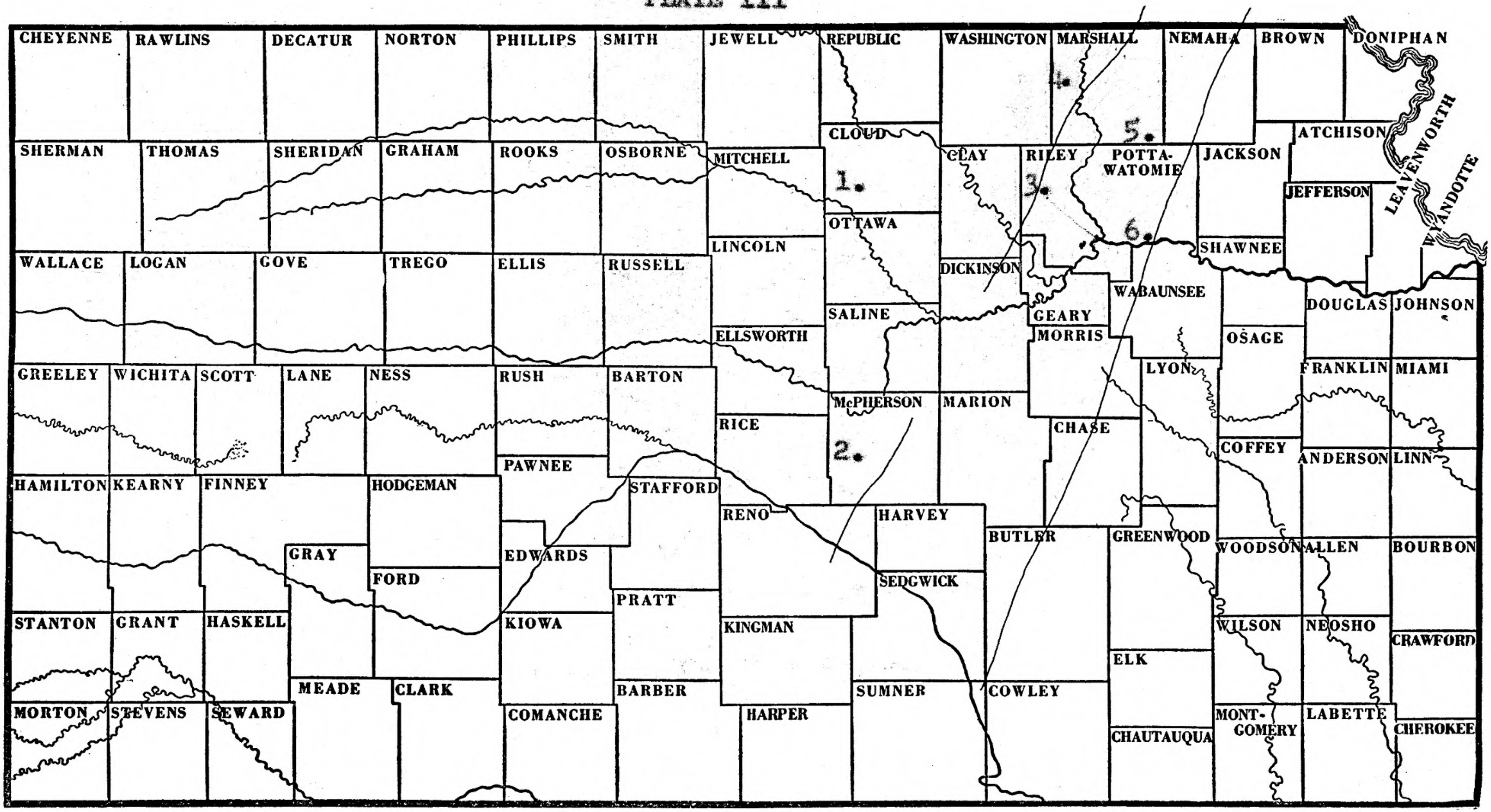
Irving Syncline. The Irving syncline named by Condra and Upp (1931) is a synclinal fold east of the Barneston or Abilene anticline and west of the Table Rock or Nemaha anticline in southern Marshall County, Kansas. The axis of the syncline is a short distance east of the Barneston anticline extending from the Riley-Marshall county line northward a short distance into Nebraska.

EXPLANATION OF PLATE III

Regional and local structures.

1. Salina Basin
2. Voshell Anticline
3. Abilene Anticline
4. Barneston Anticline
5. Irving Syncline
6. Nemaha Anticline

PLATE III


CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
4.
5.
CLOUD
ATCHISON
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLAY
RILEY
POTTA-
WATOMIE
JACKSON
LEAVENWORTH
WYANDOTTE
1.
3.
JEFFERSON
OTTAWA
6.
LINCOLN
SHAWNEE
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
DICKINSON
WABAUNSEE
SALINE
GEARY
DOUGLAS
JOHNSON
ELLSWORTH
MORRIS
OSAGE
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
LYON
FRANKLIN
MIAMI
McPHERSON
MARION
RICE
CHASE
2.
COFFEY
ANDERSON
LINN
PAWNEE
HAMILTON
KEARNY
FINNEY
HODGEMAN
STAFFORD
RENO
HARVEY
BUTLER
GREENWOOD
WOODSON
ALLEN
BOURBON
GRAY
EDWARDS
FORD
SEDGWICK
PRATT
STANTON
GRANT
HASKELL
KIOWA
KINGMAN
WILSON
NEOSHO
CRAWFORD
ELK
MEADE
CLARK
BARBER
SUMNER
COWLEY
MORTON
STEVENS
SEWARD
COMANCHE
HARPER
LABETTE
MONT-
GOMERY
CHEROKEE
CHAUTAUQUA

Abilene Anticline. The Abilene anticline has been expressed by Lee, (1956) as being formed contemporaneously with the surrounding regional structures formed during and after the post-Mississippian period of deformation. The most recent movement is expressed in the surface Permian strata. With little well drilling activity, good subsurface control of the anticline is inadequate. Subsurface maps have been made with the data available by Koons (1955), Lee (1956), Nelson (1952) and Rieb (1954). These four persons have indicated that the structural trend of the Abilene anticline is nearly parallel to the Nemaha anticline to the east, trending northeast through Clay, Riley and Marshall counties in Kansas. Koons (1955) mapped a 400 foot displacement on the eastern edge of the Abilene anticline. This displacement disappears completely in southern Clay and northern Dickinson counties, Kansas. Bunte and Fortier (1941) mapped a 400 foot displacement on the western edge of the Voshell anticline in McPherson County and a decreasing displacement toward Dickinson-Clay counties. Koons (1955) indicated that the Abilene anticline is a type of hinge fault. Work by Nelson (1952) described the fault as being normal with oblique slip movement. The strike slip element was minor and effected a clockwise rotation of the joint pattern of the area. Neff (1949) describes the causal stresses of the Abilene and Nemaha faults as the result of tension resulting from the subsidence of the basins to either side of the Nemaha anticline.

Abilene Anticline Surface Geology. The surface expressions of the area under investigation are governed by the trend of the Abilene anticline. The anticline axis strikes north 30 to 35 degrees east. The flanks dip 20 to 30 feet per mile to the west and 80 to 90 feet per mile to the southeast of the axis. The surface structure to the west of the axis indicates a terrace type of structure while to the east of the axis a monoclinal structure is indicated. The change in dip is due to the drape effects of sediments over the Abilene anticline fault scarp. Local warping is observed in the Barneston and Winfield formations. The reverse faulting in the Stovall limestone has been described by Neff (1949) as being due to compaction-sliding downward from the crest of the anticline. The slumping, due to sink-holes, in the Cresswell limestone has originated from recent erosion at the surface dissolving the underlying Grant shale; this is sufficient to form the sink-holes once an open system above a joint or fracture has developed (Hooker, 1956). A definite thinning was observed in the Doyle shale formation over the crest of the anticline while a lesser thinning was noticed in the Odell formation. Two major intermittent streams drain the area. These streams empty into the Timber Creek, a tributary of the Republican River southwest of the problem area. These two major intermittent streams follow the synclinal lows and are believed to be structurally controlled.

<u>Age of Folding</u>. The available subsurface data places the time of maximum displacement during the post-Mississippian pre-Pennsylvanian time. Consequently, the folding along the crest of the Abilene anticline originated in post-Mississippian time contemporaneously with the formation of the Nemaha anticline. Movements presumably continued along the fault zones until late Paleozoic era. Normal faults may have occurred at a time when the uppermost strata were still relatively unconsolidated but the deeper strata were more brittle as the result of a greater degree of induration. Such a condition would explain why the fault planes die out with height.

DISCUSSION

During the pre-Mississippian time the Ellis arch and the Chautauqua arch were the two major structural provinces in Kansas. Later the shifting of the Ellis arch to the south to form the Central Kansas Uplift and the Chautauqua arch to the north to form the Bourbon arch were the main structural changes in post-Mississippian time. Bunte and Fortier (1941) mapped a 400 foot displacement on the western side of the Voshell anticline. Koons (1955) mapped a 400 foot displacement on the east side of the Abilene anticline. Neff (1949) stated that:

> A remarkable parallelism between the strikes of the joint planes and the fault planes of the normal faults in Riley County suggests that they are very closely related. It is thought that the joints were formed first and that at a somewhat later date vertical displacement took place along the joint planes.

With this evidence it is very likely that the Abilene anticline and the Voshell anticline are results of a hinge fault formed from the torsion effect from changing the locations of the structures from pre- to post-Mississippian time. Further work should be done to establish the validity of the possible connection of the two anticlines.

CONCLUSION

This investigation has determined that an asymmetrical anticline exists in the problem area. It is considered to be the axis of the Abilene anticline, a post-Mississippian deformation, paralleling the Nemaha anticline to the east, striking north 30 to 35 degrees east. There is no evidence of major movement during the Quaternary, as the sediments laid down during this period show no displacement. The youngest rocks to be folded along the anticline belong to the Wolfcamp series of the Permian period. The change in dips is considered to be due to the drape effect of the sediments over the fault scarp. Good evidence of this is seen in the southeast corner of the problem area. The dip increases from 10 to 20 feet per mile to an average of 100 feet per mile.

The anticline is present across the entire length of the problem area. It trends from the northeastern corner to the south-central boundary.

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APPENDIX

The following measured sections are from the Chase group, Wolfcamp series, Permian system, in Riley County, Kansas.

(1) NW$\frac{1}{4}$ SW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 23, T. 8 S., R. 4 E.

Nolans limestone formation (19.4 feet exposed)

Herington limestone member

1.6 feet	Limestone, dense; tan-yellow, weathers tan; massive, weathers porous; concentration of small Pelecypods, Pleurophorus.
0.8 feet	Limestone, dense; tan-yellow, weathers yellowish.
1.3 feet	Limestone, soft; gray, weathers buff; platy, weathers to shaly-limestone.
1.2 feet	Limestone, hard; gray-tan, weathers tan; massive, weathers blocky.
1.2 feet	Limestone, medium hard; tan-gray; massive, weathers blocky; Pelecypods, Aviculopecten, Myalina, Mytilarca and Pseudomonotis.

Paddock shale member

11.2 feet	Shale, silty, calcareous; gray-buff, weathers buff; blocky to thin bedded.

Krider limestone member

2.1 feet	Limestone, dense; dolomitic texture; tan-gray, weathers tan; massive, weathers blocky; limonite stains; Pelecypods, Aviculopecten and Pleurophorus.

Odell shale formation (incomplete)

11.2 feet	Shale, silty; gray-green upper, maroon lower; thin bedded.

(2) SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 23, T. 8 S., R. 4 E.

Winfield limestone formation (incomplete)

Cresswell limestone member

2.5 feet	Limestone, medium hardness; gray-tan, weathers gray; massive, badly fractured; cauliflower geodes in lower zone.

Grant shale member

5.5 feet	Shale, silty, calcareous; tan, weathers gray; blocky to thin bedded; fossils sparse.

(3) NW$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 24, T. 8 S., R. 4 E.

Nolans limestone formation (incomplete)

Herington limestone member

0.7 feet	Limestone, dense; light buff, weathers tan; massive, weathers porous; reef like, concentration of small Pelecypods, Pleurophorus.
1.3 feet	Limestone, soft; gray, weathers buff; platy weathering to a shaly-limestone.
0.6 feet	Limestone, soft; gray, weathers buff; platy.
0.2 feet	Shale, silty, calcareous; yellowish-tan; thin bedded.
0.6 feet	Limestone, dense; buff-gray; weathers blocky.
1.0 feet	Limestone, medium hard; tan-gray; massive, weathers blocky; limonite stained; Pelecypods, Myalina, Pleurophorus and Pseudomonotis.

Paddock shale member

8.9 feet	Shale, silty, calcareous; gray-tan, weathers gray; thin bedded; calcareous seams at base.

(4) SE$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 36, T. 8 S., R. 4 E.

Winfield limestone formation (incomplete)

Cresswell limestone member

2.7 feet — Limestone, dense; gray-tan, weathers tan; massive, weathers blocky; iron stained; echinoid spines; crinoid columnals.

Grant shale member

8.9 feet — Shale, silty, calcareous; tan-gray, weathers gray; Brachiopods, *Chonetes*, *Derbyia*, *Dictyoclostus*; Bryozoans, *Rhombopora*; crinoid columnals; echinoid spines.

Stovall limestone member

1.4 feet — Limestone, hard; tan, weathers tan-gray; massive, weathers blocky; abundant chert nodules; Brachiopods, *Dictyoclostus*.

(5) SW$\frac{1}{4}$ SW$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 7, T. 8 S., R. 5 E.

Nolans limestone formation (incomplete)

Herington limestone member

1.2 feet — Limestone, medium hard; tan-gray; massive, weathers blocky; limonite stains; Pelecypods, *Aviculopecten*, *Myalina* and *Pseudomonotis*.

Paddock shale member

5.6 feet — Shale, silty, calcareous; gray-buff, weathers buff; thin bedded; Pelecypods, *Aviculopecten*, *Crassimarginatella* and *Mytilarca*; Bryozoans, *Fenestrellina*.

(6) SE$\frac{1}{4}$ SW$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 17, T. 8 S., R. 5 E.

Nolans limestone formation (incomplete)

Herington limestone member

1.5 feet — Limestone, dense; tan-yellow, weathers tan; massive, weathers porous; concentration of small Pelecypods, *Pleurophorus*.

0.6 feet	Shale, silty, calcareous; tan-yellow, weathers tan; thin bedded.
1.0 feet	Limestone, soft; gray to tan, weathers buff; platy.
1.0 feet	Limestone, medium hard; tan-buff, weathers blocky; Pelecypods, _Myalina_, _Pleurophorus_ and _Pseudomonotis_.

(7) SW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 18, T. 8 S., R. 5 E.

Winfield limestone formation (incomplete)

Cresswell limestone member

1.0 feet	Limestone, medium hard; gray-tan, weathers gray; massive, weathers platy.
1.0 feet	Limestone, dense; gray-tan, weathers gray; massive, weathers blocky.
0.2 feet	Shale, calcareous; gray; thin bedded.
1.0 feet	Limestone, hard; gray-tan, weathers gray; massive, weathers blocky; calcite geodes; iron stained; echinoid spines; crinoid columnals.

Grant shale member

4.3 feet	Shale, silty, calcareous; gray, weathers light gray; blocky to thin bedded; Brachiopods, _Chonetes_, _Derbyia_, _Dictyoclostus_; Bryozoans, _Rhombopora_; crinoid columnals; echinoid spines.

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

Winfield limestone formation (incomplete)

Cresswell limestone member

1.1 feet	Limestone, soft; light gray, weathers tan; platy.
0.3 feet	Shale, silty, calcareous; tan-gray.
2.1 feet	Limestone, hard, fine grained; gray, weathers tan; massive, weathers platy.

2.6 feet — Limestone, hard, fine grained; gray, weathers gray-tan; massive, weathers blocky; limonite stains.

Grant shale member

10.9 feet — Shale, silty, calcareous with clay; tan-gray, weathers tan; thin bedded; Brachiopods, *Derbyia*, *Dictyoclostus*, *Composita*; Bryozoans, *Fenestrellina*, *Polypora*, *Rhombopora*; crinoid columnals; echinoid spines; Pelecypods, *Myalina*, and *Aviculopecten*.

Stovall limestone member

1.6 feet — Limestone, hard; gray, weathers tan-gray; massive, weathers blocky; chert nodules; Brachiopods, *Composita*, *Dictyoclostus*; Bryozoans, *Polypora*; crinoid columnals; echinoid spines.

Doyle shale formation (incomplete)

Gage shale member

1.5 feet — Shale, silty, calcareous; tan-gray, weathers tan; thin bedded to platy; Brachiopods, *Derbyia*, *Dictyoclostus*, *Meekella*; Bryozoans, *Polypora*, *Rhombopora*, *Stenopora*; Pelecypods, *Aviculopecten*.

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

Winfield limestone formation (incomplete)

Cresswell limestone member

2.5 feet — Limestone, finely crystalline; gray, weathers buff; platy; non-fossiliferous.

3.5 feet — Limestone, finely crystalline; gray, weathers buff; echinoid spines and test plates.

Grant shale member

10.9 feet — Shale, silty, calcareous; gray, weathers gray; thin bedded; Brachiopods, *Chonetes*, *Derbyia*, *Dictyoclostus*; Bryozoans, *Polypora*, *Rhombopora*; Pelecypods, *Allorisma*, *Aviculopecten*; crinoid columnals and echinoid spines.

Stovall limestone member

1.7 feet — Limestone, hard; gray, weathers gray; massive, weathers blocky; chert nodules; Brachiopods, Dictyoclostus and Composita.

(10) SW$\frac{1}{4}$ SE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 2, T. 9 S., R. 4 E.

Doyle shale formation (incomplete)

Towanda limestone member

1.3 feet — Limestone, hard, dense; gray-orange, weathers buff; massive, weathers blocky; limonite stains.

3.5 feet — Limestone; yellowish, weathers light yellow to buff; very platy.

1.5 feet — Limestone; buff to light yellow, weathers buff; platy with intermittent shales.

2.2 feet — Limestone; dense; buff-orange, weathers buff; massive, weathers fractured.

2.6 feet — Limestone, medium hardness, light gray, weathers buff; massive, weathers blocky.

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

Barneston limestone formation (incomplete)

Fort Riley limestone member

20.9 feet — Limestone, covered.

7.2 feet — Limestone, hard, dense; tan-gray, weathers dark gray; massive, weathers in large blocks; iron stains; alga covered; Brachiopods, Derbyia, Dictyoclostus; good bench, locally known as "rim rock".

0.9 feet — Limestone, dense; tan-gray; platy.

Oketo shale member

5.0 feet — Shale, silty, calcareous; gray-blue, weathers gray; thin bedded; Brachiopods, Dictyoclostus, Composita, Meekella; Derbyia.

Bryozoans, Fenestrellina, Polypora, Rhombopora; Gastropods, Bellerophon; Pelecypods, Aviculopecten and Myalina.

(12) SE¼ NE¼ NE¼ Sec. 11, T. 9 S., R. 4 E.

Doyle shale formation (incomplete)

Towanda limestone member

5.4 feet	Limestone, hard; gray-orange, weathers gray-orange; massive, limonite stains; fractured in part.
2.5 feet	Limestone; buff-orange, weathers buff; platy with intermittent shale breaks.
3.0 feet	Limestone, hard, dense in part; buff-orange, weathers buff to light yellow; massive, weathers vuggy.
1.5 feet	Limestone, hard; tan-gray, weathers buff to yellow; weathers to blocky; very porous.
1.5 feet	Limestone, dense; light yellow, weathers buff; massive, weathers blocky.

Holmesville shale member

11.5 feet	Shale, silty, calcareous; thin bedded; vari-colored, greens and maroons.
1.8 feet	Limestone, medium hard; olive drab, weathers tan-gray; massive, weathers vuggy.

(13) SW¼ NW¼ SW¼ Sec. 12, T. 9 S., R. 4 E.

Doyle shale formation (incomplete)

Towanda limestone member

1.8 feet	Limestone, hard; buff, weathers light tan; massive, weathers blocky; limonite stains.

Holmesville shale member

11.3 feet	Shale; upper yellowish green; middle and lower zones covered.

1.9 feet	Limestone, medium hard; olive drab, weathers tan-gray; massive, weathers vuggy.

(14) SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 5, T. 9 S., R. 5 E.

Nolans limestone formation (incomplete)

Herington limestone member

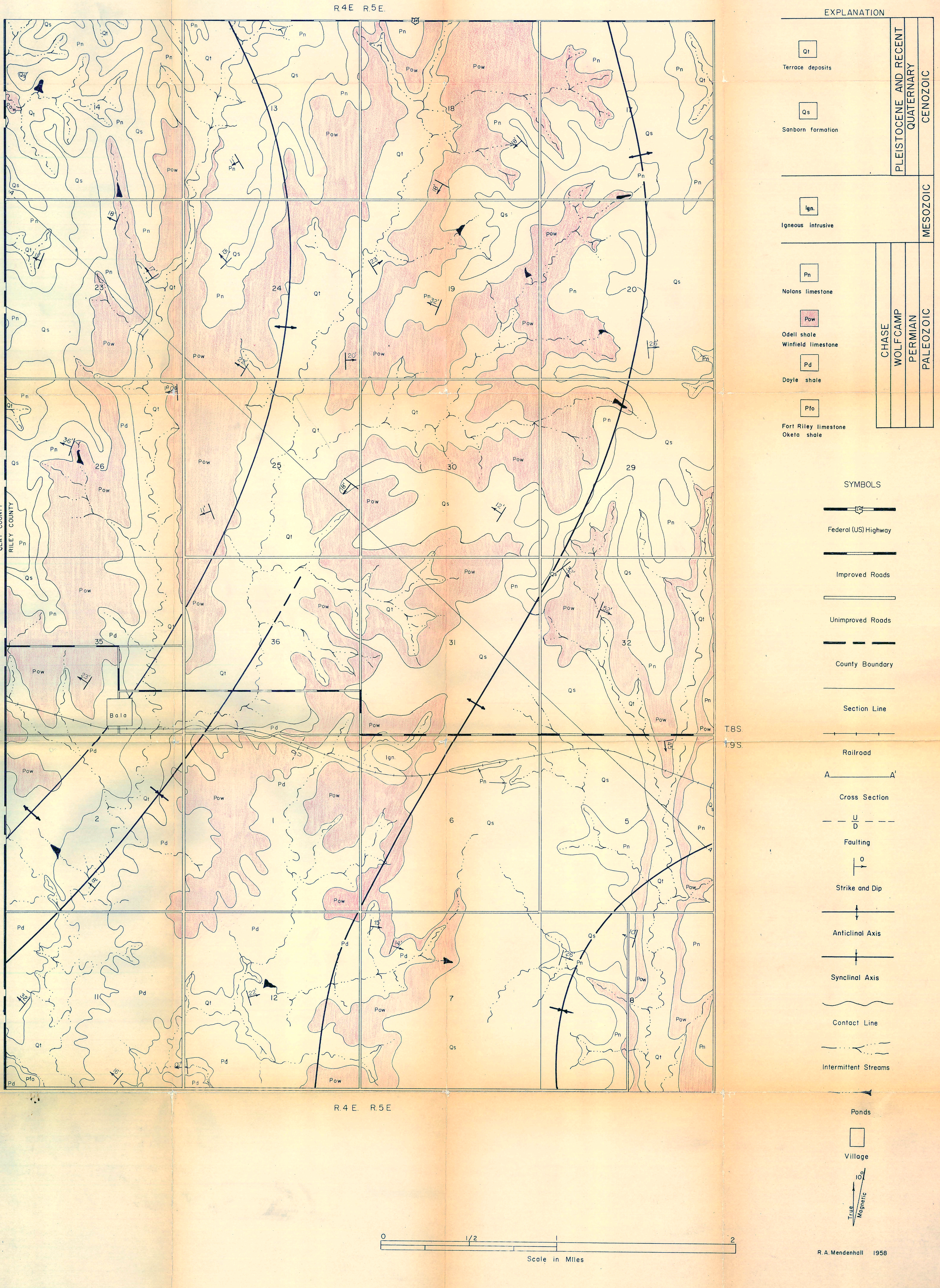
1.0 feet	Limestone, hard; gray-orange, weathers gray; massive, weathers blocky; limonite stains.
0.2 feet	Shale, silty; buff.
1.0 feet	Limestone, dense; tan to gray, weathers gray; massive, weathers blocky.
0.1 feet	Shale, silty to clayey; gray to dark tan.
0.7 feet	Limestone, hard; tan to gray; weathers blocky.

Paddock shale member

9.5 feet	Shale, clayey; gray to dark tan, weathers tan; thin bedded.

Fig. 1. Geologic Map of the Bala Area Riley County, Kansas.

A GEOLOGIC MAP OF THE BALA, RILEY COUNTY, KANSAS AREA



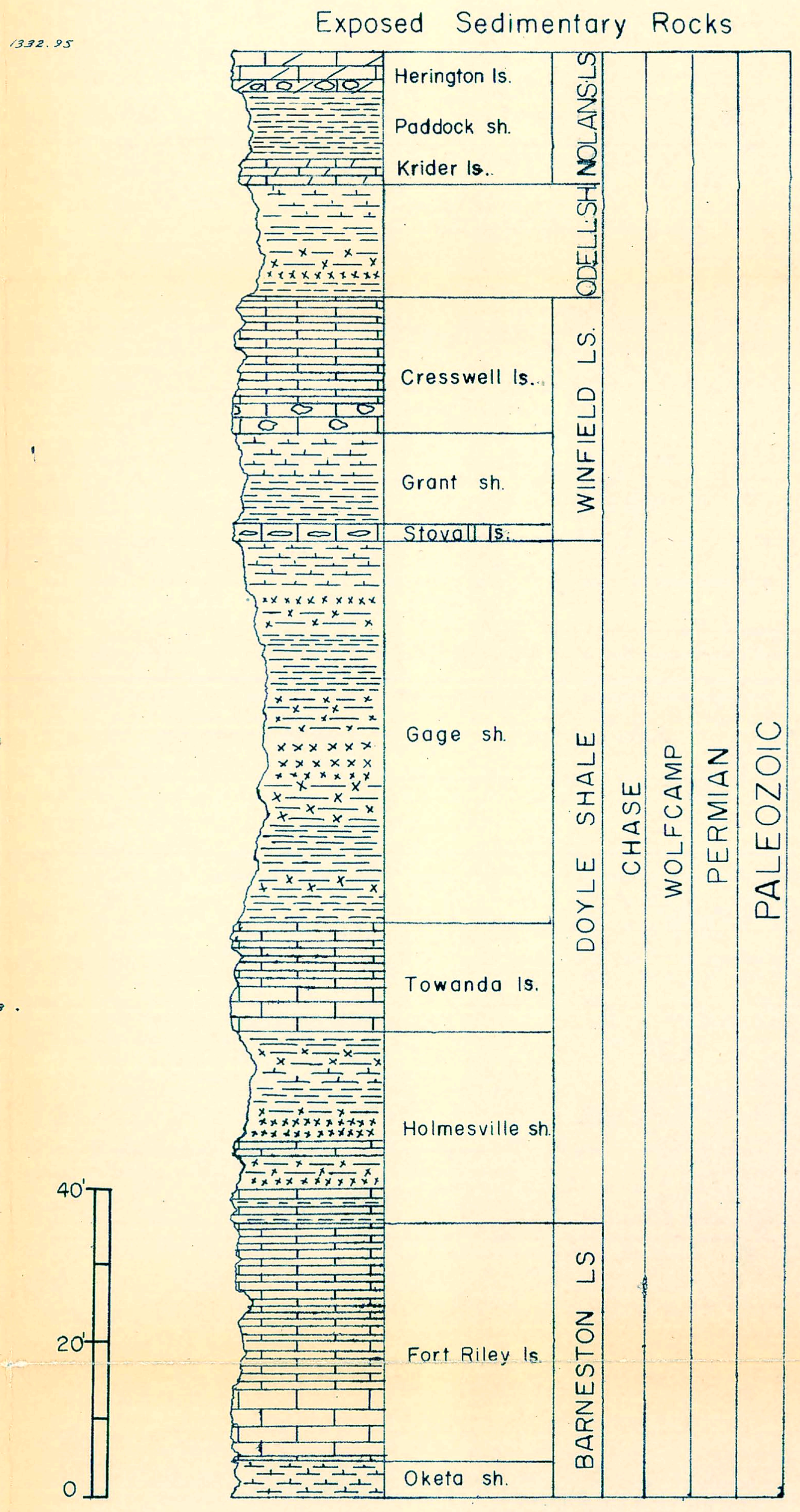
0 1/2 1 2

Scale in Miles

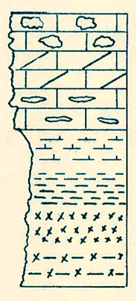
R.A. Mendenhall 1958

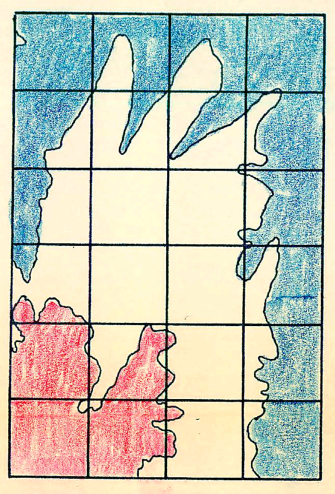
Fig. 2. Structure contour map on the base of the Cresswell limestone formation.

STRUCTURE CONTOUR MAP OF AN AREA IN RILEY COUNTY, KANSAS



Explanation





Index Map showing outcropping rocks used in structural mapping

Nolans ls.

Winfield ls.

Doyle sh.

Contours on base of Cresswell Limestone
Contour interval 10 feet
Sea level datum

True
Magnetic

0 1/2 1 2
Scale in Miles

R. A. Mendenhall

Fig. 3. Structure Cross-Section of the Bala Area Riley County, Kansas.

STRUCTURE CROSS-SECTION

Scale
Horizontal 1" = 1320'
Vertical 1" = 20'

R. A. Mendenhall 1958

SURFACE GEOLOGY OF BALA, RILEY COUNTY, KANSAS

by

Richard A. Mendenhall

B. S. Kansas State College
of Agriculture and Applied Science, 1956

AN ABSTRACT OF THE THESIS

submitted in partial fulfillment of the

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MASTER OF SCIENCE

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OF AGRICULTURE AND APPLIED SCIENCE

1958

This investigation covers an area of 24 square miles. The small village of Bala, Riley County, Kansas, lies north of the southwest corner of the problem area. The crest of an anticlinal structure crosses the area from the northeast corner to the south central boundary. This crest is believed to be the surface expression of the subsurface Abilene anticline. The rapid change in dip in the southeastern corner of the area is evidence of subsurface faulting.

Much of the Kansas geological literature has described the Abilene anticline as a subsurface ridge that parallels the Nemaha anticline to the east. The Abilene anticline trends northeasterly through the counties of Clay, Riley and Marshall. Numerous geologists have briefly described the subsurface expression of the Abilene anticline with the scanty information available. Several geologists have described the surrounding surface expression of the anticline. The purpose of this investigation was to see if the supposed subsurface Abilene anticline is revealed on the surface. An area along the believed to be crest of the anticline was selected. After the selection of the problem area, the stratigraphy was identified, sections measured and the structure elevations were obtained with the alidade and plane table. These elevations were later checked with an altimeter.

The outcropping rocks in the area are both sedimentary and igneous. The outcrops measured belong to the Chase group, Wolfcampian series of the Permian system. The hills or divides are covered by unconsolidated Quaternary sediments. The igneous intrusion is believed to be Cretaceous age.

The folding of the Abilene anticline originated in post-Mississippian time contemporaneous with the formation of the Nemaha anticline. Movements continued intermittently along the fault zones until the end of the Paleozoic era. There are no visible indications of movement later than the Paleozoic era.

The change in dip within the lower Permian outcrops is considered to be the result of a draping of the rocks over the fault scarp and intermittent movements along this zone of weakness. The thinning of the shales is the result of compaction over the crest. The thrusting of Stovall is the result of pressure relief formed from valley erosion ajacent to the crest of the anticline.