A MAGNETIC INVESTIGATION OF THE NEMAHA ANTICLINE IN WABAUNSEE, GEARY, AND RILEY COUNTIES, KANSAS

by

BILLY L. BAYSINGER

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Approved by:

Claude W. Shenkel Jr.
Major Professor

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INTRODUCTION

One of the major geologic structures in Kansas is a buried mountain range that trends northeast-southwest across the east central portion of the state. This range is referred to as the Nemaha Anticline or the Nemaha Ridge and extends from Omaha, Nebraska, into northern Oklahoma. This investigation deals with a magnetic survey over the Nemaha Anticline in parts of Wabaunsee, Geary, and Riley Counties, Kansas (Plate I).

A magnetic map was constructed and compared to structure contour maps constructed on the Precambrian, the "Hunton", and the Mississippian rocks. Large magnetic anomalies define subsurface structural anomalies, and usually smaller structural anomalies are correlated with magnetic anomalies. Profiles were constructed to supplement the comparison between the magnetic map and the structure contour maps.

Location

Geography. Wabaunsee County, in northeastern Kansas, occupies 800 square miles. It is bordered on the north by Pottawatomie and Shawnee Counties, on the east by Shawnee and Osage Counties, on the south by Lyon and Morris Counties, and on the west by Morris, Geary, and Riley Counties. The county seat is Alma. This investigation included slightly more than the northwest one-fourth of the county and included T. 10 S., Ranges 9, 10, and 11 E.; T. 11 S., Ranges 9 and 10 E.; T. 12 S., Ranges 8, 9, and 10 E.; and T. 13 S., Ranges 8 and 9 E. This is an

EXPLANATION OF PLATE I

Map of Kansas showing portions of the three counties included in this investigation, and the axis of the Nemaha Anticline (1), Salina (2), and Forest City (3) Basins.

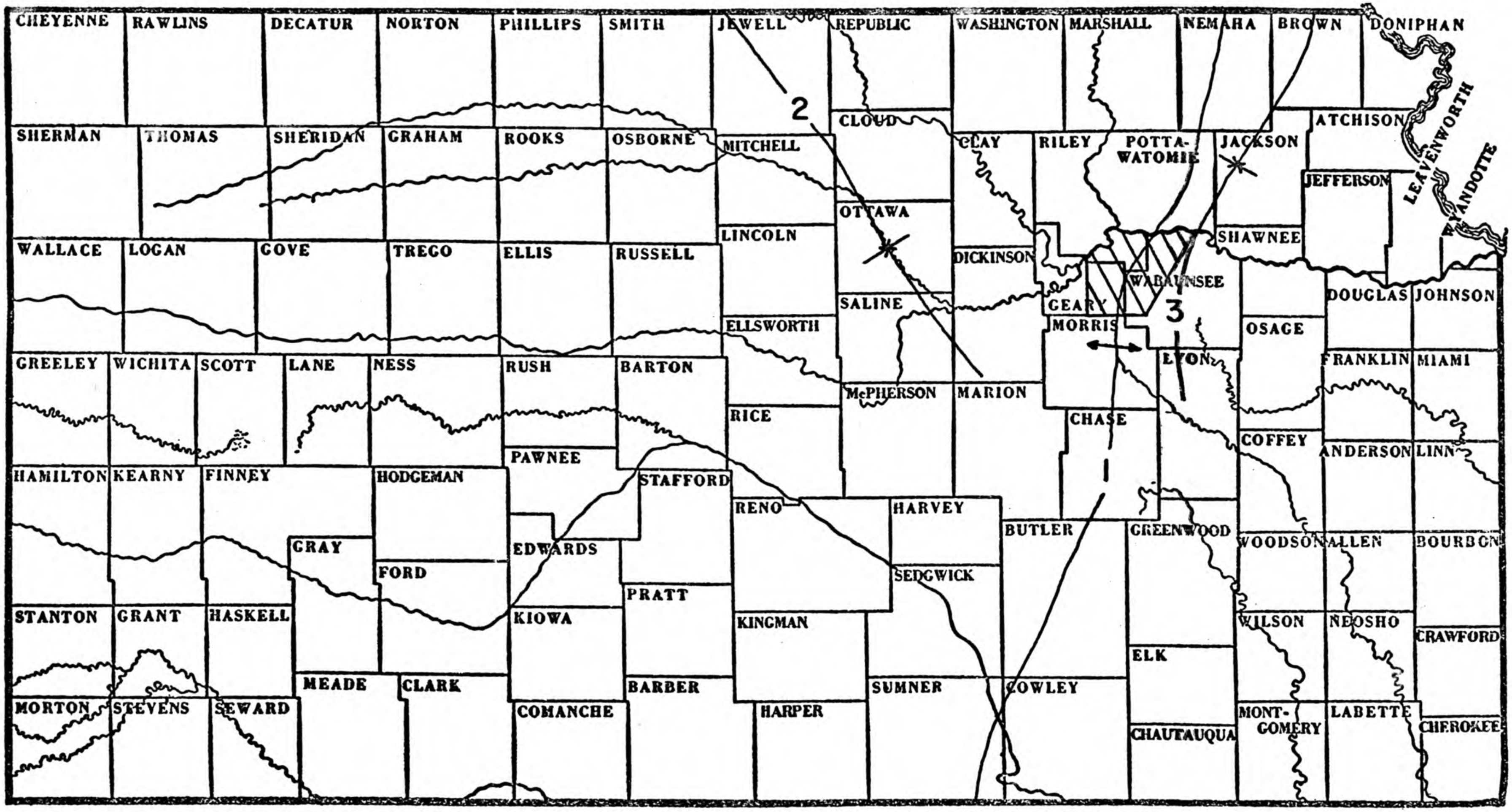

CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLOUD
CLAY
RILEY
POTTA-WATOMIE
JACKSON
ATCHISON
LEAVENWORTH
WYANDOTTE
JEFFERSON
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
LINCOLN
OTTAWA
DICKINSON
SHAWNEE
WABAUNSEE
GEARY
SALINE
DOUGLAS
JOHNSON
ELLSWORTH
MORRIS
OSAGE
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
McPHERSON
MARION
LYON
FRANKLIN
MIAMI
RICE
CHASE
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
MONT-GOMERY
LABETTE
CHEROKEE
CHAUTAUQUA
1
2
3

PLATE I

area of approximately 210 square miles within which 303 magnetic readings have been plotted.

Geary County is an area of 378 square miles. It is bordered on the north by Riley County, on the east by Riley and Wabaunsee Counties, on the south by Morris and Dickinson Counties, and on the west by Dickinson and Clay Counties. The county seat is Junction City. This investigation included approximately the eastern one-half of the county and included T. 11 S., Ranges 7 and 8 E.; T. 12 S., Ranges 7 and 8 E.; and T. 13 S., Ranges 7 and 8 E. This is an area of approximately 160 square miles within which 205 magnetic readings were taken.

Riley County occupies 598 square miles. It is bordered on the north by Washington and Marshall Counties, on the east by Pottawatomie and Wabaunsee Counties, on the south by Wabaunsee and Geary Counties, and on the west by Clay County. The county seat is Manhattan. This investigation included only the southeast corner of the county and included T. 10 S., Ranges 7, 8, and 9 E.; and T. 11 S., Ranges 7, 8, and 9 E. This is an area of approximately 110 square miles; 192 magnetic readings were made within this area.

Physiography. The area in Wabaunsee, Geary, and Riley Counties which was included in this investigation lies within the Osage Plains section of the Central Lowlands, a province of the Interior Plains Major Physiographic Division.

Two principal rivers, the Smoky Hill River and the Kansas River, are near the area investigated. The Smoky Hill River is approximately seven miles west of the western boundary of the area investigated and the Kansas River coincides with the northern boundary of the area investigated. The tributaries of these two rivers are responsible for the well-developed dendritic drainage pattern which exists throughout this area.

Regionally the sedimentary rocks dip less than ½° to the west, and the present erosional plain dips less than ½° to the east. Erosion has dissected the area into a series of southeast-facing escarpments known as the Flint Hills. Their steep bluffs consist of resistant limestones of early Permian age and occur in the western one-third of the area. Rolling hills constitute the landscape in the eastern two-thirds of the area.

The average relief of the area is approximately 300 feet and the average altitude is about 1200 feet above sea level.

Review of the Literature

Published Geologic Data. A detailed history of the previous work done on the Nemaha Anticline is presented by Swett (1959). He states that Dr. Erasmus Haworth in 1915 examined granite in well cuttings from the Nemaha Anticline but could not believe that it was granite because it was close to the surface. Haworth described the cuttings as a modified form of sandstone with unusually large amounts of feldspar. Moore and Haynes in 1918, according to Swett, first mentioned the buried Nemaha Mountains after identifying the cuttings in Dr. Haworth's previously collected samples of granite. Moore (1920), Fath (1920), Ley (1926), and Thomas (1927) were among the earlier pioneers in describing the Nemaha Anticline. Normal faulting in post-Mississippian times has been postulated for the origin of the Nemaha Anticline from the time it was known to traverse Kansas (Fath, 1920; Thomas, 1927). Lee (1943) described the stratigraphy and structural development of the Forest City Basin, which is adjacent to, and east of, the Nemaha Anticline. In this paper he discussed the structural history of the Nemaha Anticline. Lee and others (1948) described the stratigraphy and structural development of the Salina Basin, which is adjacent to, and west of, the Nemaha Anticline.

Jewett (1941) described the geology of Riley and Geary Counties. He dealt primarily with stratigraphy but did mention a structural feature south of Zeandale and nearly in superposition on the buried Nemaha Mountains. He called it the Deep Creek Fold. In describing the geologic structures in Kansas, Jewett (1951) suggested a fault origin for the Nemaha Anticline.

Hilpman and Goebel (1960) wrote a Kansas Geological Survey petroleum hot-spot report on Geary County which constitutes the published literature solely concerning the subsurface geology of Geary County.

Unpublished Geologic Data. For the most part, geologic investigations and interpretations in and around the area of this thesis have been done by students in geology at Kansas State University and reported on in unpublished Masters' theses.

Neff (1949) described the fracture pattern of Riley County; Beck (1949) discussed the Quaternary geology of Riley County; and Mudge (1949) discussed the pre-Quaternary geology of Riley County. Mudge discussed a structural feature south of Zeandale which he called the Salina Dome. This was formerly noted by Jewett as the Deep Creek Fold.

Mudge and Burton (1950), in reporting on the construction materials in Wabaunsee County, included stratigraphy but made no structural analysis.

Nelson (1952) described the surface structures that are reflected from the structures on the basement complex in Marshall and Riley Counties. He stated that the Zeandale Dome, formerly referred to as the Deep Creek Fold and the Salina Dome, is on the Nemaha Anticline.

Rieb (1954) described the structural geology of the Nemaha Anticline and concluded that the structure of the anticline is a result of vertical uplift in a zone of weakness in post-Mississippian times and did not originate by normal faulting because the anticline is not a normal fault scarp throughout its length. He did indicate, however, that faulting has occurred along the east flank of the Nemaha Anticline in northwest Wabaunsee County.

Koons (1955) discussed faulting as a possible factor in the creation of the Nemaha Anticline. He stated, however, that the eroded anticline was present prior to the suspected fault movement. Koons stated that faulting has occurred along the east flank of the Nemaha Anticline in Sec. 33, T. 10 S., R. 10 E. of Wabaunsee County. His investigation included the portion of the anticline from the northern border of Kansas to the northern border of Butler County, Kansas. He also believed that the fault exists throughout the length of the anticline.

Ratcliff (1957) defined and described the surface structure of the Nemaha Anticline in northeast Pottawatomie County.

Bruton (1958) described the fault area in southeast Riley County and denoted the Zeandale Dome as the surface structure south of Zeandale. Gasaway (1959) described the surface expression of the Nemaha Anticline in southeastern Riley County and northwestern Wabaunsee County. He structurally mapped the surface strata on the eastern flank of the Nemaha Anticline as an increase in dip of 160 feet per mile. He also mapped 80 feet of closure on the Zeandale Dome in southeastern Riley County. Swett (1959) mapped and described the surface expression of the Zeandale Dome and placed the surface crest of the dome in Sec. 34, T. 10 S., R. 9 E.

Sternin (1961) described the subsurface geology of Geary and Morris Counties.

Magnetic Data. Three papers have been published on magnetic data pertaining to areas near that of this investigation, but none have been published on the area investigated.

Hambleton and Merriam (1957) summarized the geophysical activity in Kansas from 1932 through 1956. In this paper they described the results of Woollard's transcontinental gravitational and magnetic traverse from New Jersey to California. The Kansas portion of the traverse passed through Kansas City, Lawrence, Topeka, Manhattan, Beloit, and Colby. This transcontinental profile was about two miles north of the area of this investigation. Woollard states that correlation does not exist between the magnetic profile and the configuration of the surface of the Precambrian basement on the Nemaha Anticline. Thus, they conclude that lithologic changes in the basement probably account for the magnetic anomalies on a regional scale. Hambleton and Merriam (1957) also described an aeromagnetic profile flown by Meuschke and others in 1957 for the United States Geological Survey. This profile was from Manhattan, Kansas, in Riley County east to St. Marys in Pottawatomie County and was flown over part of the area covered by Woollard's transcontinental ground profile. General correlation does exist between the basement configuration and magnetic values along this smaller profile.

Magnetic susceptibility of most rocks is directly proportional to ferromagnetic minerals present. Magnetite and ilmenite are the only ferromagnetic minerals known to occur in measurable quantities in Kansas rocks. The average sedimentary rock has a magnetite-ilmenite content of .09 percent, average granite 2.03 percent, and average basalt 6.53 percent (Merriam and Hambleton, 1959).

Agocs (1959) prepared two east-west aeromagnetic profiles across Morris and Wabaunsee Counties over the Nemaha Anticline. His northernmost profile is near the southern boundary of this investigation. He also found a marked magnetic susceptibility contrast on the western approach to the Nemaha Anticline which probably indicates a change in the basement complex from mafic igneous rock west of the anticline to granite in the anticline itself.

Purpose of Investigation

The purpose of this investigation was:

1. To depict the truncated edge of the Mississippian rocks. Mississippian and older rocks lie in angular unconformity under the Pennsylvanian rocks. Thus, Mississippian rocks are absent in portions of the area investigated. It was hoped, due to variation in lithology, that the edge of the Mississippian rocks could be depicted by correlation of well data with megnetic anomalies.

2. To attempt structural correlation of magnetic anomalies with known structural anomalies so that prediction of unknown structural anomalies could be made by the magnetic investigation.

3. To supplement or contradict the available data on the possible existence of a fault on the east flank of the Nemaha Anticline and to suggest the presence of other faults in the area that have no surface expression. Rieb (1954), Koons (1955), Lee (1955), Kotoyantz (1956), Sternin (1961), and others advocate the possibility of a fault on the east flank of the Nemaha Anticline. Gasaway (1959) suggests differential compaction as the reason for the surface expression of the Zeandale Dome and for the steepening on the east flank of the Nemaha Anticline.

4. To test the feasibility of this instrument as an important aid in the geophysical exploration for petroleum; that is, to predict possible structural traps for petroleum by magnetic anomalies.

Method of Investigation

A model M-49A Varian portable magnetometer was used in the survey. This instrument weights less than 20 pounds and measures a total magnetic field intensity reading in an interval as short as six seconds. The principle of the instrument's operation is that the nucleus of the hydrogen atom (the proton) acts as a minute bar magnet. A strong magnetic field is created within the sample (usually water) as the result of wire coiled around the sample and attached to a battery as an electric source. When this magnetic field, which is much stronger than, and approximately perpendicular to, the earth's magnetic field, is applied to the proton sample, many protons will be oriented with this newly induced field. When the polarizing field is released and these protons precess about the earth's field, a sufficient number of protons will now be precessing together coherently so that they will provide a detectable precession signal from which field strength can be obtained. After three seconds, the orientation of the protons becomes random again.

A reading was taken every half a mile. It is believed that this spacing would provide a sufficient number of readings to depict the local structural attitude of the basement rocks 1000 to 3000 feet below the surface.

Roads were used where available and accessible. Continual jarring and close proximity to such things as fence lines, railroads, telephone and electric wires, and automobiles may inhibit the readings. To eliminate this outside interference, readings of the instrument were made by walking approximately one hundred feet from the road, and four or five readings were taken within a small area to ensure an accurate reading. In this way about five readings could be made in an hour, or about forty per day.

GEOLOGY

Stratigraphy

The thickness of the sedimentary rocks is about 3000 feet in the southwestern corner of the area in the Salina Basin. In the Forest City Basin, on the eastern flank of the Nemaha Anticline, the sedimentary rock cover is about 3500 feet thick. On the Zeandale Dome, the thickness of the sedimentary rock cover is about 1000 feet.

The rock units cropping out in the area investigated are Paleozoic sedimentary rocks ranging in age from Pennsylvanian to Permian. Unconsolidated Quaternary rocks occur on some of the upland areas (Bruton, 1958) and in some of the stream valleys (Gasaway, 1959).

Precambrian Sequence. The Precambrian rocks in this area are probably granite or granite gneiss (Sternin, 1961). Farquhar (1957) identified cuttings from wells drilled into the Precambrian in the Nemaha Anticline as fragments of schist, gneiss, and quartzite. A layer of weathered granite generally overlies the unweathered Precambrian surface in northern Kansas.

Paleozoic Sequence. The description of the Paleozoic Sequence was taken from Sternin (1961) who described the sequence from a well drilled in NE¼, SE¼, SE¼, Sec. 24, T. 16 S., R. 5 E.

Sternin found less than 100 feet of sandstone and shaley dolomite of upper Cambrian age, lying nonconformably upon the Precambrian rocks. The 1000 foot thickness of sedimentary rocks from lower Ordovician to upper Mississippian is primarily cherty and shaley dolomites and limestones, with the exception of St. Peter sandstone, which is approximately 50 feet thick and of Ordovician age, and the Chattanooga shale, which is approximately 150 feet thick and of Devonian-lower Mississippian age. Two thousand five hundred feet of alternating limestones and shales constitute the Pennsylvanian and Permian Systems. Only the lower-most Permian (Wolfcampian Stage) is represented in the area.

Structure

Regional Structure. The regional structures present in the area of this investigation are the Nemaha Anticline, the Salina Basin, and the Forest City Basin (Plate II). The Nemaha Anticline trends N. 20° E. through this area, separating the Forest City Basin on the east from the Salina Basin on the west. The axes of the Forest City Basin and the Nemaha Anticline are nearly parallel, and the axis of the Salina Basin trends northwestward, parallel to the Central Kansas Uplift.

The Nemaha Anticline is an asymmetrical anticlinal fold,

EXPLANATION OF PLATE II

Post Mississippian regional and local structures.

1. Nemaha Anticline
2. Salina Basin
3. Forest City Basin
4. Zeandale Dome

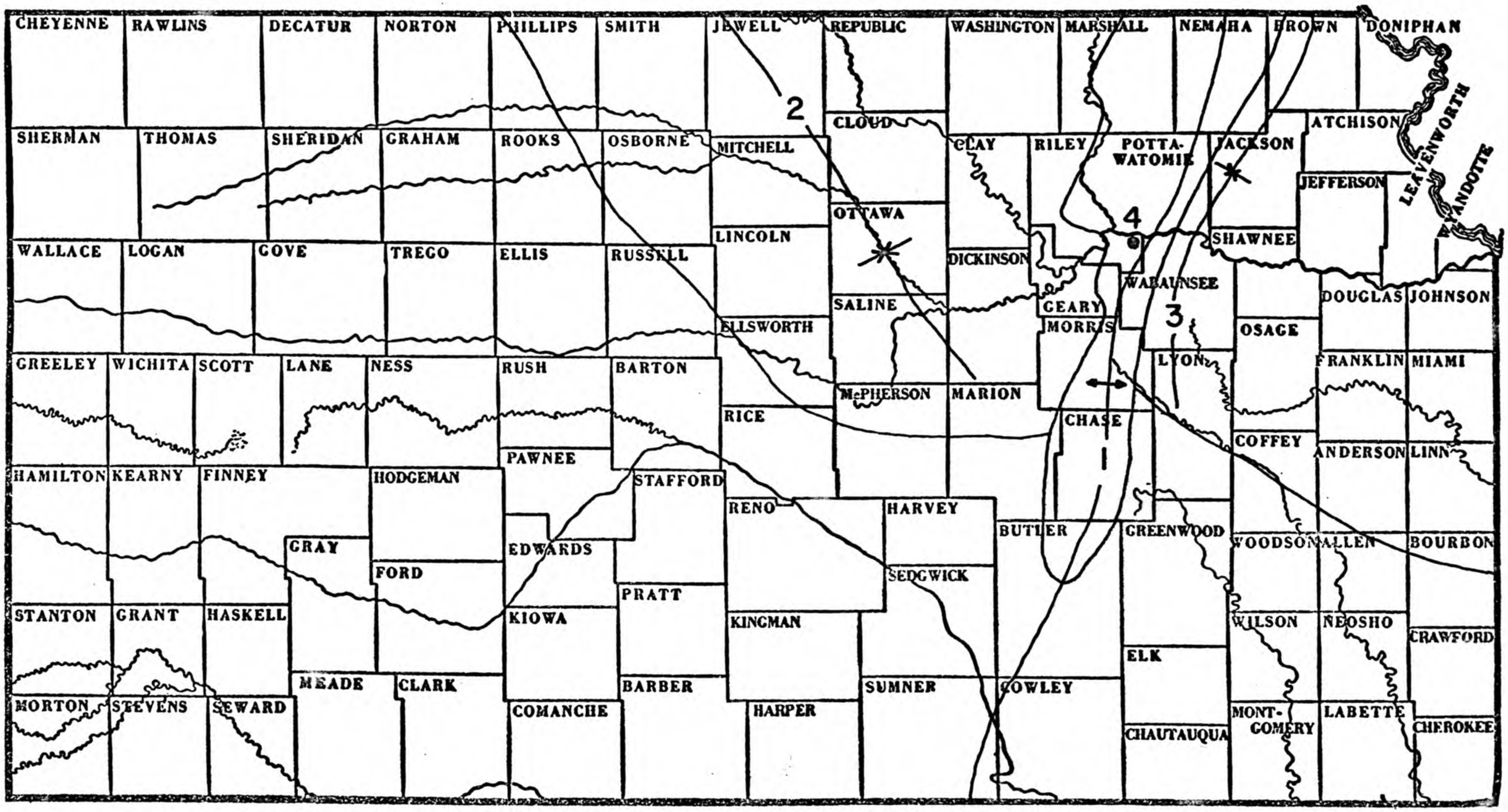

CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
2
CLOUD
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
CLAY
RILEY
POTTA-
WATOMIE
JACKSON
ATCHISON
JEFFERSON
LEAVENWORTH
WYANDOTTE
OTTAWA
4
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
LINCOLN
DICKINSON
SHAWNEE
WABAUNSEE
GEARY
SALINE
DOUGLAS
JOHNSON
ELLSWORTH
MORRIS
3
OSAGE
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
LYON
FRANKLIN
MIAMI
McPHERSON
MARION
RICE
CHASE
COFFEY
ANDERSON
LINN
PAWNEE
1
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
MONT-
GOMERY
LABETTE
CHAUTAUQUA
CHEROKEE

PLATE II

having a much steeper east flank than west flank. The configuration of the eastern flank resembles a normal fault scarp in the subsurface (Rieb, 1954). No wells have penetrated the fault zone; however, the general consensus is that the fault does exist in the subsurface (Rieb, 1954), (Koons, 1955), (Lee, 1955), (Kotoyantz, 1956), (Sternin, 1961). Plunging southward, the anticline terminates south of Oklahoma City, Oklahoma.

Local Structures. The Zeandale Dome is a local structural dome on the Nemaha Anticline in the vicinity of Zeandale, Kansas. The dome is nearly symmetrical along the north-south axis but is slightly asymmetrical along the east-west axis, with a noticeably steeper west flank (Swett, 1959). Swett concluded that the surface expression of the Zeandale Dome was the result of differential compaction of sediments over a structural high in the granite surface.

Mudge (1949) and Bruton (1958) mapped seven normal surface faults in southeastern Riley County which is within the area of this investigation. These faults strike northeast with a maximum displacement of 25 feet. Swett (1959) searched the area extensively for the above mentioned faults but found no evidence of displacement.

Structural History

Five periods of regional deformation affecting this area are recognized by Lee (1956) and Lee and others (1948). These periods are the pre-St. Peter deformation; post-St. Peter, pre-Chattanooga; early Mississippian through Permian; post-Permian, pre-Cretaceous; and post-Cretaceous through the present. The northern portion of the Nemaha Anticline, the Southeast Nebraska Arch, was elevated during the pre-St. Peter deformation. Post-St. Peter, pre-Chattanooga deformation created subsidence of the Southeast Nebraska Arch and development of the North Kansas Basin. Uplift and faulting of the Nemaha Anticline was initiated during Mississippian through Permian deformation splitting the North Kansas Basin into two separate basins, the Salina Basin and the Forest City Basin. Post-Permian, pre-Cretaceous deformation tilted the region westward, giving this area a very small westward dip. The deformation that occurred following deposition of Cretaceous sediments elevated Cretaceous and older strata approximately 2000 feet to their present altitude in addition to a slight regional tilting to the north. Thus, with the northerly tilting superposed on the western dip already present, there exists the present-day northwesterly regional dip.

MAGNETIC INVESTIGATION

General Statement

A magnetic map was contoured directly from the field readings. This map was interpreted for positive and negative anomalies, and these anomalies were compared to structural anomalies delineated upon structure contour maps constructed on the surfaces of the Precambrian, "Hunton", and Mississippian rocks. Five east-west profiles through the area of investigation were employed to clarify the relationship between the magnetic anomalies and geologic factors that might be related to these anomalies.

Interpretation of Magnetic Map

The magnetic map was contoured with a fifty gamma contour interval (Plate VIII). Varian Associates, manufacturer of the instrument used, states that the magnetometer readings may be in error as much as twenty gammas, that is, plus or minus ten gammas. For this reason, a fifty gamma contour interval was used to mask the small error of the magnetometer and to present a nearly true picture of the magnetic anomalies present. The minimum reading recorded was 56,600 gammas in Sec. 10, T. 12 S., R. 10 E. and the maximum reading recorded was 57,210 gammas in Sec. 34, T. 11 S., R. 7 E. Thus, a variation of 610 gammas is shown within the area of this investigation.

The Zeandale Dome is reflected on the magnetic map as a very small, broad, positive anomaly of approximately fifty gammas magnitude. Swett (1959) mapped the surface crest of the dome in Sec. 34, T. 10 S., R. 9 E. The highest magnetic reading was recorded two miles northwest of Sec. 34, but it was so small in magnitude that the crest apparently does not coincide with the magnetic high. Positive anomalies are found from two to four miles from the Zeandale Dome on the southeast, south, and southwest, and a negative anomaly is found adjacent to the dome on the west. The magnitude of the positive anomaly southeast of the dome is approximately 150 gammas and the highest reading was 57,100 gammas between sections 13 and 14, T. 11 S., R. 9 E. The positive anomaly south of the dome is in sections 16 and 17 and the highest reading was 57,030 gammas between sections 16 and 17, T. 11 S., R. 7 E. The positive anomaly southwest of the dome is in sections 2, 3, 4, 9, 10, and 11, and the highest reading was in the northwest corner of Sec. 11, T. 11 S., R. 8 E. All three of the positive magnetic anomalies mentioned are about 100 gammas higher than the highest reading taken on the Zeandale Dome. The lowest reading in the negative anomaly west of the Zeandale Dome was 56,790 gammas recorded in the southeast corner of Sec. 34, T. 10 S., R. 8 E.

A broad negative anomaly exists in the northeast corner of the area, T. 10 and 11 S., R. 10 E. The axis of this anomaly is approximately N. 30° E. Superimposed on this negative anomaly is a positive anomaly in Sections 22, 23, 26, and 27, T. 10 S., R. 10 E. The magnitude of the positive anomaly is approximately fifty gammas. An abrupt change in the magnitude of the readings is indicated by the closely spaced contours separating the broad negative anomaly from the anomaly of the Zeandale Dome. The closely spaced contour lines indicate a 200 gamma magnetic anomaly extending from Section 25, T. 10 S., R. 9 E., south to Sec. 36, T. 11 S., R. 9 E. where they angle southwestward to the southwest corner of T. 12 S., R. 9 E.

A linear negative anomaly approximately eight miles long and two miles wide trends nearly due south from Sec. 14, T. 11 S., R. 8 E., to Sec. 24, T. 12 S., R. 8 E. The magnitude of the lowest readings was 56,760 gammas in Sec. 35, T. 11 S.,

R. 8 E., and Sec. 2, T. 12 S., R. 8 E. East of the negative anomaly is a nose-like positive anomaly extending southward from the positive anomaly south of the Zeandale Dome.

A broad negative anomaly is present in the southeastern portion of the area. The axis of this anomaly is approximately N. 35° E. Within the broad negative anomaly are two small positive anomalies and two small negative anomalies. These four small anomalies are approximately 50 gammas in magnitude. One of the positive anomalies is in Sections 23, 26, and 27, T. 12 S., R. 9 E., and the other is in Sections 3, 4, and 9, T. 13 S., R. 9 E. One of the negative anomalies is in Sections 6 and 7, T. 13 S., R. 9 E., and the other is in Sections 18 and 19, T. 13 S., R. 9 E., Sections 13 and 24, T. 13 S., R. 8 E. The broad negative anomaly is in alignment with the previously mentioned broad negative anomaly in the northeastern corner of the area. The two, however, are separated by a flat, shelf-like, positive anomaly of small magnitude.

Two small positive anomalies separate the broad negative anomaly in the southeastern portion of the area. The smaller of the two positive anomalies is in Sections 27, 28, 33, and 34, T. 13 S., R. 8 E. The magnitude of this anomaly is approximately 75 gammas. The other small positive anomaly is in Sections 9, 10, 15, and 16, T. 13 S., R. 8 E., and is approximately 150 gammas in magnitude.

The negative anomaly in the south and southwestern portions of the area plunges south-southwestward out of the area of this investigation. A small positive anomaly is superimposed on the northern portion of the negative anomaly in Sections 17, 18, 19, and 20, T. 13 S., R. 8 E. The positive anomaly is approximately 55 gammas in magnitude and the negative anomaly surrounding the positive anomaly is about 150 gammas in magnitude.

A large positive anomaly encompasses over 100 square miles in the western and northwestern portions of the map. The axis of this anomaly is approximately N. 20° W. and is 350 gammas in magnitude. The largest reading was 57,240 gammas, recorded in Sec. 2, T. 12 S., R. 7 E. The crest of the anomaly is five miles long and slightly over one mile wide. At its northwestern extremity, the crest splits into a V-shaped anomaly, one leg trending N. 55° W. and the other leg trending N. 10° W. Four small negative anomalies are present on the large positive anomaly. One of these anomalies is northeast of the crest of the positive anomaly in Sections 14, 23, 24, 25, 26, and 36, T. 11 S., R. 7 E., Sections 30 and 31, T. 11 S., R. 8 E. Another is in Sections 6, 7, and 18, T. 12 S., R. 8 E. A third one is in Section 16, T. 12 S., R. 7 E., and the other one is in Sections 27, 28, 33, and 34, T. 12 S., R. 7 E. These four negative anomalies are less than fifty gammas magnitude.

At the margins of this large positive anomaly, three anomalous features exist: a small, tongue-like, positive anomaly extending southwestward at the southwestern extremity of the map; a negative anomaly extending from the broad negative anomaly in the portion of the map to the large positive anomaly; and a small positive anomaly at the northeastern extremity of the large positive anomaly. The small, tongue-like, positive anomaly is in Sections 19, 20, 29, and 30, T. 13 S., R. 7 E. and is twenty-five gammas magnitude. The negative anomaly at the southeastern margin of the large positive anomaly trends southeastward from Sec. 19, T. 12 S., R. 8 E., to Sec. 12, T. 13 S., R. 8 E. The positive anomaly at the northeastern margin is in Sections 6 and 7, T. 11 S., R. 8 E., and Sections 1 and 12, T. 11 S., R. 7 E., and is approximately eighty gammas magnitude.

Comparison of Magnetic Map to Structure Contour Maps

Structure contour maps on the Precambrian, "Hunton", and Mississippian rocks were constructed from well depths to the desired datums given on Herndon Maps. Regional structure contour maps on the Precambrian by Cole (1962), the "Hunton" by Merriam and Kelly (1960), and on the Mississippian by Merriam (1960) helped present a regional structural picture of the area. Contouring the Precambrian map was extremely difficult because an average of only one well per township was drilled a sufficient depth to encounter granite.

Precambrian. A great amount of general conformity and, in several instances, localized conformity can be seen when comparing the magnetic map (Plate VIII) to the structure contour map on the Precambrian (Plate IX).

The Zeandale Dome is shown as a large, positive, structural feature in T. 10 S., R. 9 E., which is almost the exact position as is indicated for the dome on the magnetic map. Positive structural features are indicated south and southwest of the dome and a negative structural feature is indicated west of the dome. The two positive structural features are not in superposition with the two positive magnetic anomalies south and southwest of the dome mentioned previously, which may be the result of incorrect contouring of the structure map because of insufficient well control. The negative structural feature west of the dome is in superposition with the negative magnetic anomaly in that area.

The closely spaced magnetic lines trending south from Section 25, T. 10 S., R. 9 E. are approximately one mile west of the closely spaced structural contour lines. Well data indicates that the relief is approximately 1000 feet from the western edge to the eastern edge of Sec. 5, T. 11 S., R. 10 E., which is a dip of about ten degrees to the east. This may be indicative of the presence of a fault but certainly is not conclusive. From Sec. 5, T. 11 S., R. 10 E., to Sec. 2, T. 11 S., R. 10 E. the structural contour lines show a decrease in relief on the Precambrian surface of about 1000 feet in three miles. This area of decreasing relief is in superposition with the previously discussed broad negative magnetic anomaly.

A fault is indicated along the northwestern edge of the broad negative magnetic anomaly in the southeastern portion of the map. It is reasonably certain from well data that a fault does exist in or near Sec. 21, T. 12 S., R. 9 E. In this section, a well was drilled which encountered the top of the Mississippian at an elevation of 2252 feet below sea level (or minus 2252). Two and a half miles north of this well location, the top of the Mississippian was minus 700 feet; two miles west it was minus 800 feet; and two miles southeast it was minus

1122 feet. A 200 gamma magnetic anomaly exists in this general vicinity, trending N. 45° E. from the northeast corner to the southwest corner of T. 12 S., R. 9 E. Therefore, a fault is shown on the maps, extending southwest from Sec. 31, T. 11 S., R. 10 E., to Sec. 29, T. 12 S., R. 9 E. The presumed fault is shown to trend southeast from Sec. 29, T. 12 S., R. 9 E., to Sec. 4, T. 13 S., R. 9 E. because the structure contour maps indicate such a fault.

A small positive structural feature is indicated in Sec. 9, T. 13 S., R. 9 E., which is in superposition with a small, positive, magnetic anomaly. In Sections 33 and 34, T. 13 S., R. 8 E., a positive magnetic and structural anomaly are in superposition. In Sections 17, 18, 19, and 20, however, a positive magnetic anomaly is in superposition with a negative structural feature.

A large positive structural anomaly is present throughout the western one-third of the area of investigation. This is the same area in which the large positive magnetic anomaly previously described, occurs. The crest of this structure cannot be depicted from well data because only three wells in a hundred square miles are drilled to the Precambrian. Indications are that the crest of the magnetic anomaly is from one to four miles east of the structural anomaly.

Hunton. The "Hunton" is a limestone of Silurian-Devonian age. A structure contour map on the "Hunton" (Plate X) was constructed so that a comparison could be made between it and the magnetic map (Plate VIII). The "Hunton" is well known in this area as a reservoir rock for petroleum. Three fields in the area of this investigation are producing from the "Hunton". These fields are in Sections 30 and 31, T. 11 S., R. 8 E., Sections 25 and 36, T. 11 S., R. 7 E.; another is in Sections 26 and 35, T. 11 S., R. 8 E.; and the other one is in Sections 25 and 36, T. 11 S., R. 8 E., Sections 30 and 31, T. 11 S., R. 9 E. Structural "highs" that may contain petroleum are discussed below.

One of the most promising areas to explore for petroleum is in Sections 2, 3, 4, 9, 10, and 11, T. 11 S., R. 8 E. Bruton (1958) surface mapped parts of T. 11 S., R. 8 and 9 E. and contoured a structural high in Sec. 11, T. 11 S., R. 8 E. on the Cottonwood limestone. A positive magnetic anomaly is indicated in superposition with the positive structural anomaly mapped by Bruton. Only two wells have been drilled in the general area, both of which are west of the inferred "high".

Another area of interest to petroleum explorers may be in Sections 11 and 12, T. 12 S., R. 7 E., where a segregated magnetic high is indicated on the crest of the large, positive, magnetic anomaly covering the western one-third of the map. The structure contour maps, however, do not indicate a structural high in this area.

Mississippian. In addition to the "Hunton", a structural contour map on the Mississippian rocks was constructed. Mississippian rocks are reservoir rocks for petroleum in several fields in Kansas. The wingfield pool and the Ge-See pool in Geary County, Sec. 35, T. 11 S., R. 8 E., and Sec. 27, T. 11 S., R. 8 E., respectively, are the only productions from

Mississippian rocks in the area of this investigation. Post-Mississippian uplift and erosion removed Mississippian rocks from the higher elevation as indicated by well data. Pennsylvanian deposition overstepped the tilted Mississippian and older rocks, leaving possible traps for petroleum at the edges of the Mississippian rocks. By comparing the well data in areas where the Mississippian was known to be absent with the positive magnetic anomalies, the geographical extent of the Mississippian rocks can be shown with less error. The structure contour map on Plate XI indicates where the Mississippian rocks are absent.

Explanation of Profiles

Five east-west profiles were constructed, demonstrating the relationships between anomalies on the magnetic profile and anomalies within the subsurface rocks. The surfaces of the "Hunton", Mississippian, and Precambrian are depicted on the geologic cross sections below the magnetic profile. The magnetic profile was constructed with approximately 200 gammas equaling one inch and the structural profile with approximately 1000 feet equaling one inch. Sea level was set at 56,750 gammas so that a better picture would be presented when comparing the distance between the magnetic profile and the structural profiles. The geographic location of the profiles is shown on the magnetic map (Plate VIII), and structure contour maps (Plates IX, X, and XI.)

All five profiles show a marked susceptibility contrast on the eastern and western approaches to the Nemaha Anticline. Agocs (1959a) also noted the susceptibility contrast on the western approach to the Nemaha Anticline and stated that the Precambrian basement west of the Nemaha consists of mafic rocks and the Nemaha Anticline itself consists of granite. Merriam and Hambleton (1959) pointed out that the average granite is twenty times more susceptible magnetically than the average sedimentary rock, and the average basalt is three times more susceptible magnetically than the average granite. Profile B-B', center of R. 7 E., indicates that the surface of the Precambrian rocks are approximately 500 feet below sea level and the magnetic reading directly above is 57,200 gammas. The same profile, western edge of R. 9 E., indicates that the surface of the Precambrian rocks again is 500 feet below sea level and the magnetic reading directly above is 56,900 gammas. Therefore, as Agocs suggests, the 300 gamma drop with the same surface elevation of the Precambrian probably is indicative of a lithologic change within the Precambrian basement. The granite-mafic facies change is shown on the profiles as a dashed line. The depth scale does not apply to the facies change within the Precambrian rocks because there is no way of ascertaining the depth to this change. Facies changes occurring on the Precambrian surface probably could be approximately located by thoroughly analyzing the well cuttings from the few wells that enter the Precambrian but was not done in conjunction with this investigation. The facies changes on the Precambrian surface and the depth to the facies changes shown on the profiles are only indicated in relation to the magnitude and the configuration of the magnetic profile.

Undoubtedly, a large number of the positive magnetic anomalies are the result of rises in the Precambrian surface rather than the presence of mafic rock. The proposed Precambrian surface is indicated on the profiles by dotted lines.

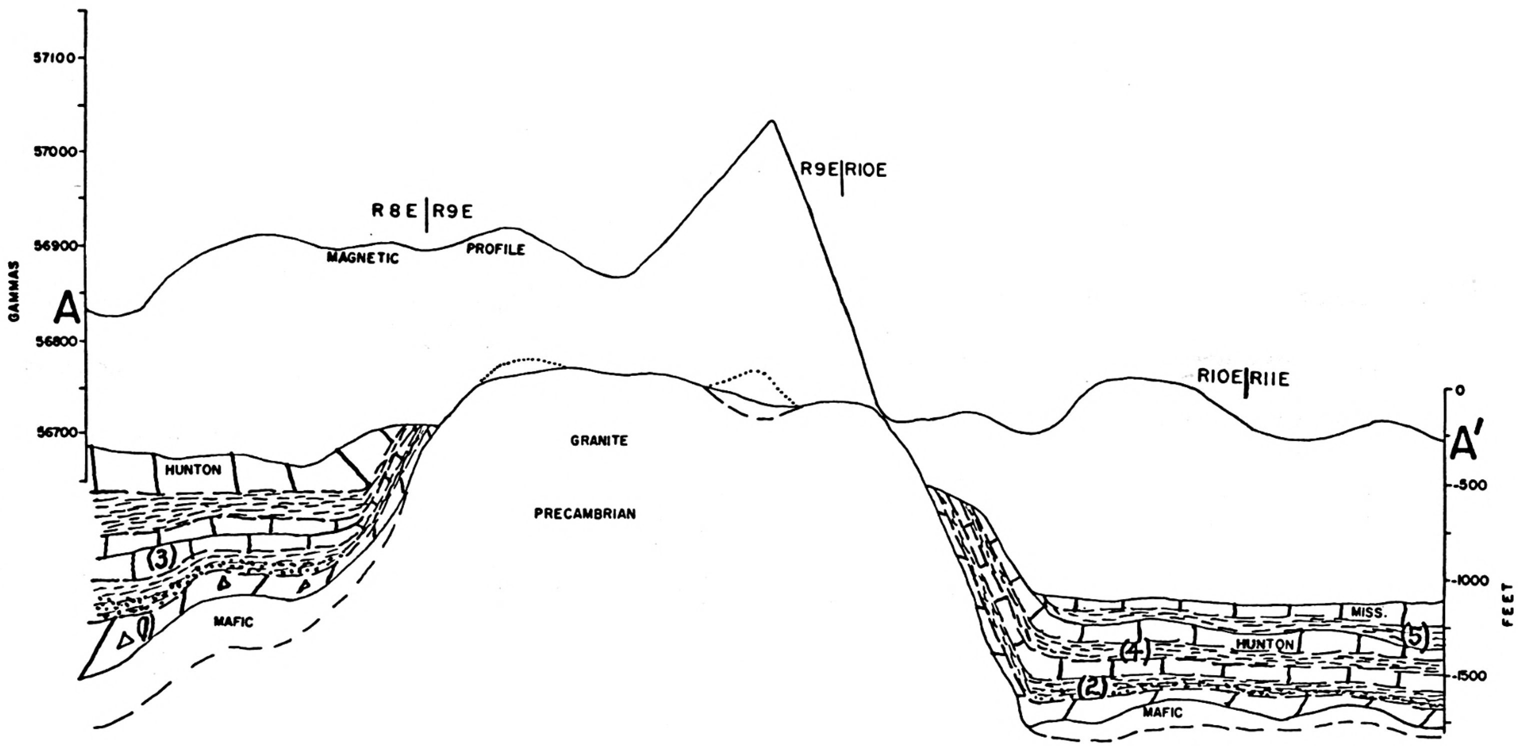
Profile A-A'. Profile A-A' (Plate III) shows the conformation between the magnetic profile and the Precambrian surface better than the other profiles. All structural anomalies are revealed as magnetic anomalies, positive to positive and negative to negative. The Precambrian surface drops rapidly at the eastern edge of R. 8 E. and at the western edge of R. 10 E. without an equivalent drop in the magnetic profile. Perhaps an adequate volume of mafic rock is present in place of granite in the Precambrian basement to account for this. Mafic rocks are also believed to be present at the eastern edge of R. 9 E., where the magnetic readings increase with no apparent increase in the altitude of the Precambrian surface. An abrupt drop in the magnetic profile at the eastern edge of R. 9 E. and the western edge of R. 10 E. is associated with a comparable drop in elevation of the surface of the Precambrian. This type of change probably indicates evidence for a fault in this area.

Profile B-B'. General conformation is revealed between the magnetic profile and the surface of the Precambrian on profile B-B' (Plate IV). A positive structural and magnetic anomaly is seen in R. 7 E. The magnitude of this magnetic anomaly is very great which is probably a result of the presence of

EXPLANATION OF PLATE III

Profile A-A' showing the relationship between the magnetic readings and the subsurface geology, Arbuckle dolomite (1), Simpson sandstone (2), Viola limestone (3), Maquoketa shale (4), Chattanooga shale (5). The dotted line indicates the inferred surface of the Precambrian, and the dashed line indicates the boundary between mafic and felsic igneous rocks.

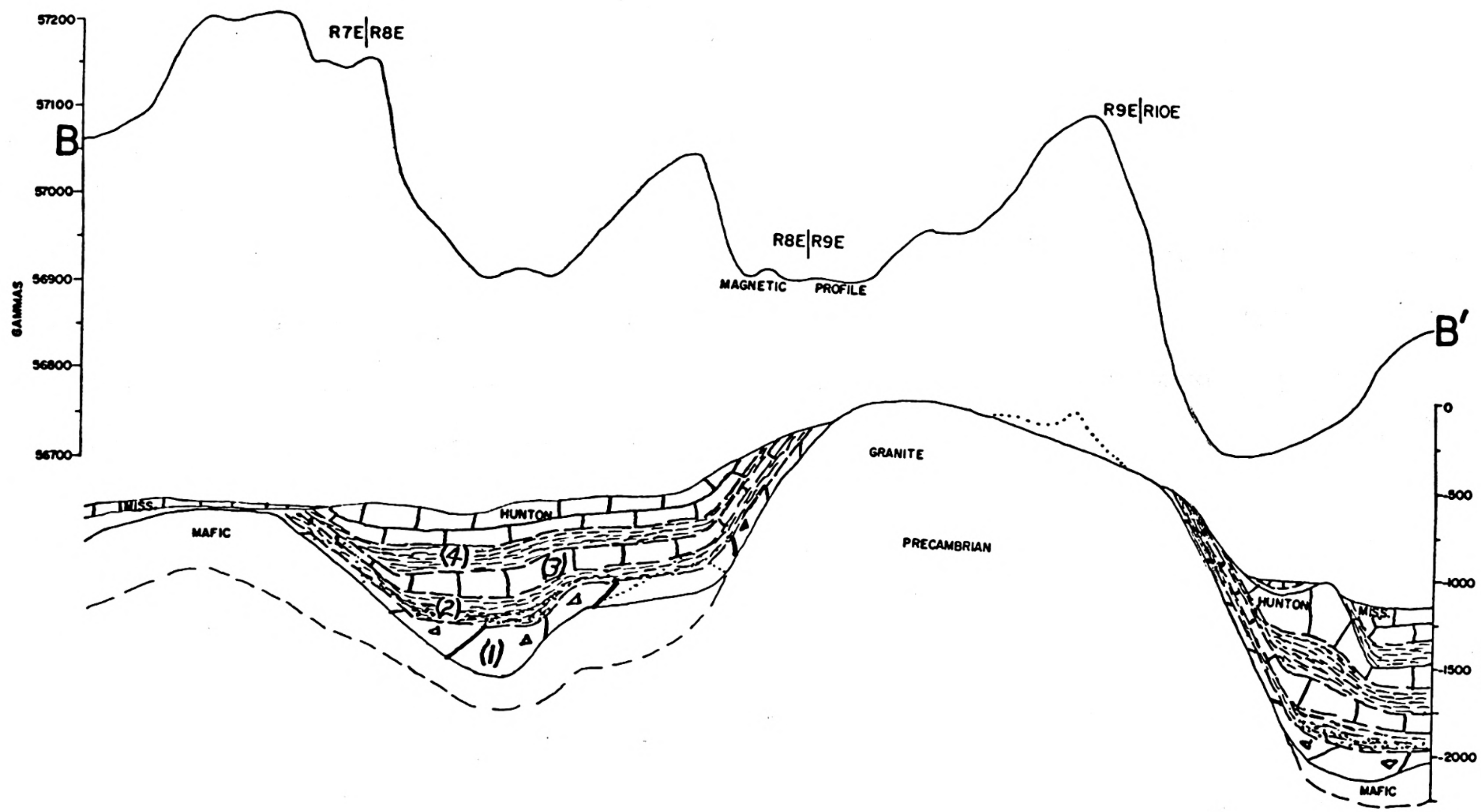
PLATE III


57100
57000
56900
56800
56700
GAMMAS
A
R8E | R9E
MAGNETIC
PROFILE
R9E | R10E
R10E | R11E
A'
0
-500
-1000
-1500
FEET
HUNTON
GRANITE
PRECAMBRIAN
(3)
(1)
MAFIC
MISS.
(5)
HUNTON
(4)
(2)
MAFIC

EXPLANATION OF PLATE IV

Profile B-B' showing the relationship between the magnetic readings and the subsurface geology, Arbuckle dolomite (1), Simpson sandstone (2), Viola limestone (3), Maquoketa shale (4), Chattanooga shale (5). The dotted line indicates the inferred surface of the Precambrian, and the dashed line indicates the boundary between mafic and felsic igneous rocks.

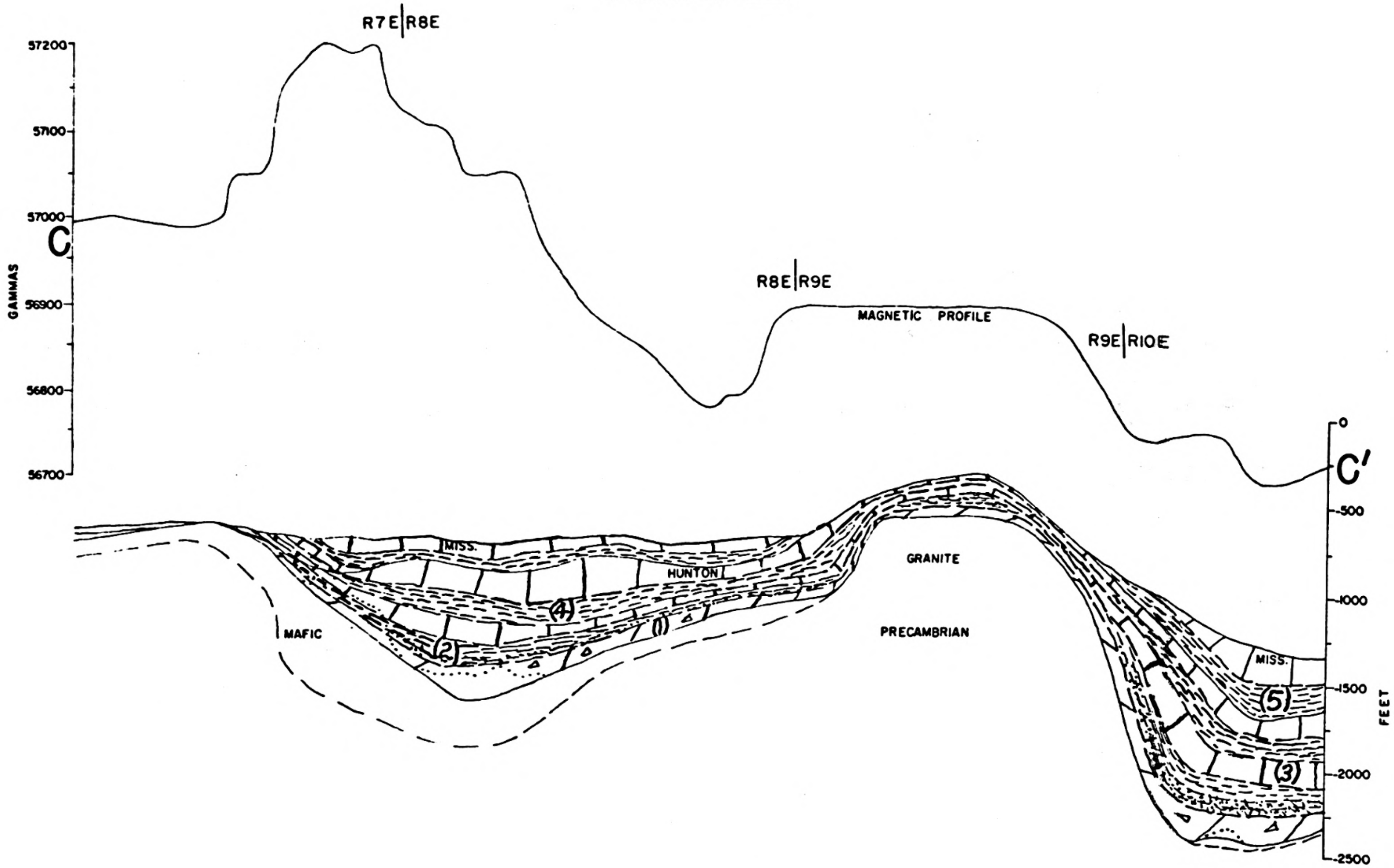
PLATE IV


57200
57100
57000
56900
56800
56700
GAMMAS
B
R7E|R8E
R8E|R9E
MAGNETIC PROFILE
R9E|RIOE
B'
0
500
1000
1500
2000
FEET
MISS.
MAFIC
HUNTON
(4)
(3)
(2)
(1)
GRANITE
PRECAMBRIAN
HUNTON
MISS.
MAFIC

EXPLANATION OF PLATE V

Profile C-C' showing the relationship between the magnetic readings and the subsurface geology, Arbuckle dolomite (1), Simpson sandstone (2), Viola limestone (3), Maquoketa shale (4), Chattanooga shale (5). The dotted line indicates the inferred surface of the Precambrian, and the dashed line indicates the boundary between mafic and felsic igneous rocks.

PLATE V

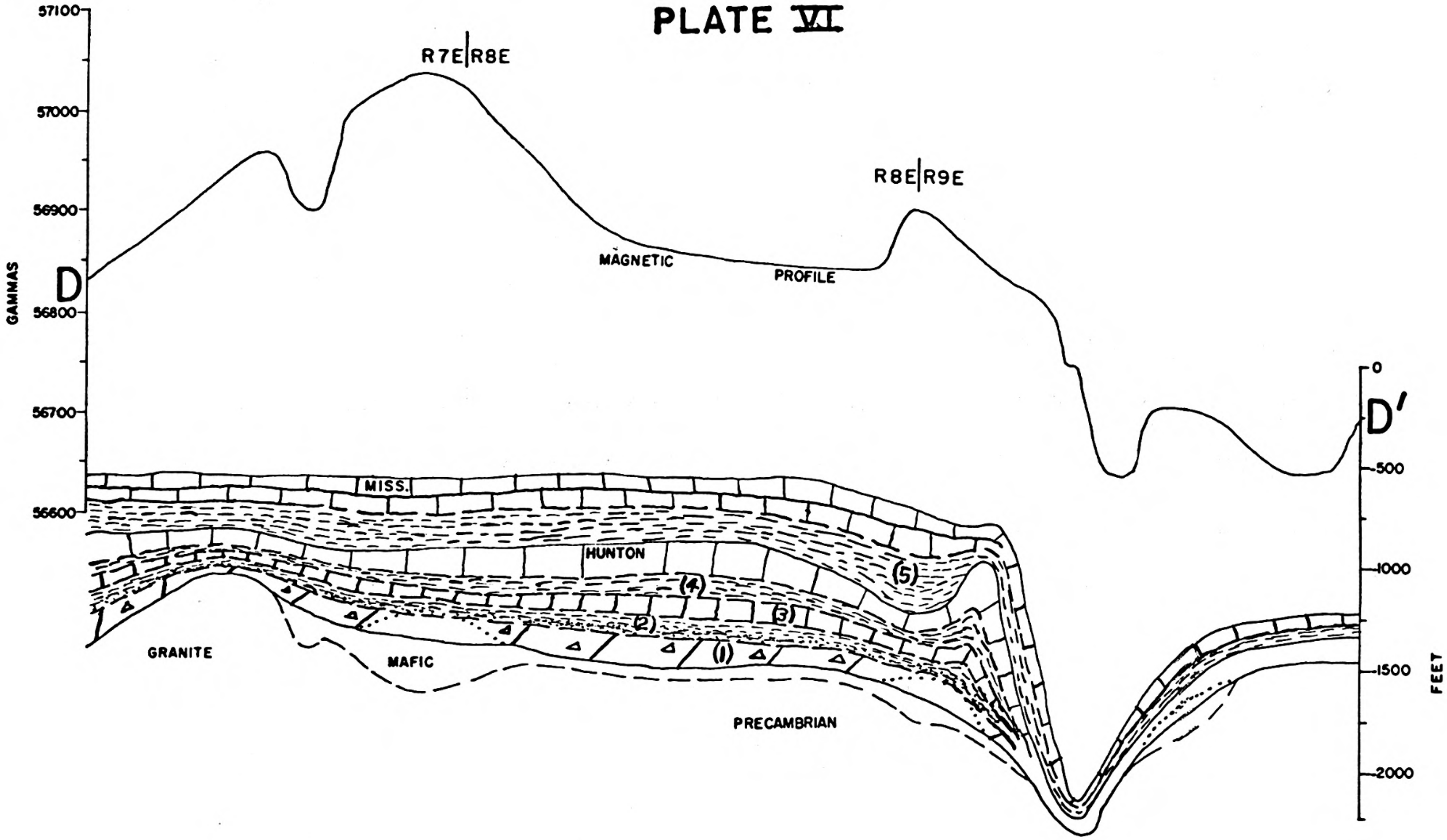


R7E|R8E
R8E|R9E
R9E|R10E
57200
57100
57000
56900
56800
56700
GAMMAS
C
C'
MAGNETIC PROFILE
MISS.
HUNTON
(4)
(1)
(2)
MAFIC
GRANITE
PRECAMBRIAN
MISS.
(5)
(3)
0
-500
-1000
-1500
-2000
-2500
FEET

EXPLANATION OF PLATE VI

Profile D-D' showing the relationship between the magnetic readings and the subsurface geology, Arbuckle dolomite (1), Simpson sandstone (2), Viola limestone (3), Maquoketa shale (4), Chattanooga shale (5). The dotted line indicates the inferred surface of the Precambrian, and the dashed line indicates the boundary between mafic and felsic igneous rocks.

PLATE VI

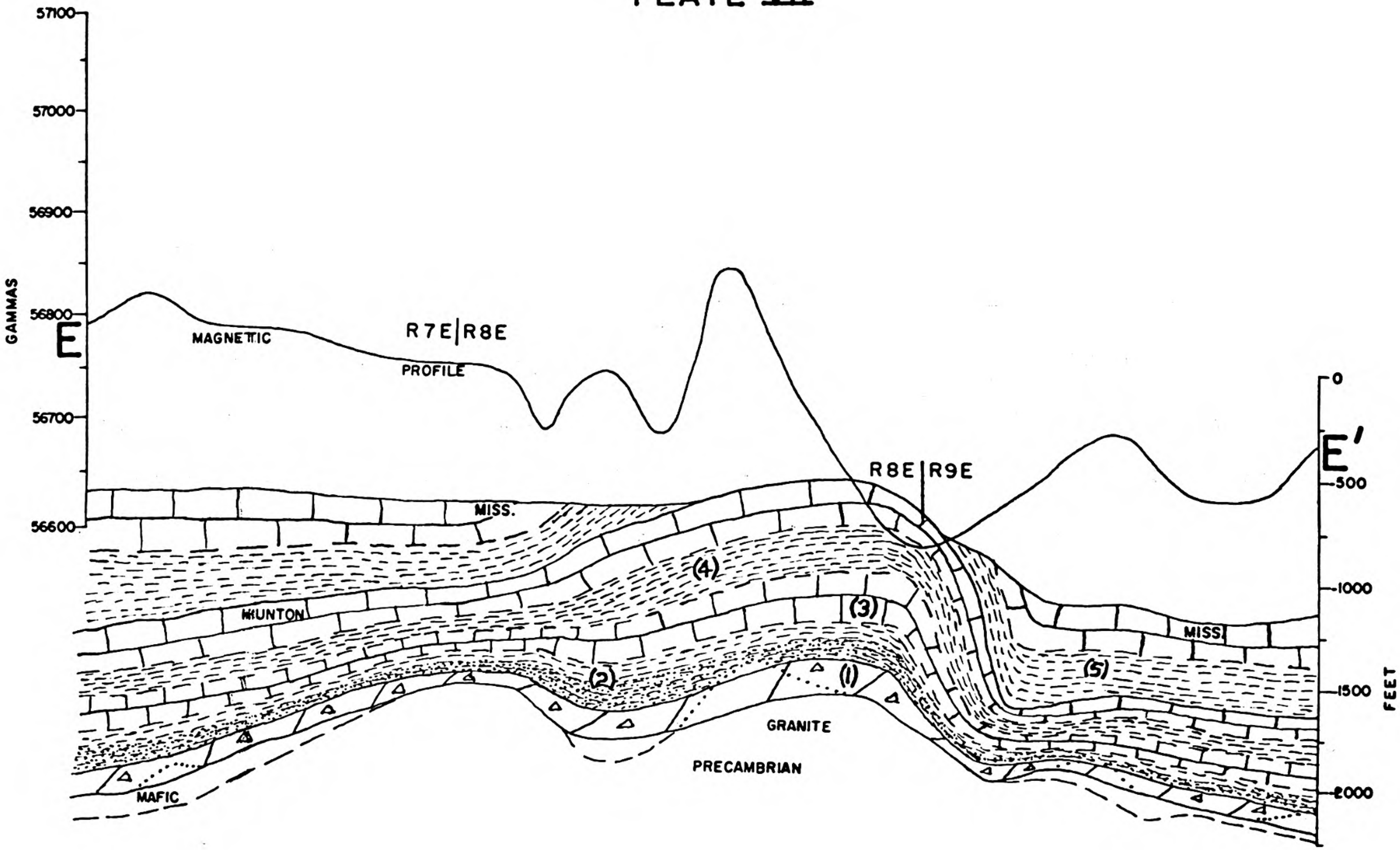


57100
57000
56900
56800
56700
56600
GAMMAS
D
R7E|R8E
R8E|R9E
MAGNETIC
PROFILE
D′
0
500
1000
1500
2000
FEET
MISS.
HUNTON
(1)
(2)
(3)
(4)
(5)
GRANITE
MAFIC
PRECAMBRIAN

EXPLANATION OF PLATE VII

Profile E-E' showing the relationship between the magnetic readings and the subsurface geology, Arbuckle dolomite (1), Simpson sandstone (2), Viola limestone (3), Maquoketa shale (4), Chattanooga shale (5). The dotted line indicates the inferred surface of the Precambrian, and the dashed line indicates the boundary between mafic and felsic igneous rocks.

PLATE VII


57100
57000
56900
56800
56700
56600
GAMMAS
E
MAGNETIC
PROFILE
R7E | R8E
R8E | R9E
E'
0
500
1000
1500
2000
FEET
MISS.
HUNTON
(1)
(2)
(3)
(4)
(5)
MISS.
GRANITE
PRECAMBRIAN
MAFIC

mafic rocks in the Precambrian basement. The Zeandale Dome, R. 9 E., is not revealed in the magnetic profile except toward the eastern boundary of R. 9 E. where a 150 gamma positive magnetic anomaly is shown with no increase in elevation of the Precambrian surface. One explanation for this may be the presence of a resistant knob of mafic rock which is shown on the profile. The magnetic readings drop rapidly at the eastern edge of R. 9 E. as they did in profile A-A'. Again this is indicative of a fault.

Profile C-C'. The positive magnetic anomaly in R. 7 and 8 E. (Plate V) is considerably offset to the east from the underlying positive structural anomaly. This may be due to a misplacement of the structural anomaly because of the few wells drilled, or to a combination of misplacing the structural anomaly and thickening of mafic rock as indicated on the profile. Minor positive magnetic anomalies are present on the major anomaly mentioned which probably are the result of surface configurations as is indicated on the profile. The Precambrian surface conforms perfectly to the magnetic profile in R. 9 E. Toward the eastern edge of R. 9 E., the Precambrian surface drops rapidly as does the magnetic profile which probably indicates a fault in the area.

Profile D-D'. The positive structural anomaly in the center of R. 7 E. is revealed in the magnetic profile as the smaller positive magnetic anomaly. The larger positive magnetic anomaly apparently has no reflection on the Precambrian surface which is probably due to the small amount of well control available when contouring the structural map on the Precambrian. Therefore, a small positive structural anomaly is presumed present with thickening of the mafic rocks. The same occurs at the eastern edge of R. 8 E. and the western edge of R. 9 E. A positive magnetic anomaly is present with seemingly no positive structural anomaly. Again a structural high is proposed along with thickening of mafic rocks. A large abrupt negative anomaly is shown in the center of R. 9 E. with a similar negative structural anomaly.

Profile E-E'. Very little conformity exists between the magnetic profile and the profile depicting the surface of the Precambrian in profile E-E' (Plate VII). West from the border of Ranges 7 and 8 E. the magnetic profile increases in magnitude and the surface of the Precambrian decreases in elevation, therefore, a lithologic change must occur in the basement rocks. West of the center of R. 8 E., the negative structural anomaly apparently corresponds to the positive magnetic anomaly directly above. Thus, a valley of mafic rocks is thought to be present in the negative structural anomaly. In the center of R. 8 E., a positive magnetic anomaly exists where a rise in the Precambrian surface is inferred by the dotted line.

CONCLUSION

This investigation has shown that considerable conformity exists between magnetic anomalies and the structural anomalies on the Nemaha Anticline. However, the magnitudes of the magnetic anomalies are not consistent with the depths to the structural anomalies. For example, the highest magnetic readings were recorded in the western portion of the area investigated, T. 11 S., R. 7 E., where the depth to the surface of the Precambrian is approximately 500 feet below sea level, and where the Precambrian surface is at the same depth in the eastern portion of the area, T. 11 S., R. 9 E., the magnetic readings are more than 200 gammas lower. The inconsistency in the magnitude of the readings is attributed to lithologic variation within the basement rocks.

Heretofore unrecognized structural highs on the "Hunton" are discussed in regard to petroleum possibilities. A magnetic and structural high that should carefully be considered in exploring for petroleum is in Sections 2, 3, 4, 9, 10, and 11, T. 11 S., R. 8 E.

Rich (1954), Koons (1955), Lee (1955), Kotoyantz (1956), and Sternin (1961) advocate the existence of a fault on the east flank of the Nemaha Anticline. From the previous information, a fault is proposed in T. 12 S., R. 9 E., but not along the entire length of the area investigated as Koons (1955) suggests.

The perimeters of the areas where Mississippian rocks are absent are depicted with perhaps more certainty than with just well data alone. Previous structure contour maps depicting the edge of the Mississippian rocks have been constructed from well data alone, whereas, in this investigation, magnetic anomalies were combined with well data to delineate areas where Mississippian rocks are absent.

ACKNOWLEDGMENT

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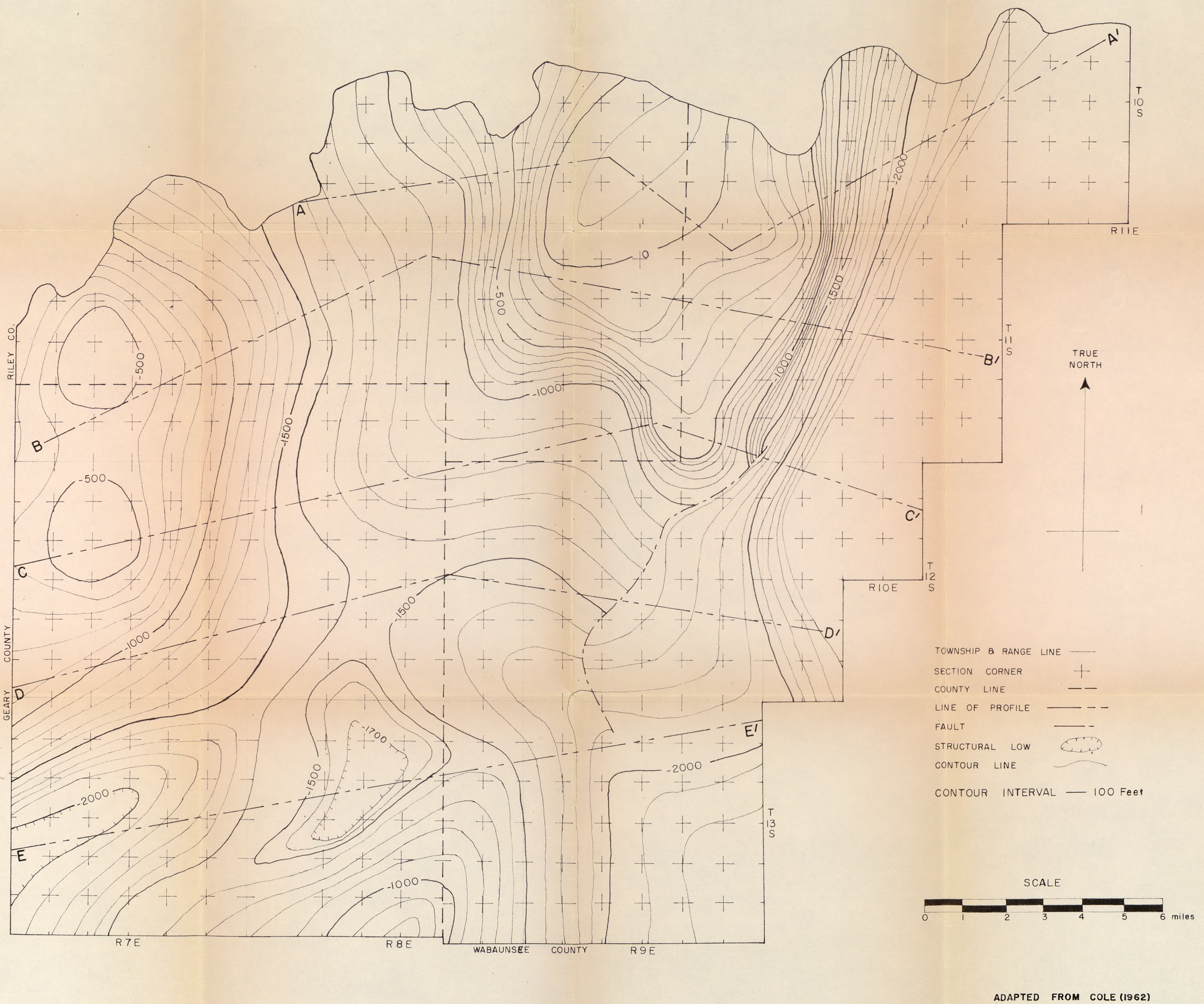
APPENDIX

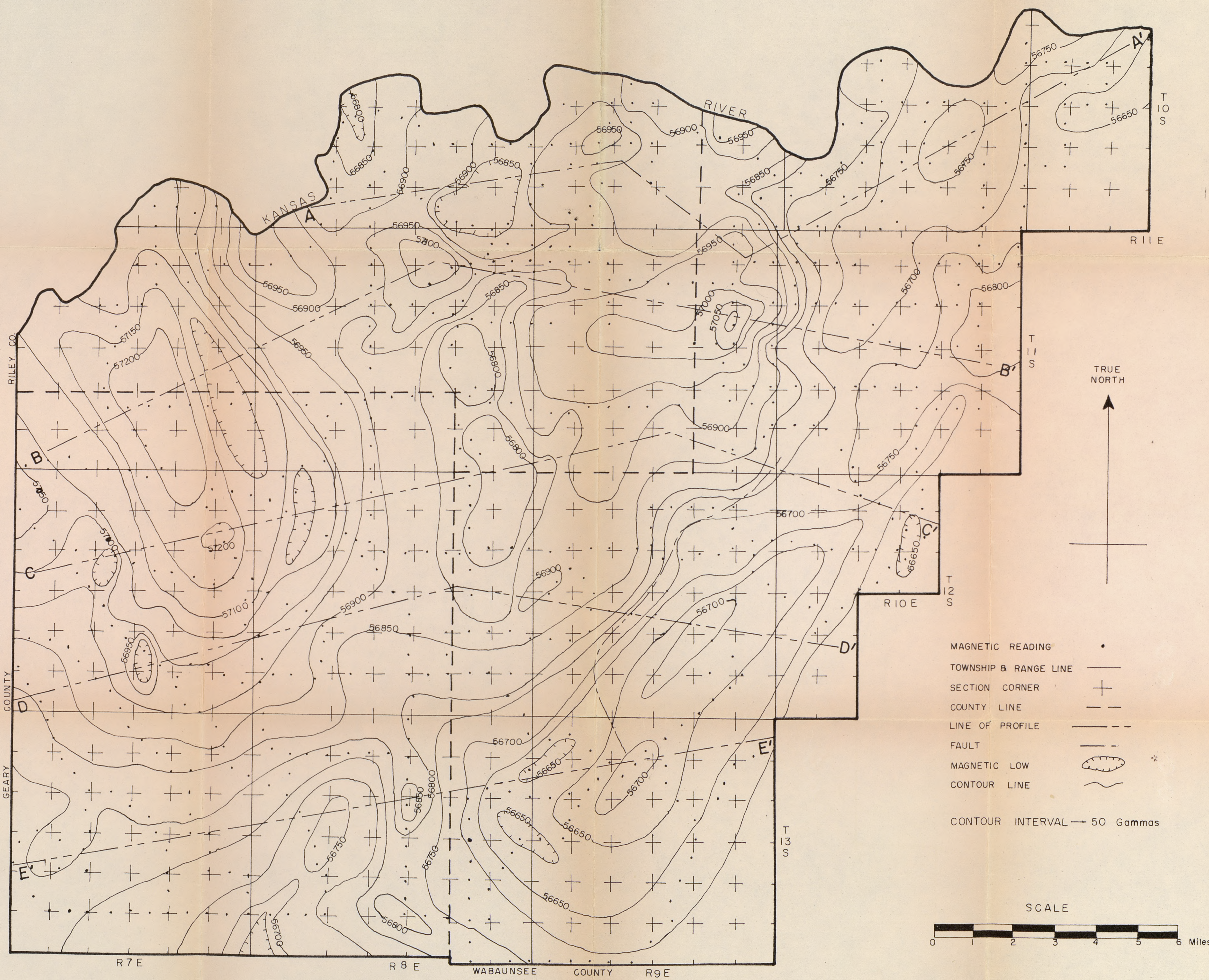
STRUCTURE CONTOUR MAP ON PRECAMBRIAN



ADAPTED FROM COLE (1962)

(VIII)

MAGNETIC MAP

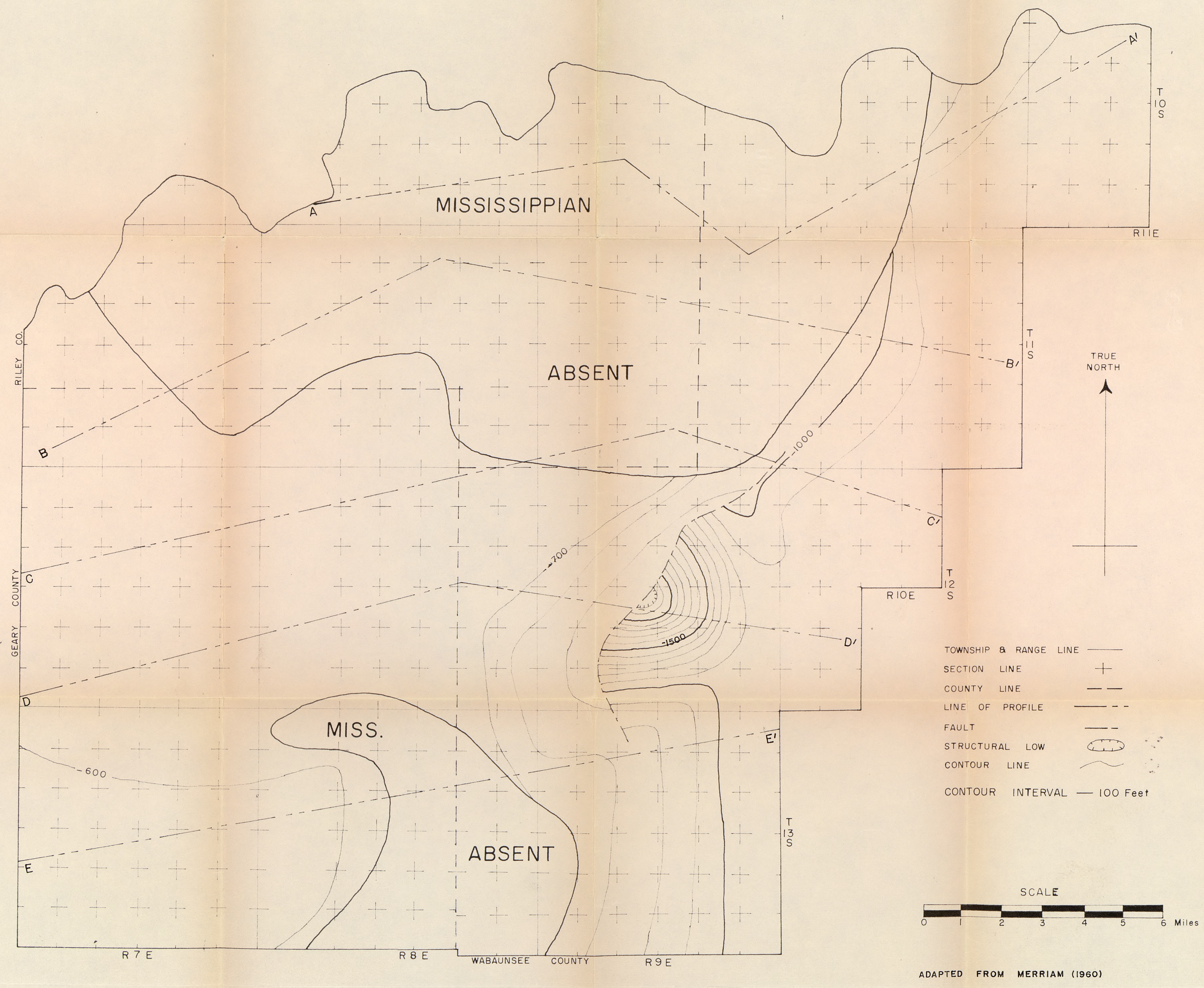


BILLY L. BAYSINGER

STRUCTURE CONTOUR MAP ON HUNTON

ADAPTED FROM MERRIAM & KELLY (1960)

STRUCTURE CONTOUR MAP ON MISSISSIPPIAN



ADAPTED FROM MERRIAM (1960)

A MAGNETIC INVESTIGATION OF THE NEMAHA ANTICLINE IN WABAUNSEE, GEARY, AND RILEY COUNTIES, KANSAS

by

BILLY L. BAYSINGER

B. S., Kansas State University, 1961

AN ABSTRACT OF THE THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

Approved by:

Major Professor

The purpose of this investigation was to complete a magnetic survey over the Nemaha Anticline in western Wabaunsee County, eastern Geary County and southeastern Riley County, and to determine the relationships between the magnetic anomalies, geologic structural features, and lithologies of the subsurface rocks.

Approximately 480 square miles were included in the survey and approximately 700 magnetic readings were taken with the M-49A Varian Magnetometer.

A complete review of the available literature was made and the more pertinent material is included within the text.

Only a brief resume of the stratigraphy is presented because the primary purpose was the structural features and analysis of their effect on the earth's magnetic field.

The magnetic map was contoured and magnetic anomalies were compared to structural anomalies delineated on structure contour maps constructed on the surfaces of the Precambrian, "Hunton", and Mississippian rocks. An interpretation of the magnetic map is presented along with possible geological explanations for the existence of most of the magnetic anomalies. A small negative magnetic anomaly and a large structural anomaly brought about the proposal of a fault in T. 12 S., R. 9 E., but not along the entire length of the Nemaha Anticline as has been proposed by some previous workers.

Five east-west profiles were constructed depicting the magnetic readings and the surfaces of the Precambrian, "Hunton", and Mississippian rocks. The five profiles, a magnetic map, and three structure maps indicate a bifurcated shaped synclinal feature in the area investigated. This synclinal area separates the Nemaha Anticline into three distinct positive areas; the Zeandale Dome in southeast Riley County and northwest Wabaunsee County, an elongated dome in eastern Geary County and southern Riley County, and a smaller structural "high" in western Wabaunsee County and southeast Geary County. The surface of the Precambrian in the elongated dome in eastern Geary County and southern Riley County is much lower in altitude than in the Zeandale Dome but has a magnetic reading that is 300 gammas higher. It is believed the variations in magnetic intensities are caused by a lithologic change in the basement igneous and metamorphic rocks.

Geologic structure contour maps on the "Hunton" and Mississippian were constructed for comparison with the magnetic map to depict structural anomalies that may be petroleum traps because both rock units are important reservoir rocks for petroleum in Kansas. A magnetic high in sections 2 and 10, T. 11 S., R. 8 E., is interpreted as resulting from a previously unrecognized structural "high" that may be a petroleum trap.