A MAGNETIC INVESTIGATION OF NORTHERN RILEY COUNTY, KANSAS

by

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Major Professor

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INTRODUCTION

Purpose of Investigation

The main purpose of this investigation was to construct and interpret a magnetic map of the northern half of Riley County to determine the magnetic axis of the Abilene Anticline, Irving Syncline and other possible structures that might occur in the area of investigation. It was also hoped that a magnetic correlation could be determined between the five igneous intrusions present in northern Riley County and the Abilene Anticline.

Dreyer (1947) made a magnetic survey of the Bala intrusion using a vertical magnetometer. Cook (1955) made a magnetic survey of the Stockdale, Leonardville, Randolph No. 1 and Randolph No. 2 intrusions using a temperature-compensated Askania vertical magnetometer. The data obtained by the present survey of the five intrusions, using a model M-49A Varian portable magnetometer which measures the total intensity of the earth's magnetic field, will be discussed in reference to the data obtained by Dreyer and Cook in their surveys.

Limitation in the use of the model M-49A Varian portable magnetometer, with respect to cultural features, was also determined. This was done by constructing magnetic profiles across various cultural features to show the extent of their magnetic influence.

Area of Investigation

Geographic Location. Riley County, in northeastern Kansas, occupies approximately 624 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 Geary and Clay counties.

The area of investigations included approximately the northern one-half of Riley county and included T. 6 S., Ranges 4, 5, 6, 7 and 8 E.; T. 7 S., Ranges 4, 5, 6, and 7 E.; T. 8 S., Ranges 4, 5, 6, and 7 E. (Plate I). This is an area of approximately 312 square miles in which approximately 2,500 magnetic readings were made.

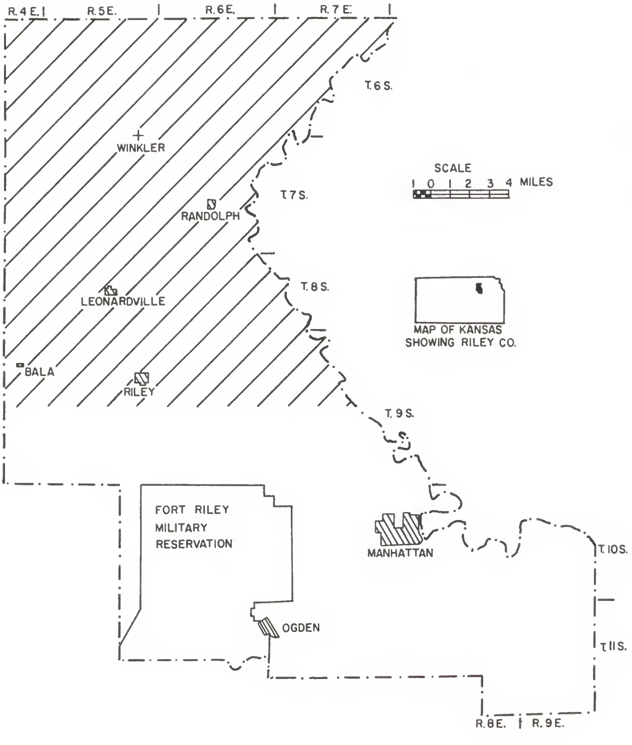
Physiography. Riley County lies in the Flint Hills Upland section of the Central Lowland physiographic province of the Interior Plains major physiographic division (Frye, 1953, p. 248). The Flint Hills Upland section is characterized by parallel series of eastwardly-facing cuesta scarps developed on cherty limestone of early Permian age.

Two principal rivers, the Kansas River and the Big Blue River, are near the area of investigations. The Kansas River is in the southern part of Riley County. The Big Blue River extends along the eastern border of Riley County. Six miles north of Manhattan, Kansas the Tuttle Creek Dam extends across the Big Blue River Valley forming the Tuttle Creek Reservoir.

EXPLANATION OF PLATE I

Map of Riley County showing area of investigation.

PLATE I


R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
T. 6 S.
WINKLER
SCALE
1 0 1 2 3 4 MILES
T. 7 S.
RANDOLPH
T. 8 S.
LEONARDVILLE
MAP OF KANSAS
SHOWING RILEY CO.
BALA
RILEY
T. 9 S.
FORT RILEY
MILITARY
RESERVATION
MANHATTAN
T. 10 S.
OGDEN
T. 11 S.
R. 8 E.
R. 9 E.

The Tuttle Creek Reservoir was built as a flood control project and covers approximately 15,800 acres at conservation level of 1,075 feet. Most of the area is drained by tributaries of the Kansas River and the Big Blue River and shows well-developed dendritic drainage patterns. The valleys of the Kansas River and the Big Blue River are mature.

The maximum relief in the area is approximately 350 feet. The highest elevation in the county is approximately 1,400 feet in the northwestern part of the county. The lowest elevation in the area is conservation level of the Tuttle Creek Reservoir of 1,075 feet.

Review of Literature

Published Geologic Data. In Riley County there are five outcrops of igneous rock. Moore and Haynes (1920) described the igneous rock of the Bala Intrusion. Byrne, Parish and Crumpton (1956) summarized the most important physical features of the five intrusions. They suggested that the igneous rock was probably intruded during the Late Cretaceous Epoch.

The geology of Riley and Geary counties was described by Jewett (1941). Jewett dealt primarily with the stratigraphy but did mention a structural high near Winkler which was caused by the Abilene Anticline. He also stated that in Nebraska the Abilene Anticline is commonly called the Barneston Arch. Jewett and Merriam (1959) presented a review of the geology of Kansas in which they discussed the geology of the Salina Basin and the occurrence of igneous rock in Riley County. Lee (1956) described the stratigraphy and structural development of the Salina Basin.

Shenkel (1959) discussed the geology of the Abilene Anticline and stated that it is a major structure extending approximately 70 miles from an area north of Abilene, Kansas, to an area near Marysville, Kansas. Shenkel gave credit to J. S. Barwick for naming and describing the Abilene Anticline. He also gave credit to G. E. Condra and J. E. Upp for applying the name Irving Syncline to the syncline that parallels the Abilene Anticline on the east.

The physiographic divisions of Kansas were described by Frye and Schoewe (1953). Frye and Leonard (1959) described the physiography of the Flint Hills. They also described the erosional history and development of the Flint Hills.

Published Magnetic Data. A transcontinental gravitational and magnetic traverse was made from New Jersey to California, Woollard (1943). Part of the Kansas portion of this traverse passed through Manhattan which is approximately six miles south of the area of this investigation. Woollard stated there is no correlation between the magnetic profile of the Nemaha Ridge and the surface of the Precambrian "basement". He concluded that the lack of correlation is probably due to changes in the basement lithology. A magnetic anomaly coinciding with a gravitational anomaly near Clay Center, Kansas, is explained as a large subsurface mass that is probably gabbro.

Dreyer (1947) conducted a magnetic survey of the Bala intrusion in Riley County with a verical magnetometer. Dreyer found an anomaly greater than 3,500 gammas with a magnetic "low" in the center. Dreyer concluded that the intrusion is a nearly vertical dike that plunges eastward.

Cook (1955) discussed the results of a magnetic survey of four igneous intrusions in Riley County in addition to the survey conducted by Dreyer. Vertical magnetic intensity maps were constructed of the Leonardville, Stockdale, Randolph No. 1 and Randolph No. 2 intrusions. The magnetic survey indicated that the intrusions were nearly vertical bodies that plunge to the southeast. Cook concluded that the intrusion may have been controlled by joints associated with the Abilene Anticline.

Merriam and Hambleton (1956) constructed a geologic cross-section along the Kansas-Nebraska border corresponding to Jensen's airborne magnetometer traverse flown along the 40th parallel in 1948. Comparison of the geologic and magnetic data showed a regional magnetic gradient increasing toward the east which is produced by thinning of the sedimentary rocks. In western Kansas, the magnetic "highs" correspond to structural "highs" and magnetic "lows" correspond to structural "lows". In eastern Kansas, Merriam and Hambleton suggest that the magnetic data reflect the distribution of the Precambrian rock types and does not reflect structures.

In most rocks, the magnetic susceptibility is directly proportional to the ferromagnetic mineral content. The only ferromagnetic minerals known to occur in measurable quantities in Kansas rocks are magnetite and ilmenite. The average sedimentary rock contains a magnetite-ilmenite content of 0.09 percent. Although the percentage of ferromagnetic minerals is generally low for sedimentary rocks, some of the Dakota sandstones have an iron oxide content of approximately 9.0 percent (Merriam and Hambleton, 1956).

Hambleton and Merriam (1957) reviewed all the published geophysical literature on Kansas through 1956. Reference is made to magnetic, gravity, electrical, seismic, and radioactive studies.

Agocs (1959) made a comparison of "basement" depths from Jensen's aeromegnetic traverse with data from wells along the northern border of Kansas. Considering that the magnetic control from only one profile was used, Agocs found generally good agreement between depths of the Precambrian "basement" obtained from aeromagnetics and depths obtained from wells.

Unpublished Data. Most of the investigation and interpretation of the geology in and around the area of investigation was done by students of geology at Kansas State University and is reported in unpublished Master's theses.

Neff (1949) conducted a study of the joint systems of Riley County. He concluded that the joint systems were caused by tensile stresses due to regional uplift and the combined forces of differential compaction and differential uplift near the end of the Paleozoic Era. Neff found that most of the normal faults in Riley County are in the southeast corner. Most of the thrust faults are in the central part of the county and are associated with the Abilene Anticline. The thrust faults are in the limestones of the Winfield Formation and are probably due to relief by erosion of stresses resulting from differential compaction and downdip plastic flow of the enclosing thick shales.

Beck (1949) discussed the Quaternary geology of Riley County and Mudge (1949) discussed the pre-Quaternary stratigraphy of Riley County. Mudge described the Abilene Anticline in the northern part of Riley County and suggested the existence of a small syncline northwest of the Abilene Anticline.

Taylor (1950) described the flexures and igneous intrusions of Riley County. A dip needle survey was conducted over the Leonardville and Stockdale intrusions by Taylor. It was determined that the intrusions were elongated in approximately the same direction as the Bala intrusion surveyed by Dreyer. Taylor concluded by suggesting that the igneous rock could have been intruded through open gash fractures caused by strike slip movement in the basement complex along the Abilene Anticline.

Nelson (1952) described the reflection of the basement complex in the surface structures of Marshall and Riley Counties. He stated that the igneous intrusions resulted from local release of pressure by strike-slip movement along the Big Blue fault which extends along the east side of the Barneston-Winkler Ridge.

Bridge (1953) studied the petrology and petrography of the igneous intrusions of Riley County. He suggested that the original magma consisted of pyroxenite or a pyroxenite differentiation of a gabbro.

Koons (1955) discussed faulting as a possible origin of the Nemaha Anticline. He stated that the Abilene Anticline seems to be due to a hinge fault that parallels the Nemaha fault with 400 feet of displacement in Marshall County and decreasing toward the south. He described the Irving Syncline as the southern extension of a trough between the Barneston and Nemaha faults.

Merryman (1957) described the geology of the Winkler area of Riley County. He stated that the dip of the beds is the result of a draping effect of the sediments over the Abilene fault scarp.

Mendenhall (1958) described the Abilene Anticline near Bala, Kansas. He suggests that the rapid change in dip of the sedimentary beds in the area of investigation is evidence of subsurface faulting.

Baysinger (1962) described a circular depression one mile northeast of Winkler, Kansas to which the name Pfaf Crater was applied. Baysinger credited Dr. C. W. Shenkel, Jr. with the recognition of the crater from aerial photographs. The crater is on the axis of the Abilene Anticline. A magnetometer survey showed a magnetic anomaly of 540 gammas in the southeastern section of the crater. Baysinger concluded that the crater possibly was formed by an igneous intrusion.

Baysinger (1963) described a magnetic survey of the Nemaha Anticline in Wabaunsee, Geary and Riley counties. He concluded that considerable conformity exists between magnetic anomalies and structural anomalies on the Nemaha Anticline. The magnitude of the magnetic anomalies did not show consistence with depths of the structural anomalies.

GEOLOGY

Stratigraphy

Sedimentary and igneous rocks crop out in the area of investigation. The majority of sedimentary rocks which crop out in the area are Permian. Outliers of Dakota Sandstone, Cretaceous age, lie disconformably on the Permian rocks in the northwestern corner of Riley County. Quaternary sediments occur in stream valleys and in some of the upland areas.

Five igneous intrusions of serpentized peridotite occur in Riley County (Plate II). Byrne, Parish, and Crumpton (1956) suggested that the igneous rocks were intruded during the latter part of the Cretaceous Period.

The thickness of the sedimentary rocks over the Abilene Anticline in the southern part of the area is about 2,800 feet. The sedimentary rocks over the Abilene Anticline thin to the north to approximately 1,600 feet where the axis intersects the Nemaha Anticline (Shenkel, 1959).

Precambrian Rocks. The Precambrian rocks in the area of the Abilene Anticline consist mainly of granite, granite gneiss, quartzite, and schist. Faquhar (1957) identified cuttings from wells drilled into the Precambrian near Clay Center as Diabase. In northeastern Kansas, a layer of weathered granite generally overlies the unweathered Precambrian surface.

Paleozoic Rocks. The description of the Paleozoic Rocks was taken from Shenkel (1959) who presented a columnar section of the sedimentary sequence from the Llewelyn No. 1 well (NE¼, NE¼, NE¼, Sec. 11, T. 9 S., R. 4 E.) in Riley County.

Shenkel showed less than 30 feet of the Arbuckle Group, consisting of cherty dolomite and dolomitic limestone, of Late Cambrian and Early Ordovician Epoch lying nonconformably on the Precambrian rocks. From Middle Ordovician to Late Mississippian, approximately 890 feet of sedimentary rocks are encountered consisting primarily of cherty and shaly dolomites and limestones, with the exceptions of the St. Peter Sandstone of Middle Ordovician Epoch, approximately 40 feet thick, and the Chattanooga and Boice Shale of Devonian and Mississippian Period, approximately 150 feet thick. Approximately 1,900 feet of alternating shale and limestone comprise the rocks of Pennsylvanian and Permian Periods.

Structure

Regional Structure. The area of this investigation is on the eastern flank of the Salina Basin which is separated from the Forest City Basin to the east by the Nemaha Anticline. The Central Kansas Uplift bounds the Salina Basin on the west. The axis of the Salina Basin is parallel to the northwestward trend of the Central Kansas Uplift.

The axis of the Nemaha Anticline trends approximately N. 20° E. through the area of investigation from an area near Omaha, Nebraska southwestward to an area near Oklahoma City, Oklahoma. The Nemaha Anticline is an asymmetrical fold having a steeper eastern limb than the western limb.

Local Structures. A major structure in the area of this investigation is the Abilene Anticline which extends approximately 70 miles from an area north of Abilene to an area near Marysville, Kansas. The axis of the Abilene Anticline trends northeast-southwest (Plate II). Near the Kansas-Nebraska border in Marshall County, the axis of the Abilene Anticline intersects the west flank of the Nemaha Anticline, Shenkel (1959). The Abilene Anticline is an asymmetrical anticlinal fold with the east flank having a greater dip than the west flank. The asymmetry of the Abilene Anticline has been interpreted by Koons (1955), Merryman (1957), and Mendenhall (1958) as evidence of a fault origin. Taylor (1950) and Nelson (1952) described a possible strike-slip fault that parallels the Abilene Anticline on the east.

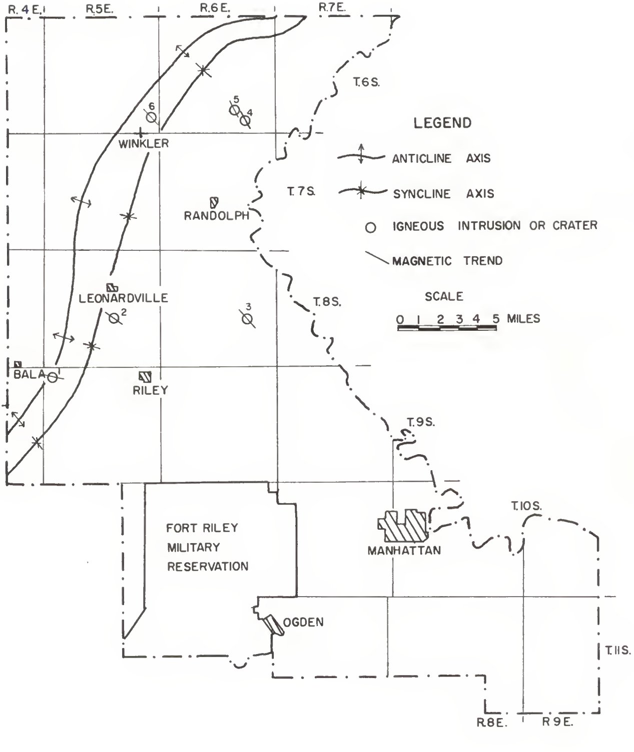
Mudge (1949) described a small syncline associated with the Abilene Anticline in the northwestern part of the county and suggested that it was responsible for the existence of the

EXPLANATION OF PLATE II

Map of Riley County, Kansas showing the location of structure (Shenkel, 1959), igneous intrusions, and Pfaf Crater.

1. Bala Intrusion	4. Randolph No. 1 Intrusion
2. Leonardville Intrusion	5. Randolph No. 2 Intrusion
3. Stockdale Intrusion	6. Pfaf Crater

PLATE II


R. 4 E.
R.5E.
R.6 E.
R.7E.
T.6S.
T. 7S.
T.8S.
T.9S.
T.10S.
T.11S.
R8E.
R 9E.
LEGEND
ANTICLINE AXIS
SYNCLINE AXIS
IGNEOUS INTRUSION OR CRATER
MAGNETIC TREND
SCALE
0 1 2 3 4 5 MILES
WINKLER
RANDOLPH
LEONARDVILLE
BALA
RILEY
FORT RILEY
MILITARY
RESERVATION
MANHATTAN
OGDEN
1
2
3
4
5
6

Dakota Sandstone outliers. A small fold was mapped extending from Bala south to the Riley-Geary County line. Small faults and flexures were found in the Stoval limestone by Mudge.

The Irving Syncline is between the Abilene Anticline to the west and the Nemaha Anticline to the east. The axis of the Irving Syncline is approximately parallel to the axis of the Abilene Anticline (Plate II).

Structural History

Five periods of regional deformation affecting the development of this area were recognized by Lee (1956). These five periods of deformation are the pre-St. Peter deformation; post-St. Peter, pre-Chattanooga; early Mississippian through Permian; post-Permian, pre-Cretaceous; and post-Cretaceous deformations.

During pre-St. Peter time there was deformation and beveling of the Southeast Nebraska Arch. A northwest trending syncline was developed southwest of the Southeast Nebraska Arch across part of the area that later became the Central Kansas Uplift.

After St. Peter time, the Southeast Nebraska Arch subsided to form the North Kansas Basin. The Chautauqua Arch, Hugoton Embayment, and the initial movement of the Central Kansas Uplift were contemporary structural developments during this time.

Deformation of the Nemaha Anticline, Abilene Anticline, and the Central Kansas Uplift began in Early Mississippian time, was culminated at the end of the Mississippian, and continued until Middle Permian time with decreasing emphasis. Regional tilting toward the north occurred during Early Mississippian time and the region was tilted in the opposite direction during Late Mississippian time.

At the end of Permian time, deformation of the Central Kansas Uplift ceased and there was a tilting of the Central Kansas Uplift and the Salina Basin to the southwest toward the Hugoton Embayment. Post-Cretaceous deformation caused a tilting of the region northward and northwestward toward the Denver Basin. The net effect of the tilting is expressed by the northwestward regional dip of the units in the Salina Basin.

MAGNETOMETER

Introduction

The model M-49A Varian portable magnetometer was used in this survey. This instrument measures the total intensity of the earth's magnetic field in an interval as short as six seconds. The Varian magnetometer weighs less than 20 pounds and is sensitive to plus or minus ten gammas.

Principle of Operation

The principle of operation of the instrument is the protons acting as minute spinning bar magnets. The protons will act as bar magnets attempting to align themselves with magnetic north and as spinning masses they will act as gyroscopes which will resist any change in orientation and will cause precession about the axis of any displacing force.

A sample of water is used to supply the protons because the nucleus of the hydrogen atom consists of one proton and the oxygen atom is not affected by the magnetic field. The water sample is placed in a polyethylene bottle which is surrounded by an induction coil. Current is applied to the induction coil causing a magnetic field which is much stronger than and approximately perpendicular to the earth's magnetic field. This causes the protons to be oriented with the newly induced field. When the polarizing field is released, at the end of three seconds, a sufficient number of protons will precess together and the frequency of their precession is measured which is directly proportional to the earth's magnetic field. After precessing for three seconds, the cycle is repeated.

Method of Investigation

Nine base stations were located throughout the area of investigation. The base stations were used to determine diurnal variations and as a check on the consistency of readings from one station to another. One or more base stations were checked at the beginning and the end of each day's survey. The station that was closest to the immediate area of investigation was checked regularly throughout the day to determine the amount of diurnal variation.

Secondary diurnal stations were established near each of the igneous intrusions. While surveying the area around each intrusion, the secondary diurnal station was occupied to determine the diurnal variation during the day. At the beginning and the end of each day, the secondary diurnal station was checked with one or more of the base stations.

The time interval between diurnal checks varied from one to two hours depending on the distance of the diurnal station from the immediate area of investigation. The diurnal variations were plotted on a graph so an approximate variation could be determined for any time during the survey. At the end of the day, the magnetic readings obtained during the survey were corrected for the diurnal variation shown by the graph which varied from 0 to 50 gammas.

Readings obtained from the magnetometer were taken at half mile intervals. It was believed that this spacing would provide a sufficient number of readings to determine the structure of the "basement" rocks. Roads were used where available. Although there was not a sufficient number of roads to take readings every half mile in part of the area, especially around Tuttle Creek Reservoir, a sufficient number of readings were obtained to depict the local structure.

To determine the size and shape of the magnetic anomalies associated with the igneous intrusions, a smaller interval between stations was used. The area around each intrusion was surveyed by taking a reading every 50 feet. An interval of 25 feet was used where there was an abrupt change in the magnetic gradient between adjacent stations. An interval of 100 feet was used where the magnetic gradient was low and the change between adjacent stations was on the order of a few gammas. The one hundred-foot interval was only used when the stations were several hundred feet from the contact of the igneous intrusions. The location of each station was determined by pacing off the distance from the preceding station and by aligning the stations in a north-south and east-west direction to correspond with fences in the area.

Pfaf Crater was mapped by Baysinger in 1962 with the same instrument used in this investigation. Two magnetic profiles were run across the crater, one east-west and one north-south, to determine if there had been any change in the total magnetic intensity during the two year period. The magnetic readings obtained during this investigation and the readings obtained by Baysinger were in good agreement.

Limitations of the Magnetometer

Magnetic Influence of Cultural Features. To eliminate interference of ferromagnetic cultural features, magnetic profiles were constructed across these features to determine the extent of their magnetic influence. Magnetic profiles were constructed for various types of fences, telephone lines, power lines, pipe lines, culverts, automobiles, railroad tracks, and a cemetery (Plates III-XI). To avoid interference from bridges, buildings, and machinery, the magnetic readings were taken at a distance approximately 100 yards from these features. Three readings were taken within the area of each station to insure an accurate reading.

It was determined from the magnetic profiles of the fences that accurate readings could be obtained by taking the readings from the center of the road (Plates III-V). Where the fences were so close to the road that an accurate reading was questioned, the reading was taken in an adjacent field approximately 50 feet from the fence. The fences with steel posts produced the largest amount of influence due to the greater quantity of ferromagnetic material present. The east-west steel post fence produced magnetic interference up to a distance of 42 feet. Fences with wooden posts did not produce any interference beyond 20 feet.

Magnetic profiles of telephone lines and power lines did not indicate any interference (Plate VI). The power lines produced an AC hum which caused the reeds on the reedmeter of the magnetometer to vibrate continuously. The AC hum is directional and by varying the orientation of coil the AC hum effect was eliminated and accurate readings were obtained. The average AC hum of the power lines in the area gave a total intensity reading of 52,155 gammas.

Cultural features showing the greatest amount of magnetic interference were the pipe lines, culverts, automobiles, railroad tracks, and the cemetery (Plates VII-XI). To avoid any possible interference from these features, the distance obtained

EXPLANATION OF PLATE III

Magnetic profile showing the influence of a barbed wire fence with steel post, on both sides of the road.

Fig. 1a. North of east-west fence to center of road.

Fig. 1b. Center of road to south of east-west fence.

Fig. 2. North-south fence.

PLATE III

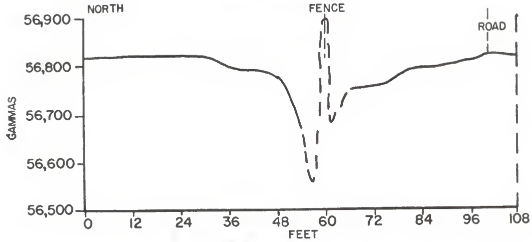


Fig. 1a.

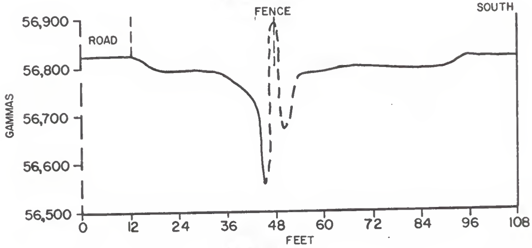


Fig. 1b.

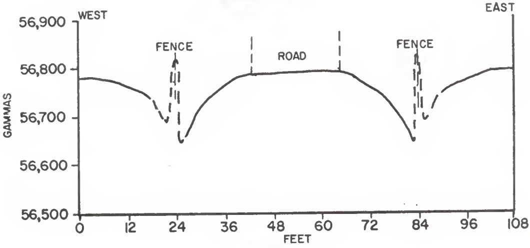


Fig. 2.

EXPLANATION OF PLATE IV

Magnetic profile showing the influence of a barbed wire fence with wooden post, on both sides of the road.

Fig. 1. East-west fence.

PLATE IV

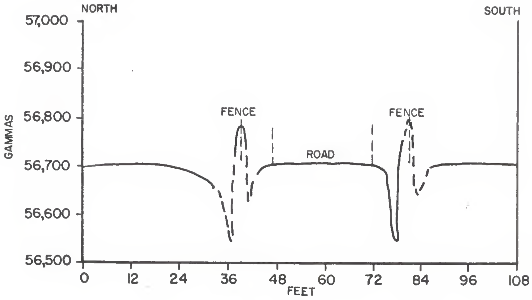


Fig. 1.

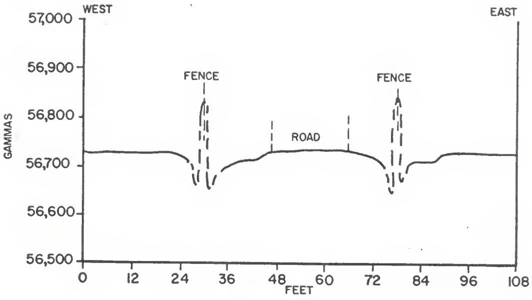


Fig. 2.

EXPLANATION OF PLATE V

Magnetic profile showing the influence of a woven wire fence with wooden post, on one side of the road.

Fig. 1. East-west fence.

Fig. 2. North-south fence.

PLATE V

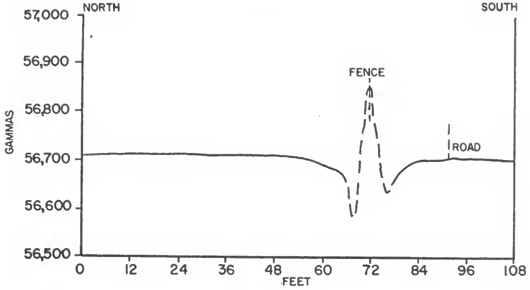


Fig. 1.

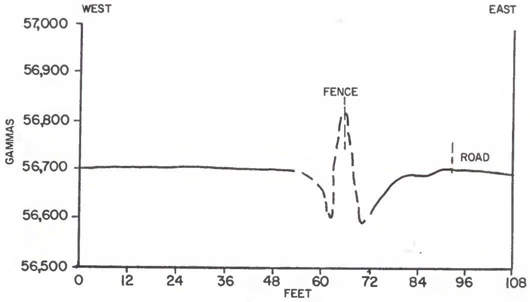


Fig. 2.

EXPLANATION OF PLATE VI

Magnetic profile showing the influence of a telephone line and a power line.

Fig. 1. Telephone line.

Fig. 2. Power line.

PLATE VI

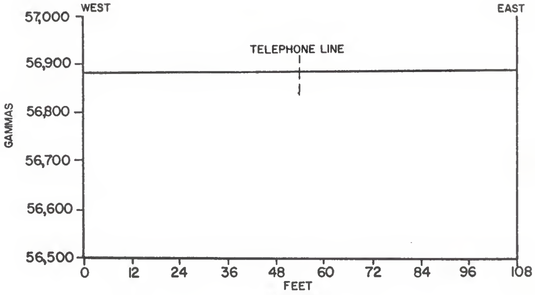


Fig. 1.

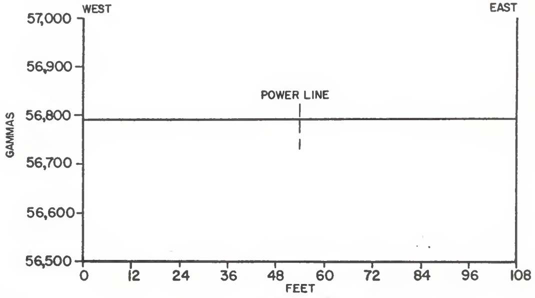
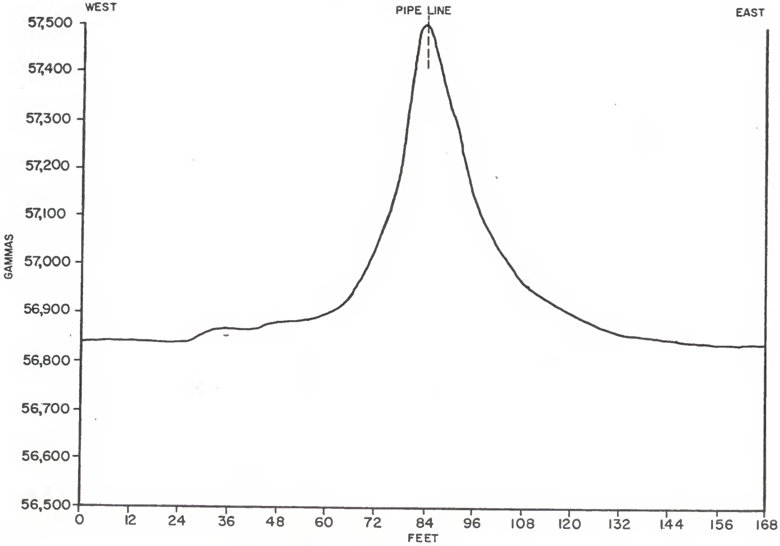


Fig. 2.

EXPLANATION OF PLATE VII

Magnetic profile showing the influence of a buried pipe line.

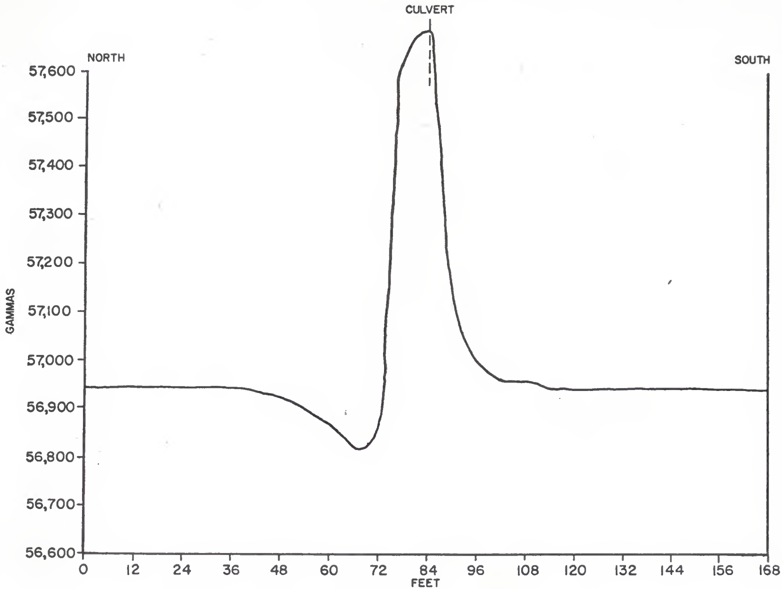
PLATE VII


WEST
PIPE LINE
EAST
GAMMAS
57,500
57,400
57,300
57,200
57,100
57,000
56,900
56,800
56,700
56,600
56,500
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
FEET

EXPLANATION OF PLATE VIII

Magnetic profile showing the influence of a steel culvert located beneath the surface of a road.

PLATE VIII


CULVERT
NORTH
SOUTH
GAMMAS
57,600
57,500
57,400
57,300
57,200
57,100
57,000
56,900
56,800
56,700
56,600
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
FEET

EXPLANATION OF PLATE IX

Magnetic profile showing the influence of an automobile.

Fig. 1. Automobile in an east-west direction.

Fig. 2. Automobile in a north-south direction.

PLATE IX

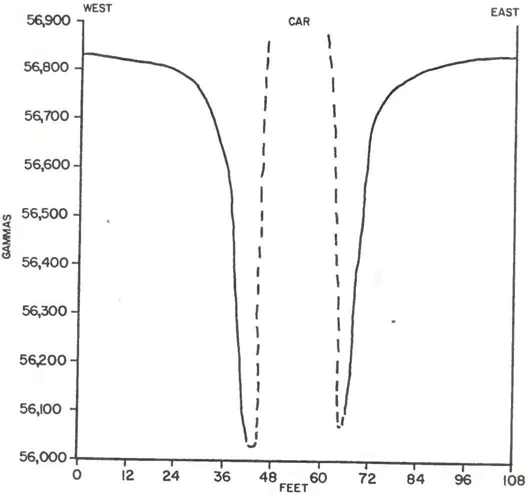


Fig. 1.

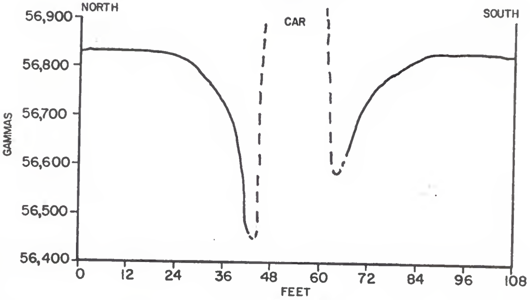
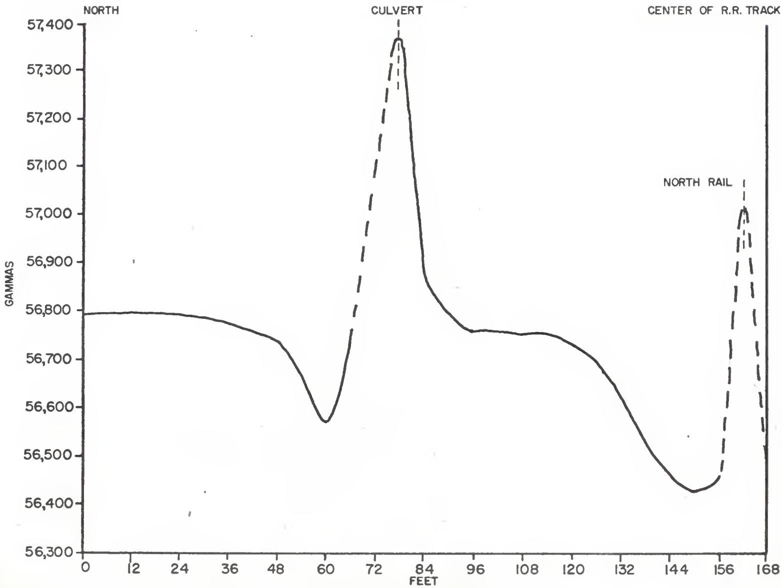


Fig. 2.

EXPLANATION OF PLATE X

Magnetic profile showing the influence of a steel culvert and a railroad track, plotted from north to center of tracks.

PLATE X


NORTH
CULVERT
CENTER OF R.R. TRACK
NORTH RAIL
GAMMAS
57,400
57,300
57,200
57,100
57,000
56,900
56,800
56,700
56,600
56,500
56,400
56,300
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
FEET

EXPLANATION OF PLATE XI

Magnetic profile showing the influence of a railroad track and a cemetery.

Fig. 1. Center of railroad tracks south.

Fig. 2. North-south profile across the west edge of cemetery.

PLATE XI

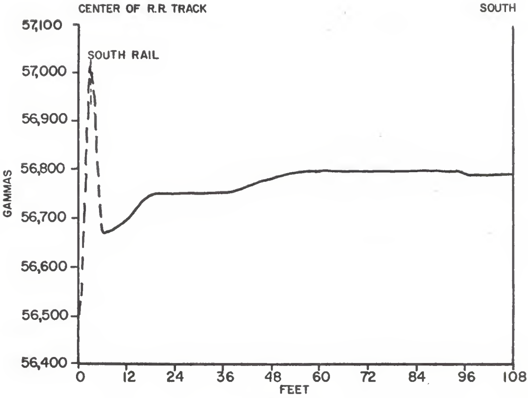


Fig. 1.

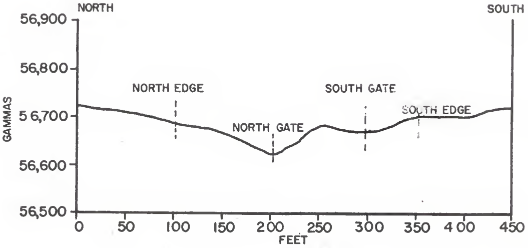


Fig. 2.

from the magnetic profile of each feature was doubled to insure an accurate reading.

High Magnetic Field Gradients. In an area of a high magnetic gradient, the intensity of the magnetic field will change rapidly in a few inches. The rapid change of the magnetic field will cause the protons to precess at different frequencies across the proton sample. The observed effect is a broad signal which causes several reeds of the reedmeter to vibrate at a small amplitude. If the magnetic gradient becomes too high, none of the reeds will vibrate.

High magnetic gradients of small extent were encountered while constructing the magnetic profiles across various types of fences, the automobile, and railroad tracks (Plates III-V and IX-XI). Larger areas of high magnetic gradients were encountered during the survey of the igneous intrusions (Plates XIV-XVIII). Dashed lines were used to indicate the approximate total intensity of the magnetic field where the magnetic gradient was so great that a reading was not obtained with the magnetometer.

MAGNETIC INVESTIGATION

Introduction

The magnetic maps were contoured directly from field readings which were corrected for diurnal variations. Separate magnetic maps were constructed for the Bala, Leonardville, Stockdale, Randolph No. 1 and Randolph No. 2 intrusions, and Pfaf Crater because of the large magnetic anomalies associated with each of these features. The magnetic map of northern Riley County has a contour interval of 50 gammas. Due to the large anomalies associated with the igneous intrusions, a contour interval of 500 gammas was used. Pfaf Crater was contoured with a 50 gamma contour interval (Baysinger, 1962). After the magnetic maps were contoured, they were interpreted for positive and negative anomalies which were compared to structural anomalies in the area. To show the relationship between the magnetic anomalies associated with the igneous intrusions and the magnetic map of northern Riley County, a map of the Stockdale anomaly and the surrounding area was constructed on an intermediate scale (Plate XII).

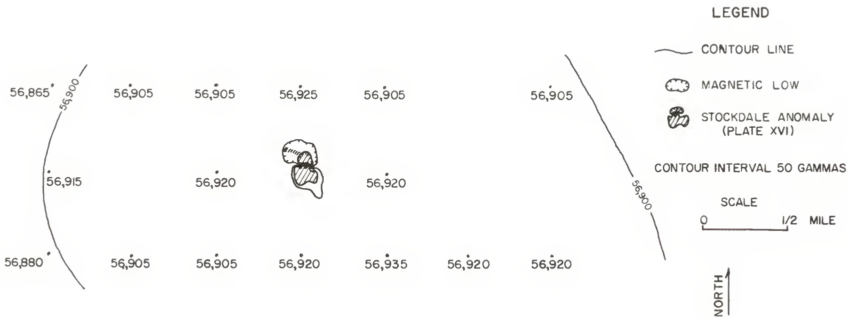
Interpretation of Magnetic Map of Northern Riley County

The six magnetic anomalies in the area were too large to be shown on the magnetic map of northern Riley County at the present scale (Plate XIII). Five of the magnetic anomalies are associated with igneous intrusions and the sixth magnetic anomaly is associated with a circular crater of undetermined origin. The Bala magnetic anomaly (Plate XIV) is in the NW ¼, NW ¼, Sec. 6, T. 9 S., R. 5 E.; Leonardville magnetic anomaly (Plate XV) is in the SE ¼, NW ¼, Sec. 22, T. 8 S., R. 5 E.; Stockdale magnetic anomaly (Plate XVI) is in the NW ¼, SE ¼, Sec. 23, T. 8 S., R. 6 E.; Randolph No. 1 magnetic anomaly

EXPLANATION OF PLATE XII

Magnetic map of Stockdale anomaly and surrounding area.

PLATE XII


56,865
56,900
56,905
56,905
56,925
56,905
56,905
56,915
56,920
56,920
56,900
56,880
56,905
56,905
56,920
56,935
56,920
56,920
LEGEND
CONTOUR LINE
MAGNETIC LOW
STOCKDALE ANOMALY
(PLATE XVI)
CONTOUR INTERVAL 50 GAMMAS
SCALE
0
1/2 MILE
NORTH

(Plate XVII) is in the NW ¼, NW ¼, Sec. 35, T. 6 S., R. 6 E.; Randolph No. 2 magnetic anomaly (Plate XVIII) is in the SE ¼, SE ¼, T. 6 S., R. 6 E.; and Pfaf Crater (Plate XIX) is in the NE ¼, NW ¼, Sec. 36, T. 6 S., R. 5 E. Excluding the six local anomalies, the minimum magnetic reading recorded was 56,640 gammas in Sec. 23, T. 7 S., R. 5 E. and the maximum magnetic reading recorded was 57,250 gammas in Sec. 2, T. 6 S., R 4 E. This gave a range of 610 gammas over the area investigated.

The Abilene Anticline is reflected on the magnetic map of northern Riley County as a linear positive anomaly approximately 400 gammas in magnitude and approximately 22 miles long. The magnetic trend of the Abilene magnetic anomaly is N. 24° E. and extends from Sec. 35, T. 8 S., R. 4 E. to Sec. 5, T. 6 S., R. 6 E. The Abilene magnetic anomaly is approximately five miles in width. The positive anomaly is approximately two miles wide from Sec. 4, T. 7 S., R. 5 E. southwestward to Sec. 35, T. 8 S., R. 4 E. The highest magnetic reading obtained on the southern portion of the anomaly was 57,230 gammas between Sec. 26 and 35, T. 8 S., R. 4 E. and the highest reading obtained on the north portion of the anomaly was 57,150 gammas between Sec. 6 and 7, T. 6 S., R. 6 E. The closely spaced magnetic contour lines extending from Sec. 2, T. 9 S., R. 4 E. to Sec. 12, T. 8 S., R. 4 E. could be an indication of the presence of a fault. A second magnetic high was found on the northern portion of the positive anomaly in Sec. 27, 28, 33, and 34, T. 6 S., R. 5 E. approximately 100 gammas in magnitude with a high reading of 57,115 gammas in Sec. 27, T. 6 S., R. 5 E. Pfaf Crater is located on the east flank of the Abilene positive anomaly in Sec. 36, T. 6 S., R. 5 E. Two isolated magnetic highs approximately 100 gammas in magnitude occur in the southern portion of the Abilene magnetic anomaly. A high reading of 57,015 gammas was obtained for the magnetic high in Sec. 19, 20, 29, and 30, T. 7 S., R. 5 E. and a high reading of 57,020 gammas for the magnetic high in Sec. 1, 11, 12, 13, and 14, T. 8 S., R. 4 E. Two small negative anomalies less than 100 gammas in magnitude were found on the Abilene positive anomaly. The lowest magnetic reading obtained was 56,900 gammas in Sec. 26, T. 6 S., R. 5 E. for the small negative anomaly in Sec. 25, and 26, T. 6 S., R. 5 E. and a low reading of 57,000 gammas between Sec. 14 and 24, T. 6 S., R. 5 E. for the small negative anomaly in Sec. 13, 14, 23, and 24, T. 6 S., R. 5 E.

A linear positive anomaly approximately 190 gammas in magnitude and approximately six miles long was found on the east flank of the Abilene magnetic anomaly. The smaller positive anomaly extends from Sec. 12, T. 9 S., R. 4 E. northeast to Sec. 20, T. 8 S., R. 5 E. The trend of the positive anomaly is N. 22° E. The highest magnetic reading obtained for the positive anomaly was 56,890 gammas between Sec. 12, T. 9 S., R. 4 E. and Sec. 6 and 7, T. 9 S., R. 5 E. The Bala intrusion is located over the positive anomaly in Sec. 6, T. 9 S., R. 5 E. A small negative anomaly was found north of this anomaly in portions of Sec. 17, 18, and 19, T. 8 S., R. 5 E. separating the positive anomaly from a small magnetic high to the north in portions of Sec. 3, 4, 5, 8, and 9, T. 8 S., R. 5 E. The small negative anomaly is less than 50 gammas in magnitude with a low reading of 56,705 gammas and the small magnetic high is approximately 75 gammas in magnitude with a high reading of 56,820 gammas. In Sec. 15, 16, 21, 22, and 28, T. 7 S., R. 5 E. There is a small negative anomaly less than 50 gammas in magnitude with a low reading of 56,725 gammas.

The Irving Syncline is reflected on the magnetic map of northern Riley County as a linear negative anomaly approximately four miles east and parallel to the Abilene positive anomaly. The negative anomaly is approximately 250 gammas in magnitude and extends from Sec. 17, T. 9 S., R. 5 E. to Sec. 6, T. 6 S., R. 7 E. The negative anomaly is approximately five miles wide with a magnetic low approximately two miles wide extending from Sec. 17, T. 9 S., R. 5 E. to Sec. 7, T. 7 S., R. 6 E. Readings obtained over the magnetic low were less than 56,700 gammas. The Leonardville magnetic anomaly is in the magnetic low in Sec. 22, T. 8 S., R. 5 E. A low reading of 56,640 gammas was obtained in a small magnetic low in portions of Sec. 14 and 23, T. 7 S., R. 5 E. Three magnetic lows of less than 50 gammas occur in the northern portion of the Irving negative anomaly. A low reading of 56,700 gammas was obtained between Sec. 28 and 33, T. 6 S., R. 6 E. in a small magnetic low in portions of Sec. 28, 29, 32, and 33, T. 6 S., R. 6 E. and a low reading of

56,680 gammas was obtained between Sec. 20 and 29, T. 6 S., R. 6 E. Two magnetic highs of less than 50 gammas were found on the east flank of the negative anomaly. A high reading of 56,810 gammas was obtained for the magnetic high in Sec. 9, 10, and 16, T. 7 S., R. 6 E. and a high reading of 56,835 gammas for the magnetic high in Sec. 23 and 24, T. 6 S., R. 6 E. and Sec. 19 and 30, T. 6 S., R. 7 E. The Randolph No. 1 and No. 2 magnetic anomalies are on the east flank of the Irving magnetic anomaly in Sec. 35, T. 6 S., R. 6 E. and Sec. 26, T. 6 S., R. 6 E., respectively.

A broad positive anomaly approximately 150 gammas in magnitude is reflected in the southeastern portion of the magnetic map. A high reading of 57,015 gammas was obtained between Sec. 8 and 9, T. 9 S., R. 7 E. The positive anomaly is approximately three miles wide and eight miles long trending N. 36° W. from Sec. 16, T. 9 S., R. 7 E. to Sec. 10, T. 8 S., R. 6 E. The Stockdale magnetic anomaly is on the northern part of the positive anomaly in Sec. 23, T. 8 S., R. 6 E.

A negative anomaly approximately 150 gammas in magnitude was found in the northwestern part of Riley County on the west flank of the Abilene magnetic anomaly which extends approximately seven miles through the area investigated from Sec. 26, T. 6 S., R. 4 S. to Sec. 4, T. 6 S., R. 5 E. The lowest reading obtained for the negative anomaly was 56,655 gammas between Sec. 7 and 18, T. 6 S., R. 5 E. Northwest of the negative anomaly there is a positive anomaly approximately 400 gammas in magnitude which is probably due to the ferromagnetic minerals present in the Dakota outliers. The highest reading obtained for the positive anomaly was 57,250 gammas in Sec. 2, T. 6 S., R. 4 E. South of the negative anomaly there are two magnetic lows and two magnetic highs approximately 50 gammas in magnitude. A low reading of 56,700 gammas was obtained between Sec. 1, T. 7 S., R. 4 E. and Sec. 6, T. 7 S., R. 5 E. in a magnetic low in portions of Sec. 25, 35, and 36, T. 6 S., R. 4 E.; Sec. 30 and 31, T. 6 S., R. 5 E.; Sec. 1, 2, and 12, T. 7 S., R. 4 E.; and Sec. 6 and 7, T. 7 S., R. 5 E. A low reading of 56,730 gammas was obtained between Sec. 24 and 25, T. 7 S., R. 4 E. in a magnetic low in portions of Sec. 13, 23, 24, and 25, T. 7 S., R. 4 E. A high reading of 56,760 gammas was obtained in Sec. 26, T. 6 S., R. 4 E. on a magnetic high in portions of Sec. 25, 26, 35, and 36, T. 6 S., R. 4 E. A high reading of 56,805 gammas between Sec. 11 and 14, T. 7 S., R 4 E. was obtained for the magnetic high in portions of Sec. 11, 13, and 14, T. 7 S., R. 4 E.

Interpretation of Magnetic Maps of Intrusions and Pfaf Crater

Double readings for a single station were obtained with the magnetometer in the negative anomalies associated with the igneous intrusion where the total intensity of the magnetic field fell below 56,300 gammas. The cause of the double readings is assumed to be a characteristic of the model M-49A Varian magnetometer where there is an extremely large magnetic

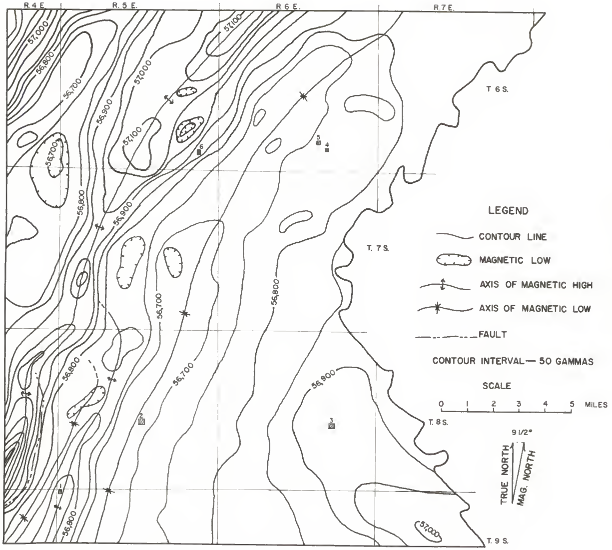
EXPLANATION OF PLATE XIII

Magnetic map of northern Riley County

Magnetic anomalies too large to be shown on this map are indicated by the shaded areas.

1. Bala intrusion, Plate XIV.
2. Leonardville intrusion, Plate XV.
3. Stockdale intrusion, Plate XVI.
4. Randolph No. 1 intrusion, Plate XVII.
5. Randolph No. 2 intrusion, Plate XVIII.
6. Pfaf Crater, Plate XIX.

PLATE XIII


R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
T. 6 S.
T. 7 S.
T. 8 S.
T. 9 S.
57,000
56,800
56,700
56,900
57,100
LEGEND
CONTOUR LINE
MAGNETIC LOW
AXIS OF MAGNETIC HIGH
AXIS OF MAGNETIC LOW
FAULT
CONTOUR INTERVAL — 50 GAMMAS
SCALE
0 1 2 3 4 5 MILES
9 1/2°
TRUE NORTH
MAG. NORTH

gradient which does not affect the interpretation of the data and therefore can be neglected.*

<u>Bala Intrusion</u>. The Bala magnetic anomaly has a positive anomaly greater than 3,900 gammas and a negative anomaly of approximately 2,000 gammas on the north flank of the positive anomaly (Plate XIV). The highest total intensity reading obtained was 60,700 gammas and lowest reading was 54,780 gammas. The total magnetic anomaly is approximately 550 feet wide and 1,150 feet long. The magnetic trend is N. 77° W.

The positive anomaly has a gradient of 130 gammas/foot on the north and a gradient of approximately 20 gammas/foot toward the south and southeast. Two magnetic "highs" are on the positive anomaly. The smaller magnetic "high" has a total intensity reading of 60,060 gammas and is approximately 400 feet east of the larger magnetic "high" which has a total intensity reading of 60,700 gammas. Due to the large magnetic gradient over the highest part of the positive anomaly, magnetic readings were not obtained on the magnetometer. A negative anomaly of less than 500 gammas is on the south flank of the positive anomaly between the 57,000 and 57,500 gamma contour lines. The lowest reading obtained in the negative anomaly was 56,615 gammas.

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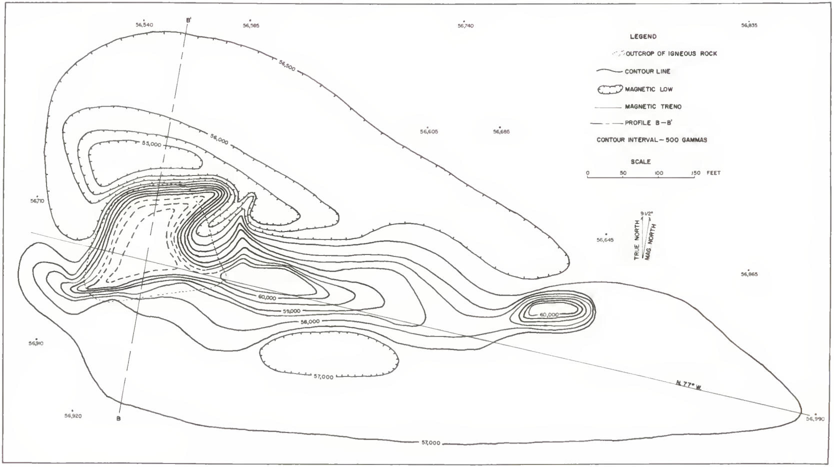
* A letter was sent to the Varian Associates in Palo Alto, California explaining the characteristics of the double readings obtained. After examining the data, the Varian Associates concluded that the cause of the double readings is due to a peculiarity of the instrument.

EXPLANATION OF PLATE XIV

Magnetic map of Bala intrusion.

PLATE XIV


LEGEND
OUTCROP OF IGNEOUS ROCK
CONTOUR LINE
MAGNETIC LOW
MAGNETIC TRENO
PROFILE B — B'
CONTOUR INTERVAL — 500 GAMMAS
SCALE
0
50
100
150 FEET
TRUE NORTH
MAG NORTH
9 1/2°
N. 77° W.
B'
B
56,540
56,585
56,740
56,835
56,605
56,686
56,645
56,865
56,710
56,910
56,920
56,990
56,500
56,000
55,000
60,000
59,000
58,000
57,000

The large negative anomaly has a gradient of approximately 10 gammas/foot toward the south, extending from the north side of the anomaly. The gentle slope grades into a gradient of 130 gammas/foot along the northern flank of the positive anomaly. The lowest readings obtained in the negative anomaly were toward the southwestern part of the anomaly. An extension of the negative anomaly, along the south flank, extends into the large positive anomaly toward the magnetic high producing a magnetic low with a magnetic high on each side of the extension.

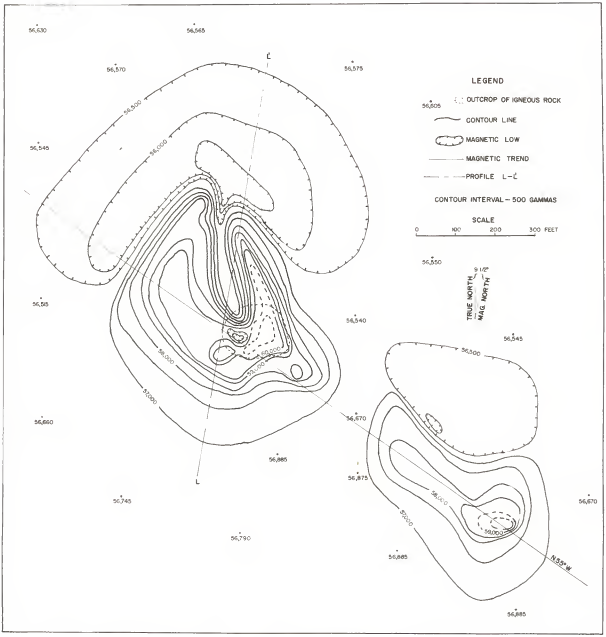
The general shape of the Bala positive anomaly conforms very well with the work done with the Schimdt-type vertical magnetometer (Dreyer, 1947). The major differences between the anomaly found by Dreyer and that of this survey is the large negative anomaly along the north flank of the positive anomaly found during this investigation and the large magnetic "low" found in the center of the positive anomaly by Dreyer. Dreyer indicated the magnetic trend of the anomaly to be N. 69° W. while the magnetic trend was indicated to be N. 77° W. by the data obtained in this survey.

Leonardville Intrusion. Two magnetic anomalies are associated with the Leonardville intrusion (Plate XV). The largest of the two magnetic anomalies is approximately 150 feet northwest of the smaller magnetic anomaly. The northwest magnetic anomaly is characterized by a positive anomaly greater than 2,900 gammas and a negative anomaly approximately 700 gammas.

EXPLANATION OF PLATE XV

Magnetic map of Leonardville intrusion.

PLATE XV


LEGEND
OUTCROP OF IGNEOUS ROCK
CONTOUR LINE
MAGNETIC LOW
MAGNETIC TREND
PROFILE L–L'
CONTOUR INTERVAL – 500 GAMMAS
SCALE
0 100 200 300 FEET
TRUE NORTH
MAG. NORTH
9 1/2°
N55°W
L
L'
56,500
56,000
57,000
58,000
59,000
60,000
56,630
56,565
56,570
56,575
56,605
56,545
56,550
56,515
56,540
56,545
56,660
56,670
56,885
56,875
56,745
56,790
56,885
56,670
56,885

The highest total intensity reading obtained for the northwest magnetic anomaly was 60,705 gammas and the lowest reading was 55,800 gammas. The highest reading obtained for the southeast anomaly was 59,600 gammas and the lowest reading was 55,885 gammas. The northwest magnetic anomaly is approximately 950 feet long and 900 feet wide while the southeast magnetic anomaly is approximately 600 feet long and 550 feet wide. The magnetic trend of the anomalies is N. 55° W.

The northwest positive anomaly has a gradient of 40 gammas /foot on the north and a gradient of approximately 15 gammas/ foot toward the south. Two magnetic highs are located on this anomaly. The smallest magnetic high has a high reading of 59,435 gammas and is located 100 feet southeast of the larger magnetic high which has a high reading of 60,705 gammas. Magnetic readings were not obtained over most of the larger magnetic high due to the large gradient. A small negative anomaly of less than 1,000 gammas is on the north side of the larger magnetic high between the 59,500 and 60,000 gamma contour lines. The lowest reading obtained in the magnetic low was 58,530 gammas.

The northwest negative anomaly has a gradient of approximately 6 gammas/foot toward the south extending from the north flank of the anomaly. Along the north flank of the northwest positive anomaly, the gentle gradient grades into the high gradient of 40 gammas/foot. The lowest reading obtained in the negative anomaly was 55,800 gammas near the central portion of the anomaly along the southern flank. Near the central portion of the negative anomaly, an extension of the anomaly extends into the large positive anomaly producing a magnetic low with a magnetic high on each side of the extension.

The southeast positive anomaly is characterized by a gradient of approximately 15 gammas/foot toward the north and south. The highest magnetic reading obtained for this anomaly was 59,600 gammas. Neither a magnetic "high" nor a magnetic "low" was found between the southeast and northwest magnetic anomalies.

The southeast negative anomaly has a gradient of three gammas/foot extending toward the south from the northern flank which becomes larger along the northern flank of the positive anomaly. The lowest reading obtained in the negative anomaly was 55,885 gammas. An extension of the negative anomaly toward the magnetic high of the positive anomaly was not found.

Cook (1955) found two separate positive anomalies associated with the Leonardville intrusion which conforms with the positive anomalies determined by this investigation. Cook indicated only one negative anomaly which extended along both the northwest and southeast positive anomalies while two separate negative anomalies were found by this investigation. Cook did not find an extension of the negative anomaly into the positive anomaly as was found by this investigation for the northwest anomaly. Cook indicated the magnetic trend of the anomalies to be N. 53° W. which is only two degrees different than the

N. 55° W. magnetic trend indicated by this investigation. Beside the two main differences outlined, both investigations show very good agreement for the magnetic shape and trend of the magnetic anomalies associated with the Leonardville intrusion.

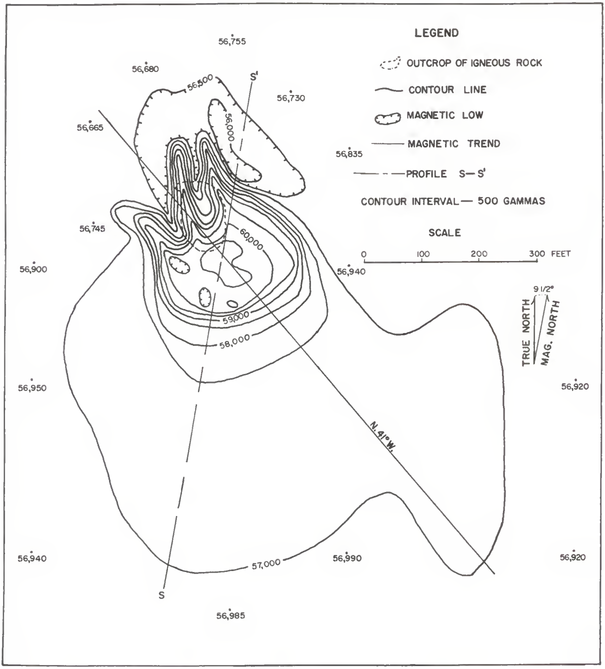
Stockdale Intrusion. The Stockdale magnetic anomaly is characterized by a positive anomaly greater than 4,000 gammas and a negative anomaly of 1,125 gammas (Plate XVI). The highest total intensity reading obtained over the positive anomaly was 60,930 gammas and the lowest reading obtained over the negative anomaly was 55,795 gammas. The total magnetic anomaly is approximately 1,000 feet long and 850 feet wide. The magnetic trend of the anomaly is N. 41° W.

The positive anomaly has a gradient of 45 gammas/foot on the north flank and a gradient of approximately 12 gammas/foot toward the south and southeast becoming almost zero between the 57,500 and 57,000 gamma contour lines. Two magnetic highs are on the positive anomaly. The smaller magnetic high has a total intensity reading of 60,500 gammas and is approximately 25 feet south of the larger magnetic high which has a high reading of 60,930 gammas. A magnetic low of less than 6,000 gammas is located approximately 50 feet west of the magnetic high and a magnetic low of less than 200 gammas is located 25 feet south of the largest magnetic high. Both magnetic lows are between the 60,000 and 60,500 gamma contour lines. There are only two locations with the positive anomaly that a reading was not

EXPLANATION OF PLATE XVI

Magnetic map of Stockdale intrusion.

PLATE XVI


LEGEND
OUTCROP OF IGNEOUS ROCK
CONTOUR LINE
MAGNETIC LOW
MAGNETIC TREND
PROFILE S—S'
CONTOUR INTERVAL— 500 GAMMAS
SCALE
0
100
200
300 FEET
9 1/2°
TRUE NORTH
MAG. NORTH
56,755
56,680
56,730
56,665
56,835
56,745
56,900
56,940
56,950
56,920
56,940
56,990
56,920
56,985
56,500
56,000
60,000
59,000
58,000
57,000
N. 41° W.
S'
S

obtained due to the large magnetic gradient.

The large negative anomaly has a gradient of approximately 7 gammas/foot toward the south extending from the northern flank of the negative anomaly. The gentle gradient grades into a high gradient of 45 gammas/foot along the northern flank of the positive anomaly. The lowest readings obtained in the negative anomaly were toward the southeastern portion of the anomaly. There are two extensions of the negative anomaly into the magnetic "high" of the positive anomaly producing a magnetic "low" with a magnetic "high" on each side. The western extension of the negative anomaly is probably due to an extension of the positive anomaly toward the west.

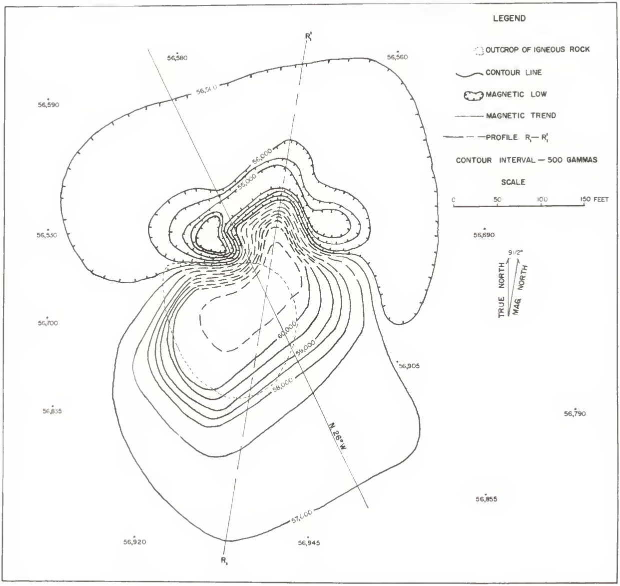
Cook (1955) did not find the two extensions of the negative anomaly into the positive anomaly. The negative anomaly indicated by Cook was larger than the negative anomaly determined by this investigation. Cook indicated the magnetic trend of the anomaly to be N. 33° W. which is only eight degrees different than the N. 41° W. magnetic trend indicated by this investigation. These features are the only main differences between the two investigations. Both investigations tend to confirm each other on the magnetic anomaly associated with the Stockdale intrusion.

Randolph No. 1 Intrusion. The Randolph No. 1 magnetic anomaly is characterized by a positive anomaly greater than 3,800 gammas and a negative anomaly of approximately 2,800 gammas (Plate XVII). The highest total intensity reading obtained

EXPLANATION OF PLATE XVII

Magnetic map of Randolph No. 1 intrusion.

PLATE XVII


LEGEND
OUTCROP OF IGNEOUS ROCK
CONTOUR LINE
MAGNETIC LOW
MAGNETIC TREND
PROFILE R1— R1'
CONTOUR INTERVAL — 500 GAMMAS
SCALE
0
50
100
150 FEET
TRUE NORTH
MAG. NORTH
9 1/2°
R1'
R1
N 26° W
56,580
56,560
56,590
56,500
56,000
55,000
60,000
59,000
58,000
57,000
56,530
56,690
56,700
56,905
56,835
56,790
56,855
56,920
56,945

for the positive anomaly was 60,540 gammas and the lowest reading for the negative anomaly was 53,895 gammas. The length of the positive and negative anomalies is approximately 525 feet and the width is 500 feet. The magnetic trend of the anomaly is N. 26° W.

The positive anomaly has a gradient of 66 gammas/foot on the north flank and a gradient of 12 gammas/foot toward the south. Detail of the positive anomaly was unattainable due to the very large magnetic gradient over the extreme magnetic high of the anomaly. Only one reading of 60,540 gammas was obtained and the rest of the magnetic high is inferred.

The large negative anomaly has a gentle gradient of 16 gammas/foot extending toward the south from the northern flank of the anomaly. Near the north flank of the positive anomaly, the gentle gradient becomes larger. The lowest readings in the negative anomaly were obtained in the central portion of the anomaly. There is an extension of the negative anomaly toward the magnetic high of the positive anomaly producing a magnetic low bounded by a magnetic high. The extension occurs along the southwestern portion of the negative anomaly.

Cook (1955) surveyed this anomaly with a vertical magnetometer, therefore, his survey was not bothered by the extremely large magnetic gradient over the positive anomaly. This enabled Cook to determine the positive anomaly in more detail while a major portion of this anomaly is only inferred by this investigation. The two surveys conform very well with each other; both surveys indicate approximately the same shape and magnitude of the anomaly. The magnetic trend indicated by Cook was N. 25° W. while the magnetic trend is indicated to be N. 26° W. by this investigation.

Randolph No. 2 Intrusion. The Randolph No. 2 magnetic anomaly is the smallest of the magnetic anomalies associated with the igneous intrusions. This anomaly is characterized by a positive anomaly of approximately 2,045 gammas and a negative anomaly approximately 885 gammas (Plate XVIII). The highest total intensity reading obtained for the positive anomaly was 58,800 gammas and the lowest reading for the negative anomaly was 55,870 gammas. Both the negative and positive anomalies are nearly symmetrical except at the contact between the two anomalies where the magnetic gradient is larger. The length of the total anomaly is approximately 75 feet and the width is 60 feet. The magnetic trend of the anomaly is N. 28° W.

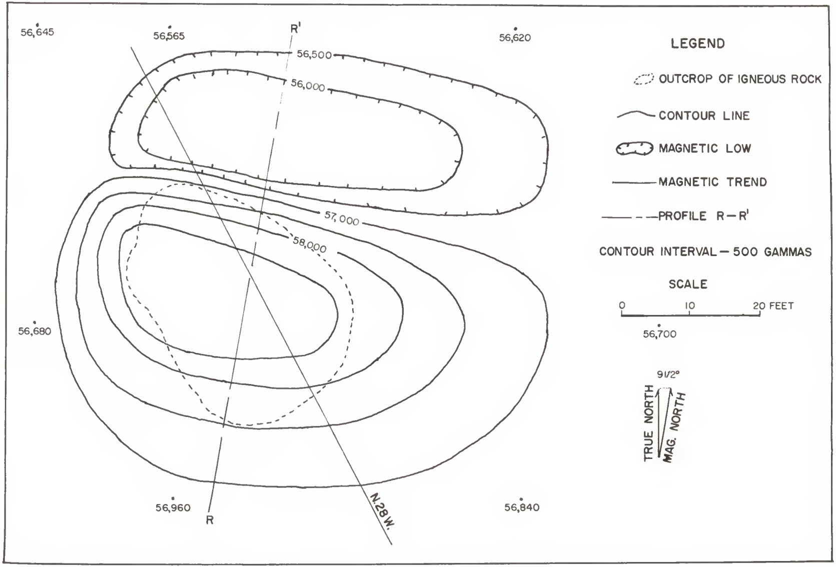
Cook (1955) shows the Randolph No. 2 magnetic anomaly completely surrounded by a small negative anomaly which was not found by this investigation. Cook indicated a magnetic trend of N. 26° W. which is only two degrees different than the N. 28° W. magnetic trend indicated by this investigation. The two surveys confirm the data obtained during each investigation with the exception of the negative anomaly surrounding the positive anomaly indicated by Cook.

Pfaf Crater. Pfaf Crater was initially surveyed with the

EXPLANATION OF PLATE XVIII

Magnetic map of Randolph No. 2. intrusion.

PLATE XVIII



LEGEND
OUTCROP OF IGNEOUS ROCK
CONTOUR LINE
MAGNETIC LOW
MAGNETIC TREND
PROFILE R—R'
CONTOUR INTERVAL — 500 GAMMAS
SCALE
0
10
20 FEET
9 1/2°
TRUE NORTH
MAG. NORTH
56,645
56,565
56,620
56,680
56,700
56,960
56,840
56,500
56,000
57,000
58,000
R'
R
N.28 W.

Varian magnetometer by Baysinger in 1962 and a field check, with the same instrument, was made during this investigation to determine if there was any variation in the total gamma reading during the time span. The readings obtained by the field check agreed with the magnetic readings obtained from the magnetic map constructed by Baysinger. The magnetic map was modified during this investigation to eliminate areas in question which were not indicated by the magnetic data obtained by Baysinger (Plate XIX).

The magnetic anomaly associated with Pfaf Crater is an elliptical high trending N. 42° W. The highest total intensity reading obtained over the anomaly was 57,160 gammas which produced a positive anomaly of 310 gammas. A negative anomaly was not associated with the Pfaf magnetic anomaly.

Explanation of Magnetic Profiles

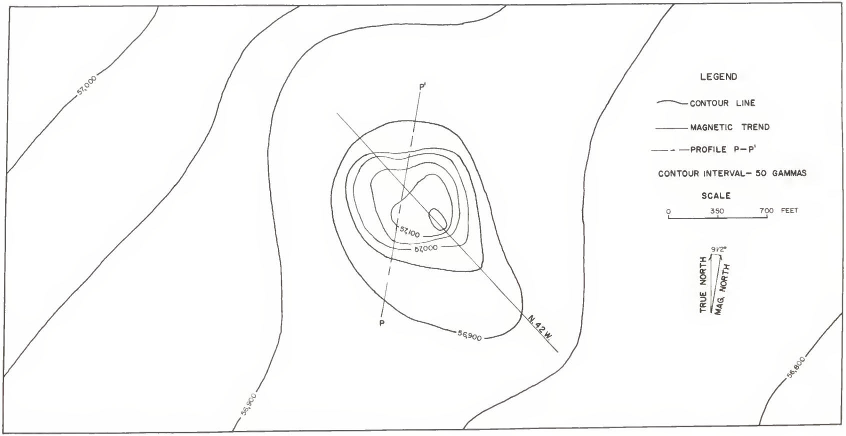
Magnetic profiles were constructed parallel to magnetic north across the magnetic anomalies of the five igneous intrusions to determine the relationship between the positive and negative anomalies (Plates XX, XXI). A magnetic profile was constructed parallel to magnetic north across the magnetic anomaly of Pfaf Crater which was compared to the magnetic profiles of the igneous intrusions (Plate XXI).

The large negative anomalies associated with the igneous intrusions are due to the high magnetic suceptibilities of the masses and the inclination of the earth's magnetic field in

EXPLANATION OF PLATE XIX

Magnetic map of Pfaf Crater.

PLATE XIX



LEGEND
CONTOUR LINE
MAGNETIC TREND
PROFILE P—P'
CONTOUR INTERVAL— 50 GAMMAS
SCALE
0
350
700 FEET
TRUE NORTH
MAG. NORTH
9 1/2°
57,000
56,900
56,800
57,100
P
P'
N. 42 W.

the area of this investigation which is approximately 70° N. As the intrusions are approached from magnetic north, a negative effect is recorded while over the intrusions a positive effect is recorded by the magnetometer which is related to the high magnetic susceptibility of the igneous rock.

The lowest readings obtained in the negative anomalies were associated with the Bala magnetic anomaly (Plate XX) and the Randolph No. 1 (Plate XXI). The low readings for both of the anomalies were approximately 1,000 gammas lower than the low readings for the negative anomalies for the other intrusions. This is due to a larger magnetic gradient associated with the Bala and Randolph No. 1 intrusions which is indicated by the lack of magnetic readings obtainable over the upper limits of the positive anomaly. A very large magnetic gradient was indicated over part of the Leonardville positive magnetic anomaly by a lack of obtainable magnetic readings. The magnetic profile of the Leonardville magnetic anomaly was constructed so the extension of the negative anomaly into the positive anomaly would be shown (Plate XX). The negative extension is indicated on the magnetic profile by a magnetic low which separates the main part of the positive anomaly and produces a smaller high to the north. The magnetic profile of the Stockdale magnetic anomaly is bounded by a negative anomaly on the north (Plate XX). The horizontal distance between the high and low values shown by the magnetic profiles of the Bala, Leonardville, Stockdale, and Randolph No. 1 anomalies is approximately 150 feet.

The magnetic profile of the Randolph No. 2 magnetic anomaly is represented by a broad positive and negative anomaly (Plate XXI). The magnitude of the positive anomaly is approximately 2,000 gammas less than the magnitude of the positive anomalies of the other intrusions. The small magnitude of the positive anomaly for the Randolph No. 2 magnetic anomaly is attributed to the small mass of igneous rock present. The distance between the high and low values shown by the magnetic profile is approximately 25 feet.

The magnetic profile of the Pfaf magnetic anomaly does not correlate with the magnetic profiles for the magnetic anomalies associated with the igneous intrusions (Plate XXI). The magnitude of the positive anomaly is approximately 2,500 gammas less than the magnitude of the Randolph No. 2 magnetic anomaly. The horizontal distance between the high and low values indicated by the magnetic profile is approximately 900 feet.

CONCLUSION

This investigation has shown considerable conformity between the magnetic anomalies and known structural anomalies in northern Riley County. The magnitude of the anomalies is not always consistent with the depth of the structural anomalies. The highest magnetic reading obtained, except for the magnetic anomalies associated with the igneous intrusions, was 57,250 gammas in Sec. 2, T. 6 S., R. 4 E. which is caused by the

EXPLANATION OF PLATE XX

Magnetic profile plotted in a magnetic north direction across the:

Fig. 1. Bala magnetic anomaly,

Fig. 2. Leonardville magnetic anomaly,

Fib. 3. Stockdale magnetic anomaly.

PLATE XX

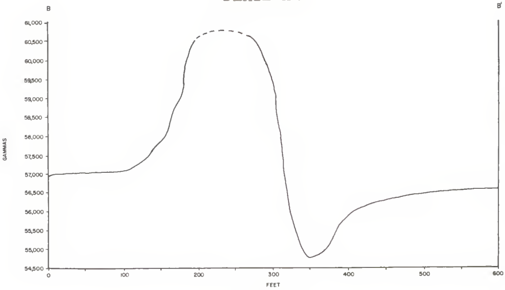


Fig. 1

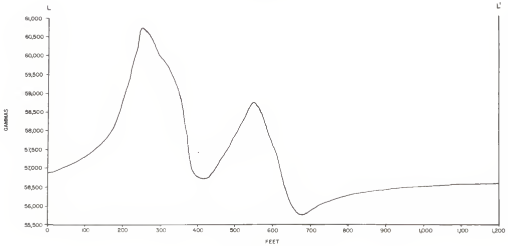


Fig. 2.

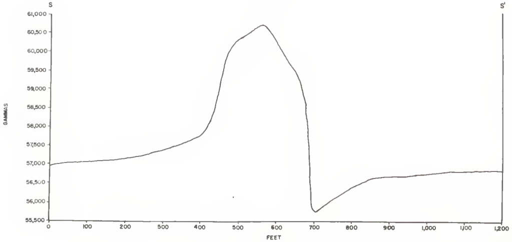


Fig. 3.

EXPLANATION OF PLATE XXI

Magnetic profile plotted in a magnetic north direction across the:

Fig. 1. Randolph No. 1 magnetic anomaly,

Fig. 2. Randolph No. 2 magnetic anomaly,

Fig. 3. Pfaf Crater magnetic anomaly.

PLATE XXI

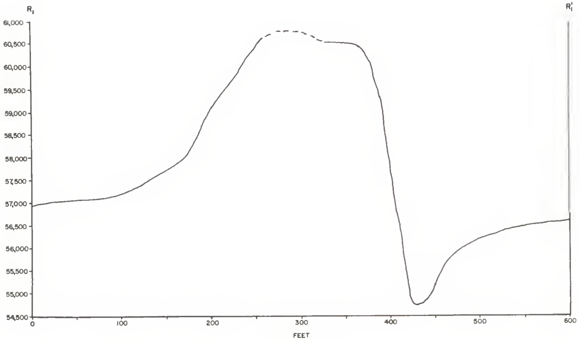


Fig. 1.

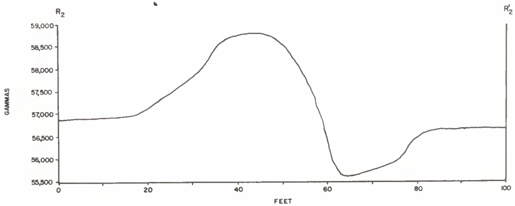


Fig. 2.

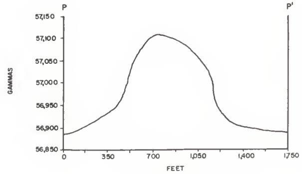


Fig. 3.

ferromagnetic minerals present in the Dakota sandstone outliers. The highest magnetic reading obtained for the magnetic anomaly of the Abilene Anticline was 57,230 gammas between Sec. 26 and 35, T. 8 S., R. 4 E. where the depth of the Precambrian surface is greater than to the north where the magnetic readings were approximately 100 gammas less. The inconsistency in the magnitude of the readings in this area is attributed to lithologic variation at depth. Throughout the rest of the area of northern Riley County, the magnitude of the magnetic anomalies tend to be consistent with the depths of the structural anomalies. In the areas around the igneous intrusions, the magnitude of the magnetic anomalies reflect the structural configuration of the intrusive mass. The consistency in the magnitude of the magnetic anomalies over the majority of the area investigated is attributed to the structural configuration of the Precambrian surface.

The axes of the Abilene Anticline and the Irving Syncline are indicated by the axis of the magnetic anomalies corresponding to each fold. The increased width of the magnetic anomaly of the Abilene Anticline from Sec. 9, T. 7 S., R. 5 E. northward is attributed to the erosion of the Mississippian rocks leaving the Precambrian surface exposed to erosion at the end of the Mississippian Period. The erosion of the Precambrian surface is also indicated by the small magnetic highs and lows in this area.

Mendenhall (1958) mapped a small anticline and syncline east of Bala, Kansas which corresponds to positive and negative magnetic anomalies. It is proposed that the axis of the anticline, in the area covered by this investigation, extends from Sec. 12, T. 9 S., R. 4 E. to Sec. 32, T. 7 S., R. 5 E. where it intersects the east flank of the Abilene Anticline and the axis of the syncline extends from Sec. 11, T. 9 S., R. 4 E. to Sec. 8, T. 8 S., R. 5 E. The negative magnetic anomaly in the northwestern part of Riley County confirms the existence of the syncline mapped by Mudge (1949).

Taylor (1950, p. 18), Nelson (1952, pp. 58-59), Koons (1955, p. 24), Merryman (1957, p. 22), and Mendenhall (1958, p. 28) advocated the existence of a fault as the possible origin of the Abilene Anticline. From the magnetic data, a fault is proposed in T. 8 S., R. 4 E. which would help explain the high magnetic readings obtained in this area, but not along the entire length as suggested by the previous workers.

The magnetic anomalies associated with the igneous intrusions were undetected by the magnetic survey which was conducted over northern Riley County where the magnetic readings were taken at half mile intervals. A correlation of the magnetic anomalies of the igneous intrusions with the magnetic anomaly of the Abilene Anticline could not be made. The Bala and Stockdale intrusions are on positive magnetic anomalies while the Leonardville intrusion is in a negative anomaly. The Randolph No. 1 and Randolph No. 2 intrusions are on the east flank of the Irving magnetic anomaly.

The magnetic anomalies determined for each of the igneous intrusions tends to confirm the magnetic anomalies found by Cook (1955) and Dreyer (1947). Therefore, the conclusions as to the shape of the igneous intrusions were taken from Cook and Dreyer and only the magnetic trend of the anomalies was changed.

The Bala and Leonardville intrusions are probably vertical or steeply dipping dikes plunging southeast. The Bala magnetic anomaly trends N. 77° W. and the Leonardville anomaly trends N. 55° W. The Stockdale intrusion is probably a parallelepiped-shaped body trending N. 41° W. and plunging to the south-southeast. The Randolph No. 1 intrusion is probably a south-southeast plunging truncated cylindrical or prismatic body trending N. 26° W. The Randolph No. 2 intrusion is probably a south-southeast plunging finger-like pipe trending N. 28° W.

Baysinger (1962, p. 18) concluded, with some doubt, that the Pfaf Crater was formed by an igneous intrusion and suggested a comparison of the magnetic anomalies of the igneous intrusions and Pfaf Crater was needed. After comparing the magnetic anomalies of these features, it is very doubtful if Pfaf Crater was formed by an igneous intrusion.

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A MAGNETIC INVESTIGATION OF NORTHERN RILEY COUNTY, KANSAS

by

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A. A. Highland Junior College, 1960
B. S. Kansas State University, 1962

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

1964

AN ABSTRACT OF THE THESIS

The purpose of this investigation was to construct and interpret a magnetic map of the northern half of Riley County to determine the magnetic axis of the Abilene Anticline, Irving Syncline and other possible structures. Magnetic surveys were conducted over the five igneous intrusions and Pfaf Crater in northern Riley County and compared to work done by previous investigators. The area of this investigation covered approximately 312 square miles over which approximately 2,500 magnetic readings were taken.

Limitation in the use of the model M-49A Varian portable magnetometer, with respect to cultural features, was determined by constructing magnetic profiles across these features to show the extent of their magnetic influence.

A complete review of the available literature was made and a brief summary of the relevant material is included within the text. A brief summary of the stratigraphy, structural geology, and structural history of the area investigated is presented.

The magnetic map of northern Riley County was contoured and interpreted as to positive and negative anomalies in the area of investigation. Because of the large magnetic anomalies associated with the igneous intrusions and Pfaf Crater, separate magnetic maps of these features were constructed.

The magnetic anomalies associated with the igneous intrusions were interpreted for positive and negative anomalies and

compared to the surveys of Cook and Dreyer. Magnetic profiles were constructed parallel to magnetic north across these features to determine the relationship between the positive and negative anomalies. The magnetic anomalies of the igneous intrusions tend to confirm the magnetic anomalies found by Cook and Dreyer. After comparing the magnetic anomalies of Pfaf Crater and the igneous intrusions, it is believed that Pfaf Crater was not formed by an igneous intrusion.

The axes of the Abilene Anticline and Irving Syncline are indicated by the axis of the magnetic anomalies corresponding to each fold. The magnetic map indicates a small syncline that separates a small anticline extending from T. 9 S., R. 4 E. to T. 7 S., R. 5 E. where it intersects the Abilene Anticline. The large positive anomaly over the axis of the Abilene Anticline adjacent to the small syncline brought about the proposal of a fault in T. 8 S., R. 4 E. but not along the entire length of the Abilene Anticline as suggested by previous workers. In the northwestern corner of Riley County, a large positive anomaly was found which was caused by the ferromagnetic minerals present in Dakota sandstone outliers. It is believed the variation in magnetic intensity is caused by the structural configuration of the basement rocks except where material of high magnetic susceptibility was encountered at the surface.