MAGNETIC SURVEYS

By
J. G. GROHSKOPF
and
C. O. REINOEHL

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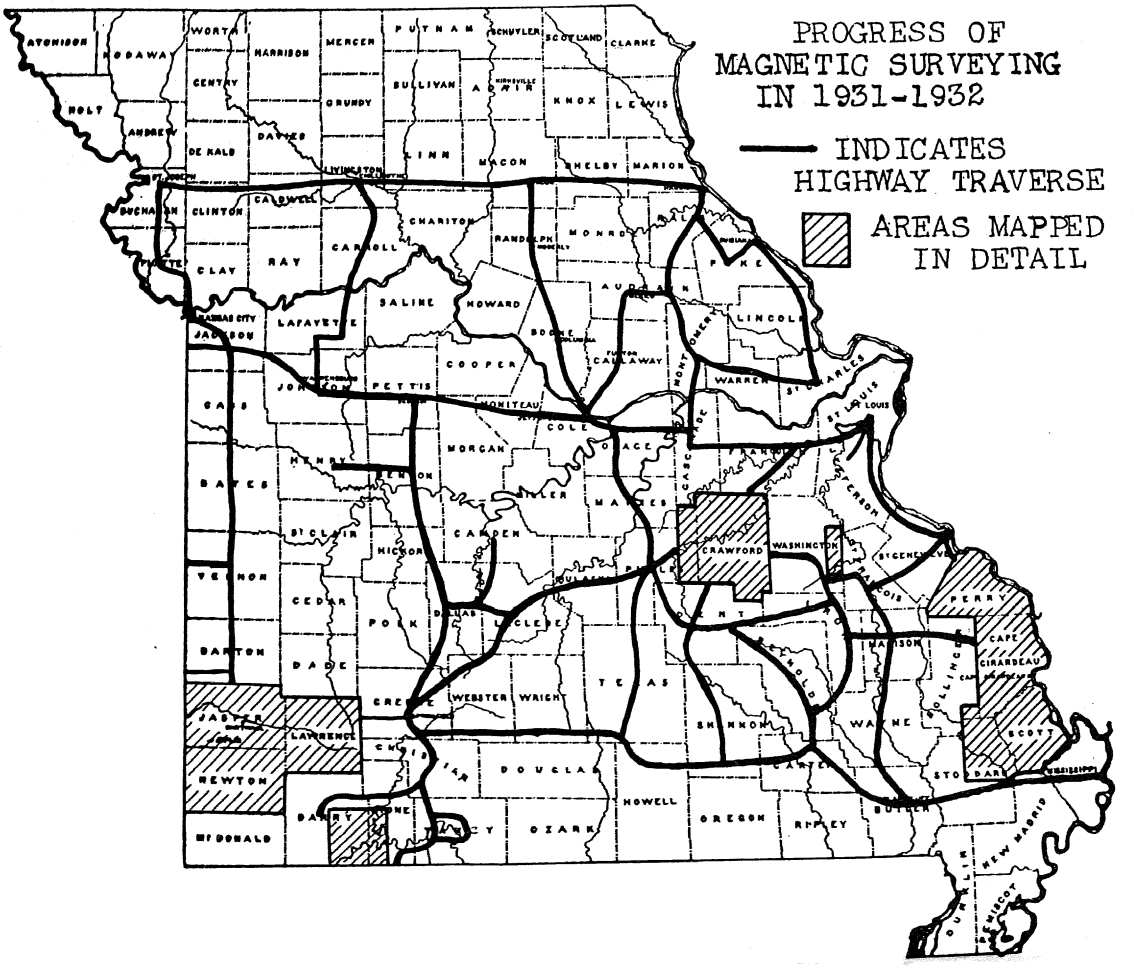
MISSOURI BUREAU OF GEOLOGY AND MINES
H. A. BUEHLER
Director and State Geologist
ROLLA, MISSOURI

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS


PROGRESS OF MAGNETIC SURVEYING IN 1931-1932
INDICATES HIGHWAY TRAVERSE
AREAS MAPPED IN DETAIL
ATCHISON
HOLT
ANDREW
BUCHANAN
DE KALB
CLINTON
CALDWELL
CLAY
RAY
CARROLL
CHARITON
LIVINGSTON
GRUNDY
MERCER
HARRISON
WORTH
GENTRY
DAVIESS
PUTNAM
SULLIVAN
LINN
MACON
SCHUYLER
SCOTLAND
CLARKE
KNOX
LEWIS
SHELBY
MARION
RANDOLPH
MONROE
PIKE
AUDRAIN
LINCOLN
WARREN
ST. CHARLES
ST. LOUIS
SALINE
LAFAYETTE
JACKSON
KANSAS CITY
HOWARD
BOONE
COLUMBIA
CALLAWAY
MONTGOMERY
COOPER
JOHNSON
PETTIS
MONITEAU
COLE
MORGAN
BENTON
HENRY
BATES
ST. CLAIR
HICKORY
CAMDEN
MILLER
MARIES
OSAGE
GASCONADE
CRAWFORD
WASHINGTON
FRANKLIN
JEFFERSON
ST. FRANCOIS
STE. GENEVIEVE
PERRY
CAPE GIRARDEAU
VERNON
CEDAR
POLK
DALLAS
LACLEDE
PULASKI
BARTON
DADE
GREENE
WEBSTER
WRIGHT
TEXAS
SHANNON
WAYNE
BOLLINGER
JASPER
LAWRENCE
NEWTON
MCDONALD
BARRY
STONE
TANEY
DOUGLAS
OZARK
HOWELL
OREGON
CARTER
RIPLEY
BUTLER
STODDARD
SCOTT
MISSISSIPPI
DUNKLIN
NEW MADRID
PEMISCOT

APPENDIX IV

MAGNETIC SURVEYS

By J. G. Grohskopf and C. O. Reinoehl.

GENERAL STATEMENT.

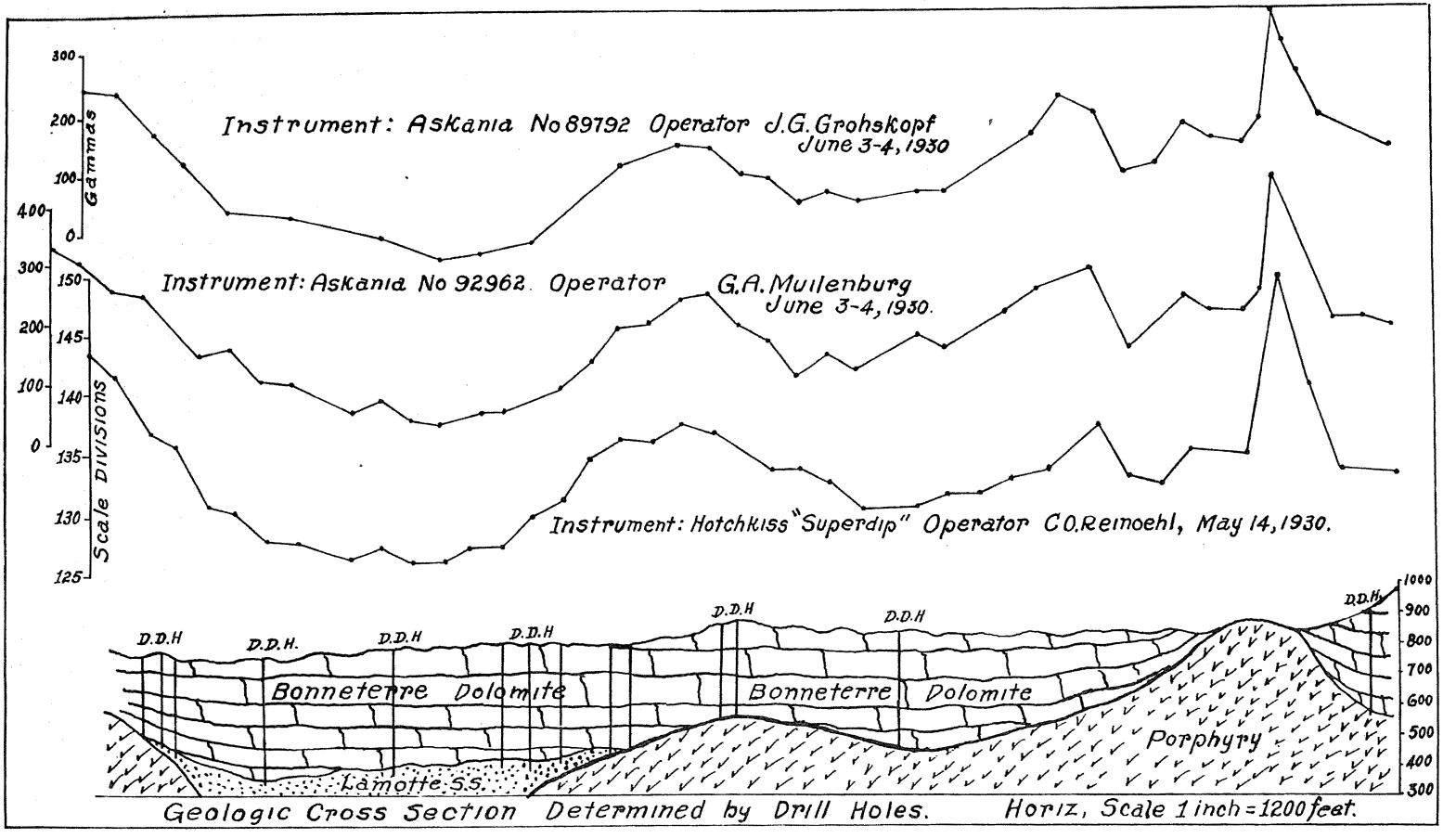
The magnetic investigations carried on by this Bureau during the previous biennial period gave results that apparently were important in a consideration of the ore deposits and geologic structure throughout the State. Some of these results were discussed briefly in Appendix III of the 56th Biennial Report to the General Assembly.

The investigations have been extended during the present biennial period. Because of lack of funds, the Industrial Club of St. Louis and the Tri-State Lead and Zinc Ore Producers' Association paid for all field work during the year 1931. During 1932 the Survey has continued with its own funds what field work has been undertaken. Some of the results that have been obtained are outlined in this report. The map on the opposite page, (Pl. I), indicates the character of work that has been done up to the present time.

In order to determine the magnetic anomalies in the vicinity of some of the principal structural features and principal ore producing territories, surveys have been made in both Southwest and Southeast Missouri, taking observations at mile intervals. The entire Tri-State Lead and Zinc District has been surveyed with the financial assistance of the Tri-State Lead and Zinc Ore Producers' Association.

Many iron ore deposits have been surveyed through the financial assistance of the Industrial Club of St. Louis. During the present season, the Survey has mapped Crawford County, Cape Girardeau, Scott, Perry, and a portion of Stoddard County. Surveys are now progressing in the barite district in Washington County. The major portion of the State has been gridded by traverse lines so that detailed surveys can be started at any point.

The Ste. Genevieve station of the U. S. Coast and Geodetic Survey has been adopted as a standard reference point for both Missouri and Illinois.



Magnetic profiles over porphyry ridge.

The Illinois Geological Survey is carrying on similar work and the results in the two states, by accepting the same reference point, will, in the future, be comparable.

In the surveys two Askania vertical magnetometers are now being used. All readings are reported in gammas[1] and referred to the base station at Ste. Genevieve. Corrections are made for latitude and longitude, temperature and daily variation. The values shown are anomalies, that is, they represent the amount any particular reading is above or below normal for that area. In areal work readings are spaced at approximately mile intervals with major control points about every ten miles. In work over iron prospects and in the study of deep well water supply problems, the readings are taken at closer intervals, usually about 100 feet apart.

INFLUENCE OF IGNEOUS ROCKS.

From a study of the results obtained by these surveys to date, it is evident that the magnetometer can be used to advantage in determining regional geologic features which are a result of the attitude or character of the underlying basement igneous rocks, providing the latter are not covered by too great a thickness of overlying sedimentary strata. Geologic investigations which have been made in conjunction with magnetic surveys have shown that buried porphyry and granite ridges affect: (1) the thickness, character and position of the overlying sediments, (2) the circulation of ground water, (3) the location, in most instances, of folds, faults and fractures, (4) and, at least to some extent, the location of ore deposits. The magnetometer is being used by this Bureau primarily as a geologic aid in making preliminary studies of regional structures. Where, as in certain types of iron ore, there is an abundance of magnetite present, it may be used in detailing local deposits. The results obtained in the latter type of survey are shown in the description of the Silver Hollow iron deposit, pp. 15-18.

In order to determine the effect of the underlying igneous rocks, a number of magnetic surveys were made where previous drilling had determined the configuration of the porphyry surface. The cross-section (Pl. II) illustrates the concordance of mag-

[1]A gamma is 1/100,000 gauss. A magnetic field of one gauss is a field of such strength that a unit pole situated in it experiences a force of one dyne. The unit pole is the pole which placed in air one centimeter from an equal pole repels or attracts it with a force of one dyne.

netic intensity with the profile of the underlying porphyry. This survey was run across a known geological succession about three miles from Fredericktown. The lines of traverse were run with three instruments and by three men on different dates. Two of the traverses were run with Askania vertical field balances and one with a Hotchkiss "Superdip" magnetometer. The geological cross-section was prepared by E. T. Campbell, Geologist for the St. Louis Smelting and Refining Company, from their drill records, designated on the profile as D. D. H. As shown by the cross-section, the only formations outcropping along the line of traverse, are the Bonneterre dolomite and the pre-Cambrian porphyry. The area has a rolling topography with porphyry hills rising gradually from the sediment filled valleys giving a local relief of about 100 feet. Readings were taken at intervals of 200 feet.

In general, the three magnetic profiles check each other with uniformity, with only a few minor exceptions. The magnetic profiles also check the geology very closely for where the porphyry rises rapidly the magnetic intensity increases rapidly and vice versa. Between the porphyry outcrop and a point 800 feet to the west the magnetic intensity does not maintain a gradual increase but drops very suddenly and then rises very slowly as the outcrop is approached. It rises rapidly over the outcrop with another rapid drop after the point of outcrop is passed.

The cause of the break in the magnetic profile just west of the outcrop is not known, as no drilling was done in that area. Many other surveys made in southeast Missouri give the same result. Near Bonneterre, at a place where a magnetic "high" was mapped, mine records showed that drifts had run into a porphyry peak. Several surveys around Fredericktown show that magnetic "highs" correspond to porphyry peaks as determined by drilling.

A similar profile was obtained in a magnetic survey over a buried prophyry ridge in Iron County.[1] The results of magnetometer surveys in Missouri indicate that regional pre-Cambrian "highs" are reflected by magnetic "highs."

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[1]Biennial Report State Geologist to the 56th Assembly, 1931. Fig. A, Pl. IV, Appendix III.

INFLUENCE OF FAULTING.

A number of surveys have been made in areas of considerable faulting. An example of a survey made by spacing the readings relatively close together is shown in Fig. 1.

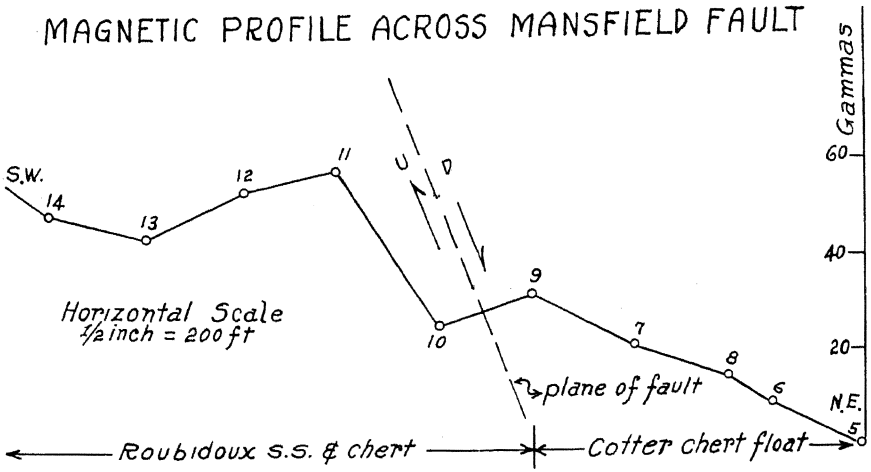


FIG. 1. Magnetic profile across Mansfield fault.

This fault, as shown, drops the Cotter dolomite against the Roubidoux sandstone, the displacement being about 200 feet. The strike of this fault is N. 20 W., and the dip of the fault plane is 70 degrees. The location of the fault plane is known within close limits from detailed geologic work.

The line of magnetic traverse was run approximately at right angles to the strike of the fault. The corrected readings are shown in Fig. I. The numbers refer to the stations occupied, which were spaced 200 feet apart. The length of the traverse is about 4,000 feet, of which approximately 2,000 feet are shown. The fault plane is located between stations 9 and 11.

Along the line of this traverse, there is a gradual increase in magnetic intensity to the southwest. There is an abrupt change, however, in the vertical intensity from stations 9 to 11, due to the presence of a fault. The upthrown side has the higher intensity.

Similar results were obtained in a survey over the Mine La Motte fault in Madison County. The upthrown side of this fault gave higher intensities than the downthrown.

The results over other faults are shown in Pl. III, and IV. These results show that the downthrown side has a lower intensity than the upthrown. A traverse across the Cape Au Gris fault in Lincoln County gave similar results, again the upthrown side had the higher intensities.

JOPLIN ZINC-LEAD DISTRICT.

The magnetic survey of the Joplin Zinc-Lead District, (Pl. III, in pocket) was made in 1931, in cooperation with the Tri-State Zinc and Lead Producers' Association. The Missouri portion of the survey which includes Lawrence, Newton and Jasper counties is shown.

Stratigraphy. The stratigraphy of the region is so well known that only the briefest summary is necessary. The most widely exposed rock is the cherty "Boone" limestone of Mississippian age, which includes representations of the Reeds Springs, Burlington, Keokuk, and Warsaw formations. Overlying this are local patches of shale, sandstone and limestone, belonging to the Carterville formation of Chester age. The youngest rocks exposed are remnants of Cherokee shale and sandstone of Pennsylvanian age, which occupy channels and sink holes in the eroded surface of the Mississippian formations. This formation becomes more continuous to the west in Oklahoma and Kansas.

Below the Boone, are shales and limestones of Kinderhook age, though these may be locally absent. The Mississippian rests everywhere, so far as known, on the beds of the upper Canadian, including the Cotter and Jefferson City formations. The section continues downward in essentially its normal development to the base of the Gunter sandstone, but below it the Ozarkian and Cambrian units are much thinner than farther east in the Ozark Region.

So far as known, from sample studies of deep wells, the pre-Cambrian rock within this area is granite.

Structure. Siebenthal[1] has mapped a structure in this area, called the "Joplin Anticline." It trends northwest and southeast through the city of Joplin. The west dips are much the steeper being as great as 75 feet in a half mile. There is a decided plunge to the northwest, and locally the deformation is as great as 150 feet.

A few faults have been recognized in the district. The Ritchey zone trends nearly east and west for a distance of 25

[1]Geol. Atlas of the United States, Joplin District Folio No. 148, U. S. Geol. Survey.

miles through southern Lawrence County and into the adjacent portion of Newton. The south side is downthrown about 150 feet.

Another displacement, known as the Chesapeake fault, trends northwest and southeast across the northeast corner of Lawrence County, for a distance of 15 miles and continues into the adjacent counties. The northeast side is downthrown about 150 feet.

Still farther to the northeast, the Sac River fault, parallels the Chesapeake structure, across the corner of Lawrence County, for a distance of a little over three miles. The northeast side is downthrown about 50 feet.

In western Newton County, the Seneca fault has been traced from Spurgeon southwest through Racine and Seneca. Within the state it is known for a distance of about eight or ten miles. It has been described as a long narrow fault block, with a displacement of about 100 to 150 feet.

The configuration of the pre-Cambrian granite is not known, because of the scarcity of deep wells reaching the basement complex.

Magnetic Results. The U. S. Coast and Geodetic Survey magnetic station at Mt. Vernon was used as a base to which all readings have been referred. In general, readings were taken at every section corner, and in some cases because of inaccessability, a few were omitted or taken at intermediate points. The readings were plotted, and the anomalies contoured at intervals of 100 gammas.

The anomalies vary from a minimum of —479 gammas to a maximum of +832. The areas of high intensity fall roughly into three parallel belts, trending northwest and southeast. Each of these belts consist of several more or less independent magnetic "highs," separated by saddles of lower magnetic intensity. In addition, there are certain "highs" that do not fall within these main belts.

The eastern belt extends diagonally from the extreme southeast corner of Lawrence County to a point a few miles east of the northwest corner. It consists of three areas of high intensity. The most pronounced one, in the northwest corner, reaches a little over 500 gammas, with a "high" of about 300 gammas near the center, and another "high" of about 400 gammas southeast of Aurora.

The central belt of "highs" begins about 4 miles north of Pierce City. The belt is marked by two small "highs" of 300 gammas each, and northwest of them at Sarcoxie is the most pronounced anomaly, 832 gammas, of the entire district.

Another "high" of over 600 gammas is located a few miles east of Carthage. The lines of force then spread into one of the largest "highs," areally speaking, in the district, and upon which there are superimposed two local "highs" of over 700 gammas each northwest of Carthage.

The third, or western belt starts in a broad area of moderately high intensities in the southeast corner of Newton County. On this belt a "high" of over 500 gammas occurs southeast of Neosho, another of peculiar horseshoe shape is located north of Neosho. The belt ends at a "high" of about 350 gammas west of Spring City.

No attempt will be made to give a detailed interpretation of the relationship of structure to the magnetic intensities at this time. In general it will be noted that the areas occupied by the faults, with the exception of the Seneca block, occur in magnetic "lows." The Ritchey fault is in a sharp magnetic "low" for a distance of 15 miles. The Chesapeake fault is in a broad "low" area magnetically, with the upthrown side giving higher intensities than the downthrown at the southeast end; however, as the peculiar bend in the fault is approached the "low" does not follow its northwest trend but swings almost due east and west. The Sac River fault is magnetically "high" on the upthrown side and magnetically "low" on the downthrown side. The crest of the Joplin anticline is in a magnetic "low." According to H. S. McQueen,[1] the general area around Sarcoxie is structurally high.

As mentioned before, the configuration of the pre-Cambrian surface is not known. It is believed, however, that the magnetic "highs" are caused by buried granite or porphyry ridges, as this has been found to be the case in surveys made in the Central Ozark Region. There is no reason to believe that conditions are materially different in this area.

The most outstanding feature of this map is the position and distribution of the ore bodies with respect to the magnetic "highs." The ore bodies are found in the magnetic "lows" or on the flanks of the "highs;" none are found on the "highs."

[1]Personal communication.

This fact should be considered in prospecting in that it indicates that the magnetically "high" areas are, apparently, unfavorable for the occurrence of ore bodies.

CRAWFORD COUNTY.

The Index map, (Pl. I), shows the location of the county which has an area of about 710 square miles. The magnetic survey (Pl. IV, in pocket), was made in the winter of 1931 and 1932, in cooperation with the Industrial Club of St. Louis.

Stratigraphy. No detailed stratigraphic work has been done, but reconnaissance work shows that the oldest rock outcropping is a knob of granite in secs. 8 and 16, T. 35 N., R. 2 W., near the postoffice of Czar and that beds as old as Davis outcrop around this knob. The Davis formation of Cambrian age is exposed in the intensly faulted Crooked Creek area in sec. 17, T. 36 N., R. 4 W. The Potosi and Eminence are widely exposed in the southeast part of the county, the Gasconade and Roubidoux occur widely through the central portion, while the Jefferson City and possibly the Cotter are limited to the area northwest of Meramec River, and in the latter area the uplands are extensively capped with patches of basal shale and sandstone of the Cherokee formation of Pennsylvanian age.

Structure. In general the formations are highest in the southeast corner of the county with a gradual but locally much disturbed regional dip to the northwest.

High dips are found encircling the granite knob at Czar, and likewise the porphyry knob exposed in sec. 36, T. 38 N., R. 1 W., about five miles east of the county line. In sec. 7, T. 40 N., R. 2 W., porphyry was encountered in a well at a depth of 30 feet. In the area between these two highs, beds of Potosi age outcrop at numerous points, indicating an intervening buried ridge. The sediments are also extremely high in the Crooked Creek area in sec. 17, T. 36 N., R. 4 W.

An outstanding feature of the structure in the county is the large block dropped between the Cuba fault on the west, the Palmer fault on the south, and the Berryman-Leasburg fault on the east. At the south end of this fault block, the throw is as great as Roubidoux against Potosi but decreases northward, with Roubidoux abutting Jefferson City.

Magnetic Results. The magnetic base chosen for this work is the U. S. Coast and Geodetic Survey station at Steel-

ville, to which all readings have been referred. The readings were taken at mile intervals over all passable roads, but because of the rugged character of the area and the season of the year, large areas do not have a sufficient number of readings for completeness. This, no doubt, affects the position of the magnetic contour lines, and it is possible that a closer correlation might be obtained with additional readings more equally spaced.

The dropped block between the faults is magnetically "low." In the southern portion the values vary from —500 to 0 gammas while in the northern portion the variation is from 0 to +300 gammas. The Cuba fault is in a magnetic "low," and a magnetic "low" roughly parallels the downthrown side of the Palmer fault.

On the upthrown side of the Leasburg fault, an extensive magnetic "high" continues from sec. 13, T. 38 N., R. 2 W., to the porphyry well in sec. 7, T. 40 N., R. 2 W. The crest of this anomaly is over 800 gammas through long distances, and rises to over +1,500 gammas at numerous points. It will be recalled that porphyry outcrops about 5 miles east of the "high" located in sec. 13, T. 38 N., R. 2 W., and observations not shown on this map indicate that it is on the continuation of this large major magnetic "high." Also Potosi dolomite outcrops widely on this "high," indicating relatively thin sedimentary cover, and extraordinarily high position of the exposed formations. This large "high" is believed to mark the position of an extensive system of porphyry ridges at comparatively shallow depths.

The most striking anomaly so far found in the State occurs in this county. It is on the trend of the porphyry ridge just described, in secs. 3 and 4, T. 39 N., R. 3 W., and secs. 27, 34 and 35, T. 40 N., R. 3 W. The magnetic intensity varies from a minimum of +1,500 gammas to a maximum of +4,861 gammas in one-half mile in an east-west direction. Thus the total anomaly of 4,861 represents about 9% increase of the earth's field. This area is commonly referred to as the "Bourbon High" from its location at that town. The explanation of this intense variation is difficult because no subsurface data are available. At the well in which porphyry was reached at 30 feet, and which is about 5 miles northeast of Bourbon, the anomaly was +1,703 gammas. A well drilled for water at Bourbon was still in sediments at 200 feet. The beds at the surface do not show any dip greater than usual for the Roubidoux sandstone near the Gasconade dolomite contact. The dips observed could have resulted from solution

of the underlying dolomite with subsequent caving of the sandstone. Thus, there would appear to be valid reason for believing that this remarkable magnetic "high" is not caused by a peak on the main porphyry ridge. If it is not caused by the porphyry, the only other assumption is that it is caused by some unusual concentration of magnetic material. The two most reasonable explanations for such a concentration are either a large basic intrusive or a body of magnetic iron ore of the Iron Mountain type. Actual observations directly on basic intrusions have given variations of this order of magnitude; a deep well in Dent County encountered basic igneous rock at 1,750 feet, and magnetic readings around this location gave an anomaly of +700 gammas above normal. This anomaly is so much less than the one observed at Bourbon that it does not throw any additional light on the exceptional condition at that place.

Actual observations across the Iron Mountain ore body show anomalies varying from —3,200 to +6,000 gammas. These would probably show clearly through a considerable sedimentary cover.

All that can be said, at this time, is that the "Bourbon High" is considerably greater than any thus far observed elsewhere in Missouri under sedimentary cover, and the anomaly is probably caused either by a buried basic intrusive, or a body of magnetic iron ore. The latter possibility would justify a deep test.

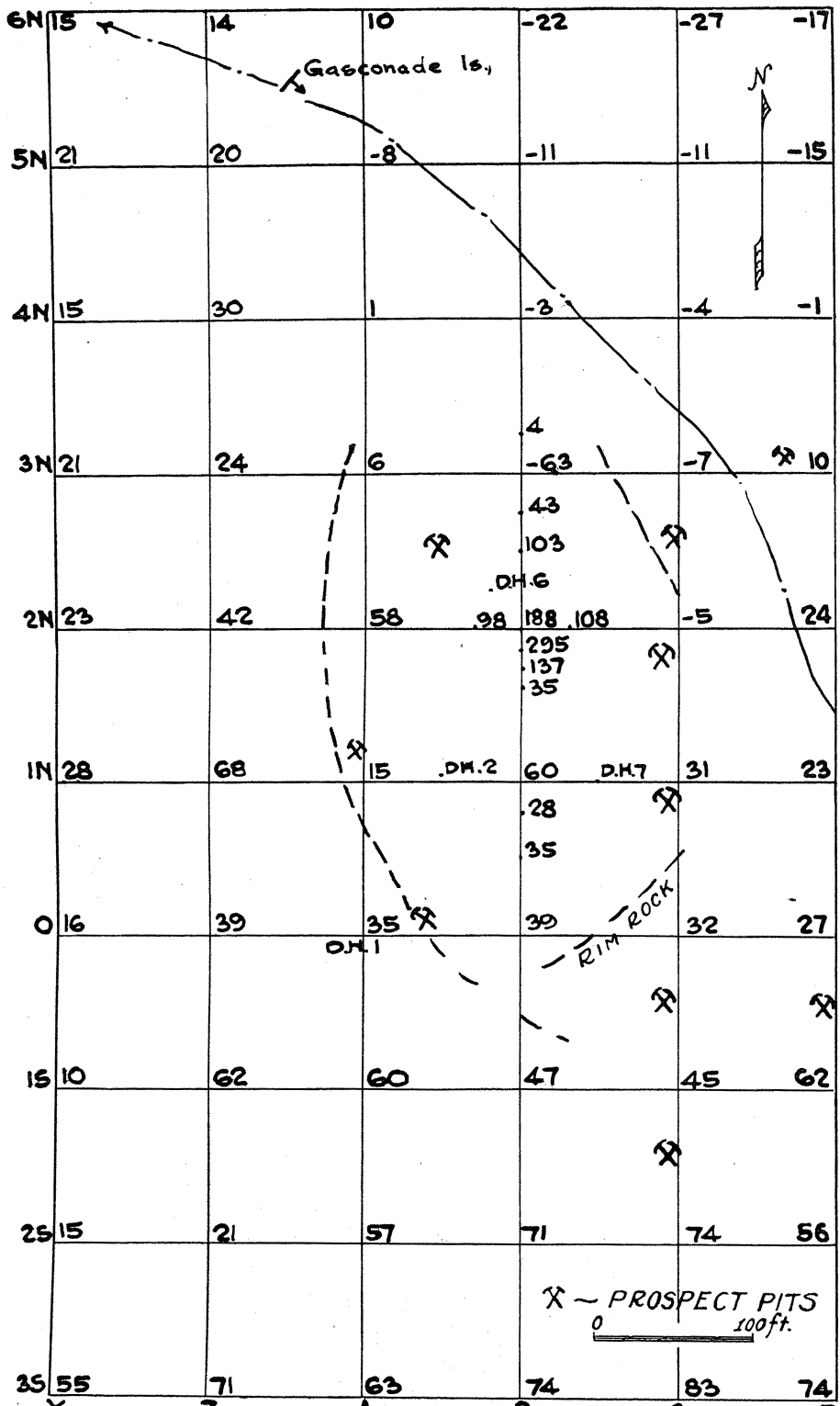
Another significant result of the survey is the distribution of the filled sink type of iron ores. The map shows that they are almost entirely in the magnetic "lows," or on the flanks of the magnetic "highs." This fact should be borne in mind in searching for future deposits.

IRON ORE DEPOSITS.

Silver Hollow Mine. This mine (Pl. V) is in the Meramec State Park, sec. 8, T. 40 N., R. 1 W., 7 miles southeast of Sullivan, Franklin County. It is on a small spur off a main ridge and lies about 25 feet above the level of a large valley which is a tributary of Meramec River. It is a typical iron filled sink of the kind described by Crane.[1]

The sink occurs in Gasconade dolomite. Dipping sandstone rim rock may be traced almost completely around the deposit.

[1]Crane, G. W., "Iron Ores," Mo. Bur. Geol. & Mines, Vol. X, Second Series, Page 89.



Magnetic survey of Silver Hollow Mine.

The area encircled by the rim rock is about 400 feet long by 200 feet wide. Within this area several boulders of blue ore are found at the surface, and test pitting has shown soft red ore within a few feet of the surface. The prospect was drilled in 1917 by the Southern Acid and Sulphur Company. Seven holes were put down, and all of them are reported to have shown good ore. The magnetic survey was made over the area in May, 1931. First an area 1,000 feet in length by 500 feet in width was gridded and stakes set 100 feet apart. The area of ore and rim rock outcrop is about in the center of the grid. Observations were then made with the magnetometer at each of these stakes. An inspection of the map (Pl. V) indicates that there is a gradual decrease in intensity from south to north over the area. This is interpreted as being a regional condition and was later proved by observations not shown on this plate. Also, it will be noted that stations Z 1 N, B 3 N, B 2 N, and B 1 N, are at variance with the areal normal, or to put it in other words they vary markedly from adjoining stations. Station B 2 N, was later detailed by taking readings at close intervals. A maximum value of 295 gammas was obtained 12½ feet south of B 2 N, with a minimum of —63 gammas 100 feet north of B 2 N. This makes a total variation of 358 gammas in 112½ feet. The total area of magnetic distortion of the normal is about 200 feet in length by 200 feet in width. This was interpreted as being the area in which the greatest concentration of blue specular hematite would be found. Such an interpretation did not rule out other parts of the area, because the soft red ore being relatively non-magnetic might occupy portions of the sink and still not be detected by the magnetometer. Similar results have been obtained in many other surveys,[1] a large number of which are on file at the Survey and may be inspected by anyone interested.

Mining developments since the survey have shown that the above interpretation is essentially correct. Blue specular hematite was found at a more shallow depth and in greater abundance at station B 2 N than at any other part of the area, while soft red hematite was found at places of no magnetic anomaly. The character of the blue ore may be shown by an average of 7 samples taken from various points in the mine.

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[1]Biennial Rept. State Geologist to the 56th Gen. Assembly, 1931. Figs. B, Pls. IV, V., App. III.

Analyses by R. T. Rolufs, of this Bureau, show 64.6% iron (Fe) and 3.62% silica (SiO_2). No determinations were made for other constituents. When the ore is powdered to 100 mesh and a magnet drawn through it, many particles adhere to the magnet. This is probably magnetite.

In regard to using the magnetometer for prospecting for these types of deposits their size must be kept in mind. Readings taken at intervals of ½ mile would not locate such deposits. Some surface indication should be present to restrict the area of survey. These indications should be, in the order of their importance, outcropping rim rock with blue and red ore in association, outcrops of red ore associated with rim rock, outcrops of rim rocks, outcrops of red ore, or outcrops of rim rock and brown ore. Also, it should be kept in mind that the lack of any magnetic disturbance does not condemn the property if other factors are favorable, because the blue ore may be absent or at such depth that no magnetic effect is obtained, nevertheless, there may be sufficient soft red ore to warrant development of the property.

GROUND WATER INVESTIGATIONS.

In recent years, the Bureau has done considerable geologic work for cities and towns relative to the location of sites that would afford adequate supplies of ground water from deep wells.

Structural features are important, and, in many instances, controlling factors in the ultimate supply of water, and in ground water investigations must be given consideration. This is especially true of the regional structural "highs." Over their crests, the formations show noticeable thinning, or in some instances, tightening of water bearing horizons. Studies of these features also show that faults or fractures are usually present on the steep side of the asymmetrically shaped "highs" and afford areas from which large supplies of water can be obtained. The regional "highs" and their associated structural features also control the general static water level in some localities and their presence possibly accounts for changes in the quality of the water.

It is believed that these regional features are reflections of "highs" in the pre-Cambrian rocks, hence their presence can be, and have been determined by surveys with a magnetometer.

These surveys have been particularly helpful in areas where outcrops were poor and limited, and in others where checks were afforded on the geologic studies.

Magnetometer work has been successfully done in connection with the study of ground water problems at West Plains, St. Clair, Clinton, and Illmo, and in the future will be used as an aid in similar investigations.

STONE AND BARRY COUNTIES.

Parts of these counties comprising the Shell Knob quadrangle were surveyed magnetically. This area is being mapped geologically, and it was thought that a magnetic survey would aid in determination of structural trends. Previous to the magnetic survey it was thought that the structures would trend northwest-southeast but the magnetic intensities have a northeast-southwest trend. Detailed mapping has later shown that the geologic structures and the magnetic features coincide.

SCOTT, STODDARD, PERRY AND CAPE GIRARDEAU COUNTIES.

These counties were surveyed in advance of geologic mapping. Near Essex in Stoddard County a circular magnetic "high" with a radius of 10 miles was mapped. Its magnetic relief is about 1,800 gammas and the top is a magnetic flat of some 4 square miles. At Brazeau in Perry County, a magnetic "high" of the same general outline was mapped, its magnetic relief is about 700 gammas. The surface geology at both places shows no abnormal structure and for this reason it is believed that these two magnetic "highs" are caused by an intrusion of some highly magnetic material. Stearn[1] has found similar magnetic "highs" in Arkansas, one of which was found by drilling to be a basic plug.

WASHINGTON COUNTY.

A magnetic survey of Washington County is now in progress. The barite producing region occurs in a magnetic "low." Further work will show the relationship of this region to the magnetic pattern of the remaining portion of the county.

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[1]Stearn, Noel H. A geomagnetic Survey of the Bauxite Region in Central Arkansas. Bulletin 5, Arkansas Geological Survey.

HIGHWAY TRAVERSE LINES.

Magnetic readings were taken at mile intervals along the highways as shown on Pl. I. A major control station was established every ten miles and referred to the base station at Ste. Genevieve. As indicated, a net work of major stations are so distributed that magnetic surveys in any area can be referred to those in other parts of the state. These traverse lines have shown the relationship of large geologic features to the magnetic intensities. It has been shown that in North Missouri, where the depth to the granite varies from 2,000 to 3,500 feet, the magnetometer will give recognizable anomalies over major geologic structures. At Chillicothe an anticline gives magnetic anomalies of about 500-gammas. In crossing the Lincoln Fold in Lincoln County anomalies vary from −400 to +200 gammas. A traverse line near Perry in Ralls County crosses a syncline in which coal occurs. The results show that the coal basin is in a magnetic "low." Similar results were obtained over the coal producing district near Panama in Vernon County. In western Missouri, many of the regional folds in Vernon, Bates, Cass and Jackson counties give magnetic anomalies.