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The Vincennes Magnetic Anomaly Lee County, Iowa

D. H. Hase
State University of Iowa

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D. H. HASE[2]

Abstract. Relative measurements of the vertical magnetic intensity in southern Lee County, Iowa, were made with a tripod-mounted, Askania Torsion Magnetometer, Type Gfz. The Vincennes magnetic anomaly is attributed to a body of magnetic rock in the Precambrian crystalline complex. From diamond drilling, the top of the body is known to be about 2900 feet below the surface. Although no unique interpretation is possible, a mathematical analysis of the magnetic data suggests that the body may be shaped something like a shallow dish approximately 1,000 feet thick through a diameter of 8 miles and tapering to a feather-edge at a diameter somewhat greater than 4 miles. The body may contain about 10 per cent of uniformly disseminated magnetite. The magnetic polarization of the body is assumed to be due entirely to the earth's present magnetic field.

Early in 1961, variations in the vertical component of the earth's magnetic field were measured in the vicinity of Vincennes, Lee County, Iowa (Figure 1) because of a magnetic anomaly which is depicted at the northeastern border of the state of Missouri[1]. The purpose of the investigation was to determine the extent and intensity of the anomaly in Iowa and its probable cause.

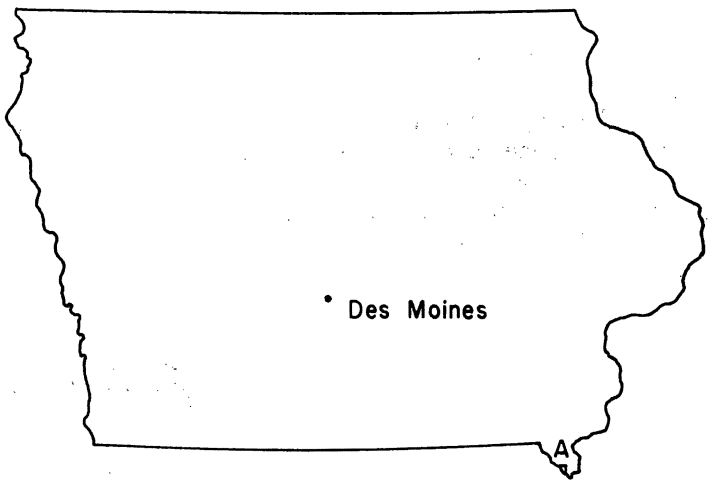

Figure 1. Index map of Iowa showing location of the Vincennes magnetic anomaly.

[1] Presented with the permission of Dr. H. Garland Hershey, State Geologist and Director of the Iowa Geological Survey.

[2] Department of Geology, State University of Iowa, Iowa City.

The investigation was made as part of an initial phase of magnetic mapping in the state. Subsequent to the early investigations, funds were allocated by the Iowa legislature for state-wide ground and airborne magnetometer surveys which are in progress.

A tripod-mounted, Askania Torsion Magnetometer, Type Gfz, was used to make relative measurements of the vertical magnetic intensity. The instrument has a scale value of 233.83 gammas per scale division and a temperature coefficient range of about 1.7 gammas per degree Centigrade through a direct reading range of about 60,000 gammas. Readings were made to an hundredth of a scale division.

Inasmuch as a single instrument was used to make the surveys, a base station was established and reoccupied at intervals of several hours during the course of each day's survey to establish a diurnal-variation curve for correcting the field measurements. The field data were corrected for temperature variations by reducing all readings to 0° Centigrade and by applying the temperature coefficient. Latitude and Longitude (Normal) corrections were calculated from the coordinates of each station relative to the base station. The north-south and east-west components of the rate of change of the vertical intensity were estimated from the U. S. Coast and Geodetic Survey vertical intensity chart (2) and extrapolated to 1961.

Eighteen magnetometer stations were established in Lee County at intervals ranging from a quarter of a mile to one mile, and a base station was established on the north side of the Des Moines River on the projection of the -100 gamma contour of the Missouri anomaly to relate the magnetic measurements in both states. Three stations were established in Missouri to determine the possible error between the observed magnetic intensity at these stations and interpolated values from the Missouri magnetic map. The greatest error obtained by this method was 100 gammas.

The corrected vertical magnetic intensity values are relative to the local base station which is about 10 miles from the Keokuk, Iowa, geodetric station.

Geologic Setting

There are no exposures in the area, and although the bedrock is overlain by about 25 to 200 feet of Pleistocene drift, the stratigraphic section is rather well known from water-well data. No Mesozoic rocks have been identified, and the Paleozoic section includes limestones, dolomites, shales and sandstones of Mississippian, Devonian, Ordovician and Cambrian age.

The magnetic anomaly occurs on the south flank of the Ben-

tonsport anticline about 8 miles south of the crest line of the structure which trends approximately northwest through Lee County. The dip on the south flank of the structure taken on the base of the Burlington limestone is about 12.5 feet per mile (3). No structure has been reported in the Paleozoic rocks in the immediate vicinity of the magnetic anomaly. In the southern part of Lee County, no holes have been drilled to the Precambrian rocks, so control is lacking on the lithology, depth and general configuration of the Precambrian crystalline complex.

In the spring of 1959, the St. Joseph Lead Company completed a drill hole located a short distance to the west of St. Francisville (Figure 2). The hole penetrated Mississippian, Devonian, Ordovician and Cambrian rocks and intersected the Precambrian crystalline complex at 2927 feet below the collar. The hole was extended to 3315 feet, a total of 388 feet in the crystalline rock, and the rock was described merely as granite on the log of the hole.

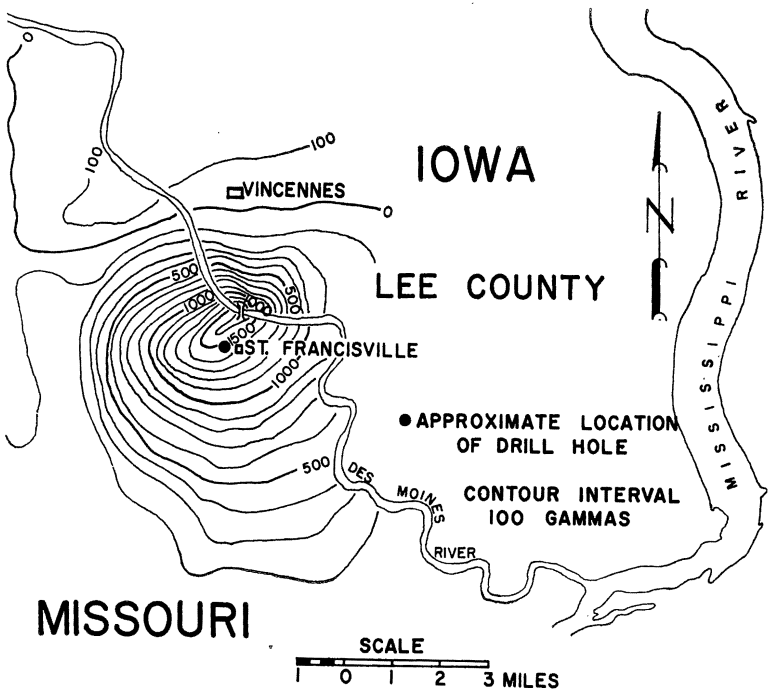

Figure 2. Vertical magnetic intensity map, Vincennes, Iowa—St. Francisville, Missouri. Portion of magnetic anomaly in Missouri adapted in part from Magnetic Map of Missouri, State of Missouri, 1943.

Interpretation of the Anomaly

The magnetic anomaly is somewhat elliptical in shape with a weak northeasterly trend but does not extend more than 2 miles

into Iowa (Figure 2). The magnetic intensity contours (isogams) south of the Des Moines River were adapted in part from the Magnetic Map of Missouri (1), the control for which was based on magnetic stations spaced approximately one mile apart. West of a line connecting Vincennes, Iowa, and St. Francisville, Missouri there is very close agreement between the Iowa and the Missouri magnetic data, but to the east of this line there is pronounced disagreement. Little more can be said about this except that it is often difficult for two different workers to arrive at exactly the same field results. On the Missouri side of the anomaly the highest isogam is 1600 gammas, whereas on the Iowa side the highest isogam is 1100 gammas.

The Paleozoic sedimentary rocks and the glacial drift do not contain significant amounts of minerals with a high magnetic susceptibility. Consequently, the magnetic anomaly can be attributed almost entirely to changes in the lithology or configuration of the Precambrian crystalline complex.

In the immediate area of St. Francisville no gravity anomaly appears on the gravity map of Missouri (4) which more or less eliminates the presence of a thick, dense rock in the Precambrian complex.

The Vincennes anomaly is well suited for analysis because it apparently is not affected by any nearby magnetic anomalies. The general shape of the anomaly suggests that the source body is probably circular in plan. The magnetic axis is apparently inclined somewhat from vertical inasmuch as in the northern hemisphere, strong positive anomalies may have weak negative anomalies on the north sides, and in general the steeper side of the anomaly is on the side toward which the magnetization vector dips (Figure 2). Inasmuch as no drill cores or cuttings of the Precambrian crystalline rock were available for measurements of the susceptibility and remanent magnetization, the resultant direction of the induced and residual magnetic fields of the rock must be assumed to coincide with the earth's present magnetic field. The inclination of the earth's magnetic field in this area is about 71 degrees.

Reasonable approximations of the possible shape, depth and magnetic susceptibility of the body producing the anomaly were obtained by using the method of Vacquier et al (5), the Peters' "slope" and "error-curve" methods (6), and the formulas and curves for geometric bodies calculated by Nettleton (7). Some relief may be present on the old Precambrian surface, but the order of magnitude very probably does not exceed a few hundred feet.

Andreasen and Zietz (8) have shown that if one of the para-

meters of depth of burial, geometric configuration and magnetic susceptibility of a magnetic rock mass is known, it is sometimes possible to calculate reasonable limiting of values for each of the other two parameters. A depth to the top of the body of 3,000 feet, which was obtained by rounding off the depth of 2,927 feet noted on the log of the drill hole, was used to facilitate calculations. The second vertical derivative of the magnetic intensity, an approximation to the curvature, was computed by the method described by Vacquier et al (5), and a curvature contour map was prepared. Although no unique shape could be derived, a good fit to the observed anomaly was obtained by computing the magnetic field of a model body consisting of a disk 4 miles in diameter and 500 feet thick above a disk 3 miles in diameter and 500 feet thick (Figure 3). Although further refinement of the model does not seem to be warranted, the magnetic data and geological sense suggest that the body might be shaped like a shallow dish thinning toward the edges.

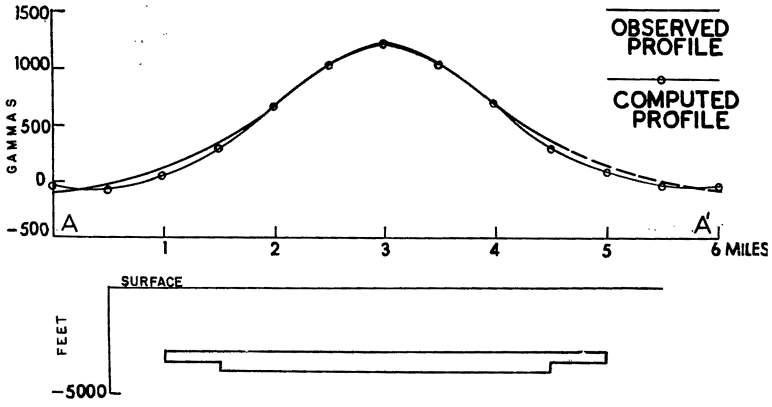

Figure 3. Observed and computed magnetic profiles over assumed body.

Assuming that the Precambrian surface is essentially horizontal and that the crystalline rock surrounding the body is an average granite with a magnetic susceptibility of 0.0027 cgs units, the body itself probably has a magnetic susceptibility of about 0.03 cgs units which would result from uniformly disseminated magnetite composing approximately 10 per cent of the rock. Computations made using a susceptibility contrast of 0.0273 cgs units and a susceptibility polarization of 0.015 cgs units provide a good fit to the observed magnetic data. The magnetic susceptibility contrast was obtained by comparing observed magnetic profiles to those computed for models with different bottom depths and susceptibilities.

Conclusions

The proposed geological situation producing the Vincennes magnetic anomaly was obtained by a method which involves computing the magnetic field of a model rock mass and comparing it to the observed magnetic field. The interpretation of magnetic data is inherently ambiguous owing to the fact that an infinite number of combinations of magnetic susceptibility, depth of burial and geometric configuration of the body can produce the same observed magnetic field. The depth to the top of the Precambrian surface and presumably also the top of the body producing the magnetic anomaly is known from diamond drilling, however, and consequently reasonable values can be calculated for the approximate geometric configuration and the magnetic susceptibility of the rock mass.

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The Lime Creek Formation in the Area of Garner, Iowa[1]

Donald L. Koch

Abstract. The rock exposed in quarries southwest of Garner, Iowa, has been in question as to its stratigraphic position, having been correlated with both Middle and Upper Devonian formations with no supportng evidence. Stratigraphic control was established by comparing lithologies present in the Cedar Valley, Shell Rock, and Lime Creek formations in exposures and noting the changes that occur in the subsurface through a detailed study of well cuttings. Lithologic and paleontologic evidence supports a Lime Creek correlation.

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