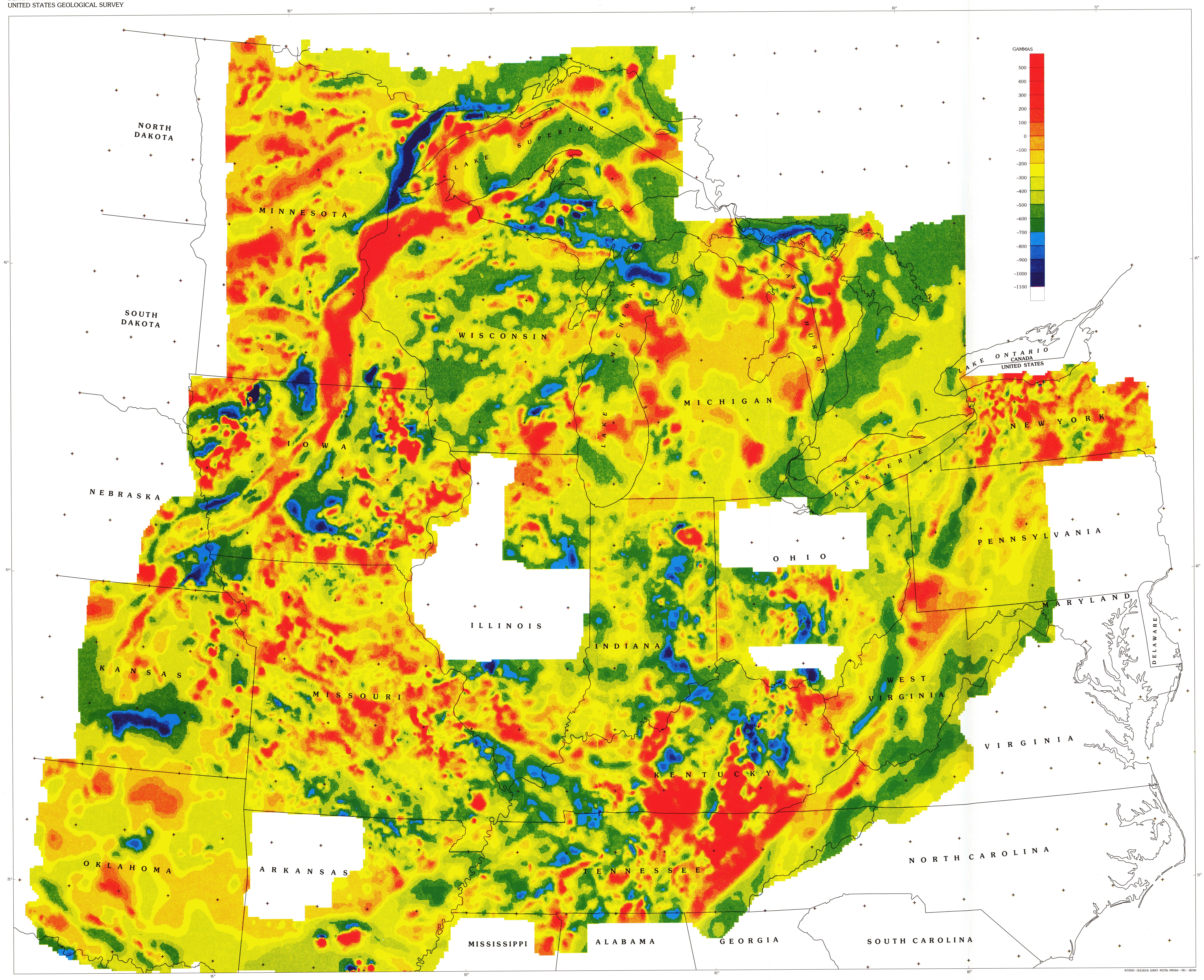

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DIGITAL MAGNETIC-ANOMALY MAP OF CENTRAL UNITED STATES: DESCRIPTION OF MAJOR FEATURES

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INTRODUCTION

Regional geologic investigations of major tectonic features are often aided by studies of their associated magnetic anomalies. The distribution of upper-crustal magnetized rock units interpreted from the anomalies may convey new information about known rock units or reveal subsurface information about unknown structures. The magnetic-anomaly map described below was compiled from digital data. It provides a synoptic view of major magnetic anomalies and contributes to information concerning the tectonic development of the midcontinent region. The availability of digital data also allows application of a variety of analytical techniques, which can be used to enhance the anomalies and provide new interpretive information.

The digital magnetic data were obtained from both ground and airborne surveys that were made at different times, spacings, and elevations. In order to construct a consistent data set, data from some surveys within a region required removal of an appropriate reference field and analytical continuation to our selected reduction level, a common surface 1000 ft above mean terrain. The precision estimated for data of the remaining third of the map area, which were merged without correcting for elevation differences, was judged by inspection to be adequate for the present map scale (1:2,500,000) and color interval (100 gammas). Although magnetic fields from several surveys were referenced to an arbitrary datum level, the field values over the entire map are expected to be generally within 100 gammas of their absolute values. Thus, the resulting map is regarded as being generated from a set of compatible data. The map compiled from these data and the features it exhibits are, hereafter, referred to simply as the magnetic-anomaly or magnetic-field map and anomalies, respectively.

A magnetic-anomaly map of this type reveals structure and lithologic contrast within magnetic basement, which in the Central Stable Region generally coincides with the surface of Precambrian crystalline rocks. Phanerozoic sedimentary units are relatively nonmagnetic and produce little or no changes in the magnetic field. The magnetic field of the midcontinent exhibits many prominent anomalies that are considered to be the expression of major geologic structures. Some of these structures have been discussed previously in the literature. Here we discuss their interrelationship and possible geologic significance of their anomalies and others previously unrecognized.

MAGNETIC SURVEYS AND DATA REDUCTION

The magnetic-field map was compiled from digital data acquired from a diverse group of magnetic surveys. Approximately 80 percent of the magnetic coverage is airborne data. These surveys were flown at elevations ranging from 500 ft (0.15 km) to 2500 ft (0.76 km) above mean terrain and with flight-line spacings ranging from 0.5 mi (0.80 km) to 6 mi (9.66 km). Aeromagnetic surveys with flight-line spacings of 4 mi or greater cover the southern peninsula of Michigan, Wisconsin, Lake Superior, Lake Michigan, Lake Huron, and central Pennsylvania. In addition to aeromagnetic surveys, magnetic coverage includes ground surveys of Oklahoma and Missouri (excluding southeastern part of the state), in which only vertical magnetic intensities were measured, and a shipborne survey of Lake Erie, from which total field measurements were available.

Digital data from the surveys in Oklahoma, Kansas, Missouri, Nebraska, Iowa, Minnesota, Wisconsin, Michigan, the Great Lakes region, Canada, and northeastern Illinois were obtained by digitizing 200-gamma contour intervals on the published maps. High-precision digitization had been previously performed by others on a number of aeromagnetic maps covering portions of central United States. Their data sets, which were used for our purpose, cover Indiana (Richardson, 1978); west-central Ohio (Harlan and others, 1979); east central Ohio, Pennsylvania, and part of southeastern Missouri (Hildenbrand and others, 1981b); and part of northeastern Arkansas (Hildenbrand and Johnson, 1977). Digital aeromagnetic data were available for the remaining surveys.

The residual magnetic field was obtained over most of the area by removing the International Geomagnetic Reference Field (1965 and 1975) after updating to the epoch in which the surveys were flown. Alternative reference fields GSFC1266 and POGO were employed for two surveys covering Indiana (Richardson, 1978) and southwestern Illinois (Johnson and others, 1980), respectively. For the relatively old ground surveys in Oklahoma and Missouri (excluding southeastern Missouri), reference fields were not removed because information regarding the time of collection and the reduction process were not available. Because these surveys merged well with surrounding aeromagnetic surveys, we conclude that a regional field had been removed; this was not indicated, however, on the source maps.

For each individual survey, an elevation of 1000 ft (0.30 km) above the mean value of the terrain elevation was selected as the datum level. This procedure should not produce any significant error because surface relief over the area is generally low. Ground and marine surveys were analytically continued upward to this level; surveys flown in a draped mode (constant elevation above terrain) were continued upward or downward as necessary. For surveys flown at a constant barometric altitude, the data were continued an amount equal to the difference between the mean terrain clearance and the selected datum level. Use of the mean terrain clearance in the continuation process considerably reduced the computations in data reduction. Before merging, magnetic field values of each survey were adjusted by a constant amount, so that they were compatible with those of adjacent surveys. The data sets were then merged utilizing one-dimension splining techniques described by Bhattacharyya and others (1979). A four kilometer grid of values, using a minimum curvature method (Briggs, 1974), was created and then contoured utilizing Applicon Incorporated[1] proprietary software.

[1]Use of a specific brand name does not necessarily constitute endorsement of the product by the U.S. Geological Survey.

The data digitized from the map compiled by O'Hara (1981) for integration into the present map requires a separate discussion. O'Hara's map was compiled from several surveys which encompass all of Minnesota, Wisconsin, Michigan, the Great Lakes region, northeastern Illinois, and parts of Canada. These surveys, which were manually merged, were not separated by us for individual processing. O'Hara computed residual fields for these surveys by subtracting an appropriate reference field, or by adjusting field values to match those of adjacent surveys for which a reference field had been removed. Some measure of error in the field values of our map may exist because the differences between survey elevations (0 to 1800 ft above mean terrain) and our reduction datum level range from −1000 to 800 ft. We do not believe, however, that these errors are appreciable, especially for studying anomalies at the present scale of 1:2,500,000 and color interval of 100 gammas.

The overall precision of the magnetic field values is unknown mainly because of the diversity of surveys used to construct the map. For example, errors caused by merging total-field intensities with vertical-field intensities from ground surveys of Missouri and Oklahoma are present but assumed small due to high inclinations of the total-field at these latitudes and to the great depth of magnetic basement within the regions of the ground surveys. This assumption seems to be borne out by the ease with which ground surveys were merged with bordering airborne surveys. In attempting to estimate the amount of error, the maximum difference between the total intensities and vertical intensities was computed for a highly-magnetized, vertical prismatic body lying at a depth of 2 km, extending to a depth of 25 km, and having a width of 4 km and a susceptibility of 3×10^{-3} emu. The resulting difference of 75 gammas is considered small for our purpose, a generalized study of anomaly patterns.

Another source of error occurs from surveys in which magnetic field values were referenced to an arbitrary datum level. These errors have been substantially reduced in the data reduction process which included adding a constant value to the magnetic field intensities of each survey so that they were compatible with those of adjacent surveys. Negligible error in the level of field values are anticipated in the Mississippi Embayment region because associated surveys were referenced to an absolute datum level and were the first to be merged. Errors become progressively larger outward from the Mississippi Embayment region but have been determined to be less than 100 gammas in Kansas and western New York, where field values from aeromagnetic surveys were referenced to an absolute datum level.

MAGNETIC TERRANE IN THE MIDCONTINENT

The resulting magnetic-field map reveals anomalies of varying intensities and wavelengths. Changes in depth to magnetic basement are a contributing factor in producing the wide variety of magnetic patterns. For example, the apparent long wavelength field over the Michigan Basin is caused, in part, by the deepening of Precambrian basement; shorter wavelength anomalies are, however, observed in Wisconsin where basement outcrops. Lithologic variations also produce diverse anomaly patterns on the map. Magnetic anomalies in Minnesota have different intensities and wavelengths than those observed in Wisconsin, although Precambrian basement outcrops in both regions. On the other hand, regions separated by large distances but characterized by magnetic fields that are similar in appearance are also identifiable. This is evident in comparing anomalies over Michigan with those of Oklahoma and anomalies of Missouri and eastern Iowa with those of northwestern New York and Lake Huron. Although we don't completely understand the nature of the source of most anomalies, we see patterns and correlations that seem worthwhile to point out.

Of particular interest are several megalineaments observed on the map which may reflect continental-scale geologic features. For our purpose a magnetic megalineament is defined as a straight or curvilinear alignment of anomalies or gradients that extends horizontally for distances greater than 500 km it may have substantial width, expressing a zone rather than a narrow feature. Examples are the New York-Alabama lineament (King and Zietz, 1978), essentially a boundary between contrasting magnetic terranes, and the midcontinent magnetic (and gravity) anomaly system (King and Zietz, 1971), a 65 kilometer-wide complex pattern of anomalies arranged in an en echelon elongate pattern for more than 900 km. The magnetic expressions of these are clearly identified on the eastern and western sides of the map; two other megalineaments and several less prominent magnetic lineaments, are described below. The principal features are summarized in figure 1. It is interesting to note that the four megalineaments primarily separate magnetic terranes of diverse appearance and that magnetic features of the midcontinent trend predominantly northeast or northwest.

MIDCONTINENT MAGNETIC HIGH AND FLANKING MAGNETIC FEATURES

The midcontinent geophysical system of magnetic and gravity anomalies is considered the most striking geophysical feature of the map and obviously represents a major crustal discontinuity. The anomalies delineate a belt of igneous rocks of the Keweenawan Supergroup that extends nearly 1,000 km from the general vicinity of Lake Superior to southern Kansas. This long semicontinuous block, averaging 65 km in width, is underlain primarily by layered mafic volcanic flows. Magnetic lows are associated with clastic rocks that occur in basins along the margins of the belt of mafic rocks. King and Zietz (1971) suggest the curvilinear or en echelon pattern of this geophysical feature indicates offsets of the mafic belt by transform faults. They conclude that due to its appreciable length, igneous composition, and en echelon pattern, the mafic belt is a continental rift which failed to develop into an ocean.

The general magnetic pattern of this midcontinent rift system changes in character along trend from Lake Superior to Kansas. Mafic extrusive rocks, primarily located near the northern and southern shores of Lake Superior (Bayley and Muehlberger, 1968), are clearly expressed by two linear intense magnetic highs that converge in northern Wisconsin. Immediately to the southwest, the midcontinent magnetic high trends southward into northern Iowa as a broad high delineating the St. Croix horst (Craddock and others, 1963), a block composed of Keweenawan volcanic rocks. Farther southwest in Iowa and Nebraska, its trend is southwest but changes to a more southerly direction in Kansas; in these regions the system generally exhibits relatively narrow flanking linear magnetic highs, presumably reflecting mafic rocks that were emplaced along the rift's border faults. More detailed descriptions, rock associations, and discussions are given by King and Zietz (1971).

In south-central Kansas the midcontinent magnetic high appears to terminate near a prominent east-west trending magnetic low. More detailed magnetic analyses by Yarger (1981), suggest that the rift system narrows abruptly to 20 km in southern Kansas and continues somewhat farther to the southwest into Oklahoma. The source of the pronounced low is interpreted by Lidiak and Zietz (1976) as a pre-Keweenawan belt of thick low-grade metasedimentary rocks, lying at depths greater than the present Precambrian surface (Yarger, 1981).

Magnetic terrane flanking the midcontinent rift system is characterized by diversified patterns, indicating varying lithologies and structures. In central Minnesota broad northeast-trending highs, terminating at or near the midcontinent magnetic high, generally coincide with mapped Archean metavolcanic, granitic, and gneissic rocks that include granulite and amphibolite facies (Sims, 1976). Intervening magnetic lows geographically correlate with Archean and early Proterozoic metasedimentary rocks. The magnetic field apparently delineates the lateral extent of these Precambrian units.

Magnetic features trending northwest in Missouri also follow Precambrian structures (Hays, 1962; McCracken, 1971) and terminate to the northwest in the vicinity of the midcontinent rift system. Their intensities are comparable to those observed in Minnesota. Kisvarsanyi (1974, 1979) suggested that the source of the northwest-trending magnetic highs in Missouri are Precambrian metasedimentary and metavolcanic rocks and layered mafic intrusions. The shorter wavelengths of the observed magnetic high zones in Missouri indicate that the distribution of these magnetized rock units is more limited in horizontal extent than those in Minnesota. Granitic or low-grade metamorphic rocks may produce the northwest-trending magnetic lows in Missouri (Lidiak and Zietz, 1976).

In Wisconsin relatively low-intensity regional anomalies flanking the midcontinent magnetic high to the east generally coincide with Archean and early Proterozoic gneisses and granites, although isolated small-wavelength highs probably reflect Early Proterozoic volcanic and mafic intrusive rocks (Sims, 1976). Broad magnetic highs in southeastern Wisconsin, northern Illinois, and possibly southeastern Iowa may be caused by Precambrian granitoid bodies. Granodiorites containing biotite and hornblende facies have been encountered in four wells in northern Illinois, sometimes at depths several hundred feet below a granitic basement (Bradbury and Atherton, 1965). Northeast-trending magnetic lineaments in southwestern Wisconsin and eastern Iowa (fig. 1) may delineate edges of these granodiorite bodies. One of these lineaments located in Iowa parallels the broad Mississippi River Arch, and therefore may also reflect concealed structures that influenced the development of this arch.

NEW YORK-ALABAMA LINEAMENT AND FLANKING MAGNETIC TERRANE

The New York-Alabama lineament (fig. 1) is marked by a series of prominent linear magnetic gradients, trending northeast from southeastern Tennessee (35°N lat and 85°10′W long) to central Pennsylvania (41°N lat and 78°30′W long). The 1600 km long lineament reflects a profound discontinuity in crystalline basement. King and Zietz (1978) suggest that the remarkable linearity of this feature is associated with substantial strike-slip displacements. They point out that the lineament may represent the southeast edge of a stable block that performed as a barrier for strong deformation of the Appalachian foldbelt. An alternative explanation given by them is that the lineament corresponds to a suture or boundary between two basement terrains with contrasting lithologic and geophysical characteristics. Whatever the cause, the geophysical feature is surely associated with a major crustal discontinuity that is expressed as a magnetic megalineament.

In the basement southeast of the lineament, highly magnetic sources are sparse, a characteristic unlike any other equal-sized region of central United States. Excluding the magnetic highs in a belt extending from West Virginia to northeast Tennessee, the intensities of magnetic anomalies in this region are similar to those located in Canada northwest of Lake Erie and Lake Ontario. Grenville terrane about 1.0–1.1 b.y. old (Lidiak and others, 1966) underlies both regions.

SOUTH-CENTRAL MAGNETIC LINEAMENT

Two other features are identifiable on the magnetic-anomaly map of the midcontinent which comply with our definition of a megalineament, although their magnetic expressions are less distinctive than those discussed above. One of these, named herein the south-central magnetic lineament (fig. 1), is the most pronounced northwest-trending anomaly on the map, as it extends at least to the New York-Alabama lineament on the southeast and may intersect the midcontinent magnetic high on the northwest.

In east-central Kentucky and Tennessee, complex high-amplitude anomalies with large horizontal dimensions are present. These highs are abruptly truncated on their southwestern edge by the south-central magnetic lineament and on their southeastern edge by the New York-Alabama lineament. Basement rocks encountered by drill holes in the regions of these intense highs consist of mafic and felsic volcanics, amphibolites, and mafic-two-pyroxene-granulites (Hinze and others, 1977). The mafic volcanics are similar in petrologic character to Keweenawan rocks observed in the Lake Superior region (Keller and others, 1975). Radiometric ages of basement lithologies in Tennessee (Hinze and others, 1977; Muehlberger and others, 1967) suggest that an igneous event occurred 1.0–1.3 b.y. ago, coinciding with the age (Keweenawan) of rift-related volcanics in the Lake Superior region. When coupled with the geometries of the associated geophysical features, these observations may indicate that the intersection of the south-central magnetic lineament and the New York-Alabama lineament depicts deep-seated structures along which the upper crust was extended and into which magma was emplaced during Keweenawan time. The intense magnetic highs in central and eastern Tennessee and in Kentucky may mark the location of large, mafic plutons of Keweenawan age.

From central Kentucky (36°50′N lat and 86°50′W long) to eastern Missouri (38°25′N lat and 90°20′W long), the south-central magnetic lineament is generally expressed as a 40 km-wide band of intricate magnetic highs which are elongate along the features principal trend (Hildenbrand and others, 1981a). Near the Kentucky-Illinois state boundary, syenite to peridotite dikes and sills of varying composition, together with explosion breccias (Clegg and Bradbury, 1956; Koeing, 1956, Heyl and others, 1965), have been encountered in the vicinity of the highs; they have Rb-Sr and K-Ar dates of approximately 260 m.y. (Zartman, 1977). Hicks dome, a structural feature of the Kentucky-Illinois fluorspar mineral district near 37°30′N lat and 88°15′W long, is located on these northwest-trending magnetic highs. The dome is an alkalic cryptovolcanic structure that consists of mineralized breccia and kimberlite dikes (Heyl and others, 1965). According to these data the portion of the megalineament from central Kentucky to eastern Missouri, appears to delineate a region intruded by mafic igneous material, which contrasts with surrounding basement. The south-central magnetic lineament in this region also parallels the St. Genevieve fault zone, a high-angle thrust fault zone which has associated normal faults (Heyl and others, 1965), and its inferred extension into Tennessee (Hildenbrand and others, 1981a).

In Missouri geologic evidence indicates a predominant northwest Precambrian structural grain (Hays, 1962; McCracken, 1971), a trend which is reflected in the magnetic data. Although obscured at least in part by a more complex background field, the south-central magnetic lineament is projected northwest as a boundary (fig. 1) separating a northern region, generally characterized by long-wavelength anomalies of variable trend, from a southern region, typified by higher gradients and amplitudes with a northwest trend. Numerous northwest-trending anticlines, synclines, and arches (McCracken, 1971) lie along or near this boundary; they include the Eureka-House Spring anticline in eastern Missouri, the Saline County arch with associated anticlines and faults in central Missouri, and the Cameron-Union Star syncline, Richmond-St. Joseph anticline, Hamilton-King City-Quitman axis, and Trenton anticline in northwestern Missouri.

The northwestern continuation of the south-central magnetic lineament beyond about 39°20′N lat and 93°10′W long is not clearly evident except as it might coincide with any one of a group of northwest-trending anomalies. If projected to the northwest, however, it intersects the midcontinent magnetic high at 40°30′N lat and 96°50′W long. In this region, the system of midcontinent magnetic anomalies abruptly changes trend to a more southerly direction. It is probable that the south-central magnetic lineament extends to this feature and beyond. If the apparent displacement of the midcontinent system is caused by the source of the south-central magnetic lineament, then it must have a component of left-lateral movement.

Structures corresponding to the south-central magnetic lineament may have influenced the tectonic development of major geologic features in the mid-continent. The south-central magnetic lineament coincides geographically with the northern boundaries of the Mississippi Embayment, Mississippi Valley graben, and the Ozark Uplift. The south-central magnetic lineament seemingly reflects a structural boundary along which these downwarps and uplift developed or their growth was impeded. It also crosses the saddle between the Cincinnati Arch in Kentucky and the Nashville Dome in Tennessee, suggesting a structural influence in the formation of this saddle.

GREAT LAKES MAGNETIC LINEAMENT

Another megalineament, named the Great Lakes magnetic lineament, is a west-northwest-trending boundary which separates regions characterized by anomalies of different wavelengths and which correlates with some major geologic boundaries. Near Lake Huron (44°N lat and 82°W long), it separates moderate-amplitude, long-wavelength anomalies to the south from anomalies with higher intensities and short wavelengths to the north. The increase in anomaly wavelength and decrease in amplitude over the Michigan Basin is due, in part, to the substantial increase in depth to Precambrian basement. The sharp change in anomaly character suggests that it also represents a lithologic boundary with rocks of higher magnetization lying to the north. It is generally assumed that a granitic basement underlies most of southern and central Michigan (Muehlberger and others, 1967), although a 65 km-wide belt of mafic rocks of Keweenawan age rocks transects the southern peninsula of Michigan along a southerly and southeasterly trend (Hinze, 1963). The observed magnetic highs immediately north of the Great Lakes magnetic lineament may indicate the presence of mafic rocks of the Keweenawan type. Other Precambrian rocks exposed nearby (Sims, 1976; Sims and others, 1980), having medium to high magnetic properties and possibly extending to the region north of the Great Lakes magnetic lineament, include (1) early Proterozoic mafic volcanics and sills similar to those encountered in northern Wisconsin (P. Sims, personal commun.), and (2) diabasic intrusions (1.25 to 2.15 b.y. old) such as those located in Canada near lat 46°30′N and long 82°W.

The eastern terminus of the Lake Superior Syncline impinges on this megalineament at 45°12′W lat and 84°45′W long. Geologic features related to the megalineament may have behaved as a structural barrier to the development of the syncline to the south. An elongate magnetic low extends from this location across Lake Michigan and the northern peninsula of Michigan to 46°15′N lat and 89°30′W long. A sharp offset in the low at 86°40′W long suggests that approximately 40 km of right-lateral displacement occurred along a transecting fault. Northwest of the offset the Menominee Iron Range and accompanying faults coincide with the megalineament and may be some aspect of the structure causing the magnetic feature.

The Great Lakes magnetic lineament transects the midcontinent magnetic high near 46°25′N lat and 91°W long in a tectonically complex region. The discontinuity in trend of the Lake Superior Syncline, which changes from southwest to west-southwest, appears to delineate a strike-slip fault with right-lateral displacement. This inferred fault is apparently expressed by linear magnetic anomalies which compromise the Great Lakes magnetic lineament. In addition, the midcontinent magnetic anomaly north of the megalineament separates into two magnetic features which follow the northern and southern boundaries of Lake Superior. The Douglas, Lake Owen, and Keweenaw faults also terminate or bend where they intersect the Great Lakes magnetic lineament. Presumably, movement along these faults may have been accommodated along the structural boundary underlying the Great Lakes magnetic lineament. The notion of a fault of this nature at this location was inferred earlier by Chase and Gilmer (1973) and Sims (1976). Sims and others (1980) suggest that the fault was reactivated as a transform fault during Keweenawan rifting.

MISSISSIPPI VALLEY GRABEN

The magnetic expression of the Mississippi Valley graben is an example of a less extensive but important feature. The graben, which probably developed in association with late Precambrian or early Paleozoic rifting (Hildenbrand and others, 1977, 1981a; Kane and others, 1979, 1981), noticeably contains the areas of principal seismicity in the upper Mississippi Embayment region, which is considered one of the most seismically active regions of eastern United States. In addition, the 1811–1812 New Madrid earthquake series, which resulted in widespread damage, occurred within the horizontal limits of the graben. Due to this intimate relation with seismicity, the graben's lateral extent becomes important to earthquake hazards and prediction studies, for which the magnetic-anomaly map can be of use.

The broad graben is defined on our map as a region of subdued magnetic expression apparently extending from eastern Arkansas (about 34°30′ lat and 91°30′ long) to western Kentucky (about 36°55′ lat and 88°45′ long). To the southwest the anomaly associated with the graben is terminated abruptly by a prominent northwest-trending feature in eastern Arkansas. Four intense magnetic highs lie within the vicinity of the feature and reflect mafic or ultramafic igneous bodies, probably like the exposed Cretaceous Magnet Cove Complex, a ring-dike complex (Erickson and Blade, 1963) and the syenite bodies near Little Rock. Extension along structures producing the northwest-trending feature may have provided channelways for ascending magma which formed these large igneous bodies. An east-northeast-trending zone of magnetic highs, associated with structures of the Ouachita Mountains, is terminated along the southwest extension of the northwest graben boundary. Although the southern terminus of the graben probably lies within this structurally-complex region, its ancestral counterpart may have extended farther to the southwest, but thrusting associated with the formation of the Ouachita Mountains may have later masked evidence of its existence.

The location of the northern terminus of the Mississippi Valley graben is not clearly defined, but it appears to end some place southeast of the south-central magnetic lineament. Richardson (1978) and Ahbe (1978), however, analyzed aeromagnetic data of southern Indiana and Illinois and suggest that northeast-trending magnetic features observed north of the south-central magnetic lineament may represent an extension of the rift zone. In this regard, Woollard (1958) suggested that a major structural break extends from the St. Lawrence Valley to the head of the Mississippi Embayment because of general alignment of earthquakes.

BASINS

The long wavelength magnetic anomalies overlying the Michigan Basin is caused by the deepening of Precambrian basement, which reaches as much as 4.2 km in depth. These broad magnetic features are similar in wavelength and intensities to those observed in Oklahoma. Increase in depths to Precambrian basement within the Anadarko and Cherokee Basins (Ham and Wilson, 1967; Snyder, 1968) is certainly a cause of the broadening of overlying magnetic anomalies; sparse magnetic control in eastern Oklahoma, however, may also be a factor in producing the apparent long-wavelength field.

Magnetic highs associated with mafic intrusions and volcanic rocks appear to characterize basement expression within major basins. In the Forest City Basin of northeast Kansas and northwest Missouri, Precambrian granitic plutons which contain a high percentage of magnetite (Denison, 1966) and produce short-wavelength magnetic highs may have influenced basin development (Yarger, 1981). Part of the northwest-trending belt of igneous rocks, inferred from the south-central magnetic lineament, crosses the Illinois Basin near its deepest part (about lat 37°50′N and long 88°W). The Anadarko Basin lies near the Oklahoma aulacogen, an extensional feature involving both intrusive and extrusive activity (Wickham, 1978) and represented on the map by northwest-trending magnetic lineaments. From gravity and magnetic interpretations Hinze (1963) suggested that linear geophysical highs extending southward and southeastward across the Michigan Basin delineate a belt of Keweenawan igneous rocks which may have been emplaced during a stage of rifting (Fowler and Kuenzi, 1978). The geophysical and geological evidence for these intrusive and extrusive rocks supports the hypothesis that the collapse of incipient rift systems is intimately related to the development of continental basins (McGinnis, 1970; Kane and others, 1979; Sclater and Cristie, 1980).

MISCELLANEOUS OBSERVED MAGNETIC FEATURES

Several other magnetic anomalies observed on the map may indicate corresponding structures that are important to the understanding of the tectonic development of the midcontinent or that determine the occurrence or release of present-day seismic energy. For example, the prominent magnetic low, trending northwest in northeastern Kentucky and north in Indiana, may be evidence of a fault zone. The recent (July 27, 1980) Sharpsburg, Kentucky earthquake of magnitude 5.5 occurred at the intersection of this linear low with the north-northwest-trending highs in northeastern Kentucky (38°12′N lat and 83°55′W long). The southeastern segment of this low parallels another significant linear low lying in western Kentucky and southern Illinois (Lidiak and Zietz, 1976; Hildenbrand and others, 1981a) and coinciding with the well-known St Genevieve Fault. The parallelism of these features may be a factor leading to a better understanding of the gross structures of this region.

In Indiana the magnetic low which trends north to about 41°N long follows Precambrian structural contours (American Association of Petroleum Geologists and U.S. Geological Survey, 1967) roughly representing the eastern edge of the Illinois Basin. The source of this low is not known but may be associated with rock units that are either reversely or weakly magnetized. In Michigan several north-trending magnetic lineaments (fig. 1), that extend to the boundary of the map (about lat 46°10′N and long 85°30′W), are aligned with the low in Indiana. These lineaments reflect, in part, the western extent of Keweenawan basalts underlying the Michigan Basin. The close correspondence in the trends of these lineaments with that of the low in Indiana may indicate that the structures or forces controlling the development of the associated magnetic sources are intimately related. The north-trending lineaments of Michigan and Indiana may then collectively represent a major discontinuity extending from 39°N lat for more than 700 km.

Another interesting magnetic feature expressed on the map is a pronounced north-northeast-trending lineament overlying eastern Michigan and crossing Lake Huron. The lineament in the Great Lakes region probably delineates the Grenville front as described by Lidiak and others (1966), Rudman and others (1965), and Stockwell (1965). Farther south in Ohio and eastern Kentucky the Grenville front is expressed as a boundary separating low-amplitude, long-wavelength anomalies to the west from anomalies with higher intensities and short-wavelengths to the east (Zietz and others, 1966; Hinze and others, 1977). The boundary, which is clearly defined on the magnetic-anomaly map, trends south-southwest to about 37°N lat and 85°W long. It may continue farther south along the magnetic low separating the broad magnetic highs in eastern Kentucky and Tennessee.

In Missouri, northeast-trending magnetic features approximately follow two major lineaments in buried Precambrian rocks, as proposed by Hays (1962), and essentially bound a zone of magnetic highs that trend predominantly northwest. This magnetic high zone coincides with numerous northwest-trending faults (fig. 1) and may be underlain by Precambrian metasedimentary and metavolcanic rocks and layered mafic intrusions (Kisvarsanyi, 1979). The two northeast-trending lineaments bounding the zone may also extend southwestward into Oklahoma as suggested by the presence of magnetic lineaments and fault zones having similar orientations.

SUMMARY

The magnetic-anomaly map of the midcontinent region reveals the presence of numerous basement anomalies that may reflect major geologic features. The intensities and wavelengths of these anomalies vary considerably within the midcontinent, suggesting that it has experienced a long and complex history which resulted in the formation of a variety of lithologies and structures. Magnetic features trend roughly northeast or northwest, although prominent north-south trending lineaments cross Indiana and Michigan. The observed linearity of many magnetic features suggests that they formed from brittle failure of the crust as opposed to plastic flow. Magnetic anomalies correlate well with major Precambrian and Paleozoic tectonic features and aid in delineating their lateral extent and associated structures.

The midcontinent magnetic high and New York-Alabama lineament are the most pronounced magnetic anomalies observed in the data. Two other megalineaments showing remarkable linearity are, however, indicated on the map and geographically coincide with several structural and lithologic boundaries in the midcontinent. Structures associated with these four megalineaments apparently influenced the evolution of some tectonic features in the midcontinent and may, consequently, express major crustal discontinuities. If one assumes these crustal discontinuities have similar origins, then their formation took place prior to or during Keweenawan time (about 1.0–1.3 b.y. ago). Keweenawan igneous rocks underlie the midcontinent magnetic high and may be present near the intersection of the south-central magnetic lineament and the New York-Alabama lineament. The crustal discontinuities conceivably developed during a period of Archean time when the crust was thin and susceptible to internal stresses. They may then express zones of crustal weakness which have played an important role in forming midcontinent geologic structures through most of geologic time. Future studies of the origin of these crustal discontinuities and their relationship with each other, known midcontinent structures, seismicity, and igneous rocks will be very helpful in understanding intra-cratonic tectonics.

The above discussions point to pertinent research areas for future consideration. The magnetic interpretations presented here will certainly be refined or modified when more detailed quantitative analyses are performed and when other geophysical and geological information is closely examined in conjunction with magnetic data.

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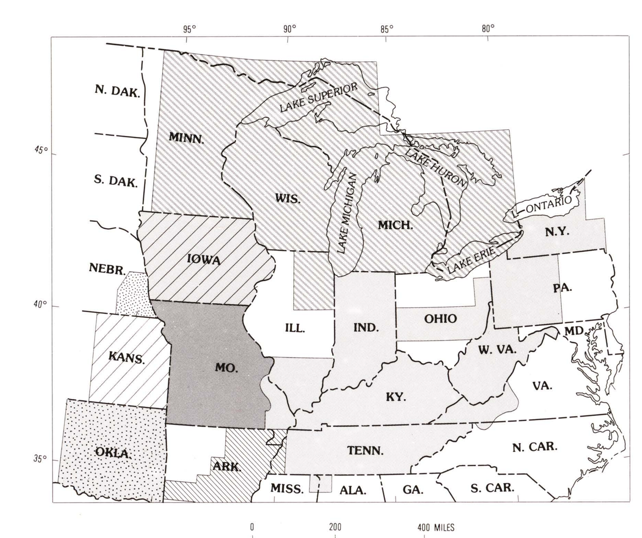

INDEX MAP SHOWING LOCATION OF MAGNETIC DATA SOURCES

SOURCES OF DATA

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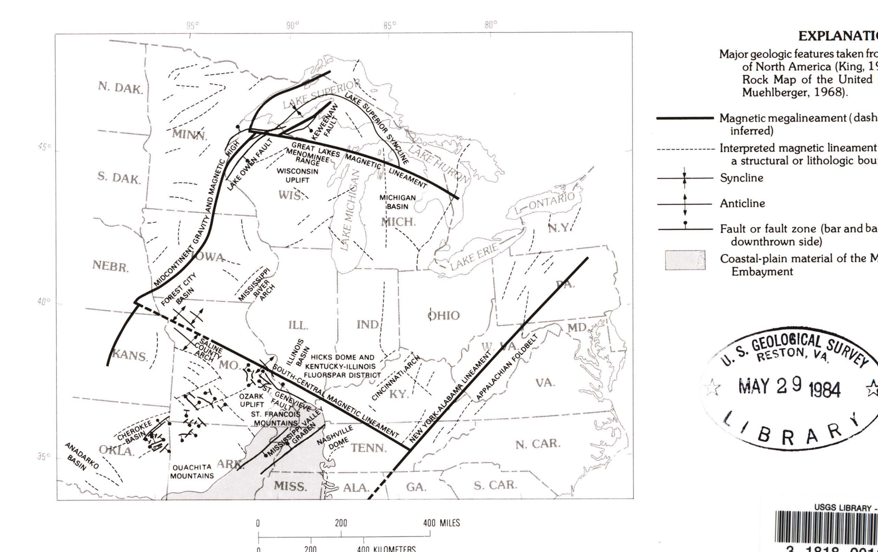

EXPLANATION

Major geologic features taken from the Tectonic Map of North America (King, 1969) and Basement Rock Map of the United States (Bayley and Muehlberger, 1968).

Magnetic megalineament (dashed where inferred)

Interpreted magnetic lineament reflecting a structural or lithologic boundary

Syncline

Anticline

Fault or fault zone (bar and ball on downthrown side)

Coastal-plain material of the Mississippi Embayment

Figure 1— GEOLOGIC FEATURES AND GEOPHYSICAL LINEAMENTS OF CENTRAL UNITED STATES