DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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GEOLOGICAL SURVEY DIVISION OF THE
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MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1360-F

INTRODUCTION

This aeromagnetic map is part of a multi-disciplinary study of the mineral-resource potential of the Iron River 1° x 2° quadrangle conducted under the Conterminous United States Mineral Assessment Program (CUSMAP). The results are presented as a folio of maps showing bedrock geology (Cannon, 1986a), surficial geology (Peterson, 1985), tectonic features (Cannon, 1986b), metamorphic grade (Wier, 1986), soil geochemistry (Alminas and others, 1984a–c; Hoffman and others, 1984a, b; Hopkins and others, 1984a, b), and Bouguer gravity (Klasner and Jones, in press). The mineral resources assessment derived from all these data is presented in a mineral-resources map (Cannon, 1985) and an accompanying circular (Cannon, 1983).

The Iron River quadrangle covers an area in the Upper Peninsula of Michigan, extending south from Lake Superior to northern Wisconsin. The bedrock is a Precambrian terrane, much of which is thickly mantled with glacial drift (Peterson, 1985). This area has a long history of iron mining, notably in the Gogebic, Marquette, and Iron River-Crystal Falls iron districts, and copper mining from the late Precambrian volcanic rocks of the Keweenaw Peninsula.

Because of the thick cover of glacial deposits, outcrops are sparse, particularly in the southern and western sections, and geophysical exploration has played a vital role in locating iron ore and in mapping the bedrock geology. Many of the geologic units, including the iron-bearing horizons, are strongly magnetized and have been mapped by their magnetic anomaly patterns in conjunction with a minimum of geologic and(or) other geophysical data. Exploration by simple dip needle surveys initiated in the late 1800's (Clements and Smyth, 1899, p. 336–373; Van Hise and Leith, 1911) was succeeded by ground magnetometer surveys (James and Wier, 1948; Prinz, 1967) and, more recently, by aeromagnetic surveys.

MAP	
I–1360–A	Mineral resources of the Iron River 1°x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
I–1360–B	Bedrock geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
I–1360–C	Surficial geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. L. Peterson.
I–1360–D	Structural and tectonic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
I–1360–E	Bouguer gravity anomaly map and geologic interpretation of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. S. Klasner and W. J. Jones.
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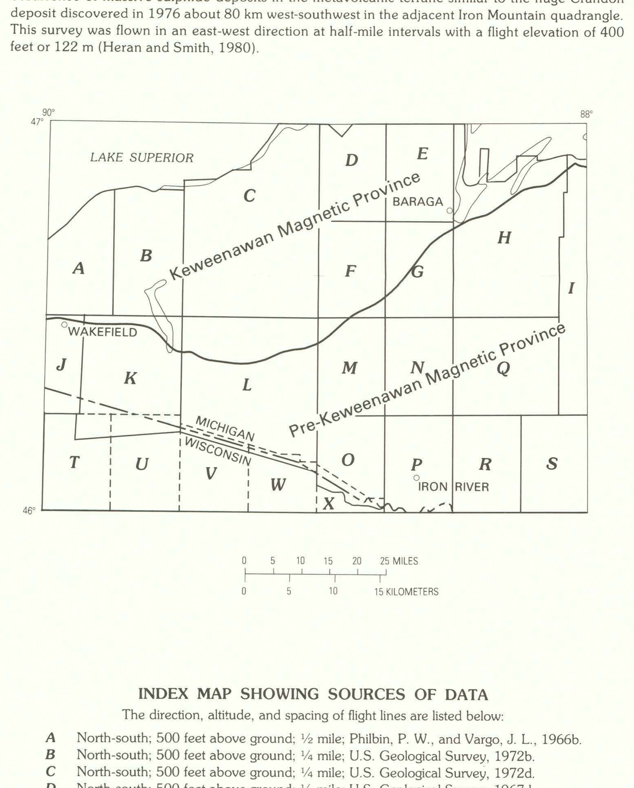
I–1360–I	Chromium distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, and R. T. Hopkins.
I–1360–J	Cobalt distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas, and R. T. Hopkins.
I–1360–K	Nickel distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas, and R. T. Hopkins.
I–1360–L	Silver distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
I–1360–M	Molybdenum distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
I–1360–N	Interpretive geochemical map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, R. T. Hopkins.

SOURCES OF DATA

The aeromagnetic map of the Iron River quadrangle is a composite of 24 separate maps as indicated on the index map. The 19 maps in the Michigan part of the quadrangle were compiled from aeromagnetic surveys conducted from U.S. Geological Survey (USGS) aircraft during an 18-year period from 1947 to 1965. Much of this work was done under a cooperative program between the USGS and the Geological Survey Division of the Michigan Department of Natural Resources to help evaluate the iron resources of the state. The magnetic data were recorded using an AN/ASQ–3A fluxgate magnetometer towed below the aircraft. Further information on instrumentation and survey procedures is given by Balsley (1952). The fluxgate magnetometer measures changes in the total magnetic field so that the resulting contour maps are based on an arbitrary magnetic datum. The five maps of the Wisconsin part of the quadrangle were compiled from an aeromagnetic survey made in 1976 by John Karl of the University of Wisconsin at Oshkosh in a program with the Wisconsin Geological and Natural History Survey to map the Precambrian areas of Wisconsin. These measurements were made using a proton magnetometer recording absolute values of the total magnetic field.

All the surveys were flown at an altitude of 500 feet (150 m) above ground. The flight lines were north-south, except for one area in the southeastern part of the quadrangle (Q, R, and S on the index map), which was flown in an east-west direction. Flight spacing was ¼ mile (0.4 km), except for a strip at the western edge of the Michigan part and all the Wisconsin part, which were flown at ½ mile (0.8 km) spacing (A, J, T-X on the index map).

Two additional sets of aeromagnetic data were used to check specific anomalies in making interpretations of the contour map. A set of aeromagnetic profiles for the Iron River quadrangle was obtained by the U.S. Department of Energy in 1977–79 concurrent with a radiometric survey of the United States under their National Uranium Resources Evaluation (NURE) program (Geometrics, Inc., 1978). These data are widely spaced (22 east-west lines 3 miles or approximately 5 km apart and 7 north-south lines averaging 15 miles or 24 km apart) and low level (400 feet or 122 m above ground). Another set of profiles in an area within 48° and 48°30′ N. and 88° and 88°30′ W. were made in 1978 as part of an airborne electromagnetic survey by the USGS to assess the occurrence of massive sulphide deposits in the metavolcanic terrane similar to the huge Crandon deposit discovered in 1976 about 80 km west-southwest in the adjacent Iron Mountain quadrangle. This survey was flown in an east-west direction at half-mile intervals with a flight elevation of 400 feet or 122 m (Heran and Smith, 1980).



INDEX MAP SHOWING SOURCES OF DATA

The direction, altitude, and spacing of flight lines are listed below:

- *A* North-south; 500 feet above ground; ½ mile; Philbin, P. W., and Vargo, J. L., 1966b.
- *B* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1972b.
- *C* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1972d.
- *D* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967d.
- *E* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967a.
- *F* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967h.
- *G* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967c.
- *H* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967j.
- *I* North-south; 500 feet above ground; ¼ mile; Case, J. E., and Gair, J. E., 1965.
- *J* North-south; 500 feet above ground; ½ mile; Philbin, P. W., and Vargo, J. L., 1966a.
- *K* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1972a.
- *L* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1972c.
- *M* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967f.
- *N* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967b.
- *O* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967e.
- *P* North-south; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967g.
- *Q* East-west; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967k.
- *R* East-west; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967i.
- *S* East-west; 500 feet above ground; ¼ mile; U.S. Geological Survey, 1967l.
- *T* North-south; 500 feet above ground; ½ mile; Karl, J. H., 1976a.
- *U* North-south; 500 feet above ground; ½ mile; Karl, J. H., 1976b.
- *V* North-south; 500 feet above ground; ½ mile; Karl, J. H., 1976c.
- *W* North-south; 500 feet above ground; ½ mile; Karl, J. H., 1976d.
- *X* North-south; 500 feet above ground; ½ mile; Karl, J. H., 1976e.

(see references to source material for citations to published maps)

REMOVAL OF THE EARTH'S MAGNETIC FIELD

The magnetic map of the Iron River quadrangle is a residual map obtained by removing the gradient of the earth's main magnetic field from the original total field data. The nineteen maps that form the basis of the Michigan portion of the map were published without the gradient removed but later were compiled as a part of the aeromagnetic map of the western part of the Northern Peninsula of Michigan (Zietz and Kirby, 1971) from which reference magnetic field was removed (Cain and others, 1965). This reference magnetic field was a precursor of the standard International Geomagnetic Reference Field (IGRF), which is currently in wide use (Fabiano and Peddie, 1969). The five maps in the southwest corner of the map in Wisconsin (T-X on index map) had the IGRF removed from the total field data during compilation. In the Iron River area, the gradients of the two fields are virtually identical, thus the maps could be matched easily without recompiling the older data. Across the Iron River quadrangle, the IGRF has a north-to-south gradient of 2.2 gammas per kilometer, which amounts to a total of 245 gammas.

GEOLOGIC SETTING

The geology of the Iron River quadrangle has been described in detail in the companion publications of the CUSMAP series (Cannon, 1986a, b). A simplified version of the bedrock geology under the Pleistocene glacial cover, prepared by Cannon, appears on the magnetic map. Only a brief summary of the geology will be given here with the emphasis on the units which have a significant magnetic expression.

The rocks in the Iron River quadrangle are all Precambrian in age except for a couple of small erosional outliers of Paleozoic sedimentary rock and the superficial layer of Pleistocene glacial deposits, neither of which are magnetic enough to have a discernable contribution to the magnetic field, and one or more small isolated kimberlite plugs of Ordovician or younger age (Cannon and Mudrey, 1981). There are three main groups of Precambrian rocks, the Keweenawan volcanic and sedimentary rocks of 1.2 billion years (b.y.) and the Marquette Range metamorphic rocks of about 2 b.y., both Proterozoic, and the Archean gneisses, granites and metavolcanics of 2.6–3.5 b.y.

The Archean rocks are exposed mainly in the cores of the large domal uplifts in the eastern and southern parts of the area. The bulk of these rocks are granitic gneiss (**Ag** on the map) with only minor amounts of more mafic rocks. These granitic rocks produce a low magnetic field having relatively few minor irregularities. Some strips of Archean volcanic rocks (**Av**) trending eastward parallel to the Gogebic Range along the southern edge of the area near the Michigan-Wisconsin border appear to be magnetic in some places but not consistently higher than the surrounding rocks.

The Archean rocks are unconformably overlain by Proterozoic X metasedimentary and metavolcanic rocks, the Marquette Range Supergroup, which include a number of iron formations and other units having high iron contents. Many of these iron-rich units produce distinctive linear magnetic anomalies. The structures produced by subsequent deformation and faulting can be mapped by tracing the trends, breaks, and offsets in the linear magnetic patterns. Although many of the iron formations produce magnetic highs, some of very high amplitude, other iron formations are relatively non-magnetic because not enough of the iron is in a magnetic form, principally magnetite.

The youngest group of Precambrian rocks are the Keweenawan volcanic rocks (**Yv**) and associated clastic rocks (**Ys**), which are located on and adjacent to the Keweenawan Midcontinent rift. This rift cuts through the older Precambrian basement of the midcontinent area from Kansas to Lake Superior and was mapped primarily by gravity and aeromagnetic surveys (King and Zietz, 1971). Throughout much of its 1000-km length, the rift is filled by mafic volcanic rocks, which are flanked, interlayered with, and in many cases, overlain by Keweenawan clastic rocks.

The areal extent of the volcanic rocks is clearly defined by the associated magnetic anomalies, which are strongly linear along the strike of the separate flow units. This magnetic signature is quite consistent and is produced by a combination of the magnetization induced by the present earth's field and a much stronger remanent magnetization acquired during the cooling of the flows. This magnetization has been measured by Books (1968) for a number of samples in Michigan. The lower Keweenawan volcanic rocks have a nearly opposite magnetization indicating that a reversal of the earth's magnetic field, and possibly, rotation of the crust occurred prior to middle Keweenawan time. The associated clastic rocks are virtually non-magnetic and the magnetic map tends to have a more subdued, smoother magnetic pattern where significant thicknesses of clastics cover the more magnetic basement or the Keweenawan volcanics.

INTERPRETATION OF THE MAGNETIC MAP

The magnetic map is divided into two major provinces or magnetic terranes. The northern province, which includes at least one-third of the map, is associated with the Keweenawan volcanic rocks and associated clastic rocks (**Yv** and **Ys** units on the map) of the Midcontinent rift system and will be referred to as the Keweenawan magnetic province. The remaining area to the south and southeast constitutes a province having a more variable magnetic pattern typical of the older Proterozoic and Archean rocks of the pre-Keweenawan metamorphic complex. This will be called the pre-Keweenawan magnetic province.

THE KEWEENAWAN MAGNETIC PROVINCE

The Keweenawan magnetic province covers the northwestern part of the map, including the Keweenaw Peninsula. This province is underlain by bedrock that is shown as either **Ys**, clastic sedimentary rocks, or **Yv**, basaltic to andesitic volcanic flows on the map. These rocks were formed late in Precambrian time during Keweenawan midcontinental rifting. The rift, which extends northeast from Kansas to the western end of Lake Superior, makes a bend eastward through Lake Superior, where it becomes a much broader, more complex feature.

The volcanic rocks and the clastic sedimentary rocks of the Keweenawan rift zone have characteristic and strongly contrasting magnetic expressions on the magnetic map. The tilted layers of volcanic flows give rise to a highly linear pattern of short-wavelength magnetic highs and lows that persist for long distances along strike. The clastic rocks, on the other hand, are associated with smoother patterns on the magnetic map.

The magnetic properties of the Keweenawan volcanics have been measured by a number of investigators (Books, 1968, 1972; DuBois, 1962; Palmer, 1970; Graham, 1953) and typically have a moderately high susceptibility and a strong component of remanent magnetization acquired when the flows cooled. The direction of remanent magnetization of the flows is quite different from that of the present field: a normal direction, 289° declination and 35° inclination, for the middle and upper Keweenawan and a reversed direction, 74° declination and −71° inclination, for the lower Keweenawan flows.

There are three areas of volcanics south of the Lake Superior in the Iron River quadrangle: a northern belt along the Keweenaw Peninsula (B on the map), a southern belt at the southern margin of the Keweenawan magnetic province known as the South Range (C on the map), and the Porcupine Mountain volcanic center (A on the map). The two gently curved belts and the circular Porcupine area are clearly delineated on the magnetic map. The belt along the Keweenaw Peninsula is about 5 km wide and is marked by a pattern of narrow, linear magnetic anomalies. These anomalies can be traced for long distances in a northeast direction along the Peninsula with only minor offsets or interruptions that are located over mapped or inferred cross-faults. The volcanic flows belong to two formations: the Portage Lake Volcanics, which is predominantly basaltic, and the unnamed formation, which overlies the Portage Lake in the western part of the belt and tends to be more andesitic in composition (Cannon, 1986a). Both formations contain intercalated clastic layers. The flows dip toward the northwest with higher angles for the oldest units and are sharply bounded on the southeast by the Keweenaw fault. The fault is expressed on the magnetic map by the abrupt boundary between the short-wavelength magnetic anomalies over the flows and the relatively low amplitude, long-wavelength anomaly pattern to the south over the Jacobsville Sandstone (**Ys**). The steep gradients of the linear anomalies over the flows indicate that the sources are at or very close to the surface.

North of the narrow belt of magnetic highs, the magnetic pattern becomes smooth and nearly featureless as the flows dip gently toward Lake Superior and are overlain by younger clastic rocks, the Copper Harbor Conglomerate, Nonesuch Shale, and Freda Sandstone. This area of smooth magnetic pattern is interrupted by one highly magnetic area in the vicinity of the Porcupine Mountains (A) where there is a large doughnut-shaped anomaly. This anomaly has a central low partially enclosed by a ring-shaped magnetic high which is open to the north. This magnetic feature coincides with a circular gravity low surrounded by highs which reach a maximum amplitude north of the shoreline (Klasner and Jones, in press). The geophysical anomalies are centered over the Porcupine Mountains anticline (Hubbard, 1975), a hook-shaped structure of volcanics, opening toward the east and enclosing a circular basin of Copper Harbor and younger sedimentary rocks. The volcanics that crop out in the Porcupine area are more felsic than the volcanics lower in the section and there is local accumulation of 300 m of extrusive rhyolite at the surface (White and Wright, 1960). The less mafic content of these volcanics gives a less pronounced near-surface magnetic expression than that observed over the flows along the rest of the Keweenaw Peninsula. The most intense magnetic anomalies are to the southeast and to the east of the Porcupine structure, where the magnetic expression is quite smooth and indicates the presence of a large volume of volcanics, probably of more mafic composition, under a considerable thickness of clastic rocks. The circular shape of this feature suggests that it was a volcanic center in middle Keweenawan time.

The other belt of magnetic highs, located south of the Keweenaw Peninsula, is associated with the lower Keweenawan volcanic rocks of the Siemans Creek Formation. The volcanics here are largely buried under varying thicknesses of Keweenawan clastic rocks of the Jacobsville Sandstone, and this belt has a much more subdued magnetic expression than the one over the Keweenaw Peninsula. The Siemans Creek dips north from a series of outcrops along the south edge of the Keweenawan magnetic province, but to the east, where the magnetic high curves toward the north, the volcanics are overlapped by the Jacobsville and are over 600 m deep at a drill hole located on the crest of the high at long. 89°16′ W. and lat. 46°30′ N. Only two outcrops of the volcanic rocks have been mapped farther east, one in the gorge of the Sturgeon River and the other at Silver Mountain (Cannon, 1986a; Campbell, 1952). In both cases, the remanent magnetization, determined by K. G. Brooks (personal communication), is in the reversed direction which is typical of the lower Keweenawan flows.

The magnetic high associated with the lower Keweenawan volcanics (C on magnetic map) has been interrupted by a series of saddles of lower magnetic values, shown by short dashed lines on the map. These saddles have a regular separation, suggestive of a system of subsequent faulting in an east-west direction, perhaps associated with a later stage in the rifting process.

Flanking the outer belt of highs along the southeastern side is a curved, apron-like area indicated by D which has a slightly lower than normal magnetic intensity and a distinct boundary at the outer edge. This area probably marks the presence of a bured thin sheet of nearly flat-lying lower Keweenawan volcanic rocks as shown in Bacon's model based on his gravity data across this feature (Bacon, 1966).

The edge of the Jacobsville Sandstone, where it wedges out to the south and east, is difficult to trace on the magnetic map. It probably is approximated by the southeast edge of the area D of slightly lower magnetic values described in the previous paragraph (**Ys** of the geologic base). The Jacobsville thickens to the north as indicated by the longer wavelength magnetic pattern on the map, but the maximum thickness is hard to estimate from the magnetic data. Calculations by Bacon (1966) based on gravity data, to fit model profiles, give thicknesses on the order of about 15,000 km of clastics overlying Keweenawan volcanic rocks. It is probable that the Jacobsville or its equivalent was once more extensive and has been eroded back to its present extent at a later date, because farther east under the cover of Paleozoic rocks in the Rock River Canyon area, a broad east-west magnetic low is attributed at least in part to Keweenawan clastic rocks. This conclusion is supported by the presence of Jacobsville Sandstone in the floor of the canyon (Whitlow and others, 1978), where the river has cut through the overlying Paleozoic rocks.

The two belts of flows (B and C) are separated by over 15 km of Jacobsville Sandstone in the eastern part of the area but converge west of Lake Gogebic to a separation of only about 3 km. The linear magnetic anomalies associated with these two groups of flows continue virtually without change for at least 25 kilometers west of the Iron River quadrangle. North of Ironwood along the Black River valley, which cuts across the entire section, one of the most complete magnetic property studies of the Keweenawan volcanic rocks was made by Books (1972). These data, constrained by a geologic section measured by Hubbard (1975) along the same river valley, were used to fit a model to a coincident north-south aeromagnetic profile. The resultant model requires a block of steeply north-dipping reversely magnetized lower Keweenawan flows to be present at depth under a wedge of clastic rocks that thicken northward to about 11,000–13,000 km near the base of the normally magnetized middle Keweenwan flows. This model can be projected eastward into the Iron River quadrangle for at least twenty miles based on the similarity of the magnetic anomalies along strike.

KEWEENAWAN ROCKS OUTSIDE THE KEWEENAWAN MAGNETIC PROVINCE

The only Keweenawan rocks found outside the Keweenawan magnetic province are the numerous dikes that cut the older Precambrian terrane. These dikes of lower Keweenawan reversely magnetized diabase produce a very characteristic magnetic low. Many are too small to show on the Iron River magnetic map at the 100-gamma contour interval but can be seen on the 50-gamma contour interval 1:62,500-scale maps (see index map showing sources of data) or on individual magnetic profiles that cross them. A typical north-south aeromagnetic profile (Balsley and others, 1949) shows at least 20 dikes in a 15-km interval. Most of the dikes strike east, though a few, in the southeastern part of the area, have a northeast strike. These dikes have been named the Baraga County dike swarm after the area where they are most abundant and have been described by numerous investigators (Graham, 1953; Balsley and others, 1949; Cannon and others, 1980). The dikes can be traced westward into the low magnetic area peripheral to the southern belt of magnetic highs but cannot be detected farther west, on the other side of the highs within the basin of Jacobsville Sandstone. The dikes appear to have formed near the beginning of the Keweenawan rifting and indicate that the region was extending in a north-south direction.

THE PRE-KEWEENAWAN MAGNETIC PROVINCE

The pre-Keweenawan magnetic province south and east of the Keweenawan magnetic province, which includes approximately 60 percent of the Iron River quadrangle, has a sharply contrasting magnetic pattern reflecting a more heterogeneous lithology than that of the Keweenawan province. Most of the bedrock is mantled by glacial drift of variable thickness, which makes geologic field mapping difficult to impossible. Outcrops are most numerous in the northeastern part of the province and rare in the southwestern part, particularly the area in Wisconsin.

The major magnetic units are iron-rich horizons within the Marquette Range Supergroup. These units include a number of iron-formations and some metavolcanic rocks. The magnetic properties of these units tend to be variable, depending not only on the iron content but also on the degree of metamorphism, which ranges from chlorite to sillimanite grade. Well-defined metamorphic nodes in the Iron River study area (Wier, 1986; James, 1955), the Watersmeet node in southeastern Gogebic County and the Republic, Peavy and Florence County nodes in the eastern part of the quadrangle, are roughly coincident with areas of higher amplitude, more continuous anomaly pattern. These high amplitudes are caused by high percentages of iron in magnetic minerals, particularly magnetite, as described by James (1955).

In the western part of the map, south of the Gogebic Iron Range (E on the magnetic map), field mapping by numerous investigators (summarized by Cannon, 1986a) has shown that the magnetic horizons in the Baraga and Menomenee Groups produce the narrow, arcuate anomalies that delineate a series of oval domal uplifts. These uplifts have an east-northeast trend and are cored by Archean rocks. The Archean rocks are predominantly granitic gneiss with lesser amounts of migmatite, amphibolite, and volcanic rocks and are generally less magnetic than iron-formations in the overlying metasedimentary sequence. This metasedimentary sequence, aside from the iron-formations, also has a low content of magnetic minerals, so that the magnetic pattern of the Archean rocks cannot be easily differentiated from the pattern associated with the younger metasedimentary rocks such as the widely distributed graywacke and slate of the Michigamme Formation of the Baraga Group.

The USGS conducted a truck-mounted magnetometer survey in 1979 in the southwestern quarter of the Iron River quadrangle to obtain better resolution of the magnetic signatures associated with the relatively non-magnetic formations flanking the linear magnetic units that outline the oval structures (King and Cannon, 1979). Approximately 800 km of traverse were obtained, mostly in a north-south direction transverse to the regional tectonic alignment exemplified by the nearly east-west orientation of the domal uplifts. The traverses were concentrated in the areas where outcrops were scarce or lacking.

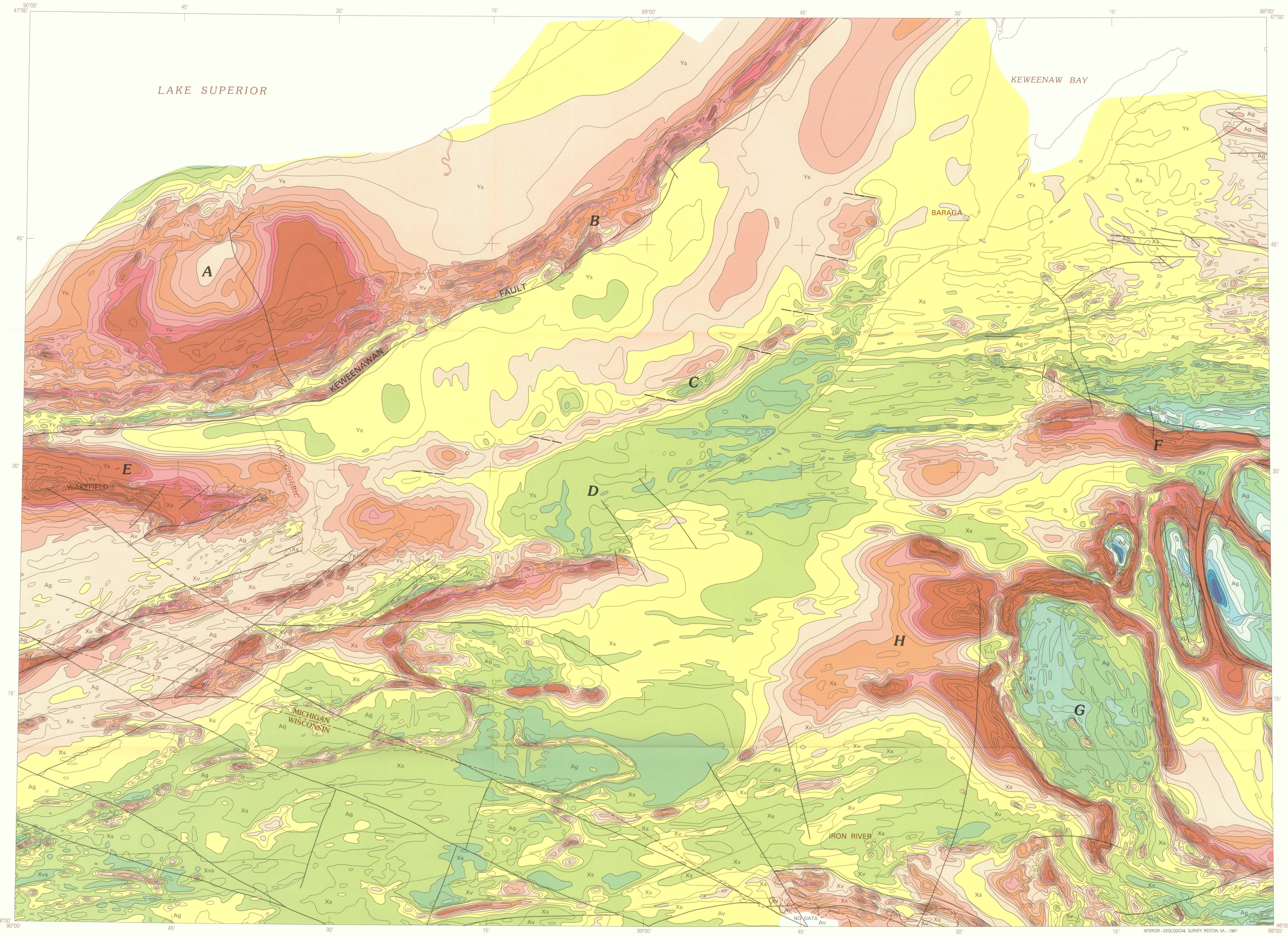
These ground magnetic data, which had the advantages of precise location and greater detail because of smaller separation between detector and source rocks, exhibit clearly distinguishable magnetic characteristics over the several lithologies present. The Michigamme Formation, which consists predominantly of slate and metagraywacke in the western part of the quadrangle, is associated with a low, nearly featureless magnetic pattern, whereas the pattern associated with the Archean gneisses, although low relative to that of the bordering iron formation, is much more variable, with occasional highs that indicate the presence of more mafic components within the granitic gneiss. Other lithologic units also have distinct magnetic charateristics. The profiles over the dolomite and quartzite units are conspicuously featureless even compared to those over the Michigamme metasedimentary rocks. An east-trending belt of Proterozoic metavolcanic rocks (**Xv**) near lat. 46°13′ N., which is marked by a distinctive area of broad magnetic highs on the contour map, is associated with magnetic profiles having many large amplitude, short-wavelength magnetic highs. There are several large positive anomalies on profiles crossing units of iron-formation at or near the base of the Michigamme. Distinctive sharp negative anomalies indicate occasional reversely magnetized lower Keweenawan dikes. These dikes, although not as numerous as in the eastern part of the area, are observed throughout the entire pre-Keweenawan terrane, although many are too narrow to be delineated on the 1:250,000-scale magnetic map.

The other main area of Archean bedrock is in the cores of uplifts in the eastern part of the pre-Keweenawan province. These uplifts are oval in shape and delineated by arcuate magnetic anomalies produced by magnetic horizons in the overlying Marquette Range Supergroup and are similar to the uplifts in the west but are not as regular in size. The uplifts south of the Marquette Range (F on the magnetic map) strike north-northwest. The largest of these is the Amasa (G on the magnetic map), which is a rather complex feature flanked to the east by the Witch Lake and other smaller uplifts with central cores of Archean gneiss. On the northwest side of the Amasa Uplift are some areas of relatively high amplitude, broad magnetic anomalies (H) that indicate magnetic rocks buried beneath a considerable thickness of non-magnetic Michigamme Formation. These anomalies may indicate doming of layers of highly magnetized iron-formation lower in the section, but it is doubtful if a large enough volume of iron-formation is present to produce magnetic anomalies of this magnitude.

Some of the metavolcanic rocks of the Hemlock Formation, which Cannon (1983) suggests are a facies of the Menominee Group, give rise to areas of higher magnetic anomalies, for example, the northwest-trending belt of metavolcanic rocks shown on the map as **Xv** near the south edge of the map at long. 88°30′ W. The Proterozoic metavolcanics may be the source of the broad magnetic anomalies, either alone or in combination with the overlying iron-formation. The presence of a substantial volume of dense volcanic rocks is also indicated by a positive gravity anomaly that coincides with the positive magnetic anomaly at H (Klasner and Jones, in press).

The eastern and western areas of magnetically well-defined oval uplifts described in the preceding paragraphs are roughly coincident with nodes of higher metamorphism. They are separated by an area of lower magnetic intensity which is underlain primarily by the Michigamme Formation. Several oval uplifts defined by iron-formation horizons are present in this area. They are oriented nearly east-west like those farther west but do not have cores of Archean rocks at or near the surface. The iron-formations tend to be much less magnetic so that they are more difficult to trace by their magnetic pattern.

North of the Marquette Range, the magnetic map is relatively subdued and featureless except for the numerous east-west linear lows associated with the reversely-magnetized lower Keweenawan dikes. Much of this area is occupied by a large, east-west trending uplift of Archean granitic gneiss which is difficult to distinguish from the surrounding Michigamme Formation on the basis of their associated magnetic pattern.



Base from U.S. Geological Survey, 1985

Geology modified from Cannon, 1986a

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 30 35 KILOMETERS

Note: The following explanation, description, and geologic symbols are for the geologic map, shown in gray.

CORRELATION OF MAP UNITS

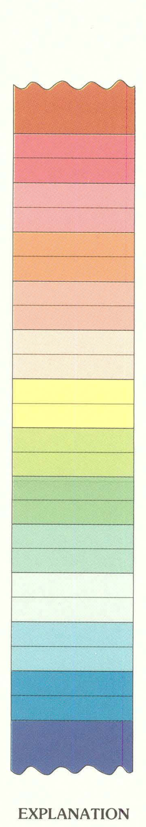
- Ys, Yv — PROTEROZOIC Y (—800 m.y. to —1,600 m.y.)
- Xs, Xvs, Xv — PROTEROZOIC X (—1,600 m.y. to —2,500 m.y.)
- Ag, Av — ARCHEAN

DESCRIPTION OF MAP UNITS

Unit	Description
Ys	**Clastic sedimentary rocks (Proterozoic Y— Keweenawan)**—Mostly sandstone and conglomerate; minor shale
Yv	**Basaltic to andesitic volcanic flows (Proterozoic Y—Keweenawan)**
Xs	**Clastic sedimentary rocks (Proterozoic X)**—Mostly graywacke, slate, quartzite, argillite, and conglomerate; lesser iron-formations and dolomite. Variably metamorphosed
Xv	**Volcanic rocks (Proterozoic X)**—Mostly mafic to intermediate (and rarely felsic) flows and pyroclastic rocks. Sedimentary interbeds are common. Variably metamorphosed
Xvs	**Interlayered volcanic and sedimentary rocks (Proterozoic X)**—Moderately to strongly metamorphosed
Ag	**Gneiss (Archean)**—Mostly granitic gneiss and foliated granite. Migmatite and amphibolite abundant locally. Includes massive granitic rocks
Av	**Volcanic rocks (Archean)**—Mostly submarine basaltic flows. Lesser volcaniclastic rocks and sedimentary rocks

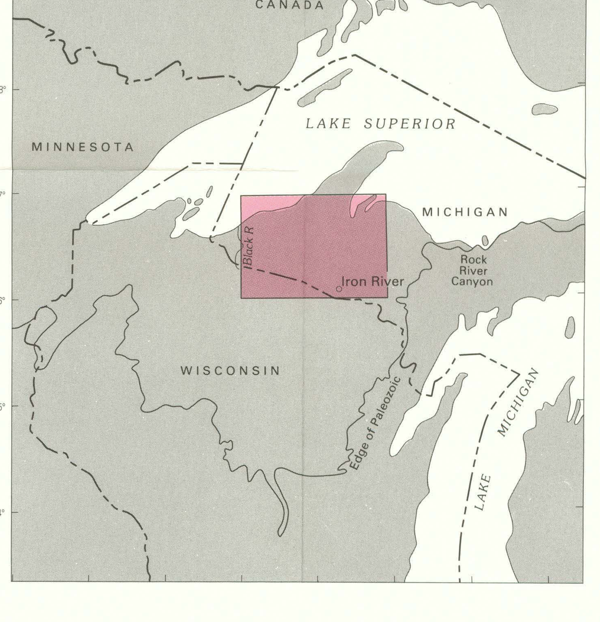
EXPLANATION OF MAP SYMBOLS

- Contact
- Fault
- Drill hole
- Magnetic anomaly cross trend
- *A* Porcupine Mountains structure
- *B* Keweenawan volcanic belt
- *C* Subsurface extension of South Range Keweenawan volcanic belt
- *D* Inferred area of lower Keweenawan volcanic rocks
- *E* Gogebic Range
- *F* Marquette Range
- *G* Amasa Oval
- *H* Inferred area of subsurface mafic rocks



EXPLANATION

Magnetic Contours—Showing total intensity magnetic field of the earth in gammas, relative to arbitrary zero level. Contour intervals 100 and 200 gammas. Main magnetic field of the earth, from Cain and others (1965) has been removed from data sources A–S. IGRF–1965 main magnetic field of the earth from Fabiano and Peddie (1969) has been removed from data sources T–X.



Location map showing the Iron River quadrangle and the edge of Paleozoic overlap.

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AEROMAGNETIC MAP OF THE IRON RIVER 1° x 2° QUADRANGLE, MICHIGAN AND WISCONSIN

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1987

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