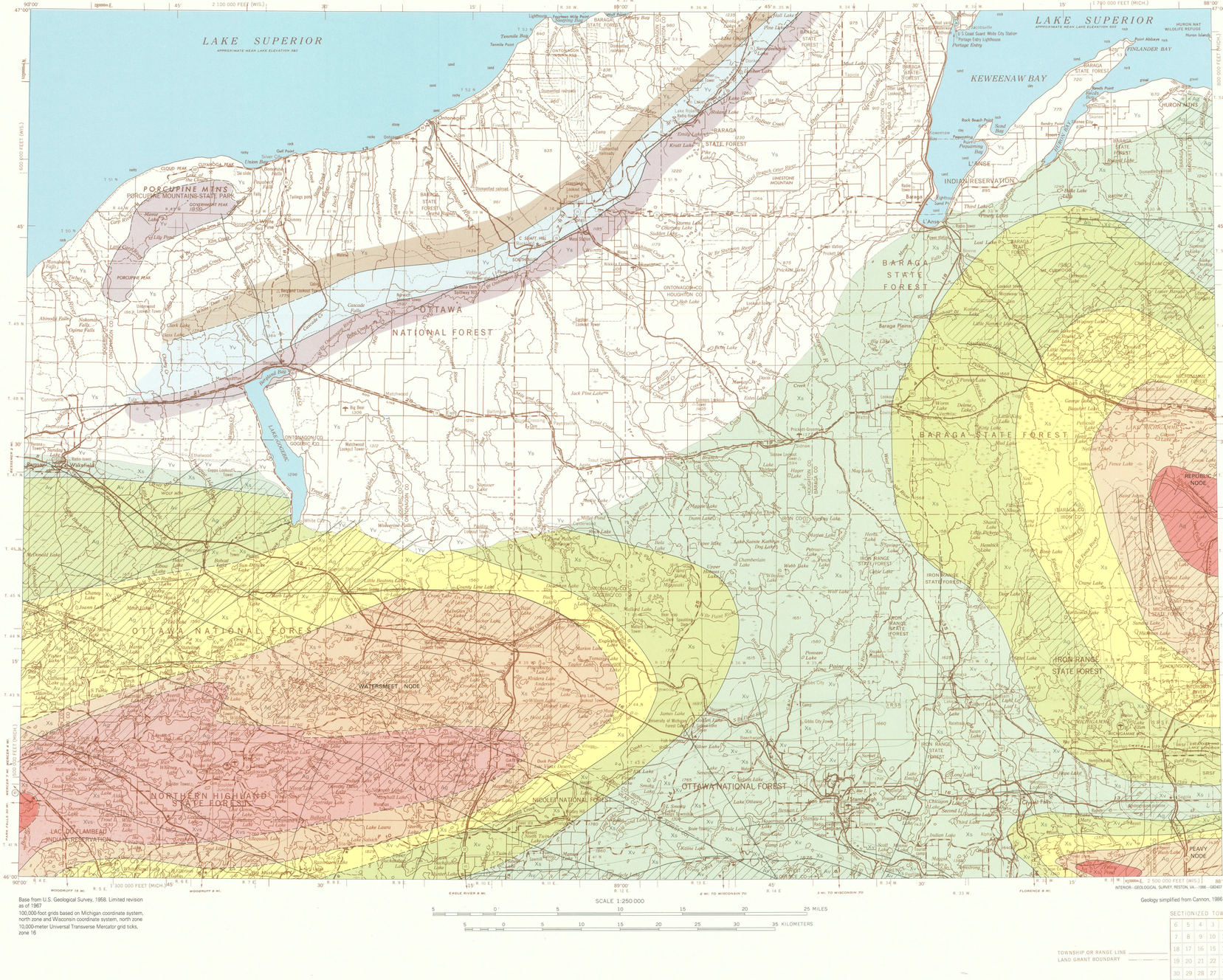
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1360-G



Base from U.S. Geological Survey, 1958. Limited revision as of 1987

100,000-foot grids based on Michigan coordinate system, north zone and Wisconsin coordinate system, north zone

10,000-meter Universal Transverse Mercator grid ticks, zone 16

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 30 35 KILOMETERS

Geology simplified from Cannon, 1986

SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

TOWNSHIP OR RANGE LINE
LAND GRANT BOUNDARY

METAMORPHIC MAP OF THE IRON RIVER 1° X 2° QUADRANGLE, MICHIGAN AND WISCONSIN

By
Karen Wier
1986

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

CORRELATION OF MAP UNITS

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

DESCRIPTION OF MAP UNITS

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 rock, Wis., immediately west of the quadrangle boundary (sec. 28, 29, 32, 33, T. 42 N., R. 4 E.). The kyanite zone is outlined on the basis of kyanite found at three localities within the quadrangle, an outcrop near Spider Lake (sec. 13, T. 42 N., R. 5 E.), a drill core near Land O' Lakes (sec. 2, T. 42 N., R. 10 E.), and abundant kyanite schist float across several sections (T. 42 N., R. 9, 10, 11, E.). West of the quadrangle, kyanite is found in the outcrops near Powell, and somewhat farther west, in outcrops long the Flambeau River (sec. 1, T. 41 N., R. 1 E., and sec. 4, T. 41 N., R. 2 E.) (Black, 1977). Staurolite is present near Watersmeet (as well as in kyanite schist near Powell); otherwise data are not available for this zone. The garnet zone west of Lake Gogebic, Mich., is very poorly defined due to sparse outcrops and lack of diagnostic mineral assemblages. The biotite zone is fairly well established in places. West of Lake Gogebic, it is defined on the basis of biotite in mafic rocks which are very scarce in the area The northernmost exposures of Proterozoic X rocks in the Wakefield area all appear to be within the chlorite zone. Although the metamorphic zones in the Wakefield area are shown as part of the Watersmeet node, it is possible that this area is a separate metamorphic domain. Interestingly, that area has remained a pocket of low-grade metamorphism throughout geologic time from Archean to Keweenawan. In the Flambeau area just outside the southwestern corner of the quadrangle, Black (1977) has proposed Proterozoic X post-metamorphic faulting to explain the juxtaposition of the high-grade kyanite terrane, shown as the core of the Watersmeet node, with the low-grade rocks to the north. More detailed work in the Wakefield area could refine the metamorphic zone boundaries.

It is worthy of note that kyanite is found only in the Watersmeet node; whereas andalusite and sillimanite, but not kyanite, occur in the Republic and Peavy nodes. This suggests that a higher pressure realm existed in the southwestern portion of the map.

Typical mineral assemblages found in the various lithologies within different Proterozoic X metamorphic zones are shown below.

Chlorite zone—(1) Peltic rocks: chlorite-sericite-quartz-plagioclase ± chloritoid. (2) Mafic igneous rocks: chlorite-epidote-actinolite-plagioclase ± quartz. (3) Iron-formation, minnesotaite-stilpnomelane-chlorite-quartz-magnetite.

Biotite zone—(1) Peltic rocks: biotite-chlorite-muscovite-quartz-plagioclase ± chloritoid. (2) Mafic igneous rocks: blue-green hornblende-epidote-plagioclase ± garnet, biotite, quartz. (3) Iron-formation: grunerite-quartz-magnetite ± actinolite, garnet, biotite.

Staurolite zone—(1) Peltic rocks: staurolite-biotite-garnet-muscovite-plagioclase-quartz ± andalusite. (2) Mafic igneous rocks; hornblende-plagioclase ± garnet, biotite, quartz. (3) Iron-formation: similar to garnet zone.

Kyanite zone—(1) Peltic rocks: kyanite-staurolite-garnet-biotite-muscovite-quartz-plagioclase. (2) Mafic igneous rocks; similar to staurolite zone.

Sillimanite zone—(1) Peltic rocks: sillimanite-biotite-garnet-muscovite-quartz-plagioclase ± staurolite, andalusite, kyanite. (2) Mafic igneous rocks: green hornblende-plagioclase ± garnet, biotite, quartz. (3) Iron-formation: grunerite-blue-green amphibole-quartz-magnetite-garnet.

EXPLANATION OF MAP SYMBOLS

Contact

Fault

EXPLANATION OF METAMORPHIC ZONES

Isograd, dashed where data are extremely sparse; map uncolored where metamorphic grade is unknown.

Proterozoic Y Metamorphism
(approximately 1.1 b.y.)

Index minerals from replacement of primary groundmass minerals and phenocrysts in Keweenawan lava flows and dike rocks. Zones are gradational. Data are insufficient to determine complete extent of zones within map area.

Probable laumontite-prehnite

Pumpellyite

Epidote

Proterozoic X Metamorphism
(approximately 1.8 b.y.)

Index minerals contained in peltic rocks or in mafic igneous rocks of equivalent grade

Chlorite

Biotite

Garnet

Staurolite ± andalusite

Kyanite ± staurolite

Sillimanite

Archean Metamorphism
(prior to 2.6 b.y.)

Pattern denotes areas of Archean rock, most of which has reached amphibolite facies except for some areas in the Wakefield region where Archean metamorphism may not have exceeded greenschist facies

INTRODUCTION

The metamorphic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, is part of a folio of 1:250,000-scale maps (see list below) prepared as a Conterminous United States Mineral Assessment Program (CUSMAP) project to assess the mineral-resource potential of the Iron River quadrangle. An understanding of the metamorphic history is important in determining the overall geologic framework of an area, particularly for predicting zones of potential for discovery of mineral deposits whose genesis involves metamorphic processes. For example, in the Iron River quadrangle, native copper deposits, some types of gold deposits, and certain types of iron ore formed by metamorphic processes are likely to exist only in rocks of suitable metamorphic grade.

The metamorphic map of the Iron River quadrangle is modified largely from James' (1955) metamorphic map of northern Michigan by incorporating data from more current published and unpublished maps. In addition, new petrographic data were obtained from the study of thin sections in existing collections from the area, as well as some samples collected by the author. Most of the latter are from areas of Keweenawan rocks where a published metamorphic base map does not exist for Proterozoic Y metamorphism.

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.

I-1360-F Aeromagnetic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by E. R. King.

I-1360-G Metamorphic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by Karen Wier.

I-1360-H Copper 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-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.

ACKNOWLEDGEMENTS

The following persons generously made available thin section collections and unpublished data and maps: W. F. Cannon, C. E. Dutton, M. P. Foose, J. E.Gair, H. W. Hubbard, H. L. James, J. S. Klasner, W. C. Prinz, R. G. Schmidt, P. K. Sims, V. A. Trent, W. S. White, and K. L. Wier of the U.S. Geological Survey; B. Parker of the Michigan Geological Survey; and J. T. Wilband of Michigan State University.

GEOLOGY

The geologic units and faults shown on the metamorphic map are simplified from the bedrock geologic map of the Iron River quadrangle (Cannon, 1986). Glacial deposits cover most of the mapped area, and bedrock exposures are sparse; therefore, geophysical and drill-core data have provided the basis for many of the geologic contacts.

Bedrock within the quadrangle is predominantly Precambrian in age, with representatives of Archean, Proterozoic X, and Proterozoic Y subdivisions.

Archean basement rocks are exposed in cores of structural domes formed in Proterozoic X time. Two Archean terranes having different ages and lithologies are recognized within the quadrangle (Morey and Sims, 1976; Sims, 1980). The southern terrane consists mainly of migmatitic gneisses and amphibolites as old as 3.5 billion years (b.y.).The northern terrane consists of granite, granitic gneiss, and subordinate greenstone belts and is about 2.7 b.y. old. These terranes are separated by a regional geophysical feature, the Great Lakes tectonic zone.

Overlying the Archean basement rocks are Proterozoic X metasedimentary and metavolcanic rocks of the Marquette Range Supergroup (Cannon and Gair, 1970) which are about 2 b.y. old. Principal rock types include metagraywacke, metavolcanic rock, slate, iron-formation, quartzite, and dolomite.

Unconformably overlying Proterozoic X rocks are 1.2 b.y. old Proterozoic Y rocks of the Keweenawan Supergroup, which consists of a thick sequence of clastic sedimentary rocks and volcanic flows. Keweenawan diabase dikes are also found cross-cutting older rocks south of the mapped area of Proterozoic Y rocks.

METAMORPHISM

Metamorphic episodes took place during each of the three major Precambrian subdivisions represented in the quadrangle: Archean, Proterozoic X, and Proterozoic Y.

Archean Metamorphism

During Archean time, there was at least one metamorphic event. It is difficult to establish any pattern of metamorphic zones associated with this event or whether more than one event took place. The obliterating effect of later Proterozoic X metamorphism, the general lack of pelitic rocks in the Archean, and the extreme sparsity of outcrops contribute to the difficulty. Most Archean rocks attained amphibolite or higher grade metamorphism as evidenced by mineral assemblages in mafic rocks containing relict high-grade metamorphic minerals such as clinopyroxene, hornblende, garnet, or rarely, staurolite, which were retrograded during the later Proterozoic X metamorphism. It is not uncommon to find relict amphibolite-grade assemblages in Archean rocks within areas overprinted by chlorite- to staurolite-grade Proterozoic X metamorphism. In the area near Wakefield, Mich., west of Lake Gogebic, Archean metamorphism appears not to have exceeded greenschist facies. Metasedimentary and metavolcanic rocks in this area do contain metamorphic chlorite, but primary sedimentary textures are well preserved.

Proterozoic X Metamorphism

Proterozoic X metamorphism took place about 1.8 b.y. ago culminating late in the deformational event known as the Penokean orogeny (Cannon, 1973). Zones of metamorphic intensity can be delineated by isograds defined by the first appearance of specific index minerals in pelitic rocks: chlorite, biotite, garnet, staurolite, kyanite, and sillimanite in order of increasing temperature. The zones define three isolated nodes of higher intensity—the Peavy, Republic, and Watersmeet nodes (James, 1955)—within a regionally more extensive low-grade (chlorite) zone. This bull's-eye pattern typifies Proterozoic X metamorphism in northern Michigan and Wisconsin. Placement of the zone boundaries, or isograds, is fairly accurate in most areas of the Peavy and Republic nodes, primarily due to more abundant outcrops and more detailed studies in the east half of the quadrangle. The zone boundaries in the Watersmeet node are very approximately located, particularly in the southwestern portion of the map where outcrops are very rare. A sillimanite zone is suggested in that area by minute sillimanite grains in kyanite-staurolite-biotite-garnet schist near Powell, Wis., immediately west of the quadrangle boundary (sec. 28, 29, 32, 33, T. 42 N., R. 4 E.). The kyanite zone is outlined on the basis of kyanite found at three localities within the quadrangle, an outcrop near Spider Lake (sec. 13, T. 42 N., R. 5 E.), a drill core near Land O' Lakes (sec. 2, T. 42 N., R. 10 E.), and abundant kyanite schist float across several sections (T. 42 N., R. 9, 10, 11, E.). West of the quadrangle, kyanite is found in the outcrops near Powell, and somewhat farther west, in outcrops long the Flambeau River (sec. 1, T. 41 N., R. 1 E., and sec. 4, T. 41 N., R. 2 E.) (Black, 1977). Staurolite is present near Watersmeet (as well as in kyanite schist near Powell); otherwise data are not available for this zone. The garnet zone west of Lake Gogebic, Mich., is very poorly defined due to sparse outcrops and lack of diagnostic mineral assemblages. The biotite zone is fairly well established in places. West of Lake Gogebic, it is defined on the basis of biotite in mafic rocks which are very scarce in the area The northernmost exposures of Proterozoic X rocks in the Wakefield area all appear to be within the chlorite zone. Although the metamorphic zones in the Wakefield area are shown as part of the Watersmeet node, it is possible that this area is a separate metamorphic domain. Interestingly, that area has remained a pocket of low-grade metamorphism throughout geologic time from Archean to Keweenawan. In the Flambeau area just outside the southwestern corner of the quadrangle, Black (1977) has proposed Proterozoic X post-metamorphic faulting to explain the juxtaposition of the high-grade kyanite terrane, shown as the core of the Watersmeet node, with the low-grade rocks to the north. More detailed work in the Wakefield area could refine the metamorphic zone boundaries.

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Staurolite zone—(1) Peltic rocks: staurolite-biotite-garnet-muscovite-plagioclase-quartz ± andalusite. (2) Mafic igneous rocks; hornblende-plagioclase ± garnet, biotite, quartz. (3) Iron-formation: similar to garnet zone.

Kyanite zone—(1) Peltic rocks: kyanite-staurolite-garnet-biotite-muscovite-quartz-plagioclase. (2) Mafic igneous rocks; similar to staurolite zone.

Sillimanite zone—(1) Peltic rocks: sillimanite-biotite-garnet-muscovite-quartz-plagioclase ± staurolite, andalusite, kyanite. (2) Mafic igneous rocks: green hornblende-plagioclase ± garnet, biotite, quartz. (3) Iron-formation: grunerite-blue-green amphibole-quartz-magnetite-garnet.

Proterozoic Y Metamorphism

The youngest metamorphic event in the map area occurred in Proterozoic Y time about 1.1 b.y. ago. Metamorphism is weak and probably did not exceed subgreenschist facies intensity. Metamorphic grade increases southeastward from the northwesternmost exposures along the Lake Superior shoreline. The southeasternmost extent of Proterozoic Y metamorphism and its overprinting effect on older rocks is not known. Jolly and Smith (1972) in their work immediately northeast of the Iron River quadrangle, defined three metamorphic zones which have gradational boundaries: laumontite, pumpellyite, and epidote. The index minerals typically occur in monomineralic patches or "metadomains." Jolly stressed the importance of using, as metamorphic zone indicators, minerals which replace the primary phenocrysts and groundmass rather than the much more variable assemblages which form in amygdules and veins. In the Iron River quadrangle, determination of metamorphic grade in the Keweenawan is likewise based on metamorphic replacement of primary minerals in volcanic rocks. The pumpellyite zone is quite well established east of about long. 89°30' W. Importantly, most native copper deposits are found in this zone (Stoiber and Davidson, 1959). Southeast of the pumpellyite zone, and in the core of the Porcupine Mountains anticline, epidote is the predominant index mineral. Data are inadequate to determine metamorphic grade of the entire Keweenawan outcrop area in the quadrangle. Much of the rock is sandstone that is too fine grained or is not the right composition to develop index minerals indicative of the metamorphic grade. More extensive sampling might provide significant information in delineating the metamorphic zones more precisely.

SELECTED REFERENCES

Note: The references listed are limited to those used in compilation of the map and those cited in the text. Background information about this folio and a more complete listing of the literature on the area are published in U.S. Geological Survey Circular 887, "Mineral resource assessment of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin." (Cannon, 1983).

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For sale by Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225