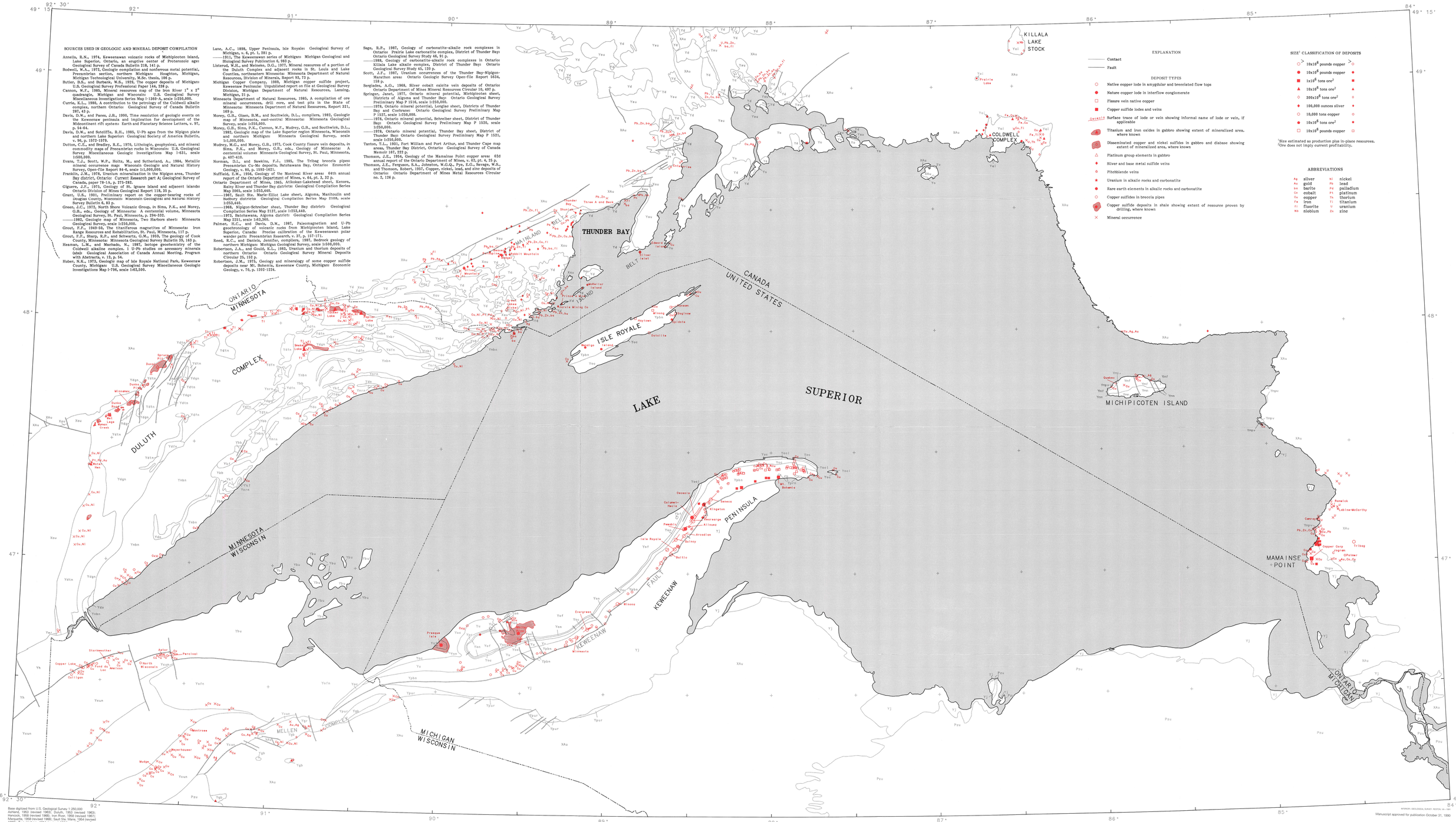



## SOURCES USED IN GEOLOGIC AND MINERAL DEPOSIT COMPILATION


Annells, R.N., 1974, Keweenawan volcanic rocks of Michipicoten Island, Lake Superior, Ontario, an eruptive center of Proterozoic age: Geological Survey of Canada Bulletin 218, 141 p.

Bodwell, W.A., 1972, Geologic compilation and nonferrous metal potential, Precambrian section, northern Michigan: Houghton, Michigan, Michigan Technological University, M.Sc. thesis, 106 p.

Butler, B.S., and Burbank, W.S., 1929, The copper deposits of Michigan: U.S. Geological Survey Professional Paper 144, 238 p.

Cannon, W.F., 1985, Mineral resources map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin: U.S. Geological Survey Miscellaneous Investigations Series Map I–1560–A, scale 1:250,000.

Currie, K.L., 1980, A contribution to the petrology of the Coldwell alkalic complex, northern Ontario: Geological Survey of Canada Bulletin 287, 43 p.

Davis, D.W., and Paces, J.B., 1990, Time resolution of geologic events on the Keweenaw peninsula and implication for development of the Midcontinent rift system: Earth and Planetary Science Letters, v. 97, p. 54–64.

Davis, D.W., and Sutcliffe, R.H., 1985, U-Pb ages from the Nipigon plate and northern Lake Superior: Geological Society of America Bulletin, v. 96, p. 1572–1579.

Dutton, C.E., and Bradley, R.E., 1970, Lithologic, geophysical, and mineral commodity maps of Precambrian rocks in Wisconsin: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–631, scale 1:500,000.

Evans, T.J., Scott, W.P., Holtz, M., and Sutherland, A., 1984, Metallic mineral occurrence map: Wisconsin Geologic and Natural History Survey, Open-file Report 84–6, scale 1:1,000,000.

Franklin, J.M., 1978, Uranium mineralization in the Nipigon area, Thunder Bay district, Ontario: Current Research part A; Geological Survey of Canada, paper 78–1A, p. 275–282.

Giguere, J.P., 1975, Geology of St. Ignace Island and adjacent islands: Ontario Division of Mines Geological Report 118, 55 p.

Grant, U.S., 1901, Preliminary report on the copper-bearing rocks of Douglas County, Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 6, 83 p.

Green, J.C., 1972, North Shore Volcanic Group, in Sims, P.K., and Morey, G.B., eds., Geology of Minnesota: A centennial volume: Minnesota Geological Survey, St. Paul, Minnesota, p. 294–332.

——1982, Geologic map of Minnesota, Two Harbors sheet: Minnesota Geological Survey, scale 1:250,000.

Grout, F.F., 1949–50, The titaniferous magnetites of Minnesota: Iron Range Resources and Rehabilitation, St. Paul, Minnesota, 117 p.

Grout, F.F., Sharp, R.P., and Schwartz, G.M., 1959, The geology of Cook County, Minnesota: Minnesota Geological Survey Bulletin 39, 183 p.

Heaman, L.M., and Machado, N., 1987, Isotope geochemistry of the Coldwell alkaline complex. I U-Pb studies on accessory minerals (abst): Geological Association of Canada Annual Meeting, Program with Abstracts, v. 12, p. 54.

Huber, N.K., 1973, Geologic map of Isle Royale National Park, Keweenaw County, Michigan: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–796, scale 1:62,500.

Lane, A.C., 1898, Upper Peninsula, Isle Royale: Geological Survey of Michigan, v. 6, pt. 1, 281 p.

——1911, The Keweenawan series of Michigan: Michigan Geological and Biological Survey Publication 6, 983 p.

Listerud, W.H., and Meineke, D.G., 1977, Mineral resources of a portion of the Duluth Complex and adjacent rocks in St. Louis and Lake Counties, northeastern Minnesota: Minnesota Department of Natural Resources, Division of Minerals, Report 93, 73 p.

Michigan Copper Company, 1985, Michigan copper sulfide project, Keweenaw Peninsula: Unpublished report on file at Geological Survey Division, Michigan Department of Natural Resources, Lansing, Michigan, 21 p.

Minnesota Department of Natural Resources, 1985, A compilation of ore mineral occurrences, drill core, and test pits in the State of Minnesota: Minnesota Department of Natural Resources, Report 321, 169 p.

Morey, G.B., Olsen, B.M., and Southwick, D.L., compilers, 1982, Geologic map of Minnesota, east-central Minnesota: Minnesota Geological Survey, scale 1:250,000.

Morey, G.B., Sims, P.K., Cannon, W.F., Mudrey, G.B., and Southwick, D.L., 1982, Geologic map of the Lake Superior region, Minnesota, Wisconsin and northern Michigan: Minnesota Geological Survey, scale 1:1,000,000.

Mudrey, M.G., and Morey, G.B., 1972, Cook County fissure vein deposits, in Sims, P.K., and Morey, G.B., eds., Geology of Minnesota: A centennial volume: Minnesota Geological Survey, St. Paul, Minnesota, p. 407–418.

Norman, D.I., and Sawkins, F.J., 1985, The Tribag breccia pipes: Precambrian Cu-Mo deposits, Batchewana Bay, Ontario: Economic Geology, v. 80, p. 1593–1621.

Nuffield, E.W., 1956, Geology of the Montreal River area: 64th annual report of the Ontario Department of Mines, v. 64, pt. 3, 32 p.

Ontario Department of Mines, 1965, Alikokan-Lakehead sheet, Kenora, Rainy River and Thunder Bay districts: Geological Compilation Series Map 2065, scale 1:253,440.

——1967, Sault Ste. Marie-Elliot Lake sheet, Algoma, Manitoulin and Sudbury districts: Geological Compilation Series Map 2188, scale 1:253,440.

——1968, Nipigon-Schreiber sheet, Thunder Bay district: Geological Compilation Series Map 2137, scale 1:253,440.

——1971, Batchawana, Algoma district: Geological Compilation Series Map 2251, scale 1:63,360.

Palmer, H.C., and Davis, D.W., 1987, Paleomagnetism and U-Pb geochronology of volcanic rocks from Michipicoten Island, Lake Superior, Canada: Precise calibration of the Keweenawan polar wander path: Precambrian Research, v. 37, p. 157–171.

Reed, R.C., and Daniels, Jennifer, compilers, 1987, Bedrock geology of northern Michigan: Michigan Geological Survey, scale 1:500,000.

Robertson, J.A., and Gould, K.L., 1983, Uranium and thorium deposits of northern Ontario: Ontario Geological Survey Mineral Deposits Circular 25, 152 p.

Robertson, J.M., 1975, Geology and mineralogy of some copper sulfide deposits near Mt. Bohemia, Keweenaw County, Michigan: Economic Geology, v. 70, p. 1232–1234.

Sage, R.P., 1987, Geology of carbonatite-alkalic rock complexes in Ontario: Prairie Lake carbonatite complex, District of Thunder Bay: Ontario Geological Survey Study 46, 91 p.

——1988, Geology of carbonatite-alkalic rock complexes in Ontario: Killala Lake alkalic complex, District of Thunder Bay: Ontario Geological Survey Study 45, 139 p.

Scott, J.F., 1981, Uranium occurrences of the Thunder Bay–Nipigon–Marathon area: Ontario Geologic Survey Open-file Report 5434, 158 p.

Sergiades, A.O., 1968, Silver cobalt calcite vein deposits of Ontario: Ontario Department of Mines Mineral Resources Circular 10, 497 p.

Springer, Janet, 1977, Ontario mineral potential, Michipicoten sheet, Districts of Algoma and Thunder Bay: Ontario Geological Survey Preliminary Map P 1516, scale 1:250,000.

——1978, Ontario mineral potential, Longlac sheet, Districts of Thunder Bay and Cochrane: Ontario Geological Survey Preliminary Map P 1537, scale 1:250,000.

——1978, Ontario mineral potential, Schreiber sheet, District of Thunder Bay: Ontario Geological Survey Preliminary Map P 1539, scale 1:250,000.

——1978, Ontario mineral potential, Thunder Bay sheet, District of Thunder Bay: Ontario Geological Survey Preliminary Map P 1521, scale 1:250,000.

Tanton, T.L., 1931, Fort William and Port Arthur, and Thunder Cape map areas, Thunder Bay District, Ontario: Geological Survey of Canada Memoir 167, 222 p.

Thomson, J.E., 1954, Geology of the Mamainse Point copper area: 62d annual report of the Ontario Department of Mines, v. 63, pt. 4, 25 p.

Thomson, J.E., Ferguson, S.A., Johnston, W.G.Q., Pye, E.G., Savage, W.R., and Thomson, Robert, 1957, Copper, nickel, lead, and zinc deposits of Ontario: Ontario Department of Mines Metal Resources Circular no. 2, 126 p.


## EXPLANATION

- Contact
- Fault

### DEPOSIT TYPES

- Native copper lode in amygdular and brecciated flow tops
- Native copper lode in interflow conglomerate
- Fissure vein native copper
- Copper sulfide lodes and veins
- Cu-Ag-Au-Pb-Zn Surface trace of lode or vein showing informal name of lode or vein, if applicable
- Titanium and iron oxides in gabbro showing extent of mineralized area, where known
- Disseminated copper and nickel sulfides in gabbro and diabase showing extent of mineralized area, where known
- Platinum group elements in gabbro
- Silver and base metal sulfide veins
- Pitchblende veins
- Uranium in alkalic rocks and carbonatite
- Rare earth elements in alkalic rocks and carbonatite
- Copper sulfides in breccia pipes
- Copper sulfide deposits in shale showing extent of resource proven by drilling, where known
- Mineral occurrence

### SIZE[1] CLASSIFICATION OF DEPOSITS

| | |
|---|---|
| ○ > | $10x10^6$ pounds copper > ○ |
| ● | $10x10^6$ pounds copper ● |
| ■ | $1x10^6$ tons ore[2] ■ |
| ▲ | $10x10^6$ tons ore[2] ▲ |
| ◇ | $300x10^6$ tons ore[2] ◇ |
| ◆ | 100,000 ounces silver ◆ |
| ○ | 10,000 tons copper ○ |
| ● | $10x10^6$ tons ore[2] ● |
| □ | $10x10^6$ pounds copper □ |

[1]Size estimated as production plus in-place resources.
[2]Ore does not imply current profitability.

### ABBREVIATIONS

| | | | |
|---|---|---|---|
| Ag | silver | Ni | nickel |
| Au | gold | Pb | lead |
| Ba | barite | Pd | palladium |
| Co | cobalt | Pt | platinum |
| Cu | copper | Th | thorium |
| Fe | iron | Ti | titanium |
| Fl | fluorite | U | uranium |
| Nb | niobium | Zn | zinc |

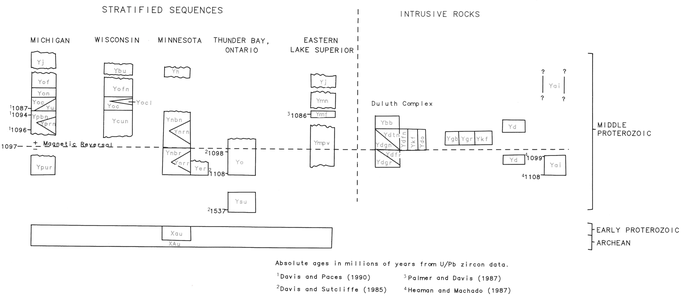
Base digitized from U.S. Geological Survey 1:250,000 Ashland, 1953 (revised 1963); Duluth, 1953 (revised 1963); Hancock, 1958 (revised 1966); Iron River, 1958 (revised 1967); Marquette, 1958 (revised 1968); Sault Ste. Marie, 1954 (revised 1969); Wausau, 1958 (revised 1969); and Wisconsin Rapids, 1958 (revised 1969) and from Ontario Department of Mines, Geological Compilation Series, scale 1:253,440, Map 2065 (Alikokan-Lakehead Sheet), Map 2136 (Sault Ste. Marie-Elliot Lake Sheet), Map 2137 (Nipigon-Schreiber Sheet), and Map 2251 (Batchewana Sheet)

Lambert Conformal Projection Standard Parallels 42°30', 48°30'

SCALE 1:500 000

10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 60 70 KILOMETERS

## CORRELATION OF MAP UNITS




Absolute ages in millions of years from U/Pb zircon data.

[1]Davis and Paces (1990)
[2]Davis and Sutcliffe (1985)
[3]Palmer and Davis (1987)
[4]Heaman and Machado (1987)

### DESCRIPTION OF MAP UNITS

**PALEOZOIC ROCKS**

Pzu Sandstone, carbonate, and shale, undivided (Silurian to Upper Cambrian)

**KEWEENAWAN UNITS (MIDDLE PROTEROZOIC)**

SEDIMENTARY ROCKS

Ybu Bayfield Group, undivided—Reddish sandstone and siltstone

Yj Jacobsville Sandstone—Reddish sandstone, siltstone, and conglomerate

Yh Hinkley Sandstone—Red to buff sandstone and shale

Oronto Group

Yof Freda Sandstone—Reddish sandstone and siltstone

Yon Nonesuch Shale—Gray to black shale and siltstone

Yofn Freda Sandstone and Nonesuch Shale, undivided

Yoc Copper Harbor Conglomerate—Reddish volcanogenic conglomerate and sandstone

Yoci "Lakeshore trap" member—Basalt flows and interflow conglomerate

VOLCANIC ROCKS

Yu Unnamed formation—Andesite and rhyolite, minor conglomerate and sandstone (normal polarity)

Portage Lake Volcanics

Ybn Basalt flows, interflow conglomerate and sandstone (normal polarity)

Yprn Rhyolite (normal polarity)

North Shore Volcanic Group

Ybbn Basalt and andesite flows, minor sandstone (normal polarity)

Yprn Rhyolite (normal polarity)

Ybbr Basalt and andesite flows, minor sandstone (reverse polarity)

Yprr Rhyolite (reverse polarity)

Yrr Basalt at Elys Peak—Basalt flows with sandstone (Puckwunge Sandstone) near base (reverse polarity)

Ymgv Mamainse Point Volcanics—Basalt, andesite and rhyolite flows, conglomerate (includes both normal and reverse polarity)

Ymn Michipicoten Island Formation—Basalt, andesite and rhyolite flows, minor tuff, conglomerate and sandstone (normal polarity)

Yo Osler Volcanics—Basalt and andesite flows, minor felsite, tuff, conglomerate, and sandstone (includes both normal and reverse polarity)

Ycun Chengwatana Volcanic Group, undivided—Basalt flows, minor conglomerate, and sandstone (normal polarity)

Ypur Powder Mill Group, undivided—Basalt and andesite flows, Sandstone and conglomerate (Bessemer Quartzite) at base (reverse polarity)

INTRUSIVE ROCKS

Duluth Complex

Ydtn Troctolite and anorthositic troctolite (normal polarity)

Ydgn Gabbro, anorthositic gabbro, and anorthosite (normal polarity)

Ydgr Gabbro, anorthositic gabbro, and anorthosite (reverse polarity)

Ydo Olivine gabbro

Ydfn Granophyric granite and adamellite (normal polarity)

Ydfr Granophyric granite and adamellite (reverse polarity)

Ybb Beaver Bay Complex—Olivine gabbro and diabase, ferrogabbro

Yd Diabase

Ygb Gabbro

Ygr Granite

Ykf Felsite

Yol Alkalic rocks and carbonatite

Ymf Intrusive rocks on Michipicoten Island—Quartz porphyritic felsite, andesite, and granophyre

**PRE-KEWEENAWAN UNITS**

Ybu Sibley Group, undivided (Middle Proterozoic)—Reddish sandstone, mudstone, conglomerate, and dolomite

Xou Animikie Group, undivided (Early Proterozoic)—Quartzite, banded iron-formation, black shale, and graywacke

XAu Early Proterozoic and Archean rocks, undivided—North of Lake Superior mostly Archean granitoid rocks and derived gneisses, greenstone, and sedimentary sequences. South of Lake Superior also contains extensive Early Proterozoic sedimentary and volcanic rocks on Archean basement

### DISCUSSION

This map illustrates the distribution and geologic character of mineral deposits believed to have formed nearly coincident in time and space with the Midcontinent rift and in response to magmatic, thermal, and tectonic events during and shortly after rifting. The classification of deposits is based on ore mineralogy, form of deposit, and type of host rock and is more descriptive than genetic. The deposits are portrayed as geologic features (in some cases individual deposits have been exploited by numerous mines) and are not classified as to profitability for mining or current or past production. In some cases we have preserved terminology traditional to the region (for example, lodes, fissures), which may no longer be in widespread use elsewhere but which provides a link to the voluminous literature on ore deposits of the region.

### DEPOSIT TYPES

All of the deposits shown with a deposit-type symbol on the map have either been past producers or have received physical exploration such as trenching or drilling and, for the most part, have been described individually in the literature cited herein. Occurrences are not classified as to deposit type because of insufficient information.

**Native copper.**—Deposits in which copper is predominantly in the native form are grouped into three categories. Lodes in amygdular and brecciated flow tops are stratabound hydrothermal concentrations that composed the most important mining horizons in the Keweenaw Peninsula of Michigan. Lodes in interflow conglomerates in the same district were also an important copper source. Fissure veins are discordant hydrothermal deposits that cut the basalt sequence. They accounted for only a few percent of total production but were favored targets in early days of exploration and mining because they contained large masses of native copper. Economic mines were restricted to the district of the Keweenaw Peninsula, but smaller deposits are in virtually every section of basalt exposed in the Lake Superior region. Prospects and small mines are widespread and date mostly from the late 1800's.

**Copper sulfide lodes and veins.**—Copper sulfides, mostly chalcocite, occur as stratabound concentrations and in veins that cut basalt sequences in a mode similar to native copper deposits. Important deposits occur on Mamainse Point (Copper Corp), which was mined in the 1960's and 1970's, and on the Keweenaw Peninsula where significant deposits were discovered in the 1970's.

**Titanium and iron oxides in gabbro.**—Primary cumulate concentrations of titanium and iron oxides are widespread in mafic intrusive rocks. Principal deposits are near the base of the Duluth Complex where several large areas of concentration are known from surface exposures and drilling.

**Disseminated copper and nickel sulfides in gabbro and diabase.**—Near the base of the Duluth Complex in Minnesota, very large resources of copper and nickel have been proven by drilling. The metals occur in primary magmatic sulfides that probably formed where early sulfide saturation was achieved by assimilation of sulfur from underlying pyritic shale. Similar but smaller deposits are in diabase dikes and sills in the Thunder Bay District of Ontario and in gabbro of the Mellen Intrusive Complex in Wisconsin.

**Platinum group elements in gabbro.**—Significant concentrations of platinum group elements are known in and near disseminated copper and nickel sulfide deposits in the Duluth Complex and in the Coldwell Complex.

**Silver and base metal sulfide veins and pitchblende veins.**—A regionally extensive set of carbonate-quartz veins that was mineralized with variable combinations of silver, lead, zinc, nickel, cobalt, barite, fluorite, and uranium extend along most of the north shore region of Lake Superior from northeastern Minnesota to Mamainse Point, Ontario. Those veins of the Island belt near Thunder Bay contain the classic five-element assemblage (Ni, Co, Ag, As, Bi). The Mainland belt contains silver, lead, and zinc whereas veins farther east near the Enterprise mine are limited to lead, zinc, and barite mineralization. These grade northward into pitchblende veins. Base metal veins near the Coldwell Complex and pitchblende veins north of Mamainse Point may be part of the same system. Although the veins vary in metal content, host rock, and temperature of formation, all are approximately of the same age and are probably genetically related.

**Uranium in alkalic rocks and carbonatite.**—Concentrations of uranium of probable primary igneous origin are known in a few intrusive bodies north of Lake Superior.

**Rare earth elements in alkalic rocks and carbonatite.**—A few areas of concentration of rare earth elements are known in the same intrusive bodies that host uranium deposits.

**Breccia pipe copper.**—Copper sulfides occur in breccia pipes that are apparently related to felsic intrusive rocks and porphyry-like alteration east of Mamainse Point. The Tribag deposit was mined in the 1960's and 1970's.

**Copper sulfide deposits in shale.**—This class, a major resource in the region, currently is mined at the White Pine mine in Michigan. The deposits are restricted to the basal part of the Nonesuch Shale and the upper part of the underlying Copper Harbor Conglomerate. Mineralization is epigenetic, but of low temperature, possibly in part of late diagenetic origin. Copper is mostly in chalcocite and native form. Mineralization of the basal Nonesuch Shale is very widespread but known significant deposits are restricted to the White Pine area and the Presque Isle syncline in Michigan.

**Occurrences.**—Concentrations of metals that have received little or no physical exploration and for which information is inadequate to determine a classification are shown as occurrences.

# MAP SHOWING MINERAL DEPOSITS OF THE MIDCONTINENT RIFT, LAKE SUPERIOR REGION, UNITED STATES AND CANADA

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1991

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