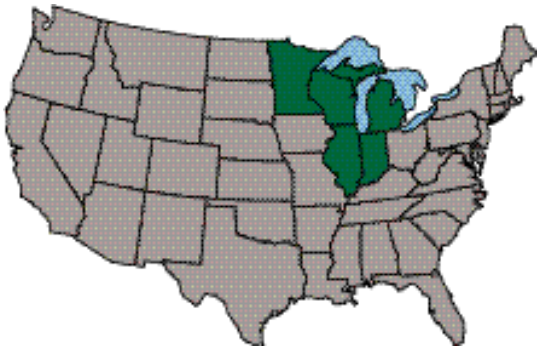
U.S. Geological Survey's Mineral Resources Program Activities in the Upper Midwest



Introduction

In the Upper Midwest, scientists of the U.S. Geological Survey's (USGS) Mineral Resources Program are conducting bedrock and surficial surveys, geophysical research, and mineral resource studies. Program scientists are working in conjunction with scientists from other divisions of the USGS and State and other Federal agencies in the region to develop an integrated resource assessment for the five-state region of Minnesota, Wisconsin, Michigan, Illinois, and Indiana.

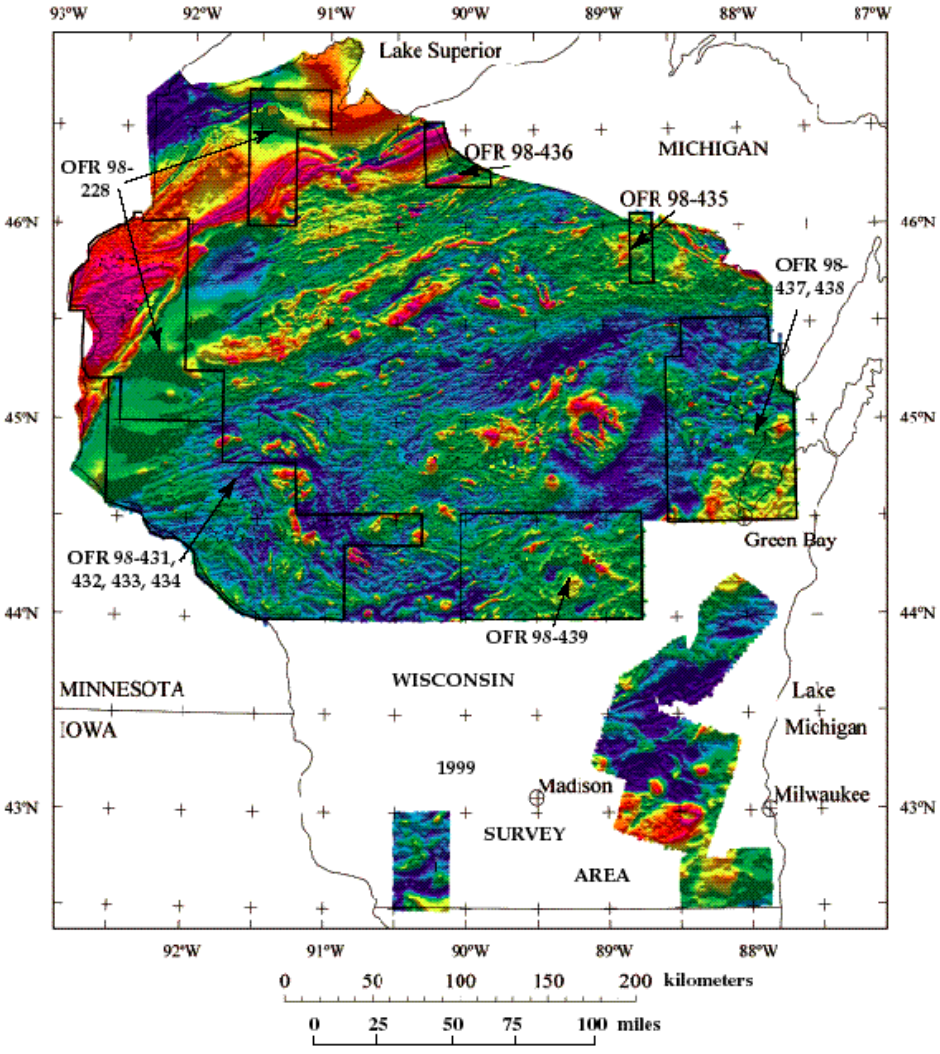


Figure 1. Index map of Wisconsin aeromagnetic data. Boxes outline regions described in USGS Open-File Reports (OFR), currently available in paper form. Red colors denote regions of strongly magnetic bedrock; blue colors denote regions of weakly magnetic bedrock. Digital versions of OFR 98-431 through 98-439 are available on compact disc (OFR 99-28). Data compiled by David Daniels, USGS.

Geophysical Investigations

Aeromagnetic data have been a cornerstone of geologic and minerals-related work in the Upper Midwest for decades. These data are invaluable in helping to understand bedrock geology in this region where rock outcrops are generally very sparse. Without these data, much of the mineral wealth of the region would remain unknown today.

As part of a multiyear effort to improve public-domain geophysical coverage in the Upper Midwest,aeromagnetic surveys have been flown by the USGS over Wisconsin during each of the last 3 years. These surveys used a flight-line spacing of 1/2 mile at an altitude of 1,000 feet. Much of the data is already available in traditional USGS Open-File Reports (fig. 1). Recently processed data in the western part of the State (OFR 98-228) reveal extraordinary geologic detail over a portion of the mineral-resource-rich Midcontinent rift that is poorly characterized because it is overlain by a veneer (< 500 feet thick) of glacial deposits and Cambrian sandstone. New data from northeastern Wisconsin (OFR 98-435,437, 438) have resulted in a new interpretation of the geologic and tectonic history of the Early Proterozoic rocks of the region.

USGS aeromagnetic surveys in Wisconsin were completed in early 1999. USGS data, when combined with the large block of data flown by John Karl, University of Wisconsin, and numerous industry data sets that are publicly available, will provide statewide coverage of aeromagnetic data for Wisconsin with flight-line spacing of 1/2 mile or better. These data are being compiled.

Mercury on Isle Royale

The National Park Service has recognized a problem with elevated levels of mercury (Hg) in fish from several inland lakes on Isle Royale National Park, a large remote island wilderness area in Lake Superior. The pristine nature of the island suggests that airborne Hg is a major contributor to these high levels.

However, as an outgrowth of work on copper mineralization on the island, USGS scientists have recognized that mineralized rocks on the island have detectable levels of Hg and represent a possible natural source of this toxic metal in aquatic ecosystems. Geochemical soil surveys were conducted in 1998 (fig. 2) around Sargent Lake and Lake Wagejo, where Hg contamination has been found, and around the island's largest known copper deposit, the now inactive Minong mine.

Analyses of soils and mine waste materials show that the copper (Cu) mineralization at the Minong deposit produces a very distinct trace-element anomaly in soil, especially in Cu content. Mercury is somewhat elevated in samples closest to the deposit, but measured values drop off quickly away from the deposit (fig. 3).

Figure 2. USGS scientists using a soil push probe to sample surficial material on Isle Royale. Photo by Michele McRae, USGS.

In contrast, samples from the drainage basins of the Hg-contaminated lakes are variable but have higher average Hg values than comparable samples from the Minong mine area. Organic soils have very high Hg values, up to 370 parts per billion (ppb) Hg (fig. 3). These same samples have much lower Cu contents than soils near the copper deposit.

Results from the Minong mine region show that native copper deposits produce detectable Cu anomalies in the soil. A lack of correlation between Cu contents and high Hg values for soils in the two drainage basins suggests that the elevated Hg values are not the result of concealed copper mineralization but may reflect input from other sources, perhaps from airborne deposition of Hg.

Geochemical Background Levels in Glaciated Regions

The spatial distribution of variations of both manmade and natural elements and compounds is important information for a variety of current issues, including environmental protection, regulation, and human and ecosystem health. The Mineral Resources Program has initiated a project that has paired objectives of providing information on the geochemical character of a large area of northern Wisconsin and simultaneously of refining techniques that will allow future studies of similar terranes to be designed and conducted with maximum efficiency.

Scientists from the USGS are working with scientists from the United States Department of Agriculture Forest Service and the Natural Resource Conservation Service to map chemical variations in soils over diverse geologic terranes in northern Wisconsin, an area that was extensively glaciated during the last Ice Age. To date, more than 400 samples have been collected and analyzed to study the relationship between the chemistry of the bedrock and that of the overlying unconsolidated materials and soils.

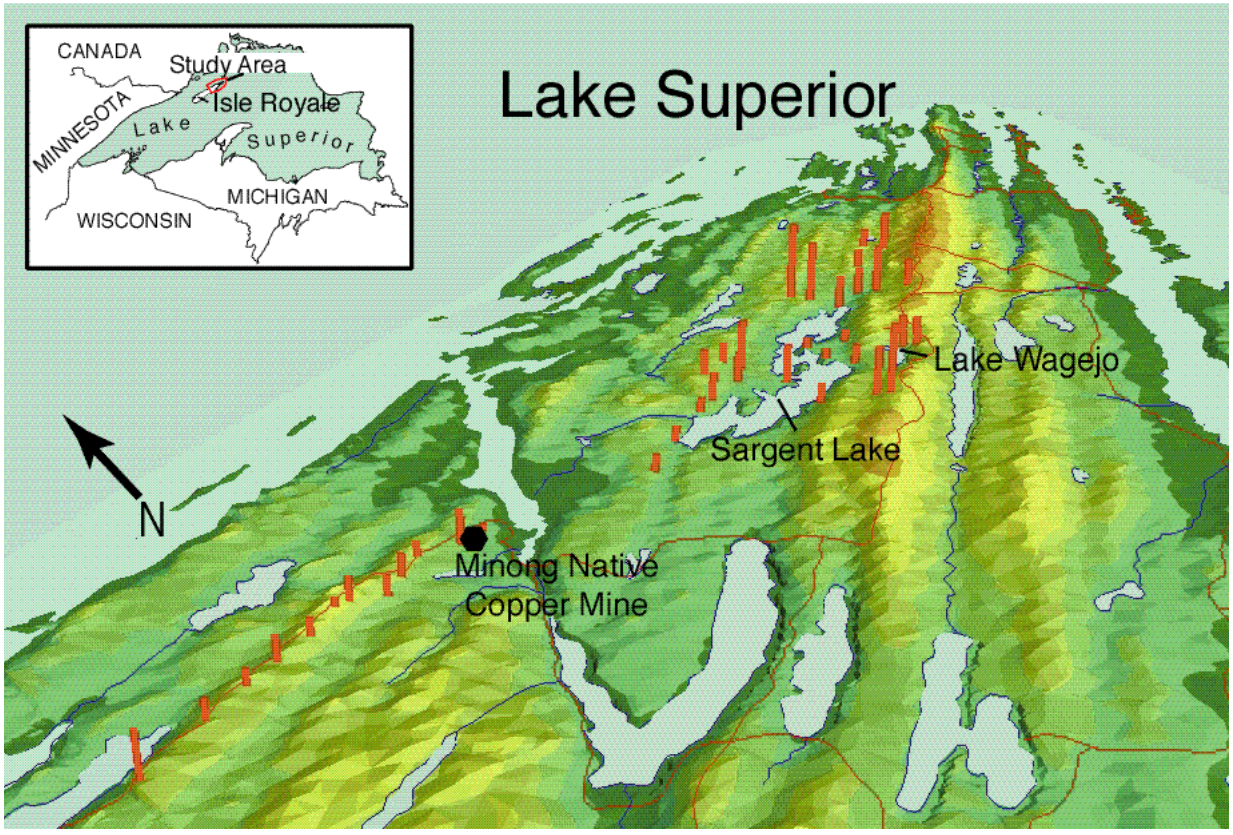


Figure 3. Three-dimensional figure depicting mercury (Hg) contents in organic soils on Isle Royale. Red bars show Hg contents; minimum value is 10 ppb, maximum value (at north end of Sargent Lake) is 370 ppb. The figure shows that Hg contents are higher in organic soils within the drainage basins of Sargent and Wagejo Lakes than in organic soils near the Minong native copper deposit. However, Hg values are highly variable, even within a single drainage basin. Trails on the island are shown as red lines.

Arsenic in Drinking Water

An 11-county area in southeastern Michigan has high levels of arsenic in water from domestic and municipal wells. The area is heavily populated, and nearly all water supplies come from local ground water. Many wells exceed the Environmental Protection Agency (EPA) standard for arsenic in drinking water of 50 micrograms per liter (µg/L) (fig. 4). Long-term exposure to elevated arsenic in water can cause human health problems including skin and intestinal conditions.

Arsenic in Michigan drinking water is believed to come from a natural source, most likely the Marshall Sandstone, a major bedrock aquifer in the region. USGS scientists from the Mineral Resources Program, in cooperation with colleagues from the USGS Water Resources Division, have initiated a study to pinpoint the geologic source of the arsenic and its mineralogic form.

Two new wells, one in Huron County and one in Lapeer County, were drilled into the Marshall Sandstone aquifer.

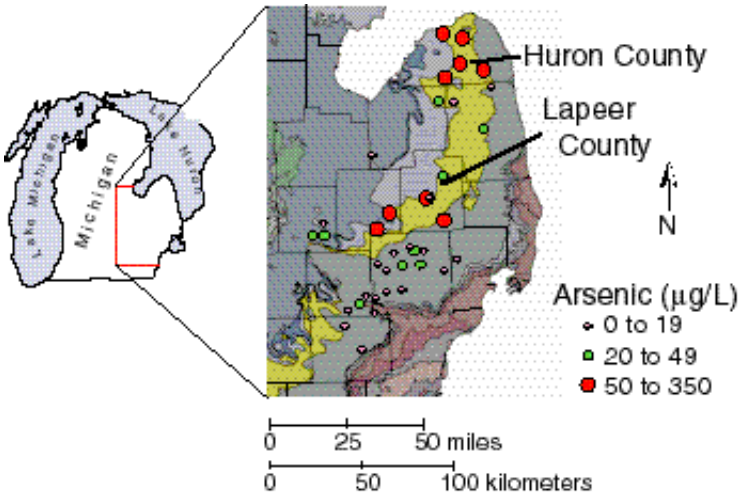


Figure 4. Geologic bedrock map of southeast Michigan showing arsenic concentrations measured in well water in micrograms per liter (µg/L). The Marshall Sandstone (in yellowish-green) is thought to be the natural source of arsenic; other geologic formations in other colors.

Water, well cuttings, and core samples from the two wells are currently being analyzed.

The Marshall Sandstone is a sparsely fossiliferous, very fine to coarse-grained sandstone with some shale or siltstone beds. Arsenic contents as high as 310 parts per million (ppm) and 140 ppm are found for shale and sandstone, respectively, from the well in Huron County. High arsenic values in rock have been correlated with the occurrence of an iron sulfide mineral, pyrite. Rocks typically contain only small amounts of pyrite, but some pyrite is rich in arsenic. Electron microprobe analyses of sandstones show that pyrite occurs as pore-filling cement or fossil replacements, commonly as small, rounded grains called framboids. Arsenic-poor pyrite zones in framboids may be rimmed by arsenic-rich zones, containing up to 6.5 weight percent arsenic (fig. 5).

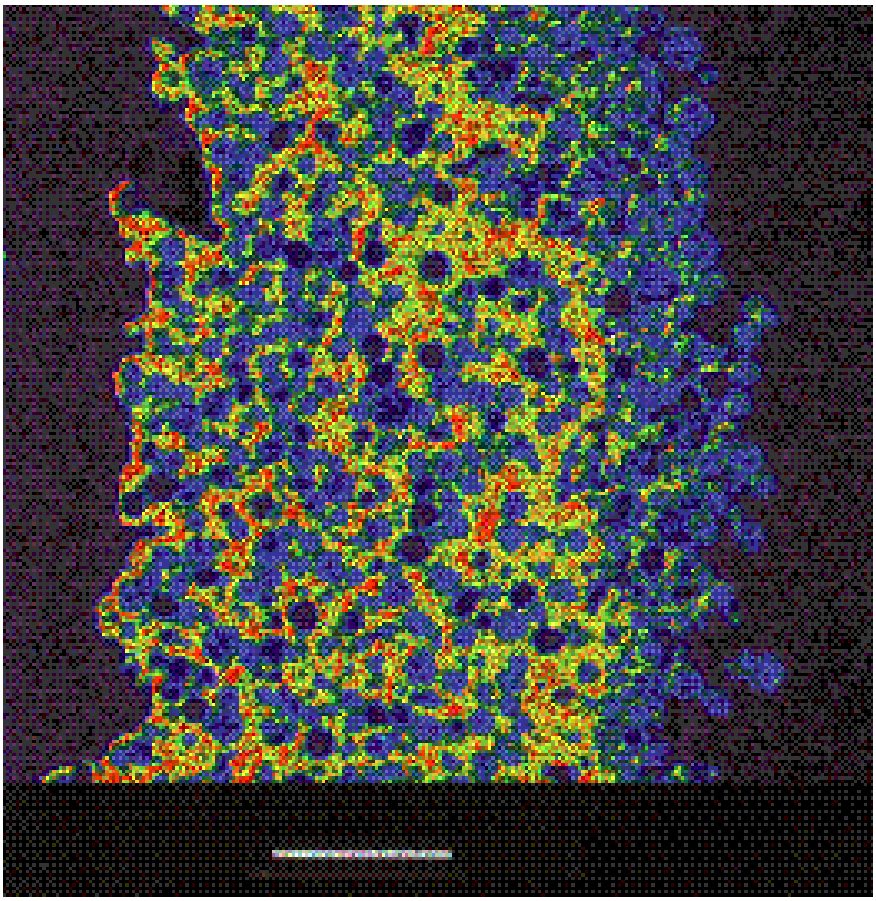


Figure 5. Wavelength-dispersive arsenic map showing arsenic distribution in a pyritized fossil fragment in a chaotically bedded, very fine grained sandstone from the Marshall Sandstone, Lapeer County, Mich. Image produced by an electron microprobe analyzer. Scale bar at the bottom of image is 50 micrometers. Pyrite framboids (small circular blue patches) are overgrown by rims of arsenic-rich pyrite (shown in yellow and red). This occurrence of arsenic-rich rims surrounding arsenic-poor areas is similar to those found elsewhere in the study area. Image by Allan Kolker, USGS.

Arsenic contents of water from the new wells can be as high as 125 µg/L. The arsenic contents of water samples collected from isolated parts of the wells show no direct relation to the arsenic content of corresponding core samples. This is consistent with preliminary geochemical modeling, which suggests that pyrite in the bedrock aquifer is not reacting with the ground water.

The origin of high arsenic values in ground water in southeast Michigan continues to be investigated. It is probable that the source of elevated arsenic in the Marshall Sandstone aquifer is arsenic-rich pyrite, but the specific geochemical reactions responsible for elevated arsenic in this region have not yet been identified. Multiple dissolution and precipitation reactions involving arsenic are likely. Biologic controls may be important.

An outgrowth of this work is an examination of the glacial till that covers bedrock in this region. Glacial deposits in the area are composed of disaggregated bedrock material from the Marshall Sandstone and another bedrock unit, the Coldwater Shale, both of which contain pyrite. It is possible that the breakdown of pyrite in the glacial deposits released arsenic, which may have been introduced into the bedrock aquifers during recharge.

New Digital Geologic Maps

In response to the USGS emphasis on digital information, two new geologic products for the Upper Midwest are being released in digital form. One is a new digital bedrock geologic map of Minnesota, Wisconsin, and Michigan at a scale of 1:1,000,000. This map, a joint publication of the USGS and the Minnesota Geological Survey (MGS), includes recent bedrock mapping by the USGS in northern Wisconsin and Michigan merged with a recent bedrock geologic map of Minnesota released by the MGS. It is currently available on the Internet from the USGS as Open-File Report 97-455 (see link at web site listed below).

The second product (OFR 99-149) describes the geology and mineral deposits of the Keweenaw Peninsula, Mich., an area of world-class native copper mineralization. A geographic information system (GIS) data base includes data on the geology, structure, mines, and mineral deposits, as well as standard cartographic base information (fig. 6). The geologic data have been structured to allow generalization by age, rock type, tectonic setting, or stratigraphic rank.

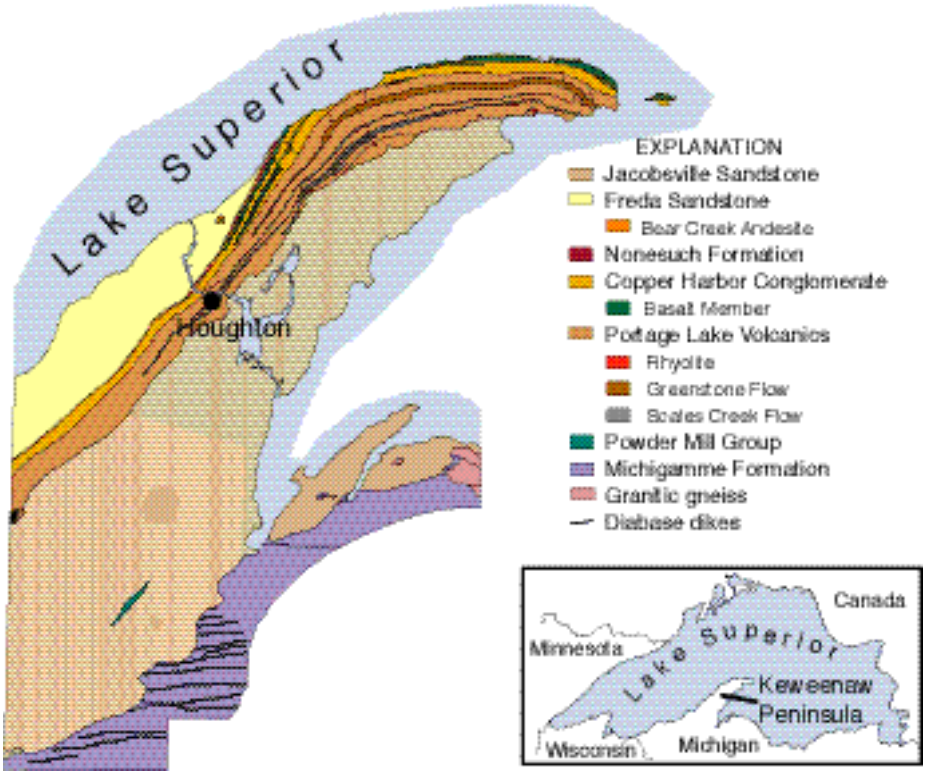


Figure 6. One GIS layer or coverage from the new Keweenaw Peninsula digital product showing a map view of different lithologic units of the bedrock geology.

Mineral Resources Assessments

For more than 150 years, mining activity has flourished in the Lake Superior region. The region has been an important producer of copper, iron, lead-zinc, fluorite, gypsum, and a number of other commodities (fig. 7), and the area still has tremendous mineral potential.

In order to meet the USGS responsibility for determining the occurrence, quality, and quantity of the Nation's mineral resources, the Mineral Resources Program is compiling and updating a nationwide digital inventory of metallic deposits and prospects; a similar inventory of industrial mineral resources is currently under development.

The mineral resources data bases can be combined with other digital layers, such as surficial geology, bedrock geology, population density, ecosystem boundaries, or watershed boundaries. For instance, the three-state digital bedrock geologic map of Minnesota, Wisconsin, and Michigan described above has been combined with an updated version of the Mineral Resources Data System (MRDS) data base for the region in USGS Open-File Report 97-455. For this three-state area, the mineral resources data base contains more than 1,500 records of mineral deposits or occurrences, with information on the commodity type, location, geology, deposit type, exploration and development history, production, reserves, and resources. With the cooperation of State Geological Surveys, this combined mineral resources data base and digital geologic map for Minnesota, Wisconsin, and Michigan is currently being expanded to include the bedrock geology and mineral deposits of Indiana and Illinois.

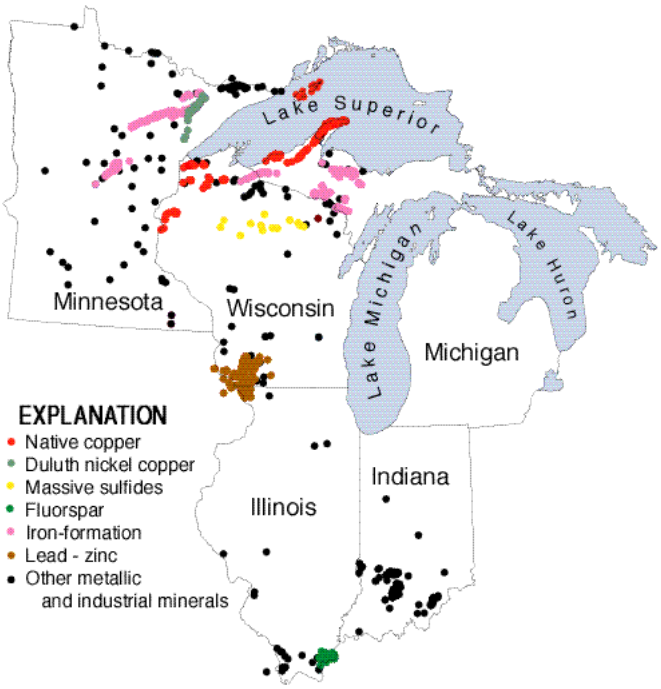


Figure 7. Selected mineral deposits in the Upper Midwest. Specific types of metallic and nonmetallic deposits are illustrated by different colors.

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