A Compendium of Mineral Resource Information, East-Central Minnesota

By

Minnesota Department of Natural Resources
Division of Minerals

REPORT 313
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EXECUTIVE SUMMARY

A Compendium of Mineral Resource Information, East-Central Minnesota

Purpose

The administration of state-owned lands includes the management of those lands for mineral resources. The Minnesota Department of Natural Resources Minerals Division administers state-owned mineral rights for the benefit of schools, the university, local units of government and the public. As a part of this responsibility, the Minerals Division has maintained mineral resource records and information. This compendium of minerals information for east-central Minnesota is provided by the Minerals Division for all people who work in the field of land management, both within various levels of government and outside government. It is intended to serve as a guide to available information, by providing maps showing the location of known mineral resources and the geographic extent of information sources, and listing a knowledgeable contact person for each theme. Further, it is intended to document the presence of some known subeconomic mineral resources, which may have a higher value in the future, and therefore should be considered in current planning. It does not contain a map of speculative resource locations for all commodities, because that would require a complex evaluation and presentation. This compendium is intended to be a starting point for all who need or want access to mineral resource information in east-central Minnesota.

Mineral Commodities and Information: An Historical Perspective

Three mineral commodities are currently being extracted in east-central Minnesota - peat for horticultural applications, aggregate for construction purposes, and dimension stone for buildings or monuments. There have been over 70 years of mining of two other mineral commodities - iron and manganese, from Crow Wing County and adjacent areas. Moreover, large quantities of iron and manganese resources are still present here, having been identified by past drilling.

It is reasonable to assume that mining for the above five commodities, as well as other minerals, could be proposed in the future in this region. The geologic setting suggests that other plausible minerals could include industrial minerals such as graphite, garnet or other abrasives, barite, beryllium, phosphate; or metallic minerals such as gold, silver, copper, lead, zinc, bismuth, chromium, platinum, nickel, or rare earth metals. There are known mineral occurrences for almost all of these commodities, but not in sufficient, known quantities for extraction. As a result, these "other" minerals are referred to here as speculative mineral resources, which would have to be discovered in larger quantity and quality to warrant development evaluation work. The private sector initiates such development evaluation, primarily spurred by market demand in the form of favorable commodity prices. All future development proposals would be subject to the compendium of law applicable to the environmental review and permitting process.
The study area (see the first map) covers the part of Minnesota that very nearly corresponds to Minnesota's Department of Natural Resources administrative region III. Our study area differs from DNR Region III boundaries in that we use county boundaries for the border with two minor exceptions. Because most of our minerals databases contain county designations, it was more practical to use entire county boundaries as much as possible. The two exceptions are small areas within Itasca and Anoka counties, which were included to accommodate the entirety of DNR Region III.

Organization and Content: Theme explanation, bibliography, and maps

The minerals information in this compendium is presented primarily in the form of maps, and is organized around seven general themes: State-Owned Lands and Mineral Leasing, Peat, Industrial Minerals, Sand and Gravel, Iron Ore and Manganese, Other Speculative Minerals, and Mineral Exploration Data (see Table 1).

A common package is presented for each theme, and contains an explanation, a bibliography or digital database reference, and a set of index maps. No part of the package was intended to stand alone. The explanation defines what is included in the theme, describes it and the maps, and summarizes the information. Each bibliography was created from those references judged most helpful. The maps for three themes were created from existing digital databases, and do not have bibliographies (see Table 1). A specialist with extensive knowledge of each theme has written the explanation, created the bibliography, and designed the theme maps. It was not practical to illustrate all of the references on all the maps.

The following maps were created by overlaying mineral resource data on a base map assembled from the Minnesota Land Management Information System (MLMIS) 100 database. MLMIS is a grid-cell based database of Minnesota's natural resources, public land survey, and ownership. The database was designed for use with EPPL7, a raster-based GIS package developed by the Land Management Information Center, Minnesota Office of Planning.

The data for MLMIS were captured from maps ranging in scale from 1:24,000 to 1:1,000,000 through grid-overlay techniques and digitizing. MLMIS was designed to be used in regional and statewide planning, not for site specific work, and is divided into two databases, based on cell size: MLMIS40 and MLMIS100. The cell size of MLMIS40 is 40 acres and is available as statewide files. The cell size of MLMIS100 is approximately 2.5 acres (the length of each side of the cell is 100 meters) and is the spatially corrected version of MLMIS40. MLMIS100 is available as county files and enables the user to better match geographically referenced data from other sources.

For this study of east-central Minnesota, staff used the public land survey files of MLMIS100 to map their "occurrence" data that were stored in tabular database formats as township, range, section, and sometimes forty. The references were mapped through digitizing the reference boundaries or by matching the township, range, and sections covered by the references with the MLMIS100 files.

For more information

As new information is acquired, each theme map and bibliography becomes outdated. Some maps are based on databases that are already a few years old. The best up-to-date source of information for each theme is the designated contact person listed below. Questions pertaining to acquiring references cited or digital data should be directed to Ellen Pioro, Librarian, at the Hibbing Minerals Office.

1. General inquiries .......................... Ellen Pioro (HB)
2. State-Owned Lands and Mineral Leases ........ Mark Kotz (SP)
3. Peat Resources ............................. Sherry Nelson (HB)
4. Industrial Minerals ........................ Matt Oberhelman (HB)
5. Sand and Gravel ............................ J.D. Lehr (SP)
6. Iron Ore and Manganese ................... Tim Pastika (HB)
7. Other Speculative Minerals ................ Richard Ruhanen (HB)
8. Mineral Exploration Data ................... Richard Ruhanen/Dennis Martin (HB)

Footnotes

(SP) Minnesota Department of Natural Resources, Division of Minerals
500 Lafayette Road, St. Paul, MN 55155-4045
Phone #: 612/296-4807 Fax #: 612/296-8939

(HB) Minnesota Department of Natural Resources, Division of Minerals
1525 Third Avenue East, Hibbing, MN 55746-1461
Phone #: 218/262-6767 Fax #: 218/263-5420
### TABLE 1

The minerals information presented here has been organized around the seven themes listed below, and each author has developed the primary content of their individual theme. Each theme package contains an explanation, a bibliography and/or a digital database reference, and maps.

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EAST-CENTRAL MINNESOTA
PUBLIC LAND SURVEY, COUNTIES, AND HIGHWAYS

Map produced by Minnesota DNR
Division of Minerals

Public Land Survey
Township and range numbers in the form TxxN and RxxW
(Townships referenced to the 5th principle meridian)

Township and range numbers in the form TxxN and RxxW
(Townships referenced to the 4th principle meridian)

County line
County name
County seat (e.g., Walker)

Highways*
- Interstate
- Trunk

* From Minnesota Department of Transportation

Copyright 1993, State of Minnesota, Department of Natural Resources
The Minnesota Department of Natural Resources (DNR) administers a data base containing information about lands (including surface and mineral rights) owned by the state. This data base is generally called the DNR Land Records System. Surface ownership information is available for all state-owned lands that are administered by the DNR as well as tax-forfeited lands, which are owned by the state but administered by the county. While the DNR administers the vast majority of state-owned lands in Minnesota, other state agencies also administer lands. Among them are the Departments of Transportation and Military Affairs and the University of Minnesota. Lands administered by these other agencies are not represented in the DNR land records.

A simplified definition of mineral rights is the right to explore for and mine valuable minerals. Mineral rights may be owned separately from the surface interest. This is commonly done when the surface is sold and the mineral rights are reserved. Unless otherwise stated in the severance deed, the mineral rights owner has a right to entry to explore for and mine minerals. Although a majority of the mineral rights currently owned by the state were acquired with the surface rights and are still owned with the surface rights, some mineral rights have been severed by the state as a result of selling the surface. The state has also acquired severed mineral rights as a result of the severed mineral interest law (Minn. Stat. Secs. 93.52-.58).

Information relating to mineral rights is also available in the DNR land records. However, due to the problems in Minnesota of fractional and obscured mineral titles and historically poor documentation of mineral rights ownership by the state, information about state-owned mineral rights is often of an "uncertain" nature.

The State of Minnesota has leased its mineral rights since the late 1800's. Information relating to iron ore, taconite, metallic minerals, and peat leases is also available in the DNR's land records system.

Information in the land records is referenced by legal descriptions based on the Public Land Survey (PLS) System. The maps provided with this report are intended to show the general spatial distribution of information available in the DNR land records. Due to the 40 acre resolution of base PLS data used to make these maps, and the small scale at which they are printed, the maps are not intended to be used to pick out individual parcels.
STATE-OWNED LANDS
SURFACE RIGHTS
EAST-CENTRAL MINNESOTA
1993

Map produced by
Minnesota DNR
Division of Minerals

Surface Administrator
- Green: Record of some DNR administered land in forty acre parcel
- Yellow: Record of some county administered land in forty acre parcel

Note: State-owned lands administered by other agencies are not shown.

Source: Minnesota DNR Land Records System, July 1993
Certainty of Mineral Ownership

- Red: Record of some state mineral ownership
- Yellow: Record of state claim to some mineral ownership
- Green: In forty acre parcel, ownership is certain
- Orange: In forty acre parcel, ownership is uncertain

Note: Mineral rights administered by agencies other than DNR are not shown.
THEME: PEAT RESOURCES

Author: Sherry Nelson  Maps: General Distribution of Peat Soils
County Soil Maps
Inventory Data and Mining Operations

The major reference materials that describe the peat resources in east-central Minnesota are documented on three index maps. These maps were designed to provide information for various levels of planning, ranging from 1) regional, broad-scale planning--General Distribution of Peat Soils; to 2) county, detailed-scale planning--County Soil Maps; to 3) site-specific planning--Inventory Data and Mining Operations. The attached "Peat Resources Bibliography" lists the complete references cited below and indexed on the maps.

The General Distribution of Peat Soils index map portrays the general distribution of peat soil deposits in east-central Minnesota. These data were adapted from a digital data base of the soil units on the Minnesota Soil Atlas Sheets (scale 1:250,000) encoded by the Minnesota Land Management Information Center. Data users should be aware that these data were produced as spatial representations for use in regional and statewide studies and were not intended for site-specific decision making. Soil units were generally compiled at a resolution of one square mile; peat soils were identified that are smaller than one square mile.

An additional reference at the state-wide level is the Geologic Map of Minnesota, Quaternary Geology (scale 1:500,000; Hobbs and Goebel, 1982). On this map the peat unit is mapped only where contiguous peat deposits exceed about 4 square miles.

The County Soil Maps index identifies various county soil maps that contain information on peat resources. The most detailed are the USDA SCS County Soil Survey maps which include peat soil delineations and descriptions. Map scales vary from 1:15,840 to 1:63,360, with most scales either 1:15,840 or 1:20,000. In this area of Minnesota, SCS soil surveys have been published in fourteen counties and are in progress in Aitkin, Cass, Chisago, and Morrison counties. Contact the county SCS offices for availability of maps in progress.

Several supplemental references are included on the county soil map index. The USDA SCS General Soil Maps (scale 1:63,360) for Aitkin, Itasca and Carlton counties are intended only for general soil information; they broadly differentiate three types of peat soils described in an accompanying text General Soil Map of Arrowhead Region. Five county level surficial geology maps (scales 1:63,360 or 1:100,000) are also referenced on this index; these maps outline areas where peat or organic deposits may occur.

The Inventory Data and Mining Operations index map shows the section locations where site-specific peat resource data have been collected. The Department of Natural Resources, Division of Minerals Minnesota Peat Inventory Project database is the primary source of site-specific descriptions of peat resources. In this area of Minnesota, 1,876 peat inventory sites are described by peat type, decomposition, depth and location to the nearest 2 1/2 acre parcel. The data collected for the detailed peatland surveys are part of this database. The Aitkin County peat map (MNDNR, Division of Minerals, 1981) and report (MNDNR, Division of Minerals, 1982) were produced primarily from Peat Inventory Project data. The report on sphagnum moss peat deposits in Minnesota identifies raised bogs in Aitkin, Carlton, Cass, Itasca and Pine counties; additional inventory data on these sphagnum moss peat deposits have been added to the database since this report was published.

Several references that provide supplemental site-specific peat inventory data are also indexed on the map. This includes eight peat sampling reports describing peat type, decomposition and site location that were prepared by Iron Range Resources and Rehabilitation. In addition, Soper's report on the peat deposits of Minnesota provides general comments on the peat resources of each county and some site-specific descriptions of peat samples.

The location of active and past peat mining operations in east-central Minnesota was compiled only from the Department of Natural Resources, Division of Minerals, Reclamation Unit's peat mining operations data files.
PEAT RESOURCES BIBLIOGRAPHY


Farnham, R., 1968, Soil Survey of Sherburne County, Minnesota: Washington D.C., U.S. Department of Agriculture, Soil Conservation Service in cooperation with Minnesota Agricultural Experiment Station, 60 p.; (41 maps, scale 1:20,000).


IRR - Iron Range Resources and Rehabilitation, State of Minnesota, 1967a, Peat Sampling Cromwell NE Bog, Carlton County (Minnesota, T49N R19W, T49N R20W): Hibbing (Now in Eveleth), Minnesota, IRRR Peat Research Office, Unnumbered p.; (Map included, scale 1" = 3520').


IRR - Iron Range Resources and Rehabilitation, State of Minnesota, 1970b, Peat Sampling South Cromwell Bog, Carlton County (Minnesota, T48N R19W, T48N R20W): Hibbing (Now in Eveleth), Minnesota, IRRR Peat Research Office, Unnumbered p.; (Map included, scale 1" = 3520').

Lehr, J. D., 1991, Aggregate resources and Quaternary geology of Wright County, Minnesota: St. Paul, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Report 294, 17 p.; (Accompanying map: Aggregate resources and Quaternary geology of Wright County, Minnesota, scale 1:100,000).

---, 1993, Aggregate resources and Quaternary geology of Isanti County, Minnesota: St. Paul, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Report 304; (Accompanying Plate 1: Aggregate resources and Quaternary geology of Isanti County, Minnesota, scale 1:100,000).


Malterer, T. J., Olson, D. J., Mellem, D. R., Leuelling, B., and Tome, E. J., 1979, Sphagnum moss peat deposits in Minnesota: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Peat Inventory Project, 44 p.; (Accompanying map: Distribution of raised bogs in Minnesota, scale 1" = 16 miles).

Minnesota Department of Natural Resources, Division of Minerals, 1981, Peat Resources, Aitkin County, Minnesota: Minnesota Department of Natural Resources, Division of Minerals. Map, scale 1:126,720; (Accompanying text: Inventory of Peat Resources, Aitkin County, Minnesota, 86 p.).

---, 1982, Inventory of peat resources, Aitkin County, Minnesota: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, 86 p.; (Accompanying map: Peat Resources, Aitkin County, Minnesota, 1981, scale 1:126,720; Appendix D: Observation Site Descriptions, 56 p.).


---, 1985, Kettle Lake Peatland Detailed Survey, Carlton County, Minnesota; R19W, T49N, Sec. 27: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Unnumbered p.; (Unpublished).

---, 1987, Kerrick South Peatland Detailed Survey, Pine County, Minnesota; R17W, T45N, Sec. 30, 31 and R18W, T45N, Sec. 36: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, 55 p.; (Unpublished).

Minnesota Department of Natural Resources, Division of Minerals, Reclamation Unit, 1985-1993, Peat mining operations data files. Hibbing, Minnesota.


Nyberg, P. R., 1987, Soil Survey of Itasca County, Minnesota: Washington, D.C., U.S. Department of Agriculture, Soil Conservation Service in cooperation with Forest Service and Minnesota Agricultural Experiment Station, 197 p.; (65 folded maps, scale 1:24,000).

Saari, C. T., 1990, Soil Survey of Todd County, Minnesota: Washington, D.C., United States Department of Agriculture, Soil Conservation Service in cooperation with Minnesota Agricultural Experiment Station, 245 p.; (56 folded maps, scale 1:20,000).


University of Minnesota, Agricultural Experiment Station, 1969, Minnesota soil atlas: Brainerd sheet: Department of Soil Science, University of Minnesota. Miscellaneous Report 90 - 1969, scale 1:250,000; (Accompanying text 35 p.).


---, 1979, Minnesota soil atlas: St. Cloud sheet: Department of Soil Science, University of Minnesota. Miscellaneous Report 159 - 1979, scale 1:250,000; (Accompanying text 62 p.).


USDA Soil Conservation Service, Carlton County Soil and Water Conservation District, and University of Minnesota Department of Soil Science, 1974b, General Soil Map of Carlton County, Minnesota: U.S. Department of Agriculture, Soil Conservation Service. Map 2 parts, scale 1:63,360; (Map units described in accompanying text: General Soil Map of Arrowhead Region).


Database Reference:
Department of Natural Resources, Division of Minerals, Minnesota Peat Inventory Project Database 1975-1993.

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Map produced by Minnesota DNR Division of Minerals

General Distribution of Peat Soils *


* Adapted from the Minnesota Soil Atlas Sheets, which are intended for broad scale planning. The above map shows the general distribution of peat soil deposits in east-central Minnesota; not all peat soils are shown on this map because of the scale of the Soil Atlas Sheets.
Map produced by
Minnesota DNR
Division of Minerals

PEAT RESOURCES
COUNTY SOIL MAPS
EAST-CENTRAL MINNESOTA
1993

Reference Maps by Author (Year)
Areas covered by references
USDA SCS® County Soil Surveys:
Anoka - Chamberlain (1977)
Benton - Sutton (1977)
Carlton - Levine (1979)
Crow Wing - Amemann, et al. (1966)
Irra - Palmham, et al. (1965)
Itasca - Nyberg (1977)
Kanabec - McMuller, et al. (1939)
Mille Lacs - Badman (1932)
Pine - Summons, et al. (1941)
Sherburne - Grimes (1968)
Stearns - Burton (1968)
Todd - Eian (1960)
Wadena - Alden (1991)
Wright - Edwards (1960)

Boundaries of areas covered by references
USDA SCS® (1974a, 1974b)
- General Soil Map
USDA SCS® (1974c)
- General Soil Map
Moores (1987 unpublished)
Lehr (1991)
Eng (1978)
Eng & Katsoulis (1984)

Counties with USDA SCS® Soil Surveys in Process
* U.S. Dept. of Agriculture, Soil Conservation Service

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The above map shows the section locations where peat inventory sites have been described.
THEME: INDUSTRIAL MINERALS RESOURCES

Authors: Matt Oberhelman  Dale Cartwright
Maps: Industrial Minerals-
Pits & Quarries
Industrial Minerals-
Known Occurrences
Other than Pits & Quarries

The first map exhibits the past and present industrial mineral pits and quarries located in this study area, exclusive of sand and gravel pits and peat mines. The industrial mineral commodities represented here include: clay, marl, silica sand, quartzite, sandstone, schist, slate, mine tailings, dimension granite, and crushed granite.

The data presented on the first map were obtained from the Minnesota Department of Natural Resource's Report 282, Inventory of Industrial Mineral Pits and Quarries in Minnesota (Nelson and others, 1990). That report is a comprehensive inventory of current and past industrial mineral mining activity in all of Minnesota, exclusive of sand and gravel. The data were collected through questionnaires sent to industry, discussions with producers, and a search of data files and literature from public agencies and academic institutions. It should be noted that the locations of the sites were not field-checked. Information reported includes the producing company, past operators, geologic formation, description of the rock or mineral, commodity uses, and a list of references for each pit or quarry.

In the report (Nelson and others, 1990), the records for each commodity are sorted alphabetically by county, and within the county, by Public Land Survey location. The combination of this map and the report permit rapid access to the data available on pits and quarries.

The second map in this theme displays known industrial mineral occurrences other than the pits and quarries. The industrial mineral commodities found to occur within this area include graphite, apatite, garnet, staurolite, fluorite, beryl, titaniferous magnetite, and a host rock that elsewhere is associated with diamonds.

The term industrial mineral occurrence is used here in a very general sense, as simply the reported presence of the mineral at a particular location. The resulting map compilation is based on this general definition applied to reference sources that are very different in nature. The map is intended only as a starting point to get access to the information.

The data portrayed are from three very different types of sources—a statewide compilation of various historic sources (Martin, 1985) and another compilation of pits and quarries (Nelson and others, 1990), two survey areas associated with mapping (McSwiggen, 1987; McSwiggen and Morey, 1989), and a site-specific report (Southwick and Chandler, 1987). The statewide compilation was an attempt to scan all historic geology-related literature for mineral occurrence information, but contained threshold concentrations of greater than 5000 ppm for fluorine or phosphate to be included (Martin, 1985). No such threshold concentration was required for garnet, staurolite, graphite, beryl, or titaniferous magnetite to be included. Within the statewide pit and quarry compilation, a staurolite and garnet occurrence was noted within a schist quarry (Nelson and others, 1990). In contrast, the two survey areas portrayed here represent the area within which many occurrences of graphite and garnet exist and often within geologic units not easily represented as point locations. Finally, the site-specific report (Southwick and Chandler, 1987) describes a drill core and associated geophysical feature as a mica-bearing olivine pyroxenite of possible lamproite-kimberlite affinity. Diamonds only occur in kimberlite or lamproite host rocks or their weathered products, but no diamonds have yet been reported from this site.

The sites shown on both maps are displayed down to the section location. When two commodities occur within the same section, both are displayed to the half section. The half section location may not represent the true location of the occurrence within the section.

INDUSTRIAL MINERALS RESOURCES BIBLIOGRAPHY


Nelson, S. L., Oberhelman, M. W., and Olson, D. J., 1990, Inventory of Industrial Mineral Pits and Quarries in Minnesota, 2 vols.: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals.

INDUSTRIAL MINERALS
PITS AND QUARRIES
EAST-CENTRAL MINNESOTA
1993

Map produced by
Minnesota DNR
Division of Minerals

Inactive (1990)
Clay
Marl
Silica Sand
Granite
Quartzite

Active (1990)
Dimension Granite
Crushed Granite

Source: Nelson, Oberhelman, and Olson (1990)
INDUSTRIAL MINERALS
KNOWN OCCURRENCES
OTHER THAN PITS AND QUARRIES
EAST-CENTRAL MINNESOTA
1993

References by type (Author, Year)

- Graphite (Martin, 1985)
- Diamond Association (Southwick and Chandler, 1987)
- Phosphate/Apatite (McSwiggen, Morey, and Weiblen, 1989; Martin, 1985)
- Staurolite & Garnet (Nelson, Oberhelman, and Olson, 1990; Martin, 1985)
- Garnet (Martin, 1985)
- Fluorine/Fluorite (Martin, 1985)
- Beryl (Martin, 1985)
- Titaniferous Magnetite (Martin, 1985)

Boundaries of reports that show additional occurrences
- Graphite Report (McSwiggen and Morey, 1989)
- Denham-Mahtowa Map (McSwiggen, 1987)
The known occurrences shown on the Sand and Gravel Occurrences and Prospects map are locations where Mn/DOT has done drilling and testing of potential aggregate sources for use in road construction projects. These are records from the ASIS database and are plotted only to the section. The actual aggregate source is usually a smaller parcel of land, often less than 40 acres in size. The ASIS database contains information on location, ownership and summaries of quality tests for aggregate sources. Additional data available in paper files for these sites include test hole logs of shallow (approximately 20 to 40 feet deep) borings, sieve data on samples taken from these borings, and usually some quality test results (percent deleterious rock fragments and percent loss according to the Los Angeles Rattler test). These locations do not necessarily indicate potential aggregate sources, since in many cases the sand and gravel has already been extracted. However, the fact that aggregate may have been mined at a particular location is useful in assessing the sand and gravel potential of adjacent areas. The ASIS database and the Sand and Gravel Occurrences and Prospects map include crushed stone aggregate sources. Since these can not easily be separated from the sand and gravel aggregate sources in the database, they are presented together, even though the subject of this section is strictly sand and gravel aggregate.

The prospects with known sand and gravel shown on the Sand and Gravel Occurrences and Prospects map are records from the APS database that indicate gravel or sand and gravel. As with ASIS, these locations are plotted to the nearest section, while the actual prospect is usually a much smaller parcel of land. For each of these records, additional data, such as driller's logs and geologist's notes are available. However, these data are currently available only in the paper files at the Mn/DOT Office of Materials Research and Standards in Maplewood.

Other information useful in assessing sand and gravel aggregate potential includes well logs, aerial photographs, and large-scale topographic maps. A database of well log records (County Well Index), in addition to paper files of well logs, is maintained by the Minnesota Geological Survey. These well logs include the driller's description of the geologic units encountered while drilling a well. Topographic maps show landforms and the location of some gravel pits. Some landforms represent areas with potential for sand and gravel resources. Interpretation of landforms using both aerial photographs and large-scale topographic maps, supplemented by Mn/DOT data and well logs, is the best method of assessing sand and gravel aggregate potential of specific areas. A limitation of this technique is that it requires considerable experience and time.

Database References:
- Aggregate Source Information System (ASIS)--Minnesota Department of Transportation, Office of Materials Research and Standards, Maplewood.
- Aggregate Prospect System (APS)--Minnesota Department of Transportation, Office of Materials Research and Standards, Maplewood.
SAND AND GRAVEL RESOURCES BIBLIOGRAPHY


---, 1984b, Surficial geology, Sherburne County, Minnesota: Minnesota Department of Natural Resources, Division of Minerals Unpublished map, Scale 1:63,360.


Hobbs, H. C., Goebel, J. E. 1982, Geologic map of Minnesota, Quaternary geology: Minnesota Geological Survey State Map Series 5-1, Scale 1:500,000.


Lehr, J. D., 1991, Aggregate resources and Quaternary geology of Wright County, Minnesota: Minnesota Department of Natural Resources, Division of Minerals Report 294, 17 p.

---, 1993, Aggregate resources and Quaternary geology of Isanti County, Minnesota: Minnesota Department of Natural Resources, Division of Minerals Report 304 (Plate I: Aggregate resources and Quaternary geology of Isanti County, Minnesota, Scale 1:100,000).


---, Unpublished, Surficial geology of Carlton County, Minnesota. Scale 1:63,360.


SAND AND GRAVEL REFERENCE MAPS
EAST-CENTRAL MINNESOTA
1993

Reference Maps by Author (Year)
Areas covered by references:
- Eng (1978)
- Eng and Katsoulis (1984a)
- Eng and Katsoulis (1984b)
- Hobbs (unpub.)
- Lehr (1961)
- Lehr (1960)

Hobbs and Gosbel (1982) covers the entire area, but is the only reference in the colored area.

Boundaries of areas covered by references:
- Anderson (1976)
- Mooers (unpub.)
- Norton (1983)
- Perkins (1977)
- Schneider (1961)

Area is covered by one or more of the five references depicted by boundaries.
Known occurrences of sand and gravel, may include crushed stone (from ASIS*).

Prospects with known sand and gravel (from APS+).

* Data from ASIS - Aggregate Source Information System (1993), Minnesota Department of Transportation
+ Data from APS - Aggregate Prospect System (1993), Minnesota Department of Transportation
The Cuyuna Iron Range is part of east-central Minnesota's Early Proterozoic geologic terrane and occupies portions of Aitkin, Cass, Crow Wing, and Morrison counties. This iron formation was discovered and named by Coyler Adams, who in 1904, encountered an ore-grade intercept in drilling near the town of Deerwood. Early exploration and subsequent mining of the iron formation showed it to have a distinctly high manganese content, thus setting the Cuyuna apart from the other iron mining districts of the Lake Superior region. Mining of this manganiferous iron ore took place from 1911 to 1984, with total shipments exceeding 106 million tons. Most mining occurred in an area known as the North Range, which lies just to the north of the cities of Crosby and Ironton. Limited underground mining also took place in the South Range (Morey and others, 1986). This portion of the Cuyuna is characterized by narrow, sub-parallel belts of iron formation, which extend from west-central Morrison County northeast for about 100 km to west-central Aitkin County. A third subdivision of the Cuyuna, known as the Emily District, extends from the Mississippi River in Crow Wing County north and west into Cass County. No mining has occurred in the Emily District, although extensive exploration has defined the iron formation and delineated manganiferous zones.

Iron ore information was derived from 5 maps (Morey and others, 1986; Strong, 1949-59; Morey and others, 1981; Southwick and others, 1988; Sims and others, 1970), and was captured at 40-acre resolution using the grid overlay technique. All 40-acre parcels from these 5 maps containing any mappable units of iron formation are classified here as iron ore resources. These datasets were captured in MLMIS40 and later transferred into MLMIS100. Due to the limitations of these MLMIS data sets (see MLMIS documentation), and the inherent inaccuracies of grid overlay data capture, digital representation of the iron formations is not exact. Therefore, always refer back to the original reference maps when more accurate information is necessary. Manganese resources were obtained from two reports (Morey, 1990; Strong, 1949-59), and include all government sections with identified or measured manganese enrichment. Please note that original reference maps used for this compilation only depict the resources outcrop or subcrop locations, and do not include information relating to their occurrence where buried beneath other bedrock units.

Although iron ore mining has ceased on the Cuyuna Iron Range, significant resources still remain. The Minnesota Department of Revenue estimates in the Minnesota Mining Directory (Lipp, 1989) that total iron ore resources (excluding taconite) exceed 22 million gross tons. This Directory also lists all iron mining properties on the Cuyuna, along with their respective production histories and remaining iron ore resources. Whereas manganese was secondary to iron ore in the history of the Cuyuna, any future development of this iron formation may likely concentrate on its areas of manganese enrichment. The manganiferous zones of the North Range and the Emily District constitute one of the largest manganese resources in the United States. However, much remains to be learned about this resource; undiscovered manganese is likely to exist and the mineralogical characteristics of this manganiferous iron formation are not fully understood. Therefore, further exploration and research into mining and metallurgical techniques is needed prior to economic development.

Maps and reports included in this summary are all available for review in the Hibbing office of the MnDNR Minerals Division. While iron formations in the main Cuyuna Iron Range (Morey and Morey, 1986) and the Emily District (Strong, 1949-59) are mapped with a fair degree of accuracy, the formations depicted in the remaining portions of this region contain varying degrees of certainty. Further geologic investigations and interpretations in areas of these formations will likely exclude some units and include others not mapped at this time. Evaluation of drill core in the MnDNR Minerals Division Drill Core Library can be used to verify the presence of iron formation on a more detailed scale.

In summary, iron ore and manganese resources have played a vital role in the history of this region, and will very likely help shape its future. This compilation of iron ore and manganese potential is intended to guide planners in their work by generally delineating these resources and referencing more detailed maps and reports. The Cuyuna Iron Range contains very good potential for development of its manganiferous iron ores. For this potential to be realized in the future, today's land use decisions must be made with these resources in mind.

IRON ORE AND MANGANESE RESOURCES


Known Occurrences by Author (Year)
Iron Formation (40-acre resolution)
- Morey, et al. (1986) and Strong (1949-59)
- Southwick, et al. (1988)
- Sims, et al. (1970)
- Morey, et al. (1981)
Manganese within Iron Formation (640-acre resolution)
- Morey, et al. (1990) and Strong (1949-59)
Boundaries of areas covered by references, given as Author (Year)
- Morey, et al. (1990)
- Strong (1949-59)
- Sims, et al. (1970)
Speculative mineral resources are those that have not yet been discovered in sufficient quantity and quality to warrant mining, but which could occur in the geologic setting of this area. Compiling the known locations of minor amounts of ore minerals and of indicator minerals is a direct way to present the information. Considerable further exploration work is required to upgrade the status of these commodities to that of identified resources. This area has a geologic setting similar to north-central Wisconsin, where economic deposits of base and precious metals have been found.

The source of information for these maps was a compilation of all publicly available information concerning ore-mineral occurrences, testpits, and drill core in the state (Martin, 1985). For the compilation in Martin (1985) the following guidelines were used to determine whether the information was included:

1. A testpit was defined to include pits, trenches, or shafts to bedrock. If bedrock was not described, the testpit was still included.
2. The open-file drill core refers either to that drill core which is available to the public for inspection or at least a log from it exists.
3. The following guidelines were used in the search for ore minerals.
   a) Minerals had to contain one of the following elements:
      Cu, Zn, Pb, Ni, Cr 500 ppm
      Co 250
      Mo 30
      As 20
      V 1500
      Ti 10%
      P 5000
      F 5000
   b) The location (minimum T-R-S) had to be cited.
   c) For the following elements, assay values greater than or equal to the following had to be cited:
      Cu, Zn, Pb, Ni, Cr 500 ppm
      Co 250
      Mo 30
      As 20
      V 1500
      Ti 10%
      P 5000
      F 5000

"The following ore mineral, indicator minerals, and industrial minerals were sought: ankerite, arsenopyrite, argentite, apatite, asbestos, alunite, barite, bornite, bauxite, carbonates, corundum, clays, chalcopyrite, diamond, fuchsite, fluorite, galena, garnet, gold, gossan, graphite, gypsum, halite, ilmenite, iron formation, magnetite, magnesite, malachite, marcasite, marble, molybdenite, muscovite, olivine, phosphates, prehnite, pyrite, pyrrhotite, scheelite, sphalerite, staurolite, sulfides, talc, tripoli, tourmaline, and zeolites.

"For the indicator minerals, any combination of two of the following had to occur to be cited: pyrite, pyrrhotite, and/or the above indicator minerals."

The information has been sorted into four map topics for clarity of presentation. Regarding the accuracy of the data points, note that the historic data for some locations were resolved only to the township; these locations were arbitrarily placed in Section 16 for mapping purposes. Likewise, forty locations given in the 1985 database as the NW of the SE should be checked in the accompanying text. When that database was built to produce maps at 40 acre resolution, those occurrences with locations known only to the section were arbitrarily assigned the NW 1/4 of the SE 1/4 in the database. These location checks may be made in Martin (1985) which contains a description of each occurrence organized by county and then by township.

**Database Reference:**

Martin, D.P., 1985, A Compilation of Ore Mineral Occurrences, Drill Core, and Testpits in the State of Minnesota: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals (occurrence data used is only from east-central Minnesota).
Occurrences in drill core, boulders, outcrops, or test pits:

- Copper
- Zinc
- Copper + Zinc + Lead + Nickel
- Copper + Zinc + Lead
- Copper + Nickel
- Copper + Zinc

Map produced by Minnesota DNR Division of Minerals.

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Source: MN DNR Occurrence Report 291
CHROMIUM, TITANIUM, AND VANADIUM
KNOWN OCCURRENCES
EAST-CENTRAL MINNESOTA
1993

Map produced by
Minnesota DNR
Division of Minerals

Occurrences in drill core
- Vanadium + Chromium + Titanium
- Vanadium
- Titanium

Source: MN DNR Occurrence Report 231
In some cases, these minerals are associated with certain types of ore minerals.

Described as mineral (occurrence type)

- Garnet + Pyrite + Tourmaline (outcrop)
- Pyrite + Pyrrhotite (outcrop)
- Pyrite + Tourmaline + Sulfur (outcrop)
- Pyrite (outcrop)
- Pyrrhotite (testpit)
- Garnet (outcrop)

Map produced by Minnesota DNR Division of Minerals.

Source: MN DNR Occurrence Report 291
THEME: MINERAL EXPLORATION DATA
PART A: BEDROCK DRILL SAMPLES
PART B: GEOCHEMISTRY REFERENCES
PART C: GEOPHYSICAL REFERENCES

Author Part A: Richard Ruhanen
Author Part B: Dennis Martin
Author Part C: Richard Ruhanen/Dennis Martin

Maps: Bedrock Drill Sample Locations Geochemistry References

Part A. Bedrock Drill Samples

The locations of available bedrock samples, both core and cuttings, for the entire state are listed in a database called the DNR Minerals Drill Core Library Index. This database contains information regarding drill site location, drill hole number, company who initiated the drilling, date completed, drill hole angle and depth, core or cuttings footage interval, and analyses available. This data is very portable, and is very easy to search for specific information. From this database, all samples within the study area were identified and portrayed on the accompanying map. Although not shown, many government sections contain more than one drill hole per section.

The database contains some records of redundant samples. Due to these redundant records, the sample intervals do not always match; some boxes contain complete but separate intervals of both core and cuttings. Repetition of the inventory number on the listing indicates these conditions. One drill hole sometimes had several owners, who had divided the samples amongst themselves, and those owners separately donated partial samples many years later, at different times to the DNR.

Database Reference:
Minnesota Department of Natural Resources, Division of Minerals, Drill Core Library Index.

Part B. Geochemistry References

Geochemistry, sometimes called geochemical prospecting, is the practical application of theoretical geochemical principles to mineral exploration, or other geological or environmental problems. The purpose of the attached map is to provide a fast assessment of the available geochemical data, a summarized view of its geographic location, and a reference citation.

Various sample media are represented in the reference surveys cited. The majority of samples cited are from groundwater and organic lake bottom sediments, with a minority of soil samples, glacial tills, and glacial boulders. This theme does not include chemical analyses of Precambrian bedrock drill core or outcrop samples.

The surveys portrayed were for the most part performed by government agencies reflecting data which is publicly available, and is currently catalogued in the DNR Division of Minerals library. An exhaustive literature search was not performed. The miscellaneous soil, water, and boulder samples portrayed are those listed on the Division of Minerals Assessment Files database as of June, 1993.

The sample areas and points portrayed are derived from figures within the references cited, with point registration to section-level accuracy where the data permits. The sample areas of Sellner (1985), Beckwith and Clark (1985), and Morey and Lively (1980), are those reported in Shettel and O'Hara (1992). Note that the Morey and Lively (1980) sample area actually represents the outer boundary of combined groundwater and bedrock samples. The border for Lively and others (1992) is copied from that reference, but its accuracy here is not clear. The sample points for the miscellaneous soil, water, and boulders cited can be researched further by determining the specific township and range location from the map, and then searching that location in the Division of Minerals Assessment Files records.

To summarize the data, all references are regional reconnaissance-scale studies, except that the miscellaneous samples from the Assessment Files are of a more detailed scale. The reconnaissance studies contain:
- 883 groundwater samples and 200 bedrock samples analyzed for 34 elements (Morey and Lively, 1980);
- 618 organic lake bottom sediments from 463 lakes analyzed for 10 elements (Sellner, 1985);
- 226 well water samples analyzed for 12 elements (Beckwith and Clark, 1985);
- 33 overburden samples from 3 rotasonic core holes analyzed for 22 elements (Martin and others, 1989);
- 66 well water samples analyzed for 25 elements (Lively and others, 1992);
- 53 glaciofluvial samples from gravel pits were processed to separate the heavy mineral fraction, which was analyzed for up to 41 elements and selected mineralogy (Nelson and others, 1992).

The miscellaneous samples from the Assessment Files include:
- 36 well water samples, three small B-horizon soil surveys, and a few glacial boulder chemical analyses.

Note that Shettel and O'Hara (1992) re-evaluated the first three above data sets, under contract to DNR, and have identified 82 subareas of anomalous trace element content pertaining to mineral exploration interest.


Minnesota Department of Natural Resources. Division of Minerals, Assessment Files: Hibbing, Minnesota, Minnesota Department of Natural Resources.


Part C. Geophysical References

The Minnesota Department of Natural Resources Division of Minerals Assessment Files contain many references of geophysics applied to mineral exploration. Such applied geophysics is the observation of seismic or electrical phenomena, or of the earth's gravitational or magnetic fields employed in the search for mineral resources. Available geophysical data provides valuable information on the geologic setting, especially for the bedrock geology that in this region lies buried beneath layers of glacial drift.

The topic of geophysical references was developed in a different data platform than all the previous themes or topics. A Geographic Information System with ARC/INFO was the platform used for this topic, and will permit more interaction with the information. The database work and maps are not yet complete, and thus cannot be distributed here. The index will be completed at a later date and become available in paper and digital form.