

EXECUTIVE SUMMARY

A Compendium of Mineral Resource Information, East-Central Minnesota

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By

Minnesota Department of Natural Resources
Division of Minerals



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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.

Location

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

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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.

THEME	MAP TITLES	BIBLIOGRAPHY AND/OR DATABASE REFERENCE	AUTHOR
State-Owned Lands and Mineral Leases	1. State-Owned Lands - Surface Rights 2. State-Owned Lands - Mineral Rights 3. State Mineral Leases	Digital database reference	Mark Kotz
Peat Resources	1. Peat Resources - General Distribution of Peat Soils 2. Peat Resources - County Soil Maps 3. Peat Resources - Inventory Data and Mining Operations	Digital database and bibliography	Sherry Nelson
Industrial Minerals Resources	1. Industrial Minerals - Pits and Quarries (including dimension stone and crushed granite) 2. Industrial Minerals - Known Occurrences	Digital database and bibliography	Matt Oberhelman Dale Cartwright
Sand and Gravel Resources	1. Sand and Gravel - Reference Maps 2. Sand and Gravel - Occurrences and Prospects	Digital database and bibliography	J.D. Lehr
Iron Ore and Manganese Resources	1. Iron Ore and Manganese - Locations and References	Bibliography	Tim Pastika
Other Speculative Minerals	1. Gold - Known Occurrences 2. Base Metals - Known Occurrences 3. Chromium, Titanium, and Vanadium - Known Occurrences 4. Indicator Minerals - Known Occurrences	Digital database reference	Richard Ruhanen
Mineral Exploration Data Part A. Bedrock Drill Samples Part B. Geochemistry References Part C. Geophysical References (not yet available)	Part A. 1. Mineral Exploration Data - Bedrock Drill Samples Part B. 1. Mineral Exploration Data - Geochemistry References	Part A. Digital database reference Part B. Bibliography	Part A. Richard Ruhanen Part B. Dennis Martin

TABLE OF CONTENTS

Executive Summary i

Location Map: East-Central Minnesota-Public Land Survey, Counties, and Highways 1

State-Owned Lands and Mineral Leases

 Explanation 2

 Maps: State-Owned Lands - Surface Rights 3

 State-Owned Lands - Mineral Rights 4

 State Mineral Leases 5

Peat Resources

 Explanation 6

 Bibliography 7

 Maps: Peat Resources - General Distribution of Peat Soils 9

 Peat Resources - County Soil Maps 10

 Peat Resources - Inventory Data and Mining Operations 11

Industrial Minerals Resources

 Explanation 12

 Bibliography 12

 Map: Industrial Minerals - Pits and Quarries (including dimension stone and crushed stone) 13

 Industrial Minerals - Known Occurrences (other than pits and quarries) 14

Sand and Gravel Resources

 Explanation 15

 Bibliography 16

 Maps: Sand and Gravel - Reference Maps 18

 Sand and Gravel - Occurrences and Prospects 19

Iron Ore and Manganese Resources

 Explanation 20

 Bibliography 20

 Map: Iron Ore and Manganese - Locations and References 21

Other Speculative Minerals

 Explanation 22

 Maps: Gold - Known Occurrences 23

 Base Metals - Known Occurrences 24

 Chromium, Titanium, and Vanadium - Known Occurrences 25

 Indicator Minerals - Known Occurrences 26

Mineral Exploration Data

 Explanation - Part A. Bedrock Drill Samples 27

 Part B. Geochemistry References 27

 Part C. Geophysical References) 28

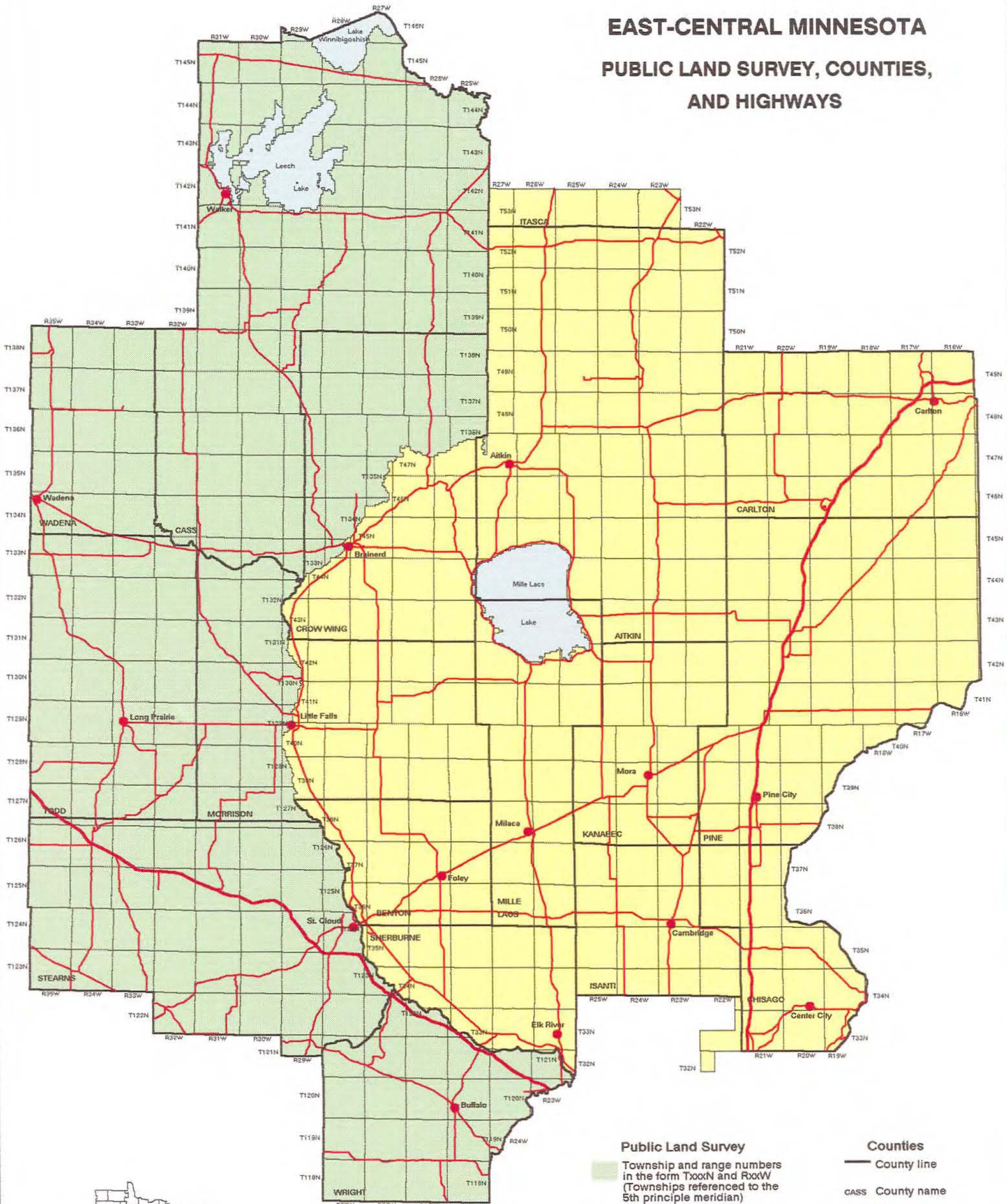
 Bibliography, Part B. (Geochemistry References only) 28

 Maps: Part A. Mineral Exploration Data - Bedrock Drill Samples 29

 Part B. Mineral Exploration Data - Geochemistry References 30

 Part C. Mineral Exploration Data - Geophysical References (Not yet available)

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



Map produced by
Minnesota DNR
Division of Minerals

- | | | | |
|---------------------------|---|-----------------|----------------------------|
| Public Land Survey | | Counties | |
| | Township and range numbers in the form TxxN and RxxW (Townships referenced to the 5th principle meridian) | | County line |
| | Township and range numbers in the form TxxN and RxxW (Townships referenced to the 4th principle meridian) | | County name |
| | | | County seat (e.g., Walker) |
| | Township line | | |
| Highways* | | | |
| | Interstate | | Trunk |

* From Minnesota Department of Transportation

THEME: STATE-OWNED LANDS AND MINERAL LEASES

Author: Mark Kotz

**Maps: State-Owned Lands--Surface Rights
State-Owned Lands--Mineral Rights
State Mineral Leases**

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.

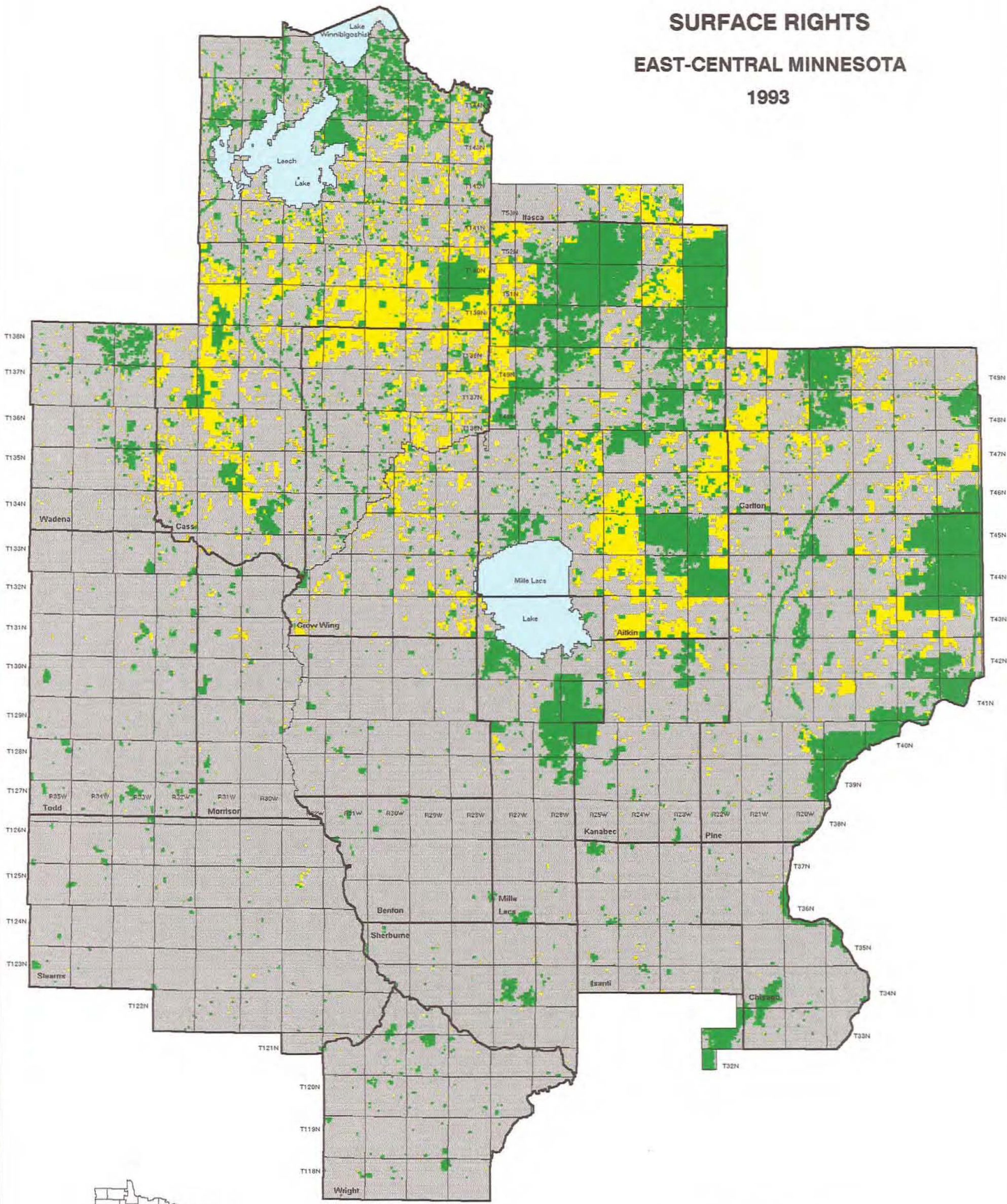
Information in the land records is referenced by legal descriptions based on the Public Land Survey (PLS) System. The maps provided with this report are intended to show the general spatial distribution of information available in the DNR land records. Due to the 40 acre resolution of base PLS data used 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 AND MINERAL LEASING

Database Reference:

Minnesota Department of Natural Resources, July 1993, Land Records System.

**STATE-OWNED LANDS
SURFACE RIGHTS
EAST-CENTRAL MINNESOTA
1993**



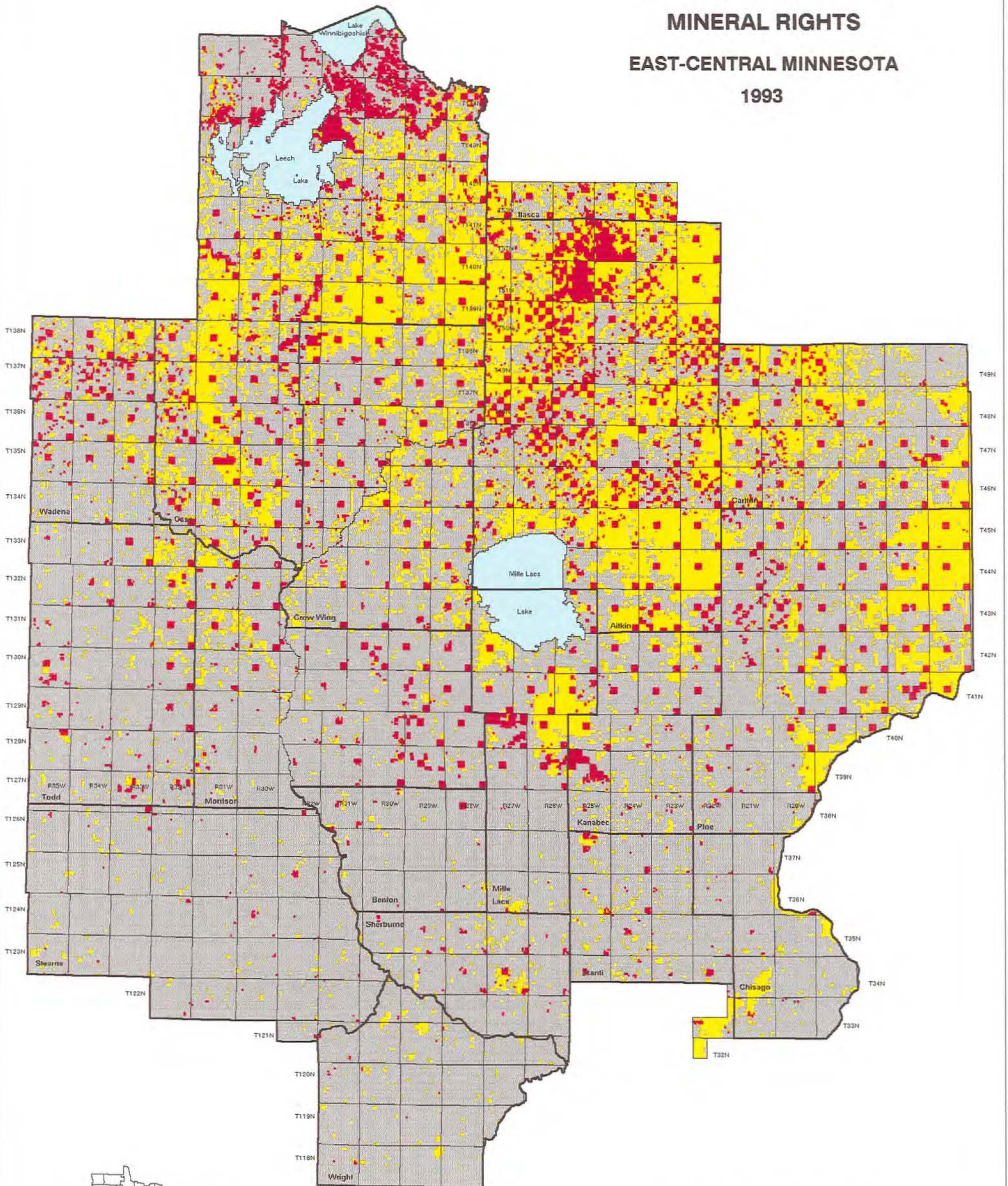
Surface Administrator

- Record of some DNR administered land in forty acre parcel
- Record of some county administered land in forty acre parcel

Map produced by
Minnesota DNR
Division of Minerals

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

STATE-OWNED LANDS MINERAL RIGHTS EAST-CENTRAL MINNESOTA 1993



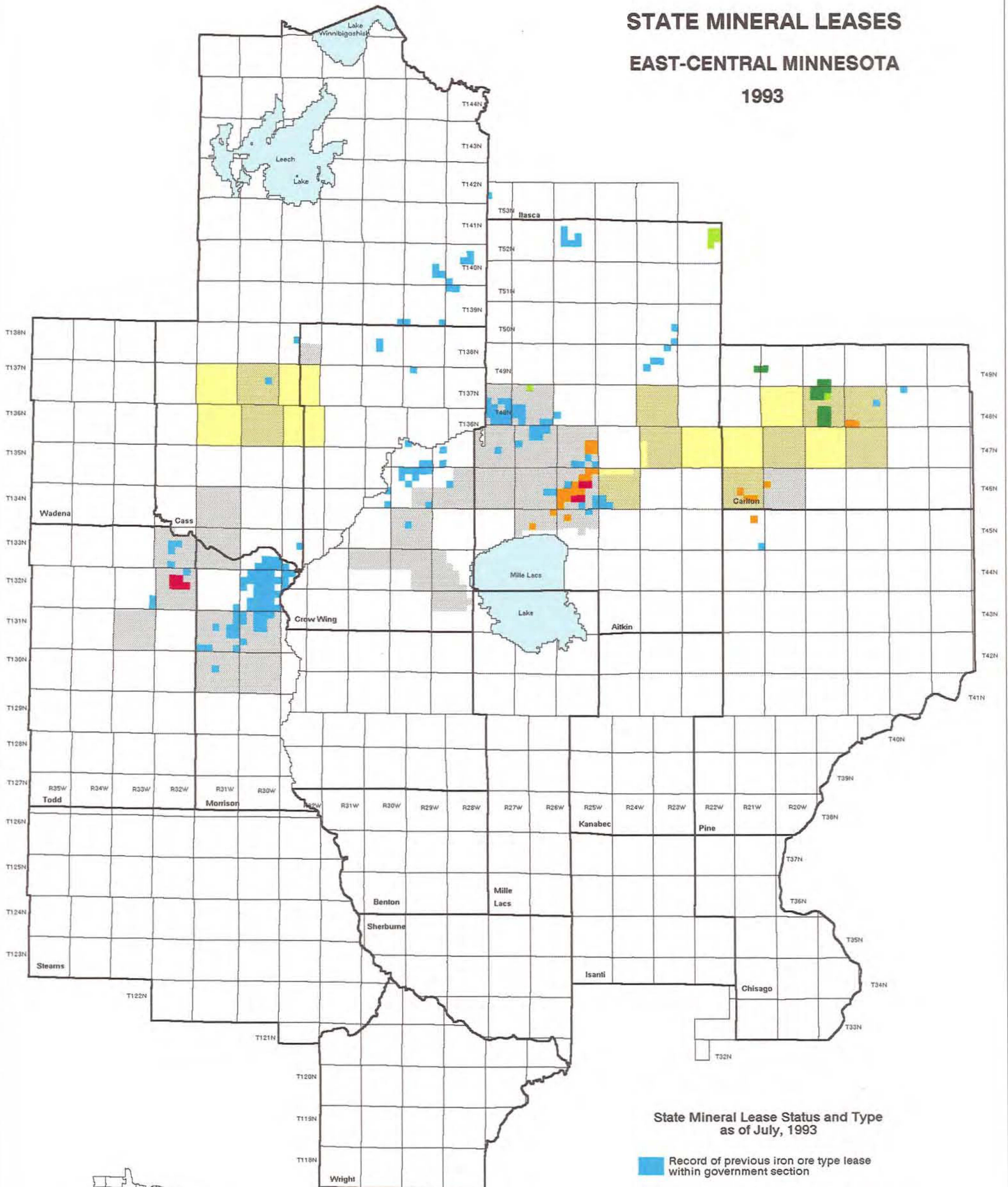
Certainty of Mineral Ownership

- Record of some state mineral ownership in forty acre parcel, ownership is certain
- Record of state claim to some mineral ownership in forty acre parcel, ownership is uncertain

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Division of Minerals

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

STATE MINERAL LEASES EAST-CENTRAL MINNESOTA 1993



State Mineral Lease Status and Type
as of July, 1993

- Record of previous iron ore type lease within government section
- Record of current metallic minerals leases within government section
- Record of previous metallic minerals leases within government section
- Record of current peat lease within government section
- Record of previous peat lease within government section
- Regional geologic reconnaissance authorization areas
- Areas offered for state metallic minerals leasing, 1966-1993



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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 2½ 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.

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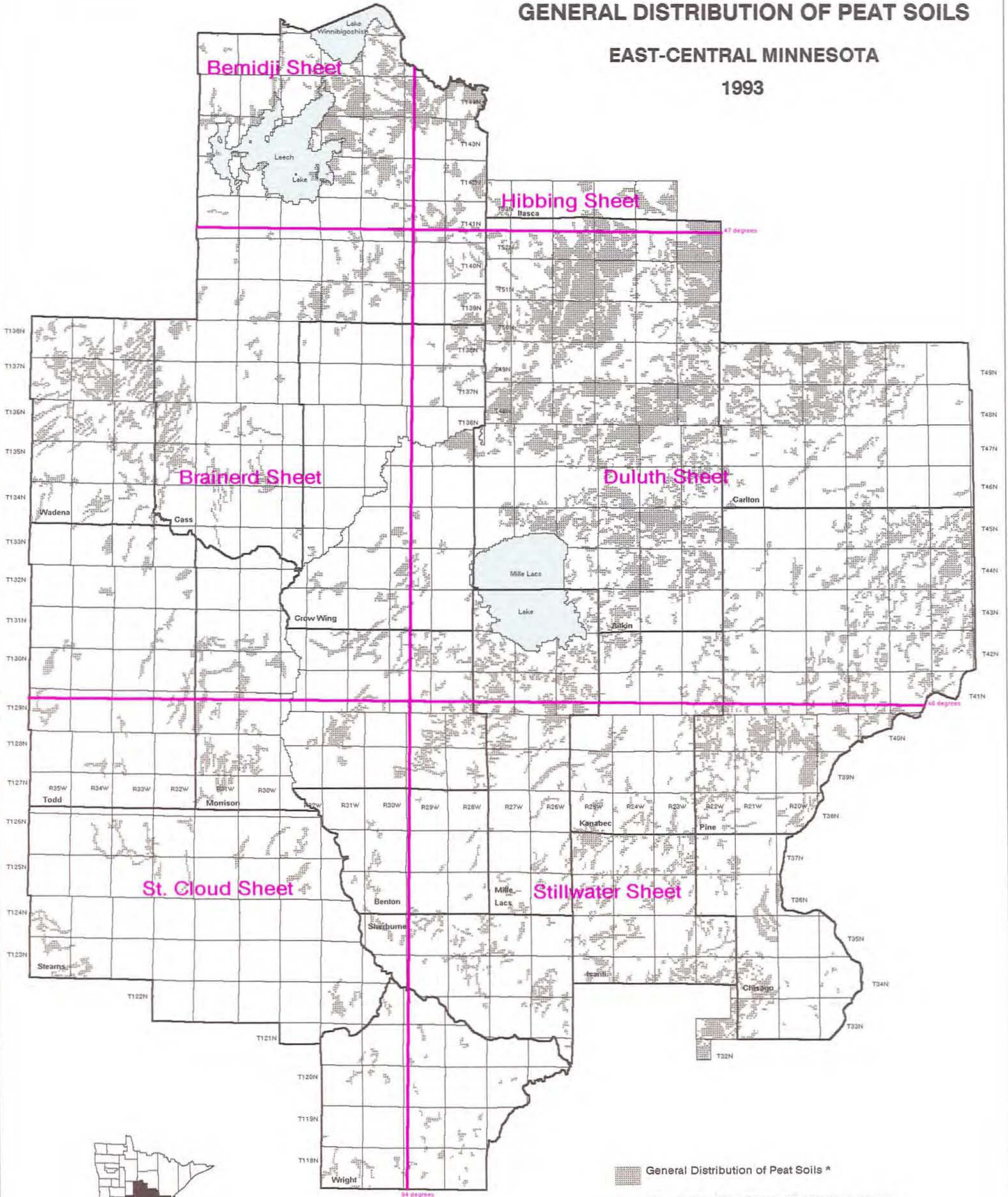
Database Reference:



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

PEAT RESOURCES GENERAL DISTRIBUTION OF PEAT SOILS

EAST-CENTRAL MINNESOTA

1993

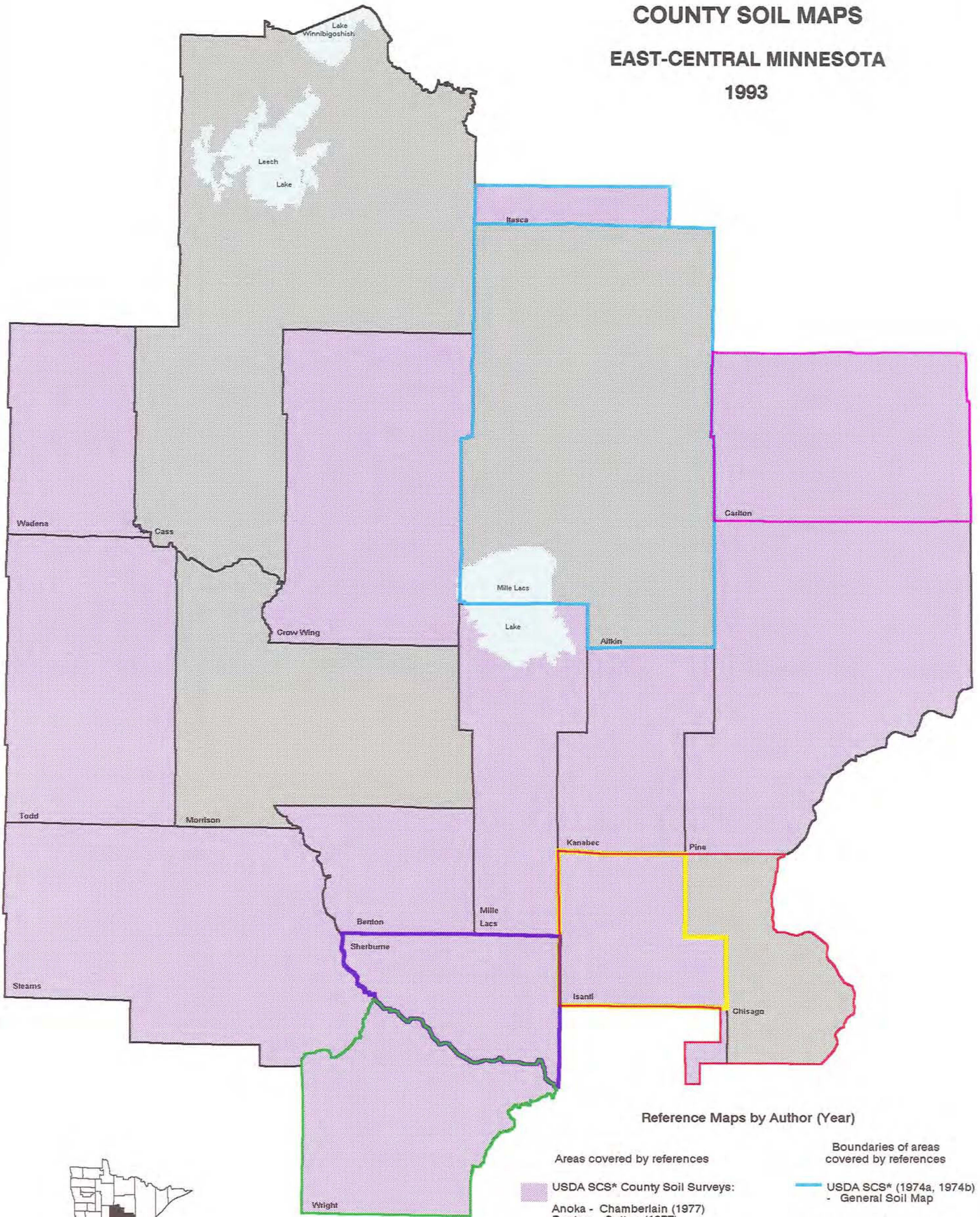


 General Distribution of Peat Soils *
 Boundaries of the Minnesota Soil Atlas Sheets, University of MN Agricultural Experiment Station (1969, 1971, 1977, 1979, 1980a, 1980b)

* 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



Map produced by
Minnesota DNR
Division of Minerals

Reference Maps by Author (Year)

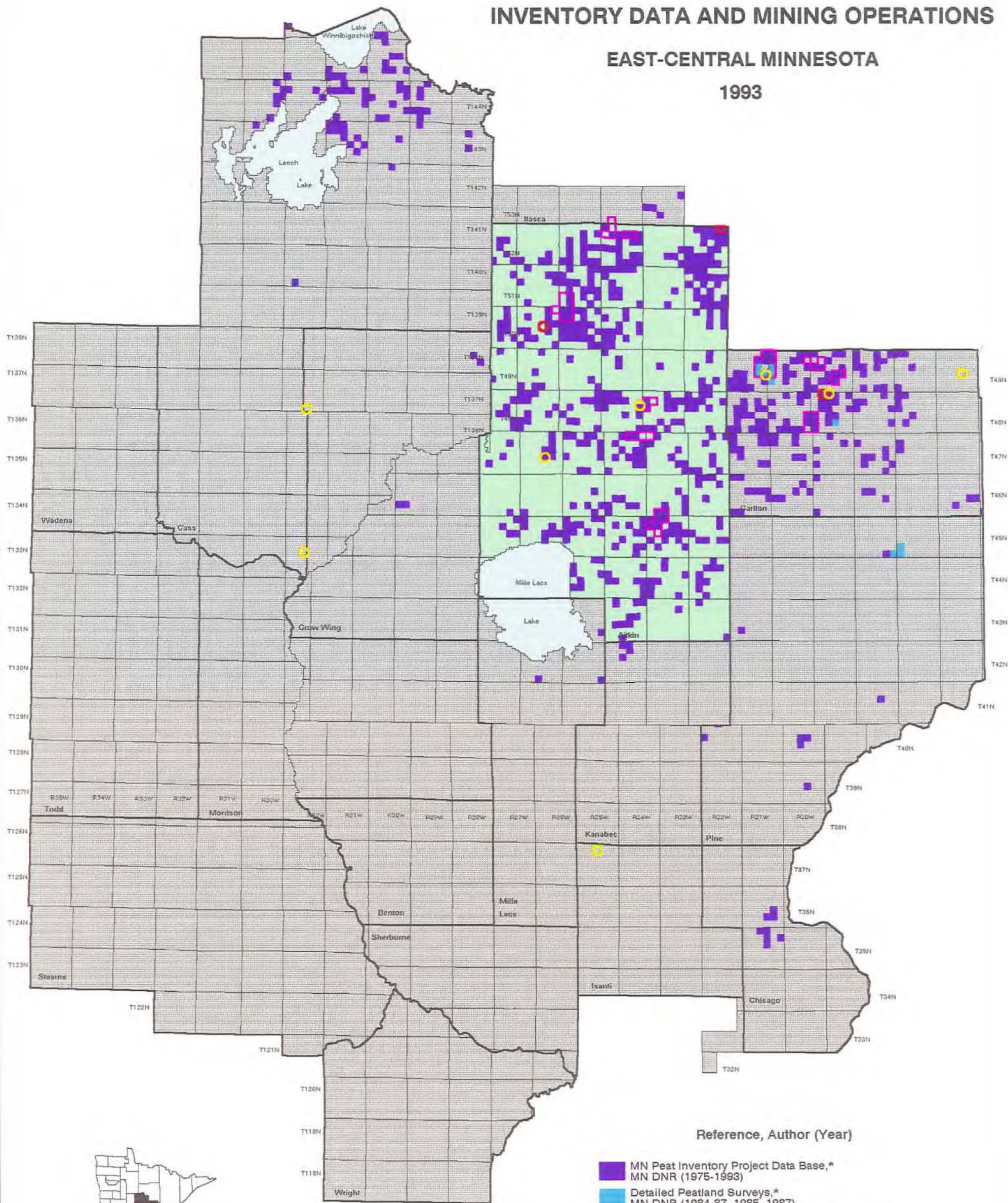
- | Areas covered by references | Boundaries of areas covered by references |
|---|---|
| <ul style="list-style-type: none"> ■ USDA SCS* County Soil Surveys:
Anoka - Chamberlain (1977)
Benton - Sutton (1977)
Carlton - Lewis (1978)
Crow Wing - Arneman, et al. (1965)
Isanti - Farnham, et al. (1958)
Itasca - Nyberg (1987)
Kanabec - McMiller, et al. (1939)
Mille Lacs - Bodman (1932)
Pine - Simmons, et al. (1941)
Sherburne - Grimes (1968)
Stearns - Sutton (1985)
Todd - Saari (1990)
Wadena - Aldeen (1991)
Wright - Edwards (1968) | <ul style="list-style-type: none"> — USDA SCS* (1974a, 1974b) - General Soil Map — USDA SCS* (1974c) - General Soil Map
Mooers (198? unpublished) — Lehr (1993) — Eng (1978) — Eng & Katsoulis (1984) — Lehr (1991) |
| <ul style="list-style-type: none"> ■ Counties with USDA SCS* Soil Surveys in Process | |

* U.S. Dept. of Agriculture, Soil Conservation Service

PEAT RESOURCES INVENTORY DATA AND MINING OPERATIONS

EAST-CENTRAL MINNESOTA

1993



Map produced by
Minnesota DNR
Division of Minerals

Reference, Author (Year)

- MN Peat Inventory Project Data Base,*
MN DNR (1975-1993)
- Detailed Peatland Surveys,*
MN DNR (1984-87, 1985, 1987)
- Aitkin County Peat Resources Map and Report,
MN DNR (1981, 1982)
- Peat Sampling Reports,*
IRRR (1965a-d, 1967a-b, 1970a-b)
- Sphagnum Moss Peat Deposits Report, Malterer, et al. (1979)
Peat Deposits of Minnesota Report, Soper (1919)
- Active Peat Mining Operations,
MN DNR (1985-1993)
- Past Peat Mining Operations,
MN DNR (1985-1993)

* 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

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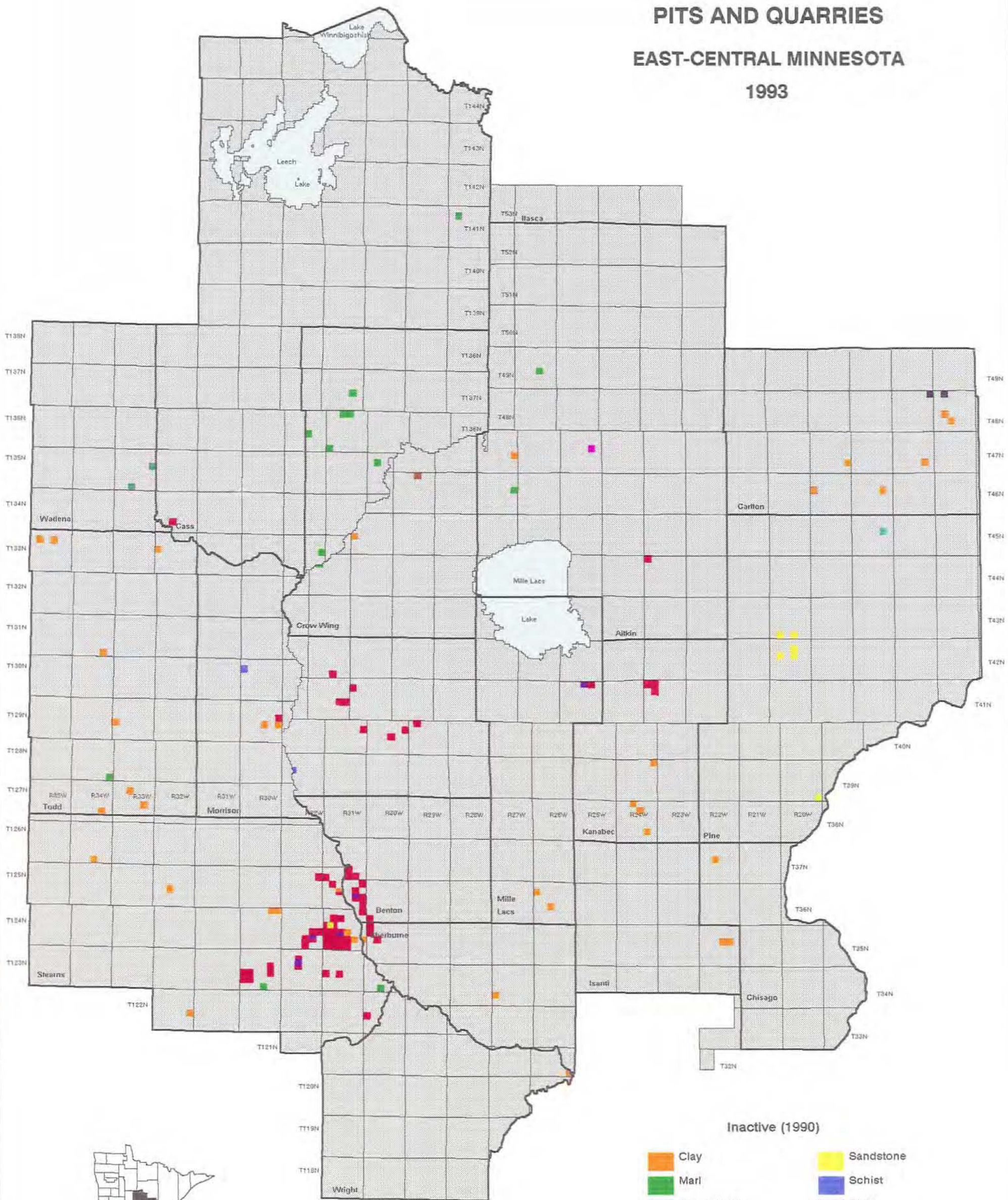
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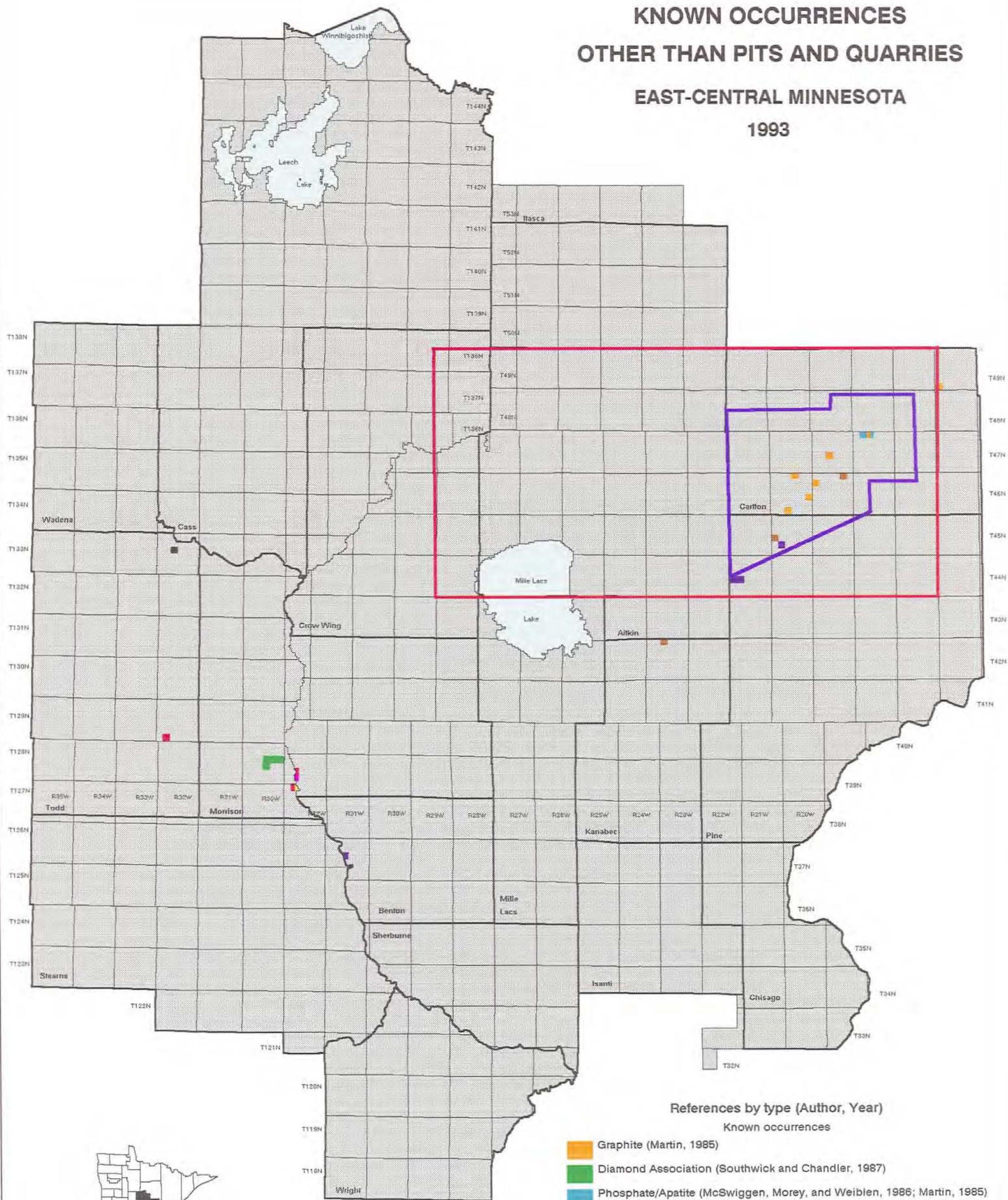
INDUSTRIAL MINERALS PITS AND QUARRIES EAST-CENTRAL MINNESOTA 1993



Map produced by
Minnesota DNR
Division of Minerals

- | | |
|---|--|
| Inactive (1990) | |
| ■ Clay | ■ Sandstone |
| ■ Marl | ■ Schist |
| ■ Silica Sand | ■ Slate |
| ■ Granite | ■ Mine Tailings |
| ■ Quartzite | |
| Active (1990) | |
| ■ Dimension Granite | |
| ■ Crushed Granite | |

INDUSTRIAL MINERALS KNOWN OCCURRENCES OTHER THAN PITS AND QUARRIES EAST-CENTRAL MINNESOTA 1993



Map produced by
Minnesota DNR
Division of Minerals

References by type (Author, Year) Known occurrences

- Graphite (Martin, 1985)
- Diamond Association (Southwick and Chandler, 1987)
- Phosphate/Apatite (McSwiggen, Morey, and Weiblen, 1986; Martin, 1985)
- Staurolite & Garnet (Nelson, Oberhelman, and Olson, 1990) (Martin, 1985)
- Staurolite (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)

THEME: SAND AND GRAVEL RESOURCES

Author: J.D. Lehr

Maps: Sand and Gravel--
Reference Maps
Sand and Gravel--
Occurrences &
Prospects

Sand and gravel aggregate is a mineral commodity that is currently mined in every county in east-central Minnesota. All of these counties have at least some sand and gravel reserves, however, a pressing issue facing both planners and aggregate producers is that the resource is often not located near where it is needed because of depletion and preemption of sand and gravel mining by other land uses. The alternative to local sources of sand and gravel is transportation from a distant source, which can very quickly double the price of this low-value, high-volume mineral commodity. This summary of information on sand and gravel resources is intended to direct both planners and aggregate producers to the types of information that may be useful in making wise decisions about this mineral resource.

The two maps presented in this section are indexes to two types of data that are useful in assessing sand and gravel aggregate potential: geologic maps of surficial materials and aggregate potential data collected by the Minnesota Department of Transportation (Mn/DOT).

The Sand and Gravel Reference Maps index shows some of the maps that can be used to assess sand and gravel aggregate potential in east-central Minnesota. This index depicts only reports in which interpretation of the distribution of surficial materials was the primary focus. Most of these maps are not aggregate potential maps, but are geologic maps of surficial materials, therefore, the aggregate potential of the various mapping units needs to be inferred from the geologic map legend for each map. In addition, most of the maps indexed are not widely available. Other maps that may be useful in assessing sand and gravel aggregate potential are soils maps or maps of surficial materials (including surficial aquifers) that accompany water resource investigations. These are not shown on the index map, but are included in the bibliography. The soils maps references can be found in the Peat Resources theme bibliography section.

The Sand and Gravel Occurrences and Prospects map shows areas for which data on aggregate resources are available. These locations were exported from the Aggregate Source Information System (ASIS) and Aggregate Prospect System (APS) databases maintained by the Mn/DOT Office of Materials Research and Standards in Maplewood.

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.*

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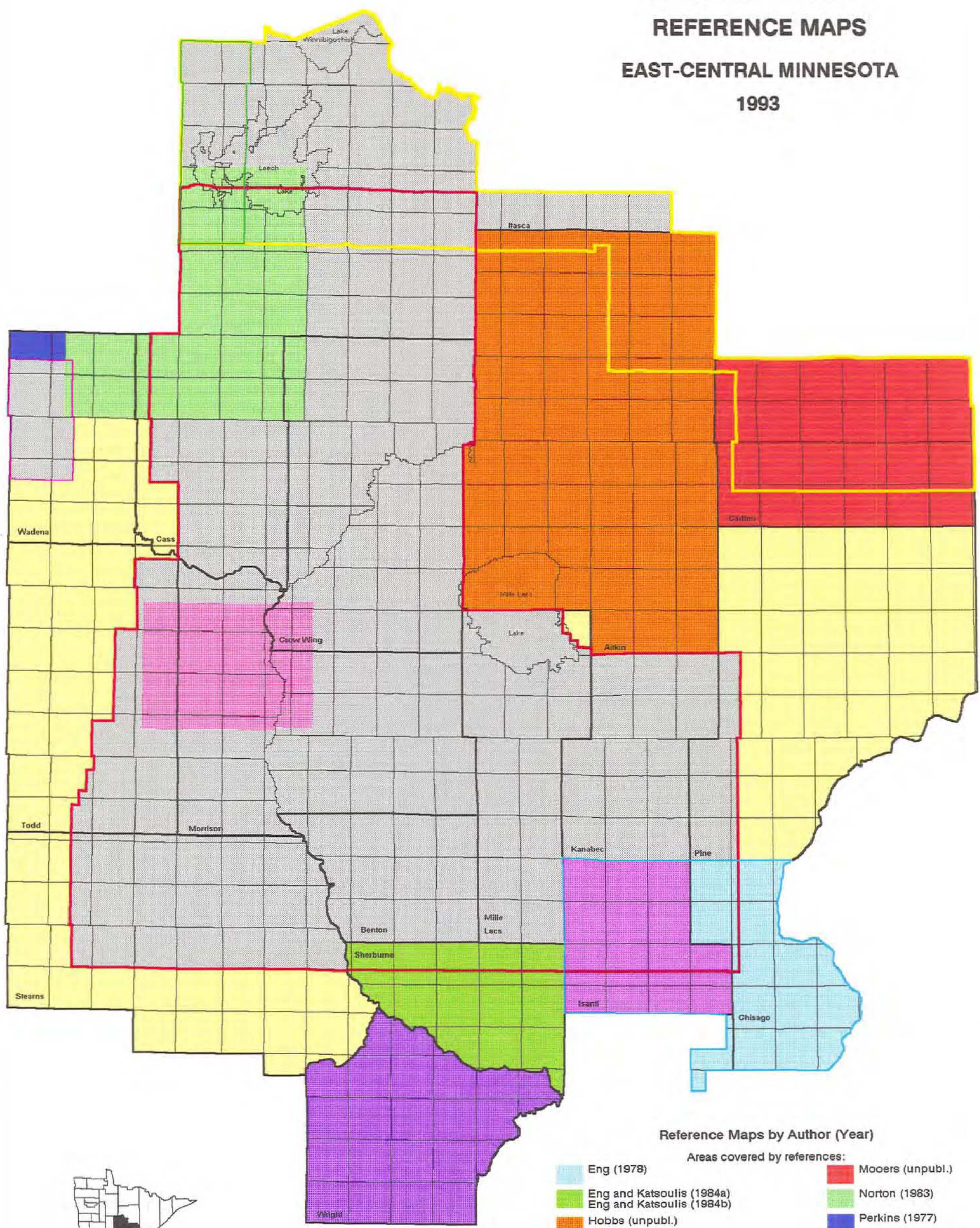
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SAND AND GRAVEL REFERENCE MAPS EAST-CENTRAL MINNESOTA 1993



Map produced by
Minnesota DNR
Division of Minerals

Reference Maps by Author (Year)

- Areas covered by references:
- Eng (1978)
 - Mooers (unpubl.)
 - Eng and Katsoulis (1984a)
 - Norton (1983)
 - Eng and Katsoulis (1984b)
 - Perkins (1977)
 - Hobbs (unpubl.)
 - Schneider (1961)
 - Lehr (1991)
 - Lehr (1993)

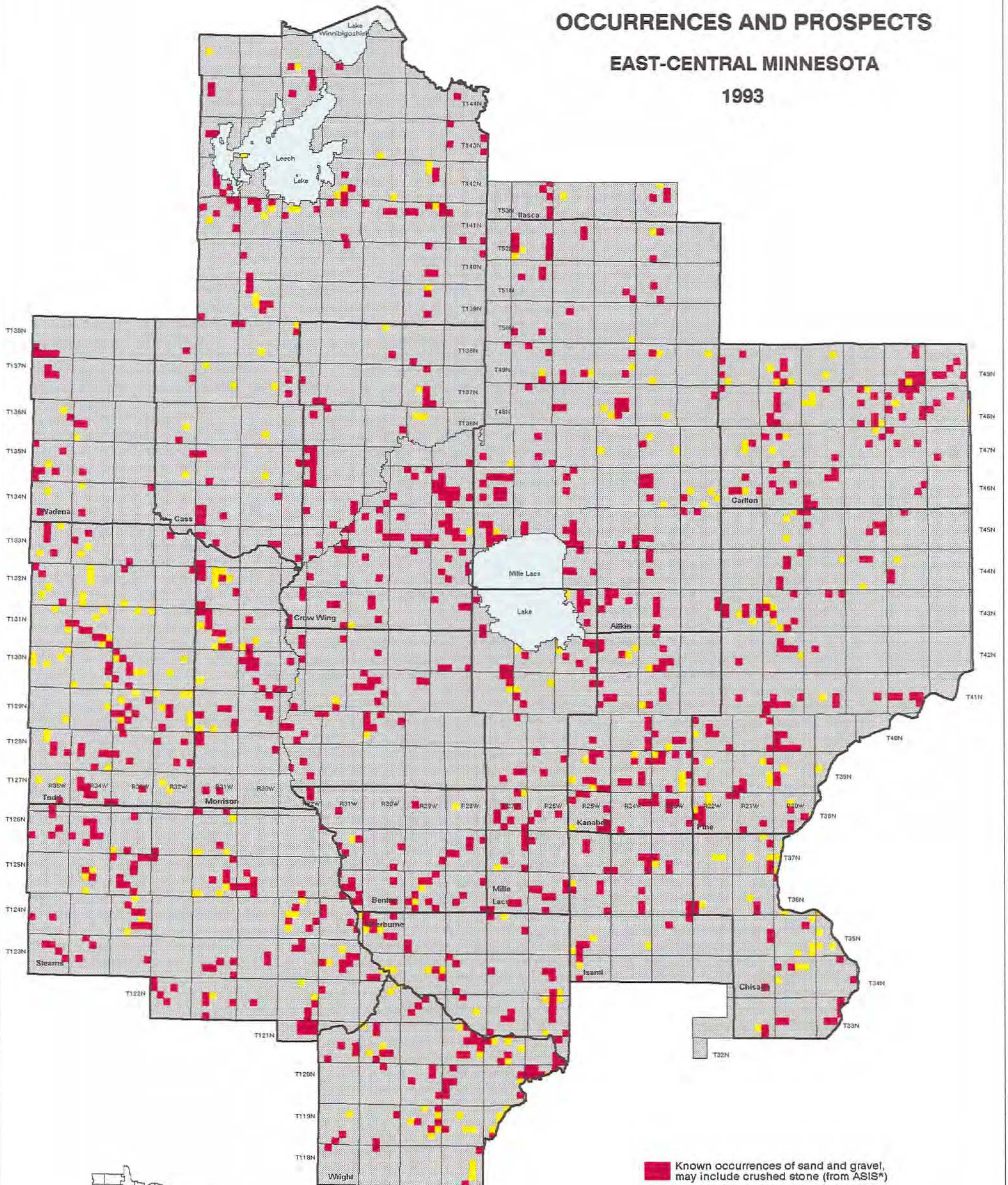
■ Hobbs and Goebel (1982) covers the entire area, but is the only reference in this colored area

Boundaries of areas covered by references:

- Anderson (1976)
- Mooers (1988)
- Dobbs and Mooers (1990)
- Sackreiter (1975)
- Eng (1978)

■ Area is covered by one or more of the five references depicted by boundaries

SAND AND GRAVEL OCCURRENCES AND PROSPECTS EAST-CENTRAL MINNESOTA 1993



- 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

Map produced by
Minnesota DNR
Division of Minerals

THEME: IRON ORE AND MANGANESE RESOURCES

Author: Tim Pastika

Map: Iron Ore and Manganese--
Locations & References

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 Cuyler 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 in the 1920's-30's. 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 BIBLIOGRAPHY

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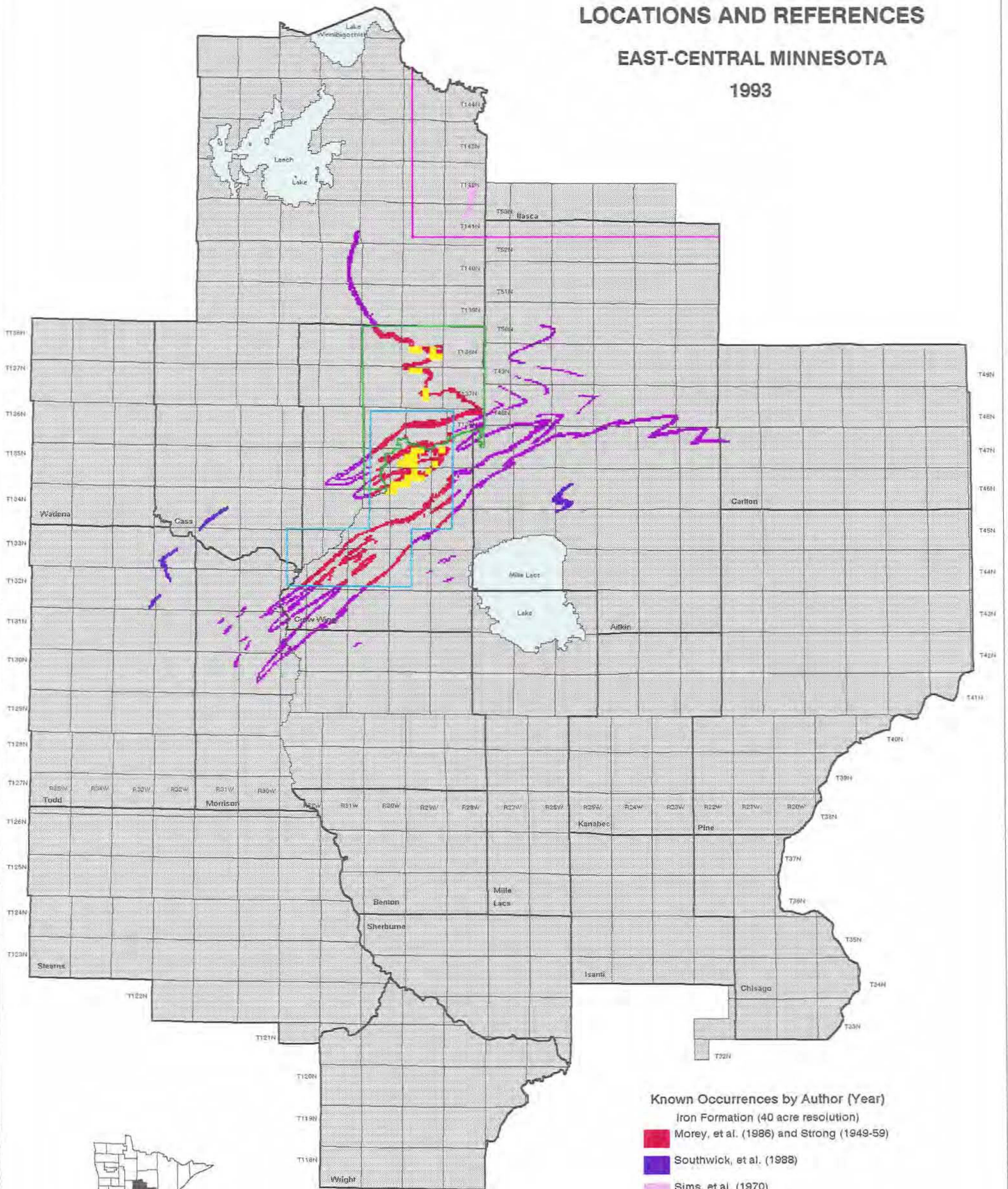
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IRON ORE AND MANGANESE LOCATIONS AND REFERENCES

EAST-CENTRAL MINNESOTA

1993



Map produced by
Minnesota DNR
Division of Minerals

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. (1986)
- Strong (1949-59)
- Sims, et al. (1970)

THEME: OTHER SPECULATIVE MINERALS

Author: Richard Ruhanen

**Maps: Gold-Known Occurrences
Base Metals-Known Occurrences
Chromium, Titanium, & Vanadium-Known Occurrences
Indicator Minerals-Known Occurrences**

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:
Au, Ag, Pt, Pd, Ir, Os, Rh, Ru, Cu, Pb, Zn, Ni, Mo, Co, V, Cr, Ti, Sn, W, Hg, Cd, Bi, Te, Se, Ba, F, Li, U, Th, Be, Nb, Ta, P, Sb, As, B, S
 - 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:

	<u>(ppm)</u>
Cu, Zn, Pb, Ni, Cr	500
Co	250
Mo	30
As	20
V	1500
Ti	10%
P	5000
F	5000

Ba	5000
U	50
U ₃ O ₈	100
Th	150
Au	0.1 (.003 oz/t)
Ag	1

"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.

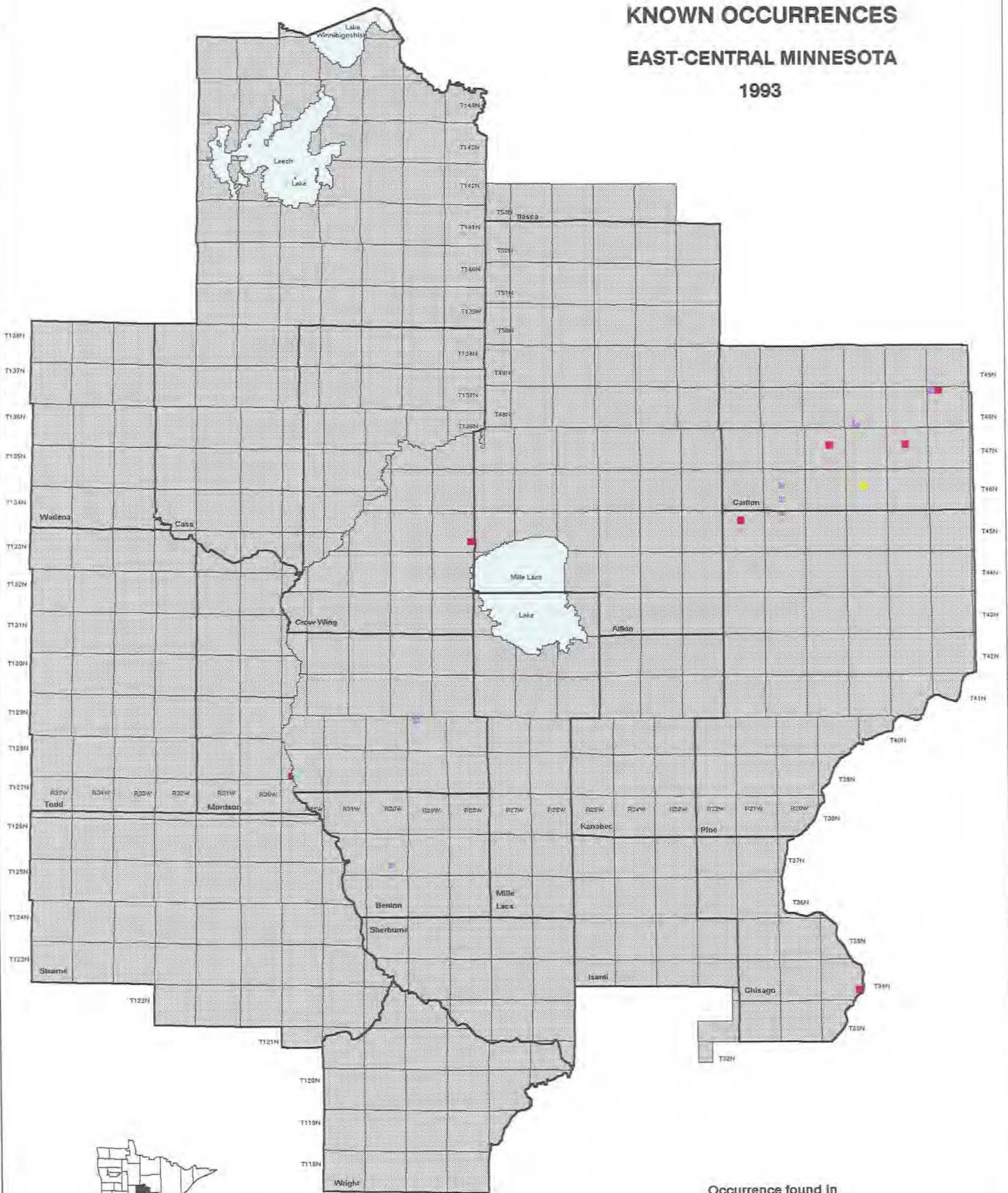
"For the indicator minerals, any combination of two of the following had to occur to be cited: pyrite, pyrrhotite, and/or the above indicator minerals."

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).

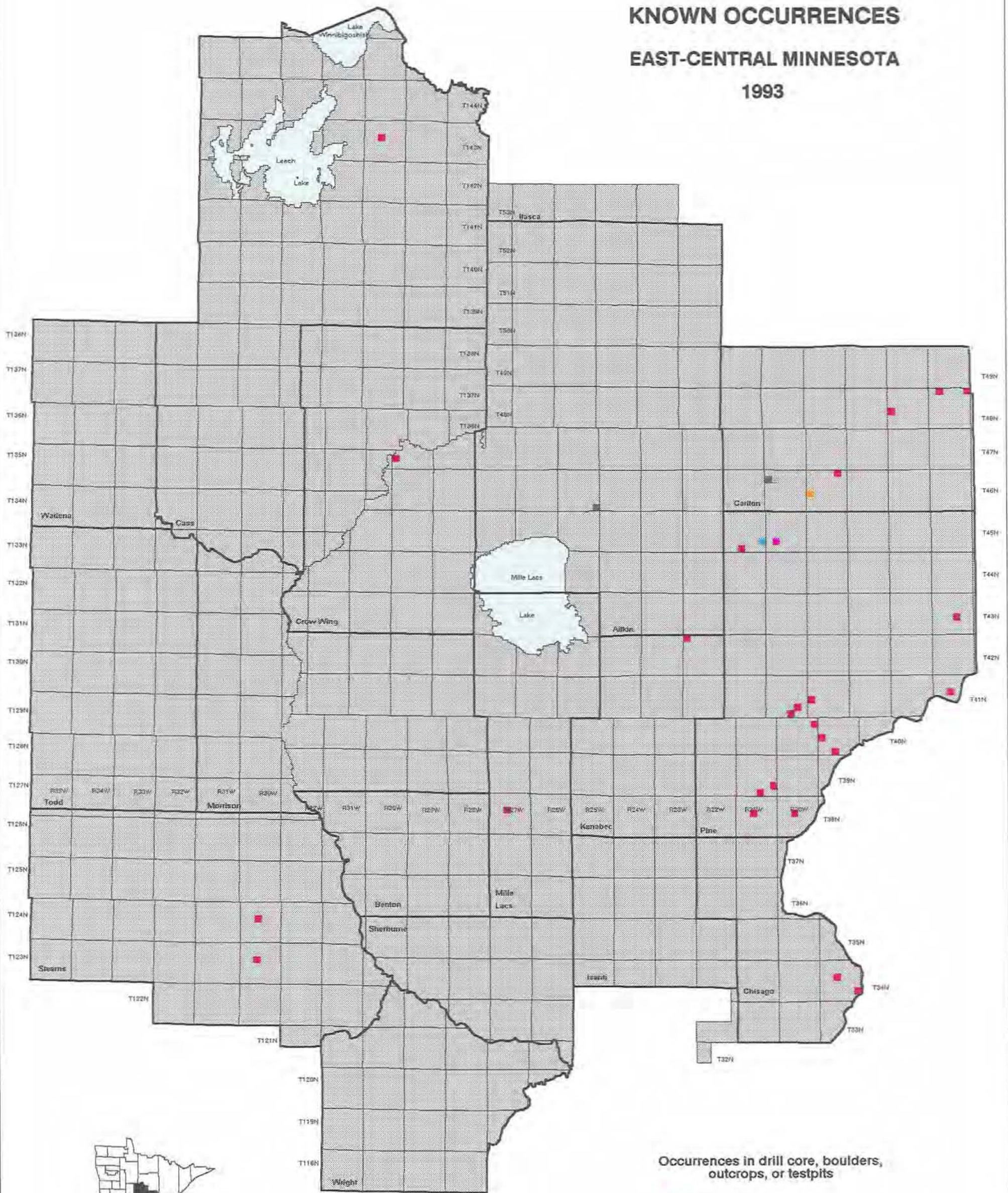
GOLD KNOWN OCCURRENCES EAST-CENTRAL MINNESOTA 1993



- Occurrence found in
- Outcrop
 - Drill Core
 - Testpit
 - Boulder

Map produced by
Minnesota DNR
Division of Minerals

BASE METALS KNOWN OCCURRENCES EAST-CENTRAL MINNESOTA 1993

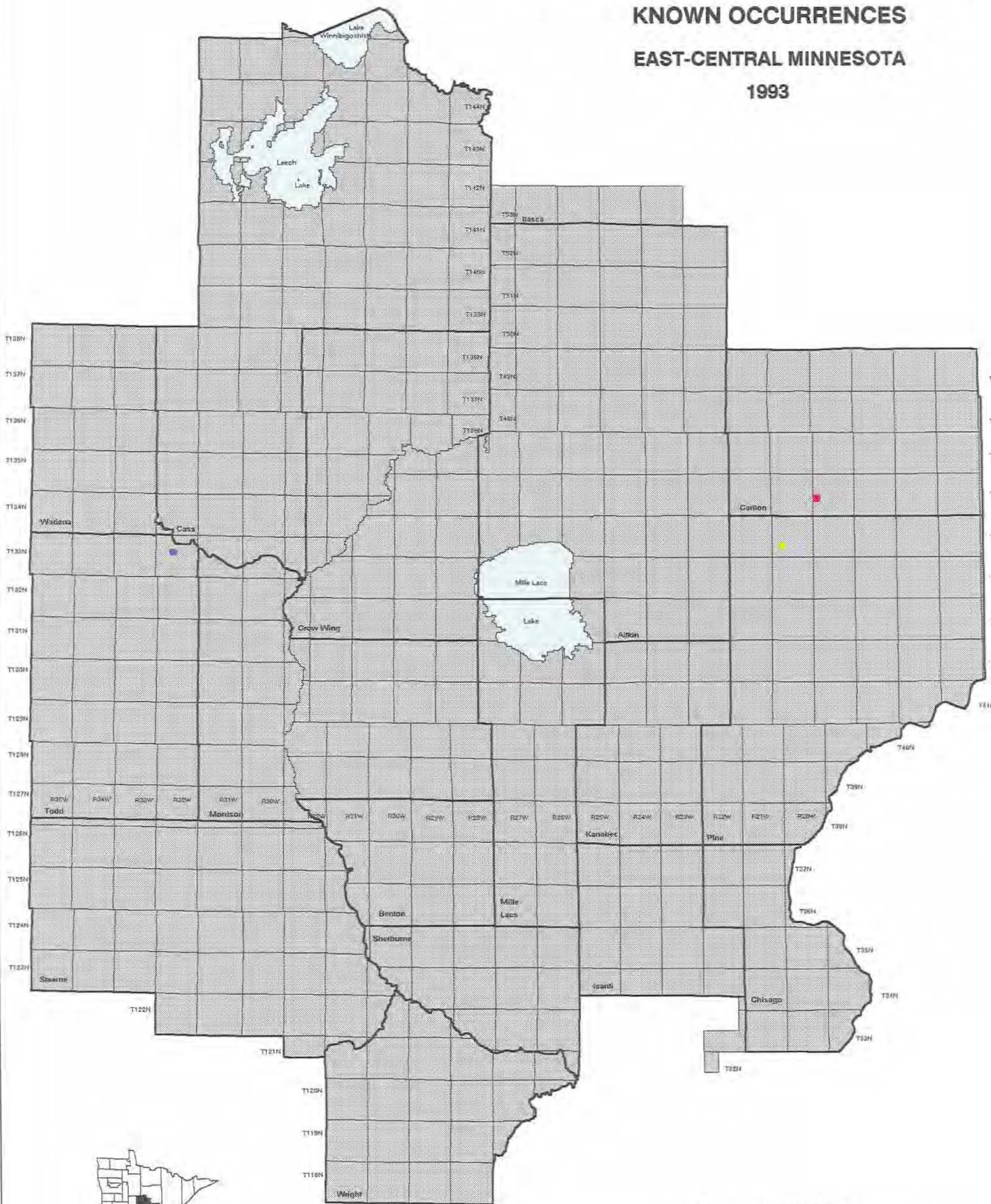


Map produced by
Minnesota DNR
Division of Minerals

Occurrences in drill core, boulders,
outcrops, or testpits

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

CHROMIUM, TITANIUM, AND VANADIUM KNOWN OCCURRENCES EAST-CENTRAL MINNESOTA 1993

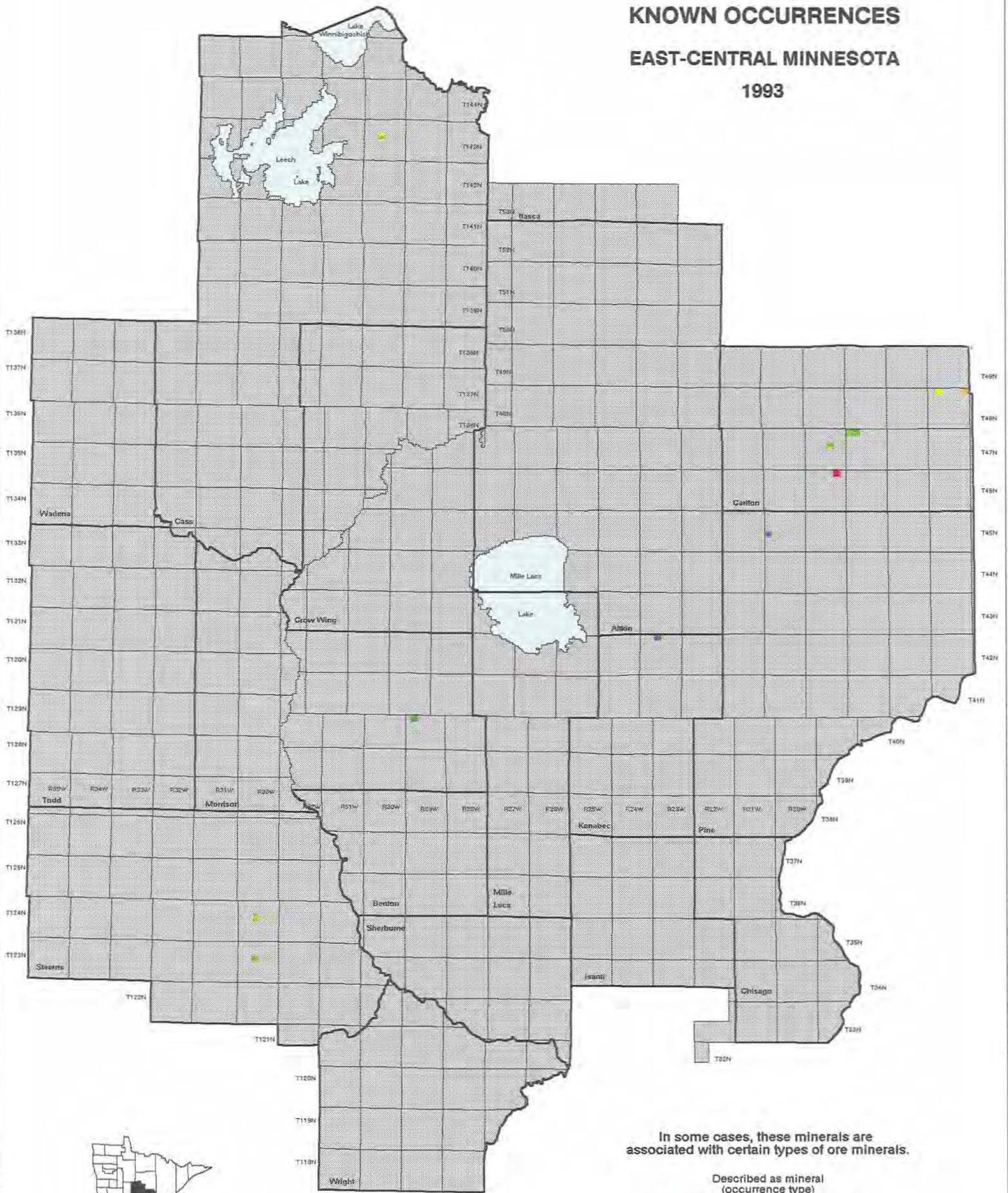


Occurrences in drill core

- Vanadium + Chromium + Titanium
- Vanadium
- Titanium

Map produced by
Minnesota DNR
Division of Minerals

INDICATOR MINERALS KNOWN OCCURRENCES EAST-CENTRAL MINNESOTA 1993



Map produced by
Minnesota DNR
Division of Minerals

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) |
| ■ | Pyrite
(testpit) |
| ■ | Garnet
(outcrop) |

GEOCHEMISTRY BIBLIOGRAPHY

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Bradshaw, P., Clews, D., and Walker, J., 197?, Exploration Geochemistry [second edition]: Golden, Colorado, Barringer, p. 4.

Lively, R. S., Jameson, R., Alexander, E. C. J., and Morey, G. B., 1992, Radium in the Mt. Simon-Hinckley Aquifer, East-Central and Southeastern Minnesota: St. Paul, Minnesota, University of Minnesota, Minnesota Geological Survey Information Circular 36, 58 p.

Lively, R. S., and Morey, G. B., 1985, Ground-water geochemical atlas for parts of east-central Minnesota: Minnesota Geological Survey, Miscellaneous Map Series Map M-58 Map 5 pls., scale 1:600,000.

Martin, D. P., Meyer, G., Cartwright, D. F., Lawler, T. L., and Pastika, T., 1989, Regional Geochemical Survey of Glacial Drift Drill Samples Over Archean Granite--Greenstone Terrane in the Effie Area, Northern Minnesota, 2 vols.: St. Paul, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Report 263.

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

Morey, G. B., and Lively, R. S., 1980, Detailed Geochemical Survey for East-Central Minnesota, Geology and Geochemistry of Selected Uranium Targets: St. Paul, Minnesota, Minnesota Geological Survey, Report Number K/UR-32, 121 p.

Nelson, S. L., Sutley, S. J., and Tripp, R. B., 1992, Chemical and Mineralogical Analyses and Geological Characteristics of Heavy Minerals from Glaciofluvial Sediments in Minnesota: St. Paul, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, a Cooperative Project with the United States Geological Survey, 100 p.

Sellner, J. M., 1985, Lake Sediment Geochemical Survey of East-Central Minnesota: Hibbing, Minnesota, Minnesota Department of Natural Resources, Division of Minerals, Report 236, 12 plates, 32 p.

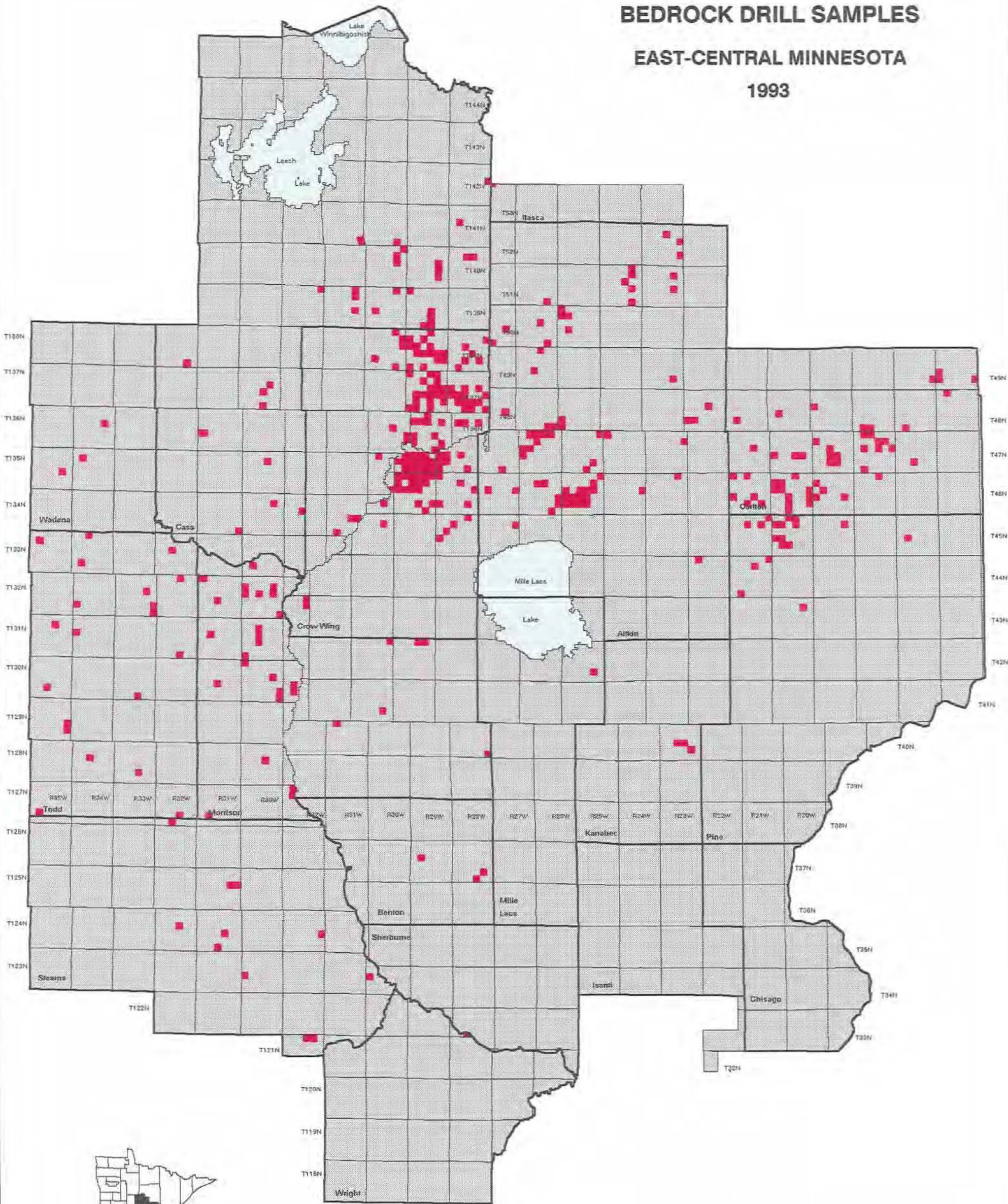
Shettel, D. L. J., and O'Hara, P. F., 1992, Reevaluation of Geochemical Data from East Central Minnesota: Boulder City, Nevada, GeoData Systems, 36 maps, 69 p.

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.

**MINERAL EXPLORATION DATA
BEDROCK DRILL SAMPLES
EAST-CENTRAL MINNESOTA
1993**



Drill Samples

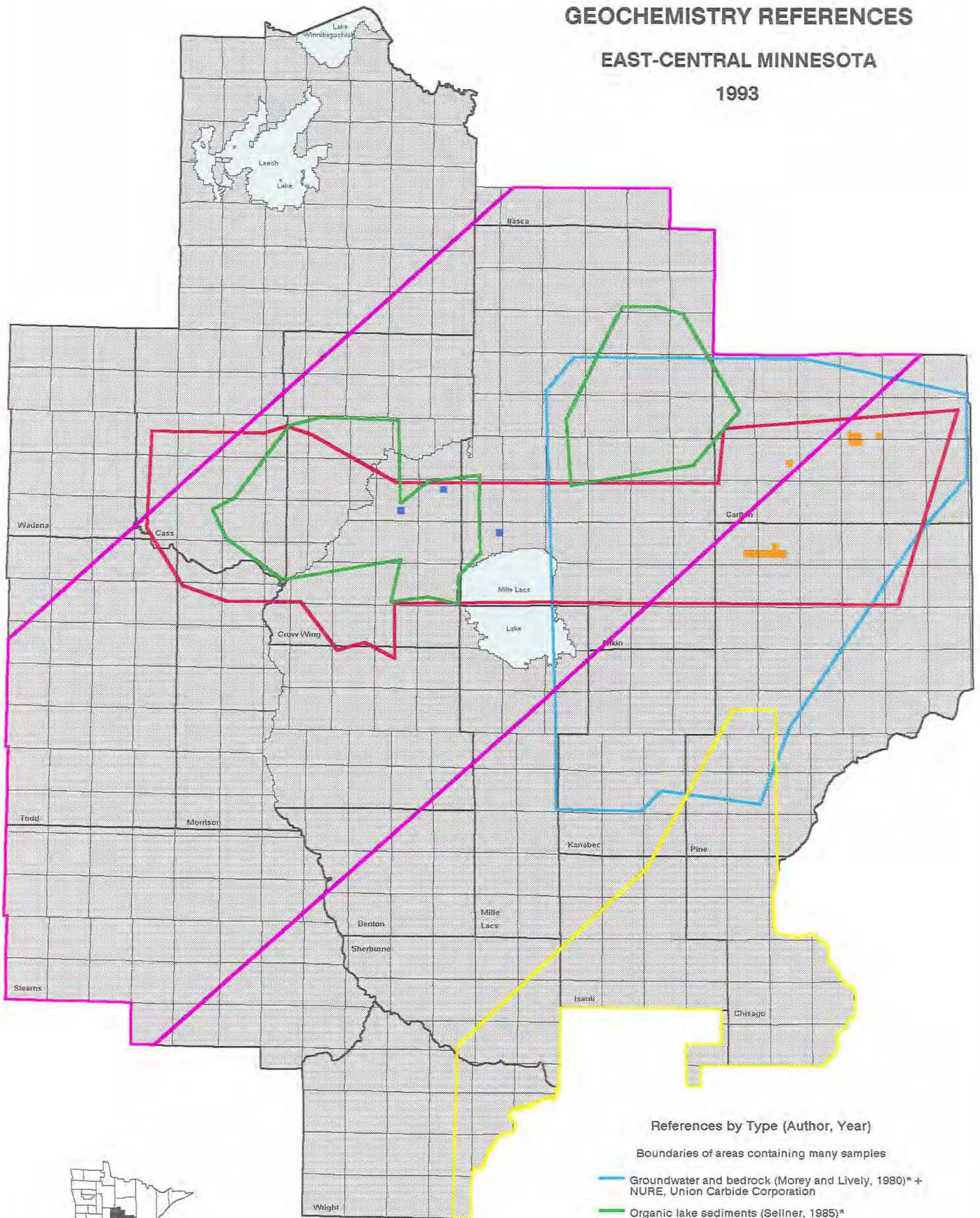
 government section containing one or more samples

Map produced by
Minnesota DNR
Division of Minerals

MINERAL EXPLORATION DATA GEOCHEMISTRY REFERENCES

EAST-CENTRAL MINNESOTA

1993



Map produced by
Minnesota DNR
Division of Minerals

References by Type (Author, Year)

Boundaries of areas containing many samples

- Groundwater and bedrock (Morey and Lively, 1980)* + NURE, Union Carbide Corporation
- Organic lake sediments (Sellner, 1985)*
- Wellwater (Beckwith and Clark, 1985)*
- Wellwater (Lively, et al., 1992)
- Heavy minerals from glaciofluvial sediments (Nelson, Sutley, and Tripp, 1992)

* Data re-evaluated by Shettel & O'Hara (1992)
+ Data re-evaluated by Lively and Morey (1985)

Government section containing one or more samples

- Miscellaneous soil, water, and boulders (MN DNR Assessment Files)
- Overburden drill core (Martin, et al., 1989)