MINERAL DIVERSIFICATION PLAN FOR MINNESOTA

Prepared By

MINNESOTA MINERALS COORDINATING COMMITTEE

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EXECUTIVE SUMMARY

Minnesota has a long history of iron ore and taconite production, but now needs to stimulate statewide development of other mineral commodities for the future. At the same time, the state must support the existing taconite industry and examine possibilities for added-value processing of that commodity.

The benefits to the state of mineral diversification include private investment in exploration, regional stability based on a diversity of mineral products, increased employment, and greater returns via taxes and royalties.

Although the surface geology hides most of the bedrock in Minnesota, current geological knowledge indicates highly favorable conditions for the discovery of a wide range of mineral deposits ranging from precious metals through non-ferrous and strategic metals to industrial minerals and construction materials. An existing mining-related infrastructure is also a positive factor.

The state role therefore is to establish and provide continuing support for mineral programs in state agencies and the university. State programs should aim at:

- Improving the competitive position of Minnesota taconite pellets.
- Extending the taconite industry by producing semi-finished or finished products.
- Increasing the probability of a precious or base metals discovery by improving the level of geologic knowledge.
- Increase private industry mineral exploration efforts.
- Enhancement of the industrial minerals industry.
- Basic research in minerals.

These programs will provide information and technology which will encourage mineral companies to come to Minnesota. Well-defined, applied projects can be assembled in each major area to address specific commodity or regional opportunities, by drawing on the available expertise and facilities.

Mineral resource development is a lengthy and complex undertaking and short-term gains from state initiatives to stimulate mineral development cannot be expected in all areas. On the other hand, there are many examples where a steady long-term effort has led to significant economic growth. The best results will be obtained with continuing, stable funding over several biennia.

The Minnesota Mineral Diversification Plan describes funding for existing programs to accelerate the development of critical basic geologic information and to carry out several well-targeted applied projects leading towards diversified mineral development.

This document contains a framework for the next 10 years and a plan for the next biennium. These have been designed by the Minerals Coordinating Committee. The plan is coordinated with other requests submitted by the Department of Natural Resources and the University of Minnesota. It shows the priorities for the work which will be undertaken should the legislature decide to provide additional funds for mineral diversification, either as a change to the DNR budget, or as direct appropriations to the organizations involved.

MINERAL DIVERSIFICATION PLAN
FOR
MINNESOTA

INTRODUCTION

What is the goal of the Mineral Diversification Plan? The goal of the plan is to stimulate development of the mineral resources in rural Minnesota. The plan emphasises diversification but also includes research and development to reduce costs for the state's taconite industry and enhance its position through the development of higher-valued products.

What is mineral diversification? Diversification expands the mineral base of Minnesota's economy. It is the discovery and development of a variety of metallic minerals such as gold, silver, platinum, copper, nickel, cobalt, and titanium. It also includes expansion of the industrial minerals industry in Minnesota, such as clays, dimension stone and silica sand. Figure 1 shows the variety of minerals which have generated exploration interest in recent years. Geologic studies have shown that these minerals have excellent potential to occur in Minnesota. Diversification also includes processing minerals into higher value, semi-finished or finished products, e.g., steel production, or clay processed for the paper industry.

Why is it needed? Minnesota's mineral economy is tied primarily to taconite pellet production, so the northern Minnesota economy is adversely affected by the current decline in the steel industry. Diversifying into other types of mineral mining along with value-added processing of taconite pellets will result in a growing, more stable, statewide rural mineral economy.

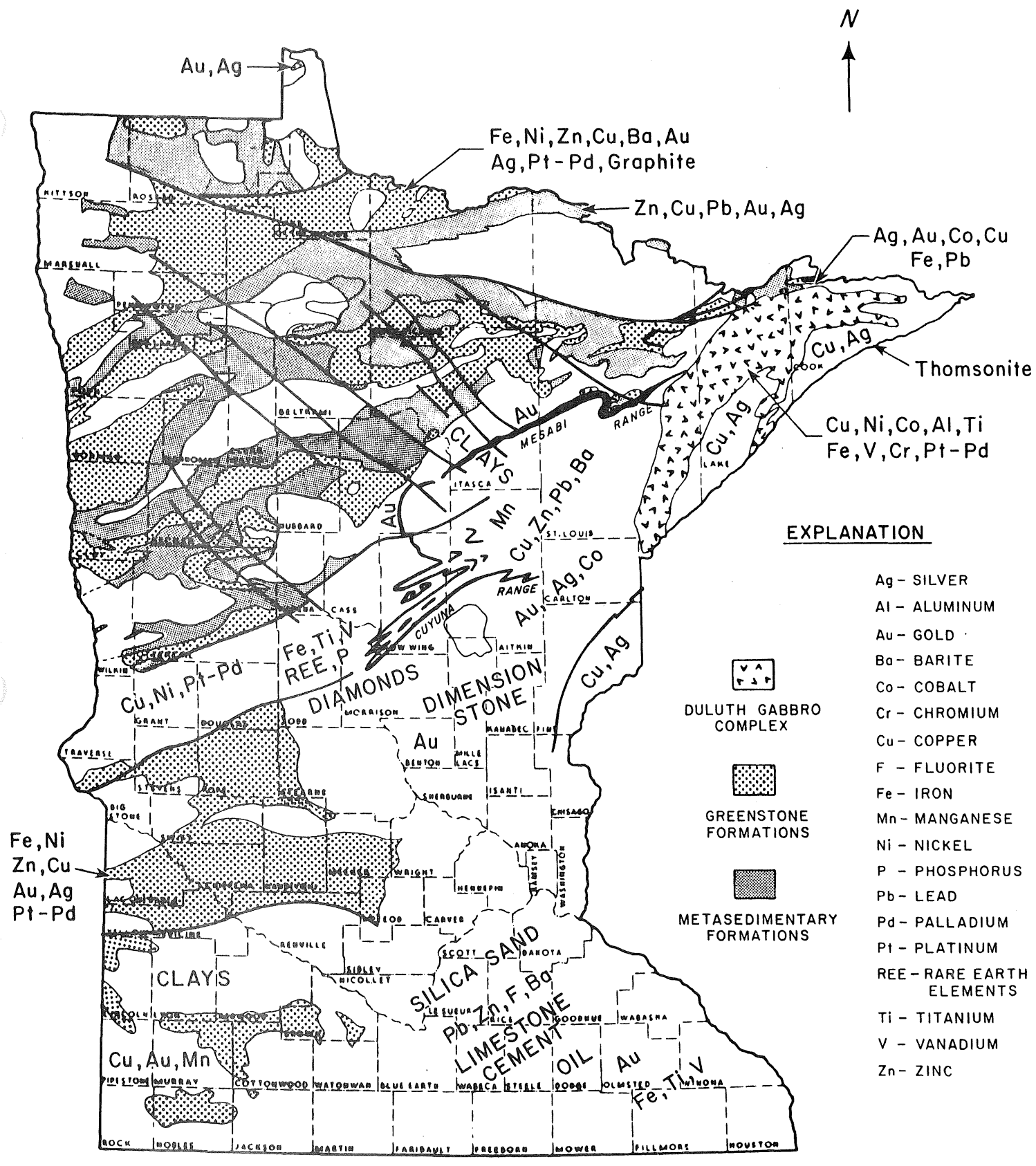
Diversification should aid rural areas throughout the state, since the potential for valuable minerals is widespread. As indicated in the recommendations contained in the report of the Governor's Commission on the economic future of the state, "diversification" and "development of adequate levels of income and jobs for the population" are two of the main goals recommended for state policy. For minerals specifically, the state should "...identify new mineral products...undertake a more comprehensive mineral's survey, and...develop a more comprehensive mineral's development policy".

How will Minnesota benefit? The benefits of investing in mineral diversification include:

1. Increased private expenditures in Minnesota by exploration companies.

2. Increased potential for the discovery of economically viable mineral resources.

3. Greater regional stability through the development of a range of mineral resource industries.



RECENT EXPLORATION ACTIVITY BY COMMODITY

FIG. 1

Arrows leading to patterned rock units do not indicate a specific site. A deposit could occur at any location within these areas.

The indicated potentials are those currently being considered by industry but do not include all possibilities.

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4. Increased employment in rural areas through job creation in exploration, mining and processing industries.

5. Increased indirect employment in service and support industries.

6. Greater returns to local and state governments through taxes and royalties. All state school districts benefit from the revenues earned in the School Trust Fund. About 80% of the fund is from mineral taxes and royalties.

State agency and university efforts do have a positive impact on mineral development activities. A recent example of increased exploration activity is leasing in areas where chrome, platinum, and gold occurrences were identified and publicized.

PROGRAM RATIONALE

Background. Minerals have played a significant part in the economic and geographical development of Minnesota. Minnesota ranks third in the nation in total non-fuel mineral production, and first in iron ore and taconite production. Among other mineral commodities produced in Minnesota, the ranking compared to all other states is 7th in peat, 10th in sand and gravel, 11th in industrial sand and dimension stone, 18th in lime, 29th in crushed stone, and 40th in clay. In terms of value and employment, iron ore and taconite have been the primary source of benefits. Taconite development has produced significant spin-off industries, as 2300 Minnesota businesses supply goods and services to this industry. At this time, Minnesota's mineral economy is dominated by taconite. Therefore, it is strongly affected by the fluctuations and cycles of the steel industry.

Minnesota has derived substantial benefits from the iron ore mining industry and should plan for additional benefits. However, economic stability in much of rural Minnesota must be tied to Minnesota's excellent potential for diversification into mining other types of metals, such as gold, silver, platinum, titanium, manganese, copper, nickel and cobalt; and industrial minerals, along with seeking to lower costs, improve quality, and provide added-value for iron mining products. Diversification can only occur from a long-term commitment to mineral development. The taconite industry is more mature, and subject to foreign competition. Its needs do not lie in the areas of exploration and mine development. However, the industry does need research and product development support to maintain and enhance its competitive position.

Geologists have said for many years that the geology of Minnesota shows high potential for development of a non-ferrous metals mining industry. Ontario, with a geological environment similar to Minnesota, mines a variety of minerals including nickel, gold, silver, copper, zinc, uranium, and iron ore. Ontario's total annual mineral product value is over four billion dollars, which is more than twice Minnesota's. Also, Ontario's mining employment is over four times Minnesota's. Eleven

different minerals each contribute more than $100 million per year. Thirty years ago the value of mineral production in Minnesota and Ontario was equal, but Ontario historically had a diverse mineral economy. The province developed successful programs to encourage exploration. Their programs include:

1. A positive attitude to mineral resource development.

2. Administrative and legislative commitment.

3. Making lands available for exploration.

4. Sharing development risk by taxation policies and incentives.

5. Streamlining regulatory policies and procedures.

6. Support for increasing the level of geologic and mineral potential knowledge.

Several of these program elements already exist to a greater or lesser degree in Minnesota. However, the state lacks sufficient geologic and mineral potential knowledge for non-ferrous minerals.

Significant gains can also be made working with the existing mining industry. Improvement of taconite pellet quality, and cost reductions can make Minnesota taconite more competitive at Great Lakes ports. While vertical integration of mineral resource production is practiced, the production of higher-added-value products near the mines in Minnesota has not been practiced by the major mineral resource companies and, in most cases, the functions of raw material production and metallurgical processing are separated. This is unfavorable from a regional point of view since there are significant benefits to be derived for our region from encouraging the greatest amount of added-value processing at, or close to, the mineral resource location. For example, the value of taconite pellets is about $30 per ton, while steel slabs are worth about $200/ton, and engineering castings about $1200/ton.

How does mineral development occur? The development and commercialization of a mineral resource is a lengthy, complex, and costly process whose major components are: exploration, evaluation, development, production, and reclamation. To attract exploration, the state must convince companies that expenditures of exploration dollars in Minnesota are worthwhile. Private industry will then make the investments needed to discover and develop mineral deposits.

Minnesota is in worldwide competition to attract industry exploration expenditures and mineral development. Corporate decisions on where to initiate an exploration and development program are based on evaluating the following points:

1. Type of mineral commodity of interest.

2. Mineral potential of the area.

3. Level of understanding of regional geology.

4. Availability of detailed local geological information.

5. Local political, economic and environmental considerations.

6. Availability of land for exploration.

7. Regional industrial infrastructure.

8. Availability of trained work force.

9. Regional mining tradition.

What is an appropriate state role? Pursuit of new mineral resources usually occurs in geological areas with the highest probability for successful discovery. Because of this the role of the state is to develop geologic and mineral potential data which serves as the framework to attract exploration, and to provide the political and economic climate that makes development predictable and attractive. This translates directly to a program that encompasses geologic and mineral potential mapping using a variety of techniques, and a strong mineral leasing program which uses the geologic data to provide new exploration targets. Figure 2 illustrates this by showing the long-term objective of the state effort. Exploration itself, however, is best left to private industry.

Besides geology, other factors relating to support and predictability are important. Mineral resource companies are being attracted to states and countries with a clearly defined, positive policy toward mineral resource development.

Can state funding accelerate mineral development? Yes. The accelerating interest in Minnesota's mineral resources by private companies demonstrates this. A measure of this is the amount of exploration activity generated by state expenditures to date. In 1980 the state had 21 non-ferrous mineral leases covering 5,248 acres, held by three companies. In 1986 the state had 660 leases covering 268,563 acres, with 22 companies actively exploring in Minnesota. There is also private and federal leasing of substantial areas - at least equal in total acreage to state leasing. This increased exploration is the result of an active mineral leasing program which has aggressively promoted the mineral potential of Minnesota. New high resolution aeromagnetic surveys showing potential for diamond and other minerals, and surveys indicating gold and platinum targets have been conducted by state agencies and have increased private exploration. There is also strong interest in expanded use of Minnesota clays and other minerals as shown in Figure 1. Companies have spent more than $40 million in the last several years exploring in Minnesota. While this activity is encouraging, we must work toward increasing the level of interest by making Minnesota more attractive for mineral exploration and development.

Figure 2. Mineral Diversification Long Term Goals and Objectives

GOAL STATEMENT

The Stimulation of Mineral Resource Development in Minnesota
- creating jobs in rural Minnesota
- increasing revenue to State
- increasing mineral value produced in Minnesota
- establish more stable economy throughout Minnesota

OBJECTIVES

Improve and Extend Minnesota Iron Industry

Improve

Example Projects

1. Develop Crush-conc Process Simulator
2. Drill-Blast-Computation System Analysis
3. Effect of Water Quality on Processing
4. Process System Optimization
5. Elimination of Rod Mills
6. Cooperative Technological Research with Industry

Extend

Example Projects

1. Development of Super-Reducible Pellet
2. Value-Added Process Development Direct Reduction
3. Specialty Steel
4. Process Modelling

Realization of a "Discovery" and Development of a Non-Ferrous Mining Industry

Increase Probability of Discovery

Example Projects

Geoscience Surveys

1. Geophysics
   - -Complete Aeromag Survey
   - -Borehole Geophysics
   - -Seismic
2. Geochemistry
   - -Glacial
   - -Regional Surveys
   - -Archean Greenstone Belts Duluth Complex
3. Remote Sensing
4. Geologic Mapping
5. Bedrock Drilling
6. Ore Deposit Modeling
   - -Define Characteristics of Other Deposits in Similar Geological Settings
   - -Compare Known Minnesota Geological Characteristics with Other Deposits
7. Resource Evaluation
8. Metallurgical Evaluation
9. Mineral Economic Evaluations

Increase Exploration Effort

Example Projects

1. Evaluate Tax Climate
2. Conduct Reclamation Studies
3. Data Base Mgmt. System
4. Mineral Services
5. Streamline Permitting Process
6. Disseminate Information
7. Regular State Mineral Lease Sales
8. Severed Mineral Ownership Research

Enhancement of the Industrial Mineral Industry in Minnesota

Example Projects

1. Clay Studies
2. Regional Resource Inventory
3. Market Specifications
4. Market Identification
5. State-wide Occurrence Mapping
6. Process Research Space Age Ceramics and Limestone Fluxing

The key factor controlling the rate of exploration at this time is the geologic data base. The major barrier to mineral discovery is the extensive glacial drift which covers the bedrock. The near-surface and known exploration targets are already under lease, so new target areas must be identified in the drift-covered areas of Minnesota. Minnesota's leasing program has shown that there is no substitute for cold, hard geologic facts when trying to attract mineral companies. Minnesota intends to provide the geologic framework and the regional evaluations of mineral potential in order to attract industry to Minnesota.

THE MINERAL DIVERSIFICATION PLAN

This plan was developed by the Minnesota Minerals Coordinating Committee. The recommended 10-year program is outlined in Table 1. It is based on a need to increase the level of knowledge of Minnesota's mineral potential and designed to achieve the goal of stimulating the development of Minnesota's mineral resources within a reasonable time. Ten years is a short time for mineral development, as the time required to develop a mine is often over five years. Beneficial results from exploration and development activities do begin occurring immediately, but the full benefit of diversifying Minnesota's mineral economy requires a long-term commitment. Funding for the 10-year program requires approximately $5.5 million per year for a total of $55 million.

Table 2 shows the plan for the first biennium. A general description for each F.Y. 88-89 program area is given in the appendix. The first biennial budget is designed considering priority needs in Minnesota to diversify and to retain a viable mineral economy. This initial program is the first step, and is based on the technical judgment of the committee. These results will be reviewed biennially, and program work will be adjusted to assure the most direct path towards accomplishing the plans objectives.

The Minerals Basic Research component of the plan is designed to provide the foundation for basic mineral research capabilities. Ten percent of the budget has been allocated to provide adequate University support in completing the program areas described in the plan. This funding would be used to build technical capability and expertise, and provide the resources to solve the applied problems.

Table 3 is a priority listing of programs. Three funding level alternatives are shown and the dollar amount recommended for each level. There are also several other mineral projects beyond current funding levels which are proposed to the legislature. The relationship of these projects to the Minerals Diversification Plan is also shown.

It is the committee's opinion that minerals diversification is extremely important and timely. It is best accomplished when there is existing company interest in Minnesota. This interest exists today and full funding of the plan provides the best opportunity to accomplish the goals of increased rural employment through mineral diversification. Lower levels of funding should also result eventually in achieving similar goals. However, the time required will be increased and results

TABLE 1: PROGRAMS AND FUNDING LEVELS FOR THE TEN YEAR MINERALS DIVERSIFICATION PLAN

PROGRAMS **	FY88-89	FY90-91	FY92-93	FY94-95	FY96-97	TOTAL
Aeromagnetic Survey -- 5th Phase	600.0					600.0
Glacial Till Geochemistry Surveys	600.0	600.0	600.0	600.0	600.0	3,000.0
Geologic Drilling & Mapping	2,000.0	2,000.0	2,000.0	2,000.0	2,000.0	10,000.0
LMIC Minerals Data Base	200.0	600.0	400.0	400.0	200.0	1,800.0
Drill Core Examination and Assay	350.0	350.0	350.0	350.0	350.0	1,750.0
Industrial Minerals Characterization and Research	1,250.0	1,000.0	1,000.0	1,000.0	1,000.0	5,250.0
Bedrock Geochemistry	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0	5,000.0
Non-ferrous Minerals Research (e.g. titanium, manganese)	500.0	500.0	500.0	500.0	500.0	2,500.0
Reclamation Studies	500.0	500.0	500.0	500.0	500.0	2,500.0
Mineral Resource Economic Evaluation	350.0	250.0	250.0	225.0	225.0	1,300.0
Improved Geophysical and Remote Sensing Base	600.0	600.0	600.0	600.0	600.0	3,000.0
Sample Analysis/Equipment	600.0	100.0	100.0	100.0	100.0	1,000.0
Determination of Mineral Rights Ownership	300.0	500.0	500.0	500.0	500.0	2,300.0
Ferrous Minerals Research	800.0	800.0	800.0	800.0	800.0	4,000.0
Mineral Occurrence Resource Evaluation	250.0	250.0	250.0	250.0	250.0	1,250.0
Value-Added Process Evaluation	500.0	500.0	500.0	500.0	500.0	2,500.0
Ore Deposit Modeling	150.0	150.0	150.0	150.0	150.0	750.0
Minerals Basic Research	1,300.0	1,300.0	1,300.0	1,300.0	1,300.0	6,500.0
TOTAL (in 000's)	11,850.0	11,000.0	10,800.0	10,775.0	10,575.0	55,000.0

** Federal/industry cooperation and matching funds may be available

TABLE 2: MINERAL DIVERSIFICATION PLAN, FISCAL YEARS 88 - 89

PROGRAMS	FY88-89**
Aeromagnetic Survey -- 5th Phase	600.0
Glacial Till Geochemistry Surveys	600.0
Geologic Drilling & Mapping	2,000.0
LMIC Minerals Data Base	200.0
Drill Core Examination and Assay	350.0
Industrial Minerals Characterization and Research	1,250.0
Bedrock Geochemistry	1,000.0
Non-ferrous Cooperative Research (e.g. titanium, manganese)	500.0
Reclamation Studies	500.0
Mineral Resource Economic Evaluation	350.0
Improved Geophysical and Remote Sensing Base	600.0
Sample Analysis/Equipment	600.0
Determination of Mineral Rights Ownership	300.0
Ferrous Minerals Cooperative Research	800.0
Mineral Occurrence Resource Evaluation	250.0
Value-Added Process Evaluation	500.0
Ore Deposit Modeling	150.0
Minerals Basic Research	1,300.0
TOTAL (in 000's)	11,850.0

** Federal/industry cooperation and matching funds may be available

TABLE 3: RELATIONSHIP OF OTHER MINERALS REQUESTS AND THE MINERALS DIVERSIFICATION PROGRAM PRIORITIES
Fiscal Years 88-89

PROGRAMS **	DIVERSIFICATION PLAN FUNDING LEVELS			DNR CHANGE LEVEL REQUEST	LCMR APPROVED
Aeromagnetic Survey 4th Phase					800.0
Aeromagnetic Survey 5th Phase	600.0	600.0			
Strategic Minerals Geochemistry					200.0
Glacial Till Geochemistry Survey	600.0	500.0	400.0	400.0	
Clay Deposit Evaluation					400.0
Geologic Drilling & Mapping	2,000.0	1,800.0	1,400.0	1,400.0	
LMIC Minerals Data Base	200.0	200.0	200.0	200.0	
Drill Core Examination and Assay	350.0	300.0	250.0	250.0	
Industrial Minerals Characterization and Research	1,250.0	450.0	200.0	200.0	
Bedrock Geochemistry	1,000.0	300.0	100.0	100.0	
Non-ferrous Minerals Research (e.g. titanium, manganese)	500.0	450.0	200.0	200.0	
Reclamation Studies	500.0	350.0	200.0	200.0	
Mineral Resource Economic Evaluation	350.0	200.0	100.0	100.0	
Improved Geophysical and Remote Sensing Base	600.0	250.0	100.0	100.0	
Sample Analysis/Equipment	600.0	400.0	350.0	350.0	
Determination of Mineral Rights Ownership	300.0	100.0			
Ferrous Minerals Research	800.0	200.0			
Mineral Occurence Resource Evaluation	250.0	100.0			
Value-Added Process Evaluation	500.0	150.0			
Ore Deposit Modeling	150.0				
Minerals Basic Research	1,300.0	650.0	350.0		
TOTAL (in 000's)	11,850.0	7,000.0	3,850.0	3,500.0	1,400.0

**
Federal/industry cooperation and matching funds may be available

will be more difficult to achieve. Ontario, as an example, has made a large commitment and has achieved substantial success.

A stable funding base is critical to the eventual attainment of mineral diversification in Minnesota, and the resultant improvement in the state's rural economy. Establishment of a diversified mineral economy requires long-term planning and persistent effort. This is recognized in designing projects, such as the aeromagnetic surveys, which are an essential first step, and will be completed for the entire state. Priorities will then shift to other evaluation techniques. At the same time, other long-term programs that have not been applied systematically, will be initiated such as bedrock geochemical surveys.

Mineral discoveries in Minnesota will stimulate additional private exploration. The local geologic knowledge gained from these discoveries will generate more exploration. Also, new techniques, like remote sensing, will likely become more important tools later on. The need for better geologic data will persist for many years to come.

Each mineral ore body is physically and chemically unique, so discoveries will create the need for new environmental studies, and process research. This is somewhat similar to what happened long ago with taconite, where the availability of the resource generated research into economic ways to use it. As time goes on, one could expect that a larger proportion of the funding will be allocated to developing economical processing methods.

ORGANIZATION STRUCTURE

The state has historically supported minerals programs in the Department of Natural Resources and the University. This initiative does not call for the creation of any new organizations, but focuses on expanding and making optimal use of existing facilities. The programs proposed in this initiative will be managed and coordinated through the Minerals Coordinating Committee. The Minerals Coordinating Committee consists of the directors of the Minerals Division of the Department of Natural Resources (MnDNR), Minerals Division of the Natural Resources Research Institute (NRRI), Mineral Resources Research Center (MRRC), and the Minnesota Geological Survey (MGS). This committee was formed in 1977 at the request of the Legislative Commission on Minnesota Resources to coordinate proposals and set priorities for minerals requests to LCMR.

It is important to clearly delineate the roles of the organizational members of the Minerals Coordinating Committee, and their responsibility in regard to this plan.

The Minerals Division of the Department of Natural Resources was formed in 1889 and manages the state's 10 million acres of mineral rights, 3 million acres of peatland, and has statewide regulatory responsibility on public and private land. It leases state land by public offering and by negotiation, and manages programs to encourage exploration, development, and to enhance the value of Minnesota minerals. It is not generally a research organization, except for reclamation studies. It

has a strong interest in selecting research priorities and managing projects to ensure that the results provide data for regulatory action, and that lead to income for the trust funds, general fund, and local governments. To support the leasing program, it conducts regional mineral potential surveys to identify new target areas, and provides data for land management decisions. In its role as the state's resource manager, it chairs the Minerals Coordinating Committee.

The university members are primarily educational and research organizations. Their capabilities and missions vary in the following ways.

The NRRI is a new unit of the university whose mission is to foster economic development of northern Minnesota's natural resources in an environmentally sound manner, and to promote private sector employment. A recent addition to NRRI's Minerals Division was the United States Steel's research laboratory and personnel. The capability of NRRI's Minerals Division includes: 1) mineral processing, process assessment, and process development, 2) geologic studies with a special emphasis on geochemistry, ore deposit modelling and resource evaluation, 3) mining with an emphasis on mine planning, mineral economics and mine evaluation, and 4) its growing research capability in industrial minerals and remote sensing/biogeochemistry.

The MRRC was formed in 1911 with a legislative mandate for education and research related to the wise development of mineral resources. Research functions range from mineral characterization through mineral separation to process metallurgical engineering. Much of its work is oriented toward identifying processing methods and developing innovative ways to extract value from mineral occurrences. While it has primary interest in Minnesota's resources, its mission covers fundamental aspects of mineral science and engineering that also contribute to knowledge on a national and international level.

The mission of the Minnesota Geological Survey (MGS) is to undertake and promote the scientific study of Minnesota's geology, and to make the results available to the public. MGS, which operates statewide, was established by legislative act in 1872. As a research and service arm of the University of Minnesota, MGS conducts basic and applied earth sciences research to elucidate the complex and challenging geology of Minnesota for the benefit of the state's citizens. MGS works to provide a scientific geological framework for the state that can be used to further mineral resource, engineering geology, and environmental geology investigations. This objective is accomplished mainly through the preparation of geologic maps at various scales, using data and interpretive insights from direct field study, geophysics, geochemistry, and test drilling.

Private industry also maintains research facilities in Minnesota which are capable of working on specific projects. It may be possible to develop private-federal cost sharing in certain instances, as has been done in the Iron Ore Cooperative Research Program.

This plan will, to the greatest extent possible, use existing capabilities, and route the work to locations where the highest quality product can be expected.

As outlined above, members of the Minerals Coordinating Committee have individual capabilities which will dictate the flow of funds for specific projects. Appropriations may be passed through the Department of Natural Resources, or may go directly to the agency performing most of the work for each project or program area with appropriate legislative oversight. In either case, the priorities remain unchanged, and the work will be coordinated by the Minerals Coordinating Committee. Table 4 provides an indication of which agencies will work on each project. Private industrial laboratories are also included.

This coordinated plan, designed cooperatively by the mission-oriented agencies, has a high probability of producing substantial economic benefits in the long term. The rate of progress depends both on the level and continuity of funding. The best results will be obtained with continuing stable funding over several biennia. While the projects are listed separately, it should be pointed out the the activities are interrelated and directed towards the common goal expressed earlier.

CURRENT STATUS OF MINNESOTA GEOLOGIC DATA

The sequence of proposed projects is tied to the level of understanding of the geology of Minnesota. Figure 3 shows the areas of Minnesota which have bedrock outcrops. The drift-covered areas are believed to have good mineral potential, but are poorly understood because of limited information on bedrock types and structures. Aeromagnetic surveying was started in the northeastern part of the state where abundant outcrop exists and current efforts are moving towards the drift-covered areas as shown in Figure 4. When the aeromagnetic survey is complete in a region, remapping the exposed bedrock geology and drilling bedrock in drift-covered areas are needed to interpret the results of the aeromagnetic survey and to produce a new, more accurate interpretation of the geology. Figures 5 and 6 show the current status of geologic mapping in Minnesota. Figure 7 is an example of the results of aeromagnetic data processing which has proven to be extremely valuable for interpretation of bedrock geology and mineral potential. Existing drill core also contributes to the geologic interpretation of aeromagnetic data and the assessment of regional mineral potential. Figure 8 shows existing bedrock drill holes - of which core samples are available in the Hibbing Drill Core Library.

Programs that evaluate the mineral potential and chemistry of bedrock from drill core, such as lithogeochemistry and regional resource evaluations, can be done more effectively with the benefit of aeromagnetic data. Aeromagnetic surveys, when supplemented by enhancement techniques such as computer-generated shaded relief maps and substantiated by shallow bedrock drilling, may reveal rock units which have high mineral potential. Concentrating in these areas with additional surveys such as glacial till geochemistry, geophysical data collection, industrial mineral surveys and research, and ore deposit

Table 4. Project Capabilities by Agency

PROGRAMS**	AGENCY					
	LMIC	DNR	MGS	MRRC	NRRI	Private Industrial Laboratories
1. Aeromagnetic Survey - 5th Phase			X			
2. Glacial Till Geochemistry Surveys		X	X			X
3. Geologic Drilling and Mapping			X			
4. LMIC Minerals Data Base	X	X	X	X	X	X
5. Drill Core Examination and Assay		X				
6. Industrial Minerals Characterization and Research		X	X	X	X	X
7. Bedrock Geochemistry			X		X	
8. Non-ferrous Research (e.g., titanium and manganese)				X	X	X
9. Reclamation Studies		X				
10. Mineral Resource Economic Evaluation					X	
11. Improved Geophysical and Remote Sensing Base		X	X		X	X
12. Sample Analysis/Equipment		X	X	X	X	X
13. Determination of Mineral Rights Ownership		X				
14. Ferrous Minerals Research				X	X	X
15. Mineral Occurrence Resource Evaluation		X		X		
16. Value-added Process Evaluation				X	X	X
17. Ore Deposit Modeling			X		X	
18. Minerals Basic Research			X	X	X	

**Federal/industry cooperation and matching funds may be available

Minnesota Geological Survey
University of Minnesota
Matt Walton, Director

GEOLOGIC MAP OF MINNESOTA

BEDROCK OUTCROPS

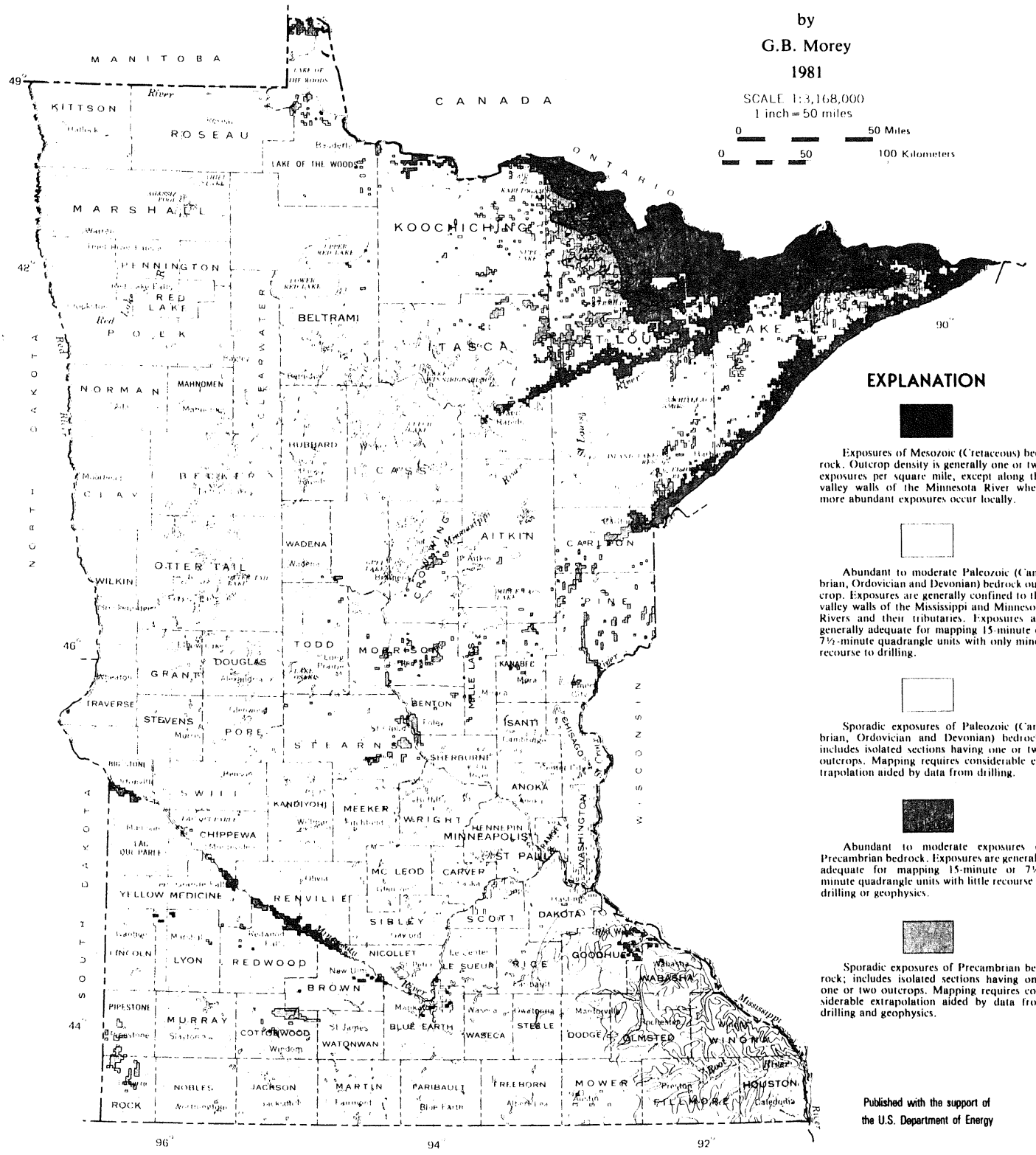
by

G.B. Morey

1981

SCALE 1:3,168,000
1 inch = 50 miles

0 50 Miles
0 50 100 Kilometers



EXPLANATION

Exposures of Mesozoic (Cretaceous) bedrock. Outcrop density is generally one or two exposures per square mile, except along the valley walls of the Minnesota River where more abundant exposures occur locally.

Abundant to moderate Paleozoic (Cambrian, Ordovician and Devonian) bedrock outcrop. Exposures are generally confined to the valley walls of the Mississippi and Minnesota Rivers and their tributaries. Exposures are generally adequate for mapping 15-minute or 7½-minute quadrangle units with only minor recourse to drilling.

Sporadic exposures of Paleozoic (Cambrian, Ordovician and Devonian) bedrock; includes isolated sections having one or two outcrops. Mapping requires considerable extrapolation aided by data from drilling.

Abundant to moderate exposures of Precambrian bedrock. Exposures are generally adequate for mapping 15-minute or 7½-minute quadrangle units with little recourse to drilling or geophysics.

Sporadic exposures of Precambrian bedrock; includes isolated sections having only one or two outcrops. Mapping requires considerable extrapolation aided by data from drilling and geophysics.

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FIGURE 3

BEDROCK OUTCROPS OF MINNESOTA

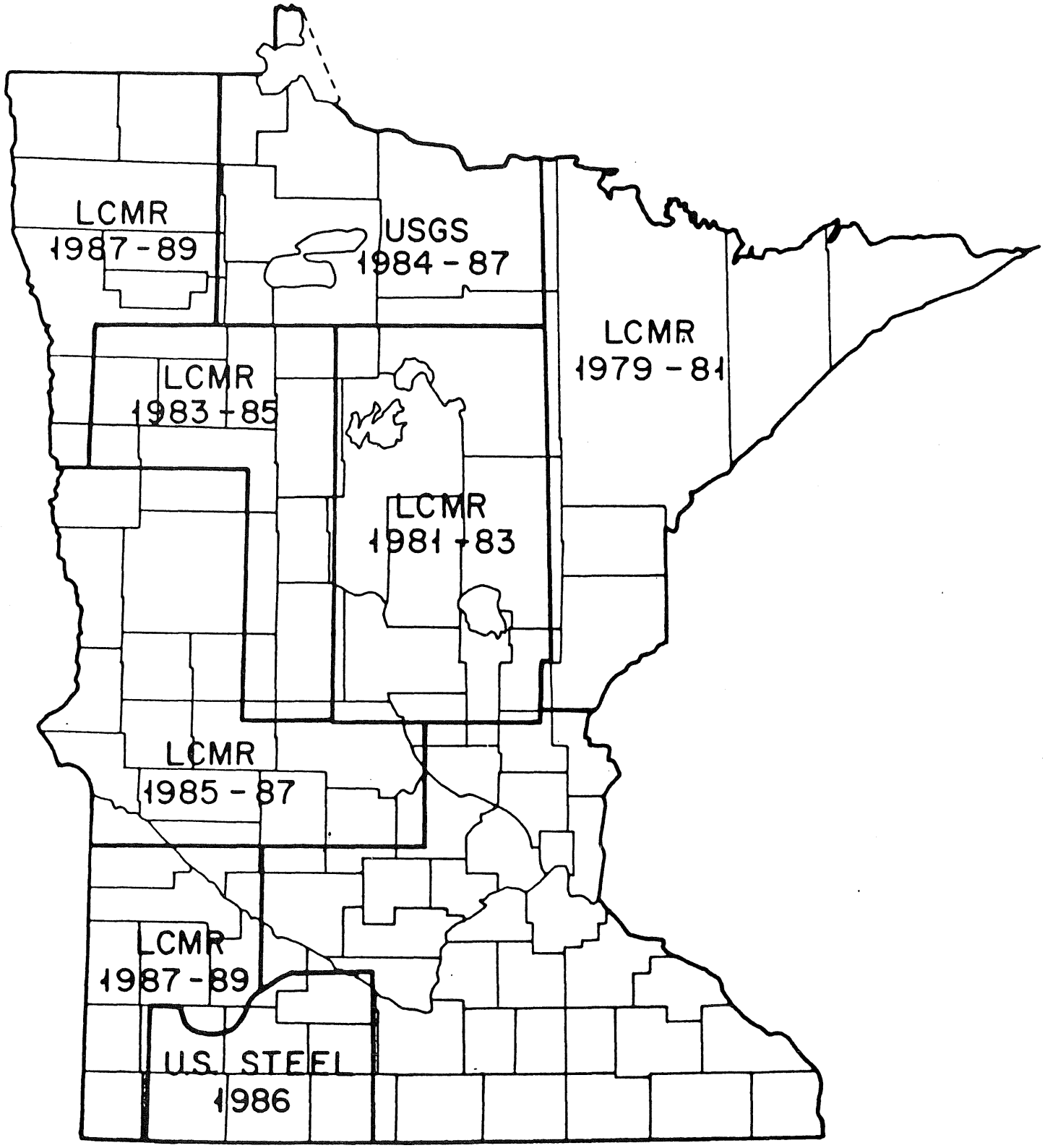

FIGURE 4 STATUS OF AEROMAGNETIC MAPPING

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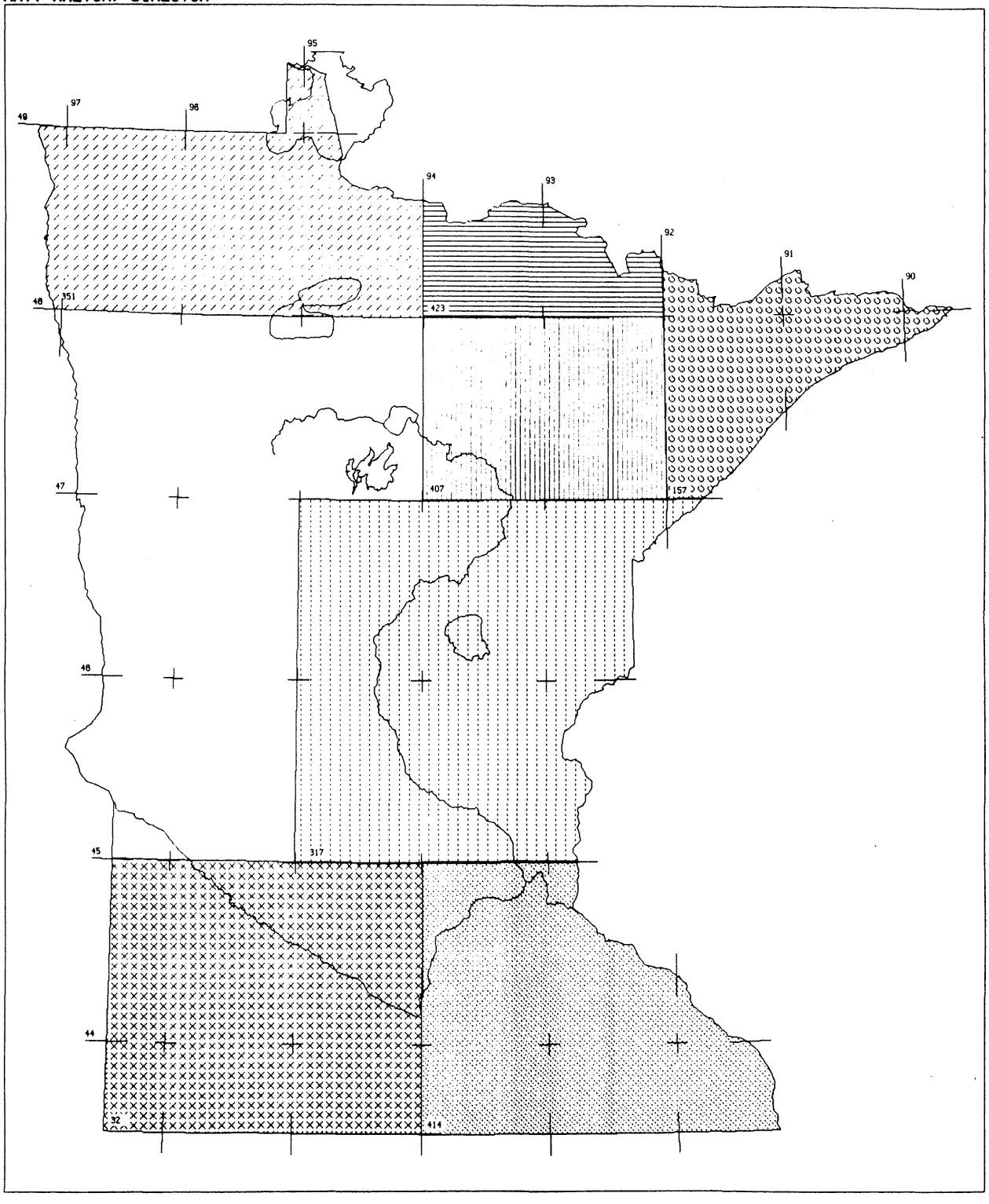

FIGURE 5 1:250,000 GEOLOGIC ATLAS SHEETS

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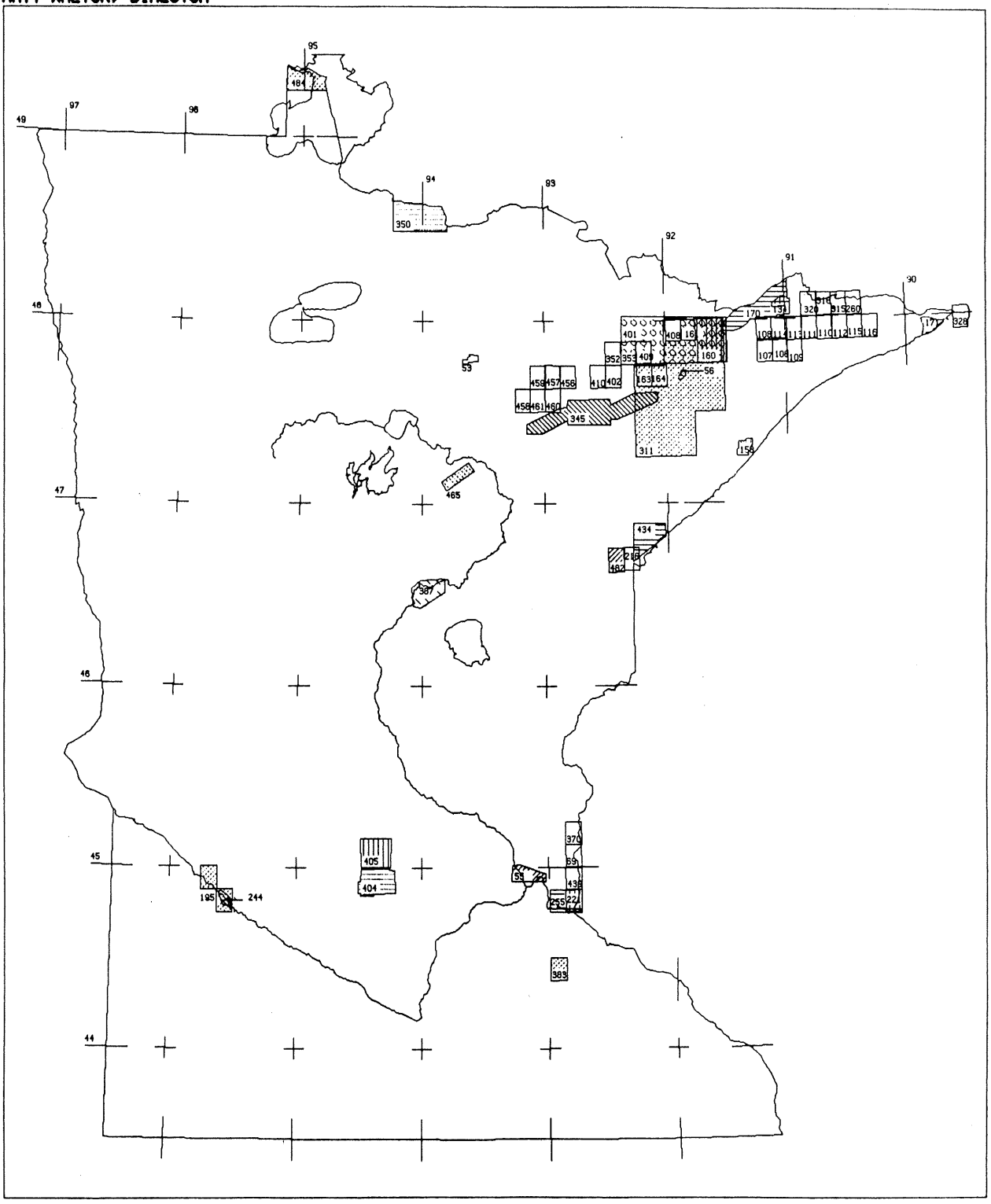

FIGURE 6 BEDROCK MAPS AT SCALES OF 1:63,360 OR LARGER

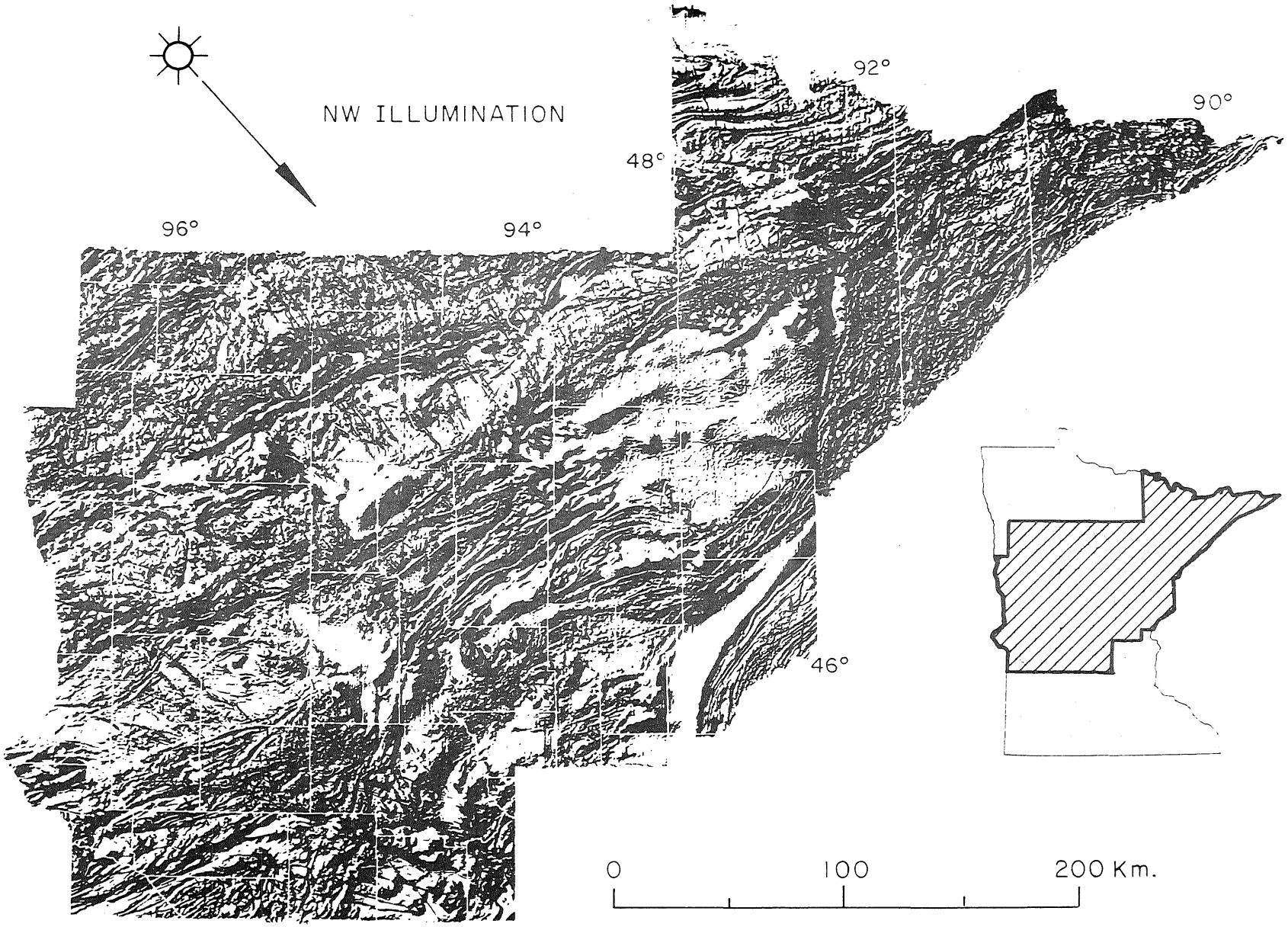

FIGURE 7 SHADED RELIEF AEROMAGNETIC MAP

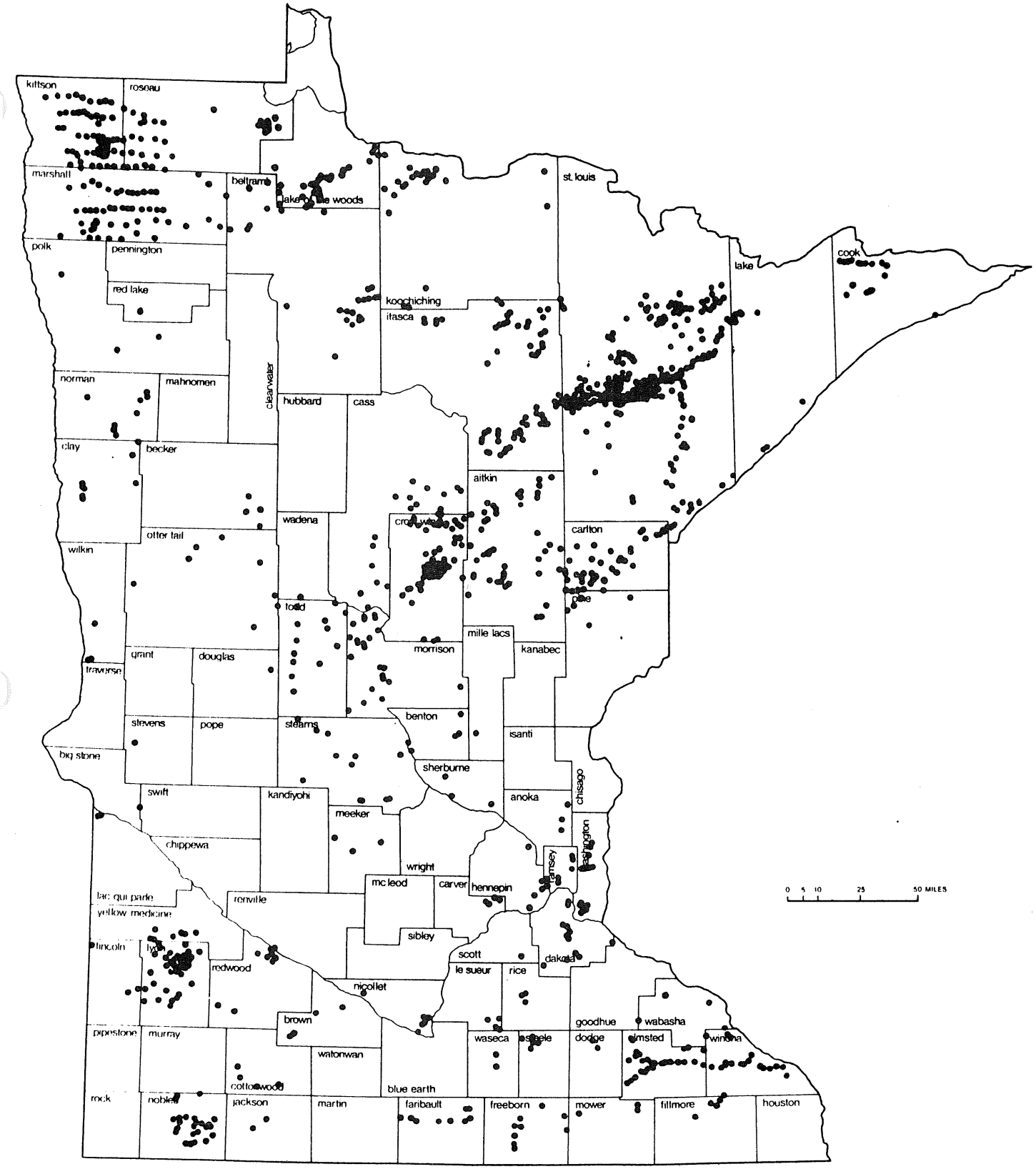

FIGURE 8 BEDROCK DRILL HOLE LOCATIONS WITH CORE AVAILABLE FOR INSPECTION

modeling can further refine the mineral potential findings and define targets for future mineral leasing. After specific mineral occurrences have been identified, economic evaluation projects, cooperative research, reclamation studies, and value-added processing research become important.

The diversification program considers the mineral development potential of the entire state.

APPENDIX

Project Descriptions for 1987-88 Biennium

1. Completion of the high resolution aeromagnetic survey of Minnesota. LCMR initiated this program in 1978. The program has been highly successful at redefining the bedrock geology in areas of thick glacial cover and indicates new targets of interest to the exploration industry. LCMR has recommended funding the fifth phase of this program in 1988-89, which will leave 20 percent of the state yet to be surveyed in following years.

2. Continuation of the till geochemistry project being conducted in the 1986-87 biennium under LCMR funding. This project has detected potentially significant gold geochemistry anomalies in northern Minnesota.

3. Continuation and expansion of subsurface geologic mapping through bedrock drilling to confirm and interpret the aeromagnetic survey.

4. Incorporation of geologic and mineral potential data into public data systems for use by the exploration industry, public, and others.

5. Examination of existing drill core samples to continue the successful LCMR Hibbing Core Repository Project being conducted in the 1986-87 biennium.

6. Identification of potential industrial mineral resource areas along with development of a statewide industrial mineral occurrence compilation and local market identification. Characterization of industrial minerals and development of process technology is required. This includes extension of the clay resources project that has been recommended for funding by LCMR.

7. Regional lithogeochemistry of bedrock in greenstones and the Duluth Complex for determining regional mineral potential and exploration target areas.

8. Research with industry where possible on known non-ferrous mineral resources, such as titanium and manganese, and development of exploration methods and techniques.

9. Reclamation studies to develop necessary information to ensure that new non-ferrous mineral development will be environmentally acceptable and meet permit requirements.

10. Mineral economic evaluations and services to assist in identifying priority commodities, preparing market studies, and identifying opportunities to improve Minnesota's competitive position.

11. Improvement of geophysical coverage and develop a remote sensing data base over areas of high mineral potential.

12. Analysis of samples taken during geologic studies. Where existing state analytical facilities cannot complete the analysis, the samples will either be sent out or equipment will be purchased depending on cost-benefit analysis.

13. Conduct mineral rights ownership research in areas of highest mineral potential.

14. Ferrous mineral research includes taconite process optimization, cost cutting measures, and expansion of the successful DNR-directed program being conducted in the 1986-87 biennium.

15. Resource evaluation of known and potential mineral occurrences, such as the successful platinum evaluations which are being conducted in the 1986-87 biennium.

16. Value-added process development for metallic minerals, including direct reduction, specialty steel production, and non-ferrous minerals processing, and process modeling.

17. Conduct ore deposit modeling studies to define characteristics of potential deposit types of Minnesota geology.

18. Conduct basic mineral processing research and mineralogical studies of Minnesota resources.