MINERAL DIVERSIFICATION
1997 REPORT TO THE LEGISLATURE

Minnesota Minerals Coordinating Committee
Minnesota Department of Natural Resources/Minerals Division
Minnesota Pollution Control Agency
University of Minnesota
Department of Civil Engineering
Natural Resources Research Institute
Geological Survey

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1997 REPORT TO THE LEGISLATURE

Prepared by the

MINNESOTA MINERALS COORDINATING COMMITTEE

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Introduction

The Mineral Diversification Program and the Minerals Coordinating Committee (MCC) were created by the Legislature in 1987 (MS 93.001 and MS 93.002). The overall goal of the program as stated in the Ten Year Plan was to "stimulate development of Minnesota's mineral resources." The authorizing legislation requires a biennial report to the Legislature which describes progress in Mineral Diversification, and recommends future action and funding. This document is the biennial report for FY1998-99. It contains a summary of projects since inception (Appendix C), a discussion of Mineral Diversification progress, and recommends actions for the upcoming biennium. In submitting this report, the MCC wishes to thank the Legislature for its past support and urges continuation of this important research effort.

Executive Summary

Minnesota is known for its great quality of life. Comparisons to other states and nations find Minnesotans healthier, better educated, and employed in higher paying jobs. Minnesotans also enjoy a tradition of environmental stewardship that allows us to live in healthy communities, breathing pure air, surrounded by productive farmlands and forests, enjoying clean rivers and lakes. Millions of visitors make tourism one of our largest industries, providing empirical evidence that Minnesota's approach to life in today's complex world continues to work -- for all of us.

Minnesota is also home to taconite mines, dimension stone quarries, aggregate mines, and clay pits that contribute more than $2 billion annually to the state's economy. Mining, along with agriculture, forest products, and computer technology, ranks among Minnesota's largest industries directly employing over 20,000 people in nearly 200 communities statewide. Mining provides these benefits without compromising the natural beauty and clean environment of the state which remains true to its name as "the land of sky blue waters."

However, we often take mining for granted. Not only in terms of its direct economic impact, but also in terms of the products that enhance the quality of our daily lives. Iron and steel made from Minnesota taconite goes into cars, ships, appliances, housing, bridges, engines, tools, and even flatware. Over the years, the development of taconite has drawn nearly $4 billion of investments in plants and machinery on the Mesabi Range. Royalties from state mineral interests are now funding scholarships at Minnesota colleges and universities. And taconite production taxes levied in lieu of local property taxes have provided northeastern Minnesota with modern schools, well-kept communities, and economic activity that has helped to sustain the region, indeed all of Minnesota, for the past one hundred years, while preserving its tradition as a state that protects and nurtures its natural gifts.

The products of mining permeate every part of our daily lives. Common products like sand, gravel, and crushed rock have supplied construction material for roads, railroads, houses, driveways, and commercial buildings. Clay is used in bricks and Portland cement. Silica sand has been an important raw material for the local glass industry which grew to support food processing. We see the products of the dimension stone quarries on commercial buildings, churches, and schools. Limestone from quarries in southeastern Minnesota has been used for roads, agricultural lime, and building stone. Mineral products support much of the quality of life we now enjoy. But as we approach the next century, mining faces many challenges.

- **Old Technology** - Technology currently being utilized in Minnesota taconite plants was developed more than 20 years ago.
- **Aging Taconite Plants** - Most plants have not significantly updated since their last expansions in the 1970s.
- **Aging Workforce** - Approximately one-third of the industry's 6,500 workers will retire in the next six years. A substantial percentage of these workers are skilled tradesman such as millwrights, electricians and electronic technicians who are not easily replaced.
- **Peaks and Valleys in Production** - Taconite production has recovered for the lows experienced in 1982 so times seem good, but it is unlikely to continue far into the future since most new steel-making capacity is based on electric furnaces.
- **Limited Basic Research** - Now that the U. S. Bureau of Mines has closed, no other agency or institution yet has committed to carry on with the basic research required to sustain the existing iron mining industry.
- **Mining Only One Metallic Mineral** - Although Minnesota is rich in other minerals besides iron, exploration and mining companies have shown minimal interest in developing other minerals such as copper, nickel, titanium, gold, platinum, and palladium.
- **Land Use Conflicts** - Taconite mines are expanding into new areas and hauling materials longer distances which potentially conflicts with Iron Range communities seeking to utilize some of these same lands for development or recreation.
- **Resource Depletion** - As the metropolitan region grows, good sand and gravel deposits are being covered by houses and shopping centers so that demand is being filled from sources which are further away and, therefore, more expensive.

In response to these challenges, the State Legislature created the **Minerals Diversification Program** in 1987. Through this program, the University of Minnesota, the Department of Natural Resources, the Minnesota Geological Survey, and the Natural Resources Research Institute have undertaken mineral research both to improve the existing industry as well as to encourage the environmentally

sound exploration and development of other Minnesota mineral resources. From taconite on the Mesabi Iron Range to kaolin clay in the Minnesota River Valley, the mineral resources of virtually every region of the state have been enhanced through research funded by the Mineral Diversification Program.

Significant progress has been made during the program's first decade, but several opportunities for development remain. For example, Minerals Diversification funding was used to initiate research on the use of lime as a pellet binder, evaluate the state's ilmenite deposits and production of synthetic rutile, locate stone for dimension stone quarries, inventory the carbonate rock resources in southeastern Minnesota, and evaluate the bedrock formations in northeastern Minnesota which are similar to the rock types found in Canadian gold mining provinces. To effectively plan and manage the continued development of Minnesota's mineral resources, the Minerals Coordinating Committee (MCC) asks that the Minnesota State Legislature expand its support of the Mineral Diversification Program. In so doing, the Legislature will renew its commitment to sustaining the long-term health of Minnesota's economy and the quality of life of its citizens.

Development of the mineral potential of Minnesota requires a systematic approach. With a plan, we will be able to explore and take advantage of new opportunities that will keep Minnesotans employed in well paying jobs while preserving the state's excellent quality of life. The following contains the MCC's plan for the next biennium. It is consistent with the Mineral Diversification goals expressed in the authorizing legislation and what has been learned over the last ten years. The plan suggests funding for minerals research as shown in the table below which is organized according to the following categories of research.

- Assistance for currently existing minerals industries—taconite, sand and gravel, dimension stone, clay, silica sand, etc.
- Evaluation of known but undeveloped resources—copper/nickel, titanium, manganese, vanadium, etc.
- Delineation of potential mineral resources—geologic mapping of regions of high mineral potential and targets for exploration.
- Support for land use and environmental issues—mineland reclamation, mine development, encroachment, etc.
- Encouragement of basic research to support the minerals industry.

Table 1 below shows the recommended allocations of Mineral Diversification funding for the Fiscal Year 1998-99 biennium.

Table 1. Mineral Diversification Program Allocations - Fiscal Years 1998-99.

Mineral Diversification Program Allocations Fiscal Years 1998-99	Budget- $,000	
	Same Level	Change Level
Assistance for currently existing minerals industries.	205	125
Evaluation of known but undeveloped resources.	50	80
Delineation of potential mineral resources.	320	140
Support for land use and environmental issues.	175	155
TOTAL	750	500

The MCC is sponsoring several legislative initiatives in addition to the Mineral Diversification Program. These are:

- A study of the hydrology of the Mesabi Range which will provide data on ground water flows that can be used for long-range planning of the integration of mine pits into the existing watersheds at a cost of $160,000 for the biennium.
- An increase of $110,000 for the biennium in the amount appropriated for Environmental Cooperative Research.
- A one-time $5.0 million appropriation for commercial demonstration of new technology for taconite processing.
- Legislation to clarify the ownership of lean ore and waste rock stockpiles on the Mesabi Range.
- Creation of a legislative task force to study the need for establishment of a statewide policy for sand and gravel issues.
- Changes to the membership of the Minerals Coordinating Committee.

The MCC is also preparing a new Ten Year Plan for Mineral Diversification which is due in January 1998. The plan will discuss many of the same issues in greater detail and will establish the direction of the Minerals Diversification Program for the next decade.

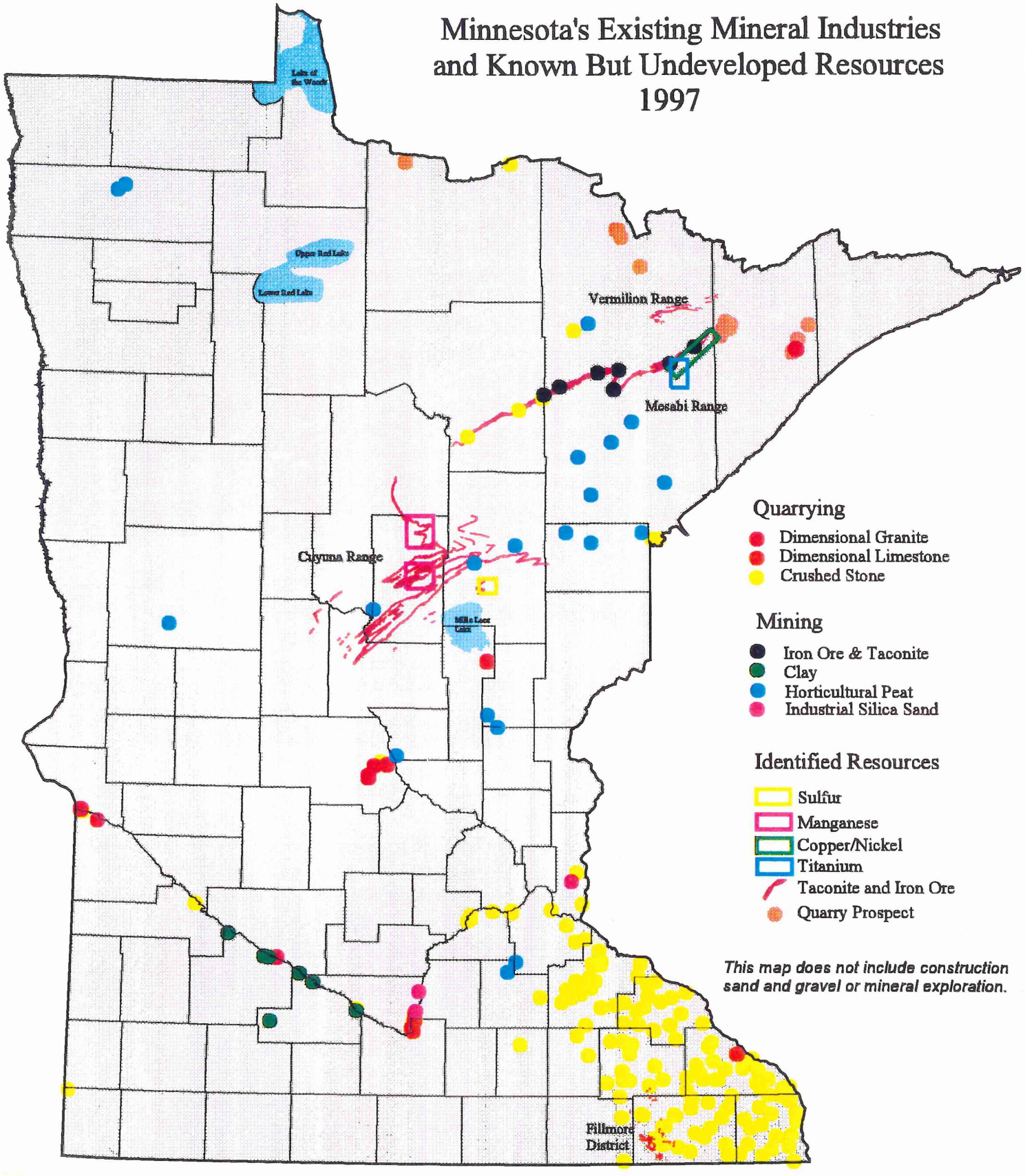

Figure 1.

The State Should Be Interested in Mineral Diversification

Mineral industries are critical to our survival as a developed society and are an essential part of all of our activities at home, at work, and at play. Mining in Minnesota is focused on two major areas: iron ore, which is the foundation of our industrial society; and sand and gravel, which is the foundation for urban development. Mineral uses range from the exotic such as germanium arsenide for electronic equipment to the familiar such as sand and gravel for construction. New uses for minerals occur on a daily basis and the demand continues to grow.

Mineral industries are a source of well paid jobs in rural areas. Miners typically earn more than many other workers and mines require a skill base that covers most types of skilled, semi-skilled, and professional labor. Wages for minerals related employment ranges from about $12 per hour to over $20 with an average near $15 per hour. Total employment costs run as high as $26 per hour. Few industries in rural Minnesota can claim the same or higher salary levels. Mines can support a viable community for a long period of time, as is witnessed by life on Minnesota's Mesabi Range. Mineral industries also provide a welcome tax base for local improvement and maintenance of government, schools, roads, and amenities. Mineral industries make a welcome contribution to the economic well-being of all levels of government and society.

However, the location of mines and quarries cannot be dictated by individual or social desire. Minerals are where one finds them and mines must be developed in those locations. The process of finding, developing, and operating a mine is long, arduous, and costly. On the one hand, the developers need expeditious handling of their requests for permits, and at the same time, the government and its citizens need to know that the mine and any associated processing facilities can be operated without long-term degradation to the environment. Mineland reclamation for beneficial use of properties for the benefit of future generations is a key goal of government.

The state may also be an owner of mineral interests. The public owns about 13 million acres of mineral rights in Minnesota. About 18 percent of the Mesabi Range is in public ownership and leases on those properties generated over $7 million for the trust funds and local governments in 1996. The state is interested in the exploration for and development of other mines and owns some known deposits such as the Minnamax copper/nickel deposit near Babbitt. The manager for minerals in the state is the Department of Natural Resources—Minerals Division. It manages an active leasing program in the hope that companies will discover and develop new deposits of gold, titanium, copper, zinc, etc.

Ten years ago the original plan asked the question "Can state funding accelerate mineral diversification?" It is clear that it can. For example:

- A small amount of state funding was allocated to a new look at the state's titanium deposits. This led to a large pilot plant study and continued interest by several companies in these known deposits.

- A project aimed at the use of lime/dolomite hydrate led to extensive plant tests on the use of pebble lime to replace both bentonite binder and limestone flux material. This area is still very active and several organizations are currently evaluating the economic feasibility of supplying lime to Minnesota's taconite plants.
- A project on iron ore value-added led to a large study of DRI at National Steel Pellet Company.
- The early work on the kaolin deposits in the Minnesota River Valley linked nicely to the local interests, and the composite effect has led to a major evaluation paper-grade kaolin from one deposit near Redwood Falls and general expansion of kaolin mining for the cement industry.
- The dimension stone inventory effort led to two lease sales, three leases, and two operating quarries in northeastern Minnesota.
- The inventory of carbonate resources in southeastern Minnesota continues to stimulate interest in new quarries and new products.
- Work on the Duluth Complex and nonferrous metals stimulated interest in the known copper/nickel deposits in that area.
- Geologic mapping efforts in southwest Minnesota led to the identification of a new, untapped aquifer near Marshall.

Again, an exhaustive list of achievements could become quite lengthy. In general, the MCC can report that the work for the taconite and industrial minerals industries has been successful and that its efforts in the nonferrous area has led to a significant improvement in the geologic data base which is available to the mineral exploration community and others.

The state has a vital interest in all phases of metallic mineral mining ranging from the initial surveys to eventual mine closure. It has programs in place to monitor and/or regulate those parts of the activity which are critical to the economic and environmental well-being of its citizens. In addition, counties have the primary role in permitting surface deposits of sand, gravel, and clay. Another important aspect of the state's activities is mineral research on problems specific to Minnesota. The Mineral Diversification Program and the Minerals Coordinating Committee are key factors in coordinating and managing the state's interest in technological and environmental research. The state has an interest in mining because mining is important to Minnesota.

Organization Roles in Mineral Diversification

The Role of the Legislature

The Minnesota Legislature can encourage responsible action by establishing policies and statutes to control mineral development. The current statutes created by the 1987 Legislature declare that [It is the policy of the State]..."To provide for the diversification of the state's mineral economy through

long-term support of mineral exploration, evaluation, development, production, and commercialization" (Minn. Stat. Sec. 93.001).

Over the last ten years, the Legislature has supported a wide variety of programs aimed at encouraging and supporting the state's mineral economy. All of the programs currently managed by the agencies or underway at the University began with legislative action. A partial list of those accomplishments includes:

- Creation of the Mineral Diversification Program.
- Continued support for Iron Ore Cooperative Research.
- Creation of the Cooperative Environmental Research Program.
- Allocation of a portion of the Permanent University Fund for minerals research.
- Support for creation of an endowed chair for minerals research at the University of Minnesota.
- Paving the way for the transfer of the U. S. Steel Research Laboratory to the University of Minnesota Natural Resources Research Institute.
- Changing the tax laws have made mineral industries more competitive.

An exhaustive list of legislative action to support and encourage mineral development would be quite lengthy, but one can see that the Legislature has spoken clearly about its desire to promote, support, and encourage responsible mineral development. Much of what was planned in 1987 was technical in nature and much has been put into place since that time. However, experience has shown that other items are also important. For example:

- land use planning will become more important in the future as suburban growth extends to areas that previously supplied the mineral resources that supported urban growth;
- training is needed for future mineral industry employees so that the expected 30 to 35 percent retirement factor expected in the next six years does not create a shortage of needed skills;
- development of appropriate business incentives to encourage mineral exploration should be considered; and
- development of risk-sharing programs will insure that the state's investment in research will be translated into commercial operation.

Legislative support has made Mineral Diversification possible and continued support will provide an even stronger base for mineral development.

The Role of the Minerals Coordinating Committee

The Minerals Coordinating Committee has had statutory life since 1987. It was created as part of the legislation authorizing the Greater Minnesota Corporation and was given responsibility for coordination of all publicly supported mineral research in Minnesota. During this period (1987-1996), the MCC has been chaired by the Director of the Minerals Division in the Department of Natural Resources. The four original members were the Department of Natural Resources (DNR),

and three units of the University of Minnesota, i.e. the Natural Resources Research Institute (NRRI), the Minnesota Geological Survey (MGS), and the Mineral Resources Research Center (MRRC). Over the last ten years the Mineral Resource Research Center closed and was replaced by the Institute of Technology—Department of Civil Engineering; the Pollution Control Agency (PCA) was added; and the U. S. Bureau of Mines (USBM) participated until its closure in 1996. The U. S. Environmental Protection Agency and Geological Survey were invited to participate.

The current plans are to expand the MCC to include members from the private sector and the Iron Range Resources and Rehabilitation Board (IRRRB). It is expected that persons representing the taconite industry, the mineral exploration industry, and the industrial minerals industry will be asked to participate. Representatives of those industries have already participated in the recommendations for the FY1998-99 biennium. It is believed that this will insure the continued relevance of the work performed by the MCC member agencies using Mineral Diversification funding. Also, the IRRRB allocates some of its revenue on minerals programs, so it is appropriate that it should be represented.

The role of the MCC contains several elements. It has specific authority to allocate the Minerals Diversification funds, to create long-term plans for minerals research, and to submit biennial budget requests for minerals research to the Legislature. The latter two elements relate to its coordinative role over all minerals related research. In that context, this document lays out a strategic plan for all known sources of public funding for minerals research. The MCC will work to insure that minerals research is conducted by the research organization best suited for the effort. Projects and concepts will be discussed to eliminate duplication of effort and encourage cooperation so that the overall research mission is internally consistent with long-term objectives. It is expected that the MCC will be the primary body communicating minerals research issues to the Governor and the Legislature. Except for the Mineral Diversification appropriation, it will not extend its reach to project selection or project approval on specific programs. For example, the Iron Ore Cooperative Research Committee will select projects in that program and the Natural Resources Research Institute will allocate the funding from Minnesota Technology, Inc. and the Permanent University Trust Fund. Occasionally, it may be asked to review solicited or unsolicited proposals submitted by individuals and organizations seeking public funding, and this will be done by establishing ad-hoc subcommittees to do the work. The primary mission of the MCC is to insure that public funds appropriated for ..."long-term support of mineral exploration, evaluation, development, production, and commercialization" (Minn. Stat. Sec. 93.001)... are used wisely and well.

The Role of the Members of the Minerals Coordinating Committee

State Agency Members

The Minerals Division which is now part of the Department of Natural Resources was formed in 1889. It manages the state's 12 million acres of mineral rights, 3.2 million acres of peat lands, and has statewide responsibility for permits to mine and mineland reclamation on public and private land. It leases state-owned minerals and manages programs to encourage exploration and development. These activities generate income for the trust funds, the general fund, local government, etc. In order

to encourage leasing, it conducts mineral potential surveys and gleans additional information from its drill core library and past exploration episodes. It conducts reclamation research at a new facility near its Hibbing office. It provides financial support and technical assistance for minerals processing research, but does not conduct that type of research on its own. It has, however, a strong interest in participation in and the setting of priorities for all types of minerals research.

The Pollution Control Agency uses its membership on MCC to insure that environmental values are included in projects selected for funding. It also recommends environmentally oriented projects to the committee and helps set the environmental research agenda. It has not become a project manager for any research started by the Minerals Coordinating Committee, although that could happen in the future. In November 1996, the Governor's Task Force on Mining and Minerals recommended that the Iron Range Resources and Rehabilitation Board (IRRRB) be added to MCC. The IRRRB funds a significant amount of minerals research annually and has a broad interest in the maintenance of the taconite industry, development of other minerals related industries in its region, and economic development in general. The participation of the IRRRB will lead to better coordination and execution of larger, worthwhile projects that require funding from several sources.

University of Minnesota Members

The University members are primarily education and research organizations with varying capabilities and missions. The NRRI was established in 1983, the MGS in 1872, and the Department of Civil Engineering (CE) in 1910. CE has a broad educational responsibility within the University's Institute of Technology and, therefore, does not participate on a large scale in either geologic or mineral processing research which are the mainstays of Mineral Diversification.

The NRRI's mission is to foster environmentally sound use of Minnesota's natural resources through research, development of technology, and business analyses. The Institute's Minerals Division has a small staff of geologists and geophysicists in Duluth, but the bulk of its work is carried out at the Coleraine Minerals Research Laboratory (CMRL), a facility which was acquired from United States Steel Corporation. CMRL, with support from its employees in Duluth, can guide minerals research ranging from geologic mapping to pilot scale minerals processing studies including economic evaluation. Over the last ten years, CMRL has become the primary publicly supported minerals research organization in Minnesota.

The mission of the MGS is to undertake and promote the scientific study of Minnesota's geology and to make the results available to the public. As a research and service arm of the University of Minnesota, MGS conducts basic and applied earth science research to elucidate the geology of Minnesota for the benefit of its citizens. MGS works to provide a scientifically sound geologic framework for the state that can be used to further investigations of mineral resources, engineering geology, and environmental geology. This objective is accomplished mainly through the preparation of reports and geologic maps at various scales, using data and interpretive insights from direct field study, geophysics, geochemistry, and test drilling.

Private Sector Members

The Governor's Task Force also recommended that three private sector members be added to the MCC and suggested participation by the taconite industry, the minerals exploration industry, and the aggregate industry. The change in membership requires legislative action, so legislation has been drafted which would effect the changes. However, planning for the FY1998-99 effort is ongoing, so the MCC has invited the Iron Mining Association (taconite), the Minnesota Exploration Association (mineral exploration), and CAMAS, Inc. (sand, gravel, and other aggregate) to participate in the development of the FY1998-99 work plan.

Process Used to Create the Biennial Budget Plan

Introduction

The new Ten Year Plan will be the product of cooperation among several groups. It is expected to be released well before its due date of January 1, 1998. This Biennial Budget Plan contains many of the ideas which will be incorporated into the Ten Year Plan. The first plan, which was released in January 1988, was written exclusively by the MCC members. This plan is the product of more interagency and public/private cooperation. In particular, the Governor's Task Force on Mining and Minerals was used as a sounding board for the concepts and ideas presented here. The process has been driven by the MCC's desire for a continuation of the coordinating committee and a filtering of its ideas through technically oriented private groups and policy oriented public groups.

The process started with an MCC request to the Commissioner of the Iron Range Resources and Rehabilitation Board for meetings of the Governor's Task Force. The MCC wanted to submit its proposals to that group to gather advice regarding direction for the next few years. At about the same time, the Minnesota Explorers Association (MExA) requested assistance from the IRRRB and suggested a symposium at which exploration issues could be discussed. A process was defined which would begin with meetings between industry representatives and the MCC at which broad guidelines for minerals research would be defined.

Mineral Exploration

On July 31, 1996, at the joint invitation of MExA and IRRRB, a group of thirty-four representatives of industry, research organizations, state government agencies, and other parties attended a Nonferrous Minerals Exploration Symposium. The goal of this symposium was to identify processes and strategies that, if adopted, would substantially increase the probability of the development of an economically significant and environmentally responsible nonferrous and precious metals mining industry in Minnesota. After the meeting, MExA formulated the following four recommendations which were refined and amplified through discussions with IRRRB and the Minerals Coordinating

Committee:

- Industry should be involved in the selection, development, and peer review of publicly funded projects aimed at enhancing the opportunity for mineral development in the state.

- The exploration data which resides in the Hibbing office of the MnDNR/Minerals Division should be published in a user friendly form.

- Incentive programs should be developed for nonferrous minerals exploration which would increase the probability of developing a new minerals industry in Minnesota.

- Exploration in Minnesota should be promoted to a targeted audience of exploration companies.

In addition, the Minerals Coordinating Committee recommended:

- Addition of two new MCC members (in addition to the three recommended by MExA) representing the industrial minerals industry and IRRRB.

- Ongoing geologic mapping, in support of exploration activities, with the MCC insuring that the geologic maps prepared by the state reflect the appropriate scale of data that will enhance the effectiveness of minerals exploration.

- Support for mineral beneficiation studies to establish the viability of economic extraction processes for minerals such as copper, nickel, titanium, and vanadium, and that the provision to do so be included in the updated Mineral Diversification Plan.

Taconite Processing

In May of 1996, the Iron Ore Cooperative Research Committee began to develop a list of research needs for the taconite industry. A meeting was held on May 21, 1996, to discuss results of a survey of general managers regarding future research. This led to a series of subcommittee meetings to discuss specific research needs in mining, concentration, pelletizing, and process control. The management structure of the program was also modified to accelerate completion of projects. In early September, DNR and IRRRB sponsored a meeting with representatives of the taconite industry to discuss research ideas. The results of the work of the IOCRP were validated at the September meeting. In addition, the MCC presented several specific ideas which were beyond the scope of the Iron Ore Cooperative Research Program. These were to:

- Maintain a flow of ideas through laboratory and pilot scale research using funds from Iron Ore Cooperative Research, Environmental Cooperative Research, Mineral Diversification, Permanent University Trust Fund, and various other research programs.

Diversity is needed in this area in order to capture ideas from many sources and allow a variety of approaches. Company input is particularly important to maintain the vigor of the programs.

- Develop a new program under which successful research projects can be tested at a plant scale.

  NRRI and DNR have identified eleven technologies which should be tested at a plant scale. It is believed that a new program which would share the risk of commercial demonstration would accelerate the adoption of these new ideas.

- Create a new taconite flowsheet using ideas generated during the last decade.

  The newest plant on the Mesabi Range is twenty years old and the oldest is forty. A new taconite flowsheet would incorporate many innovations, e.g. column flotation, high pressure roll crushers, ported kilns, etc. At this point in time, researchers do not have a good fix on the costs or productivity of such a plant, so a project should be started to provide several alternative flowsheets together with material balances, energy requirements, and capital costs. These flowsheets would be the models toward which the plants could evolve during the next 15 years. They might also be the first step in construction of a new plant to replace an older one.

- Changes to the membership of the Minerals Coordinating Committee.

  The current membership reflects public interests, and organizations which are the ultimate recipients of the research dollars. The state's experience with the Iron Ore Cooperative Research Program indicates that a management structure which incorporates a well-defined set of goals and private interests can be quite effective.

Governor's Task Force on Mining and Minerals

The proposals of the mineral exploration community, the taconite industry, and the Minerals Coordinating Committee were presented to the Governor's Task Force at a meeting in October 1996. Several items related to manganese and iron ore value-added were also presented at that time. The Task Force asked questions, refined several proposals, and defined their role in the FY1998-99 budget process. The items presented at the meeting were gathered into a single document by IRRRB staff and were carried forward into a meeting which was held at the end of November 1996. At that meeting, the Governor's Task Force endorsed a set of research and policy proposals for the upcoming biennium. Much of what the Task Force recommended has been incorporated into the MCC's Biennial Work Plan.

Mineral Diversification Funding History FY1988-97

Historical Funding

The Minerals Diversification Program has had an uneven funding history since its inception in FY1988. In the first biennium, the Governor approved an initial $1.0 million to the effort. During the session, this was increased by $500,000 so the final appropriation was $1.5 million. In the second biennium, the initial allocation was raised to $2.0 million, but this was cut by about $600,000 due to overall budget constraints. The amounts available for Mineral Diversification were reduced in subsequent sessions and for the last two biennia the Mineral Diversification appropriation has stood at $750,000. The MCC is requesting that the appropriation amount be increased by $500,000 so that the program can be restored to the levels it had in FY1992-93.

In past years, the state's Mineral Diversification appropriation was allocated to three commodity driven categories according to goals established in 1987. The system, which was used is shown in Table 2, which also shows the historical distribution of Mineral Diversification funding.

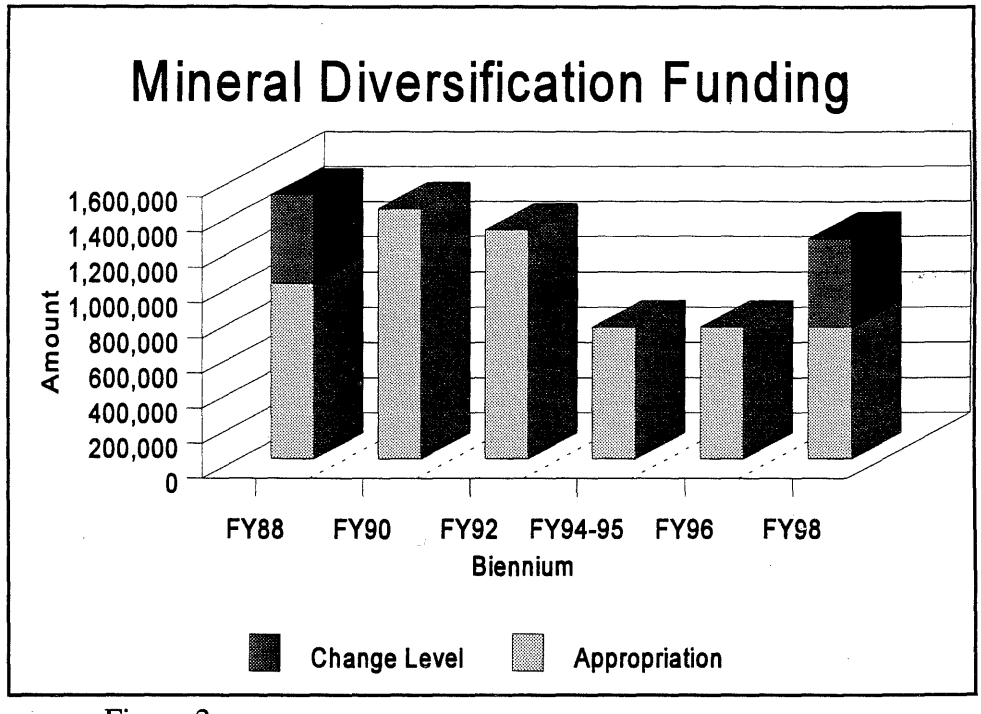

Figure 2.

The data are separated into two time periods due to significant differences in the allocation of funds to projects. In the current biennium, about one-third of the available funding was allocated to processing research on Minnesota's low-grade copper/nickel ores which are found along the line where the Duluth Complex meets the Iron Formation near the town of Babbitt. In order to accomplish this objective, funds were taken from taconite processing research, drill core logging, and industrial minerals projects. The MCC believed the shift was needed because mineral processing technology has changed sufficiently to justify another look at the copper/nickel resource. The data also show that a significant

percentage of the funding was devoted to the generation of geologic information useful to the minerals exploration industry.

Table 2. Mineral Diversification Actual Funding Distribution - Percent.

MINERAL DIVERSIFICATION ACTUAL FUNDING DISTRIBUTION - PERCENT				
MINERAL	TOPIC	FY1988-95	FY1996-97	AVERAGE
Ferrous	Processing	10	-0-	8
	Value-added	3	10	4
Nonferrous	Geological Mapping	34	36	35
	Geochemistry and Geophysics	15	16	16
	Processing	3	31	5
	Drill Core Logging	7	-0-	6
	Environmental and Other	10	4	9
Industrial Minerals	Processing	3	-0-	3
	Inventory	13	3	12
	Environmental and Other	<1	-0-	<1
Basic Research		2	-0-	<2

Allocation of Mineral Diversification Funding for FY1998-99

Much has changed since 1988 and the MCC believes it is necessary to recalibrate the program according to current and expected conditions. Under the new system, work will be classified according to its purpose. The following classes of effort will be used:

- Assistance for currently existing minerals industries—taconite, sand and gravel, dimension stone, clay, silica sand, etc., in order to maintain well paid rural jobs.

- Evaluation of known but undeveloped resources—copper/nickel, titanium, manganese, vanadium, etc.

- Delineation of potential mineral resources which range from sand and gravel to gold and diamonds. Work in this area will identify regions of high mineral potential and targets for exploration.

- Support for land use and environmental issues—mineland reclamation, mine development, minimizing land use conflicts, etc.

- Encouragement of minerals basic research.

Assistance for Currently Existing Minerals Industries

The dominant minerals industry in Minnesota is the taconite industry with about 6,500 direct employees and a product value of about $1.3 billion per year. The sand and gravel industry is a close second in value and exceeds taconite in employment. If one counts the Ready-Mix companies, the aggregate industry employs about 10,000 people. The dimension stone industry has a base level of employment of about 2,000 people with the total depending on the construction of large commercial buildings. The minerals industry is an important part of the state's economy and rivals the paper and agricultural processing industries.

At the present time, the taconite industry is surging back from the low points experienced in 1982-83. All of the existing plants are producing at or near capacity and the cost savings, which were generated over the last ten years, have made Minnesota pellets the least expensive blast furnace raw material on the Lower Great Lakes. However, new technology will be needed if the industry is to maintain itself well into the next century. The newest plants on the Iron Range are 25 years old and the oldest is now over 40. The technology employed is older yet and much has been learned over the years about taconite processing. The plants are not obsolete, but they do not have the latest and best technology, and maintenance is becoming increasingly expensive. Mineral Diversification funding would be used to take a first look at new technologies and to provide a technological template for plant evolution.

In addition, the state should maintain a level of effort on value-added iron technologies so that it can participate in the explosive growth in demand for Direct Reduced Iron (DRI). The state's role in this effort is to monitor technological development to look for technologies that might give Minnesota ore a unique advantage in the market place. It is unlikely that the state will engage in process development, but pilot plant testing of target technologies is a real possibility. This approach requires a small amount of money which can be used for monitoring and process evaluation, with the possibility of larger amounts if conditions indicate that a technology should be pursued in greater depth. The MCC will also provide technical assistance to companies or individuals who express interest in locating a value-added plant in Minnesota.

State supported research on taconite technology should lead to:

- Continuation of an economically viable taconite industry.

- Job creation that goes beyond mining and processing through creation of value-added and/or support industries.
- Maintenance of a skills base to support current and future minerals industries.
- Transfer of past and current research into the plants.

The programs listed at the end of this section aim at those objectives.

The major problem facing Minnesota's aggregate industry is maintenance of a resource base which can provide material to the Twin Cities economically. As the metropolitan population grows, the demand for aggregate grows. For example, the demand for aggregate in Minnesota is at least eight tons per person based on estimates provided by the U. S. Bureau of Mines and the voluntary aggregate tax collected in twenty three counties. The figure would likely be higher if comprehensive data were available. The issues which seem important are:

- Resource depletion though mining and urban development with the latter being the most important. At the present time, local planning allows aggregate resources to be covered by commercial and residential development.

- Suburban growth is occurring rapidly in all areas of the state and gravel mining is an unwelcome neighbor in many places.

- Larger volumes of material are being moved longer distances to supply the demand generated by suburban growth. For example, aggregate is now being moved from Moose Lake to the Twin Cities.

- No statewide standards exist for reclamation and not all companies support good reclamation practices. This puts some localities at risk due to poor mining practices.

- Technical expertise to guide mining practices is lacking in local units of government.

- Aggregate inventories are lacking in critical areas of the state since funding for geological mapping of the resource has been scarce.

- Aggregate shortages are already being felt in some places in the state, most notably along Highway 61 north of Duluth.

The list of aggregate issues is too extensive to be covered in any real way by Mineral Diversification funding. However, the Governor's Task Force on Mining and Minerals has recommended creation of a legislative committee which would gather input from stakeholders, i.e. counties, cities, construction contractors, the Department of Transportation, local citizens groups, environmental groups, etc., to determine whether there is any consensus on the need for a statewide aggregate policy. A portion of the available Mineral Diversification dollars will be used to support that effort.

During FY1998-99, the MCC will allocate Mineral Diversification funding to:

- Developing a new flowsheet for taconite production which incorporates the most recent research results.

- Supporting development of iron ore value-added technologies for application to Minnesota conditions.

- Continuing aggregate mapping in those counties or regions where the most concern has been expressed, e.g. the North Shore or counties just outside of the Metro area.

The MCC will also support an evaluation of the need for a statewide aggregate policy if the Legislature decides to initiate action in this area.

Evaluation of Known But Undeveloped Resources

The bedrock which underlies Minnesota contains valuable quantities of many different metals and minerals. The old Cuyuna Range contains several large manganese deposits. The base of the Duluth Complex near Babbitt is known to host large, low-grade copper deposits. These same rocks also contain significant quantities of ilmenite, a titanium ore, and vanadium. The problem delaying development has always been that the costs of mining and processing with current technology did not indicate a sufficient return on investment.

Development of a mineral property is a complex process, but in simplest terms it can be reduced to four basic stages.

- Exploration to determine the tonnage and grade of the deposit.
- Development of an environmentally acceptable mining plan for extraction.
- Development of a processing flowsheet to produce a marketable product.
- Economic evaluation and financing for development.

These very quickly become parallel activities because all are equally important and all of them have to be successful. The state theoretically could offer support in any of the four areas depending upon the development stage. Many of these deposits have not been studied in a long time and much has changed in the interim. The availability of new techniques hints at ways to make the deposits commercially viable.

In the next biennium, mineral processing work will be conducted on several known resources. The highest priority will be given to hydro metallurgical processing of the low-grade copper ores as a continuation of work started in the current biennium. Other resources that may be evaluated include ilmenite, a titanium ore, manganese, or vanadium, which is found as a coproduct with other ores.

The goals for the effort on known deposits are:

- To generate public information on the technical and economic feasibility of the deposits.
- To provide a strong indication as to whether the deposits can be developed under current Minnesota laws and regulations, and whether environmental concerns can be managed.
- To obtain interest from mining companies for leasing, detailed evaluation of the deposits, and eventual mine development.

Delineation of Potential Mineral Resources

The State of Minnesota has good potential for many types of minerals. As Figure 3 shows, mineral development could occur anywhere in the state with the northern half holding the greatest promise for metallic minerals and the southern half for industrial minerals. In 1987, the State of Minnesota was attracting considerable exploration interest. The price of gold was high and exploration in the United States was part of every company's program. The state was considered to be "elephant country" for both precious and base metal exploration. Recent analyses had found indications of platinum and chromite in Duluth Complex drill core and small flakes of gold were found in overburden drilling samples and bedrock outcrops. Expectations were high and mineral exploration interest was at its peak. The pendulum has swung back since 1987 and, currently, Minnesota is not attracting much exploration interest.

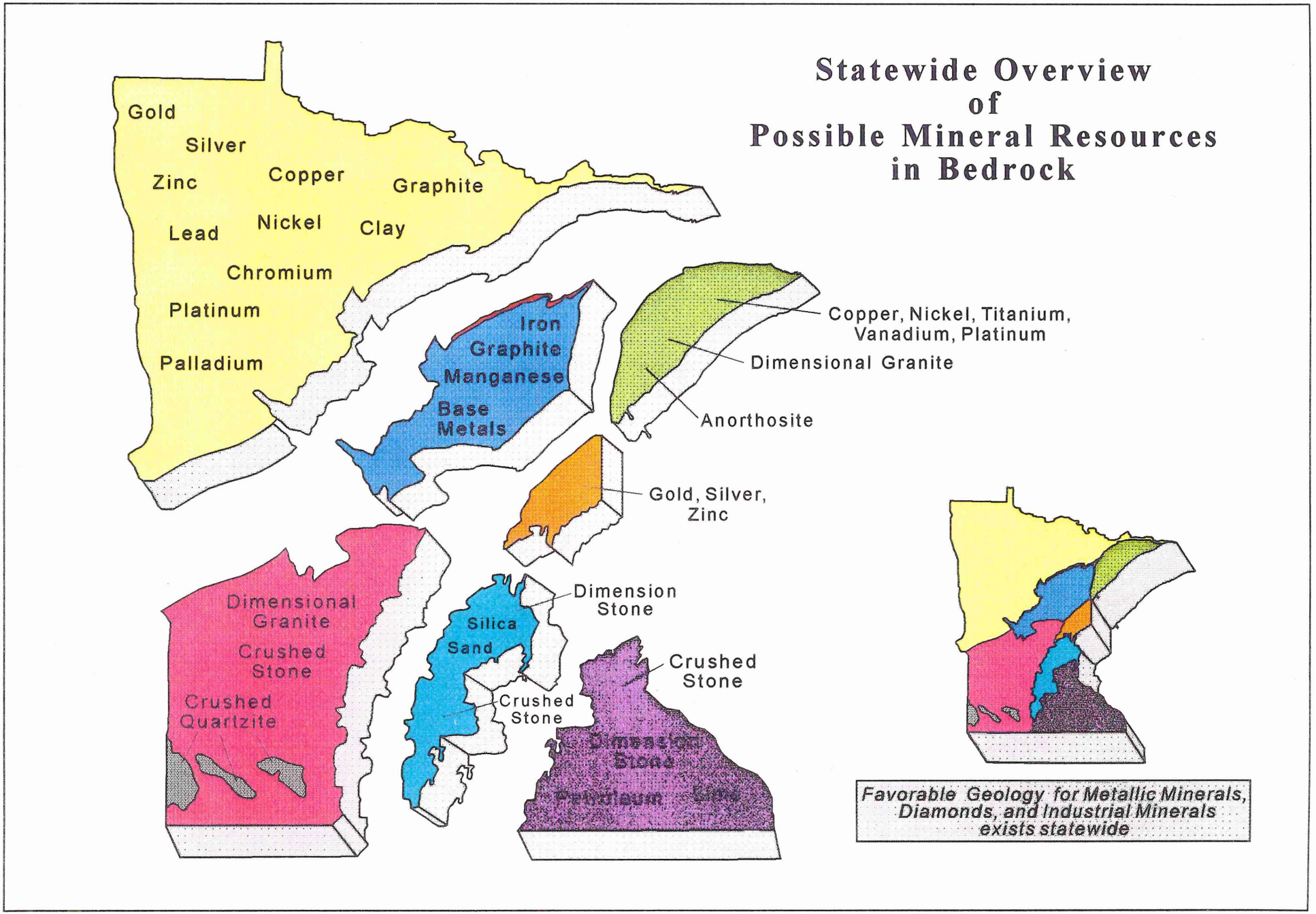
Statewide Overview
of
Possible Mineral Resources
in Bedrock
Gold
Silver
Zinc
Copper
Graphite
Lead
Nickel
Clay
Chromium
Platinum
Palladium
Iron
Graphite
Manganese
Base
Metals
Copper, Nickel, Titanium,
Vanadium, Platinum
Dimensional Granite
Anorthosite
Gold, Silver,
Zinc
Dimensional
Granite
Crushed
Stone
Crushed
Quartzite
Silica
Sand
Dimension
Stone
Crushed
Stone
Crushed
Stone
Dimension
Stone
Petroleum
Favorable Geology for Metallic Minerals,
Diamonds, and Industrial Minerals
exists statewide

Figure 3.

A large portion of the available Mineral Diversification funding will be used to increase the amount of mineral exploration in Minnesota. While one can attribute much of the decline in exploration to external factors, the state does have responsibility for acquiring and presenting data on Minnesota's geology in such a way that it will attract company interest. One can characterize the available data as follows:

- Results of research projects conducted in Minnesota—These results can be in the form of maps, geophysical grids, or chemical analyses of various types of samples. Most projects were designed to study some geologic phenomenon in a specific area, e.g. a bedrock map of St. Louis County, application of a mining camp model to a specific geologic terrane, etc. These studies brace against each other when two or more researchers report on different characteristics in the same region, e.g. a geophysical study and an geochemical study. The delineation of areas of high mineral potential can often be found by bringing the results of several studies together so that one can look at the data in a new way.

- Results of past exploration—A record of past exploration exists in the library at Hibbing. It contains the results of company effort which was usually aimed at finding specific minerals in a region. The companies usually used an ore deposit model of their own design and did not deviate from their chosen course. A good example of the foregoing is the fact that most companies overlooked the oxide zones in drill core when they were looking for base metal sulfides. This caused them to miss indications of other metals. Examination of these exploration records often show indications of interesting geology which were not part of the original exploration plan, or geologic anomalies which were not explored because the company's interest waned or money ran out. The records of past exploration are fertile ground for exploration targets.

The most important task is to make access to the existing data on Minnesota's geology easier for geologists worldwide. At the present time, a company geologist must visit Minnesota to view records at the Hibbing office of the Division of Minerals or at the offices of the other geologic organizations. The geologist must then compile and organize the data by grouping the data from an area into a consistent data base. This usually means taking a map from one source, geophysics from perhaps several sources, and geochemical data from several studies. By using computer technology including GeographicIinformation Systems, the agencies can organize the available data so that the initial work load for company geologists is significantly reduced. A byproduct of this activity is likely to be indications of possible hot spots that should be pointed out to exploration organizations. Examples of this have already occurred in the current data organization effort. However, much more can be accomplished through an accelerated data organization and publication effort.

The Governor's Task Force recommended publishing the data in the Hibbing office in a user friendly form. The MCC concurs with that recommendation and will extend it to a consolidation of useful data that exists at the Geological Survey and the Natural Resources Research Institute. At the present time, the Division of Minerals is revising its data architecture to make data publication easier. The extension of the architecture to other agencies should be straightforward since the data structures will be designed to accommodate the most important types of geologic and ownership

data. It is expected that the data publishing effort will depend on modern computer technology including the Internet, file transfer protocols, digital map presentation, and CD-ROMs.

It is also necessary to put new mineral potential data into the pipeline so that external organizations get an opportunity to view, what are to them are, unexpected results. The MCC believes geologic mapping which combines the efforts of geologists, geophysicists, and geochemists is the best way to generate new data. Coordinated map production will ensure that the final products represent the best thinking and data from all of the available sources and will maximize the amount of new information available. The use of Geographic Information Systems for geologic mapping will facilitate the coordination among the scientists and the transfer of information to exploration geologists worldwide. The MCC will undertake coordinated mapping efforts in terrane which already is considered to have high mineral potential.

During FY1998-99 work on potential minerals resources supported by the MCC will include:

- Applying computer technology to the organization and publication of minerals data available at member agencies.
- Coordinated geologic mapping of areas which appear to have good mineral potential .
- Geological studies including geochemistry and geophysics in areas which are considered to have high mineral potential.

Support for Land Use and Environmental Issues

Land use in areas which have mineral potential is a critical issue which needs attention by all levels of government. As was previously mentioned, the protection of aggregate resources near the metropolitan region is important for maintenance of the transportation infrastructure and economic growth. The Iron Range also has similar issues related to consideration of current economic development over iron ore resources that might be mined forty years from now. The governmental focus on the Minnesota River Valley and the cleanup of the river is another example of an important land use issue. The MCC does not intend to become a leader in land use questions as it is a technical group with expertise in minerals topics. However, it can use the capabilities of the member agencies to provide minerals related data to those organizations charged with the development of land use policies.

The MCC has a direct interest in mineland reclamation and reclamation research. The goal of the reclamation programs of IRRRB and DNR are to provide stable, hazard free areas after mining ceases. PCA is also interested in long-term preservation of air and water quality in mining areas. These needs meet in a series of research efforts targeted toward beneficial use of waste materials, reduction of effluents from stockpiled material, and conversion of mining areas to other uses at the conclusion of mining. For example, when mining ceases in Minntac's east and west pits it will begin to fill with ground water. The result will be a lake about eight miles long and over one mile wide.

Similar situations can be found across the Iron Range. The Cuyuna Range near Crosby is an example of the type of long-term public benefit that can accrue, even without prior thought to reclamation and secondary use. The MCC believes that better results can be achieved through long-range land use planning.

The MCC plans to use a portion of its FY1998-99 appropriation for the following land use and environmental projects:

- Waste characterization and studies of the beneficial use of waste material such as municipal solid waste compost and/or sewage sludge for mineland reclamation and revegetation of taconite tailings.

- Creation of digital topographic maps of the Mesabi Iron Range which can be used together with other techniques such as digital ortho-photos and GIS for land use planning. This region was last done in 1947 even though elevation changes affected the Mesabi Range more than any other location in the state.

- Development of a Mineral Resource Compendium for the Minnesota River Valley which will be submitted to the organizations charged with MRV land use planning.

- Waste rock characterization for potential Minnesota ores.

Encouragement of Minerals Basic Research

The MCC wishes to have a portion of the funds available for minerals research allocated to basic research. Its philosophy regarding basic research is allocation of a small amount of funding for ideas that appear interesting, may be important, but cannot yet be evaluated economically as not much is known about the topic. The members have agreed that the funds available from the Permanent University Fund are the most appropriate source of basic research money, so no allocation of Mineral Diversification money will be made for this purpose.

Mineral Diversification Budget - Fiscal Years 1998-99

The budget presented here assigns dollar amounts to the projects listed for consideration in the foregoing sections. The first column lists the research topic, the second the specific project, the third the amount to be allocated from the Mineral Diversification SAME level appropriation, and the fourth the amount that would be allocated if the Legislature approves an increase in the amount of Diversification funding. The last two columns indicate whether matching funds are expected and whether the project area was recommended by the Governor's Task Force on Mining and Minerals.

Table 3. Mineral Diversification Projects - Fiscal Years 1998-99.

Mineral Diversification Projects Fiscal Years 1998-99		Budget- $,000		Non-State[1] Matches Expected	Governor's Task Force[2]
		Base Level	Change Level		
Assistance for Currently Existing Minerals Industries	Development of a new taconite flowsheet.	125	75	Yes	Yes
	Support development of iron ore value-added technologies.	50		Yes	Yes
	Continue aggregate mapping.	30	50		
Evaluation of Known But Undeveloped Resources	Mineral Processing for known reserves, e.g. hydro metallurgical processing of the low-grade copper ore or processing of titanium ore.	50	80	Yes	Yes
Delineation of Potential Mineral Resources	Apply computer technology to the organization and publication of minerals data.	100	60	Yes	Yes
	Geologic studies including coordinated geologic mapping of areas with good mineral potential, data consolidation, geochemical and geophysical studies.	220	80	Yes	Yes
Support for Land Use and Environmental Issues	Waste characterization and use of waste material for mineland reclamation, e.g. MSW compost, sewage sludge, dredge spoil, etc.		80	Yes	Yes
	Creation of digital topographic maps of the Mesabi Iron Range.	100	50	Yes	Yes
	Minnesota River Valley—Mineral Resource Compendium.	75	25		
TOTAL		750	500		

[1] Non-state matching funds included private, federal, or other organization dollars.
[2] Governor's Task Force on Mining and Minerals recommendations — January 1997.

Appendix A

Mineral Diversification Historical Funding

The following Table A-1 is an updated version of the one which was in the 1995 report. It adds the FY1996-97 data to the spreadsheet. Table A-2 showing the history of all research expenditures also follows.

TABLE A-1. MINERAL DIVERSIFICATION PROJECT HISTORY FY1988-97

Prepared by: Minnesota Department of Natural Resources

January 1997

PROJECT DESCRIPTION	PROJECT MANAGER	FISCAL YEAR EXPENDITURES - $,000'S FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	TOTAL
FERROUS PROJECTS												
Pellet Quality and Cost												
Digital Image Analysis	USBM		15.0									15.0
Novel Iron-making	MRRC			65.4								65.4
Improved Fluxed Pellets	CMRL			50.0	50.0							100.0
Process Temperature Control	CMRL			50.0	50.0							100.0
Improved Classification	CMRL						10.0					10.0
Phase II Low-Silica Concentrates	CMRL					50.0	50.0	25.0	25.0			150.0
Water Treatment for Flotation	CMRL					25.0	30.0					55.0
Value-added Technology												
COREX Direct Smelting	DNR	27.7										27.7
Technology Survey	DNR					10.0	10.0			37.5	37.5	95.0
Direct Reduction Research	CMRL/MID							37.5	37.5			75.0
Salt Roasting of Vanadium Ores	CMRL							12.0	12.0			24.0
Oxidation/Reduction of Magnetite	CMRL							10.0				10.0
NON-FERROUS PROJECTS												
Geologic Drilling and Mapping												
Cook Area Map	MGS	173.6	176.4									350.0
Koochibel Map	MGS			175.0	175.0							350.0
Northwestern Minnesota Map	MGS					150.0	163.0					313.0
Duluth Complex Stratigraphy	NRRI					75.0	71.6	50.0	50.0			246.6
Duluth Area Map	MGS					50.0	50.0					100.0
Quaternary Map of N. Central MN	MGS					45.0	43.8					88.8
East Central Minnesota Map	MGS							120.0	120.0			240.0
Duluth Complex - Allen Quad.	MGS/NRRI									63.0	63.0	126.0
Mineralization in the Virginia Horn	MGS/NRRI									118.0	118.0	236.0
Geochemistry												
Strategic Minerals	NRRI	98.0	98.0									196.0
Glacial Till	DNR	75.0	75.0	75.0	75.0							300.0
Bedrock	NRRI	31.0	69.0	50.0	50.0							200.0
Airborne Spectral Radiometry	NRRI		25.0									25.0
Gold in the Early Penokean Orogen	NRRI					12.5	12.5					25.0
Mineral Processing												
Concentration of Ilmenite	MRRC	30.0	100.5									130.5
Cu, Ni, and PGM Flotation	CME						3.4	8.0				11.4
Cu, Ni Metallurgical Processing	CMRL									117.5	117.5	235.0

TABLE A-1. MINERAL DIVERSIFICATION PROJECT HISTORY FY1988-97

Prepared by: Minnesota Department of Natural Resources

January 1997

PROJECT DESCRIPTION	PROJECT MANAGER	FISCAL YEAR EXPENDITURES - $,000'S FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	TOTAL
Data Acquisition and Analysis												
Drill Core Examination and Assay	DNR	33.8	50.0	50.0	50.0	45.0	45.0	51.3	51.3			376.4
Minerals Data Base	MCC		50.0	25.0	25.0							100.0
Mineral Deposit Modeling	MGS		39.4	40.0								79.4
Gold Economics Study	NRRI		22.5									22.5
GPS Acquisition and Functionality	MCC						56.5	7.5				64.0
Ore Deposit Modeling	DNR									28.0		28.0
Study of "Franklin" kimberlites	MGS										6.0	6.0
Gold and Massive Sulfides- Ely	UMD-GEOL										15.0	15.0
Environmental Research												
Reclamation Research	DNR			25.0	25.0	18.0	18.0					86.0
Mineral Management												
Improved Ownership Records	St. L County		50.0									50.0
Severed Minerals Identification	DNR			25.0	25.0	10.0	10.0					70.0
Iron Range Digital Elev. Models	DNR										5.0	5.0
INDUSTRIAL MINERALS												
Aggregate Studies												
Sand and Gravel Inventory	DNR			20.0	20.0	20.0	13.5	20.0	20.0			113.5
Sand and Gravel Restoration	DNR					10.0	10.0					20.0
Mineral Surveys												
Carbonate Resource Assessment	CMRL	68.0	128.5	50.0	50.0							296.5
Clay Product Development	MRRC/CMRL	40.0	40.0									80.0
Dimension Stone Inventory	DNR			12.5	12.5	20.0	20.0					65.0
Minerals Forum	MCC		10.0									10.0
Kaolin in Central Minnesota	NRRI					30.0	30.0					60.0
Carbonate Beneficiation	CMRL					25.0	25.0					50.0
Transportation Study	NRRI					5.0	5.0					10.0
Kittson County Bloating Clays	CMRL					12.5	12.5					25.0
Kaolin Resource Assessment	NRRI							42.5	42.5			85.0
Minnesota River Valley Resources	ALL										24.0	24.0
BASIC RESEARCH	U of M			50.0	50.0							100.0
FISCAL YEAR TOTALS		577.1	949.3	762.9	657.5	613.0	689.8	383.8	358.3	364.0	386.0	5741.7
BIENNIAL TOTALS		1526.4		1420.4		1302.8		742.1		750.0		

TABLE A-2. STATE FUNDING FOR MINERALS RELATED RESEARCH

Trends for the FY1984 to FY1997 Period

July 1, 1983 to June 30, 1997

PROGRAM	ACTUAL EXPENDITURES- M$ FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	TOTAL
GENERAL FUND															
Direct Reduction	750.0	750.0	550.0	550.0											2,600.0
Iron Ore Cooperative Research					303.0	303.0	313.5	313.5	325.0	325.0	325.0	325.0	311.0	311.0	3,155.0
Mineral Diversification					577.1	949.3	762.9	657.5	613.0	689.8	383.8	364.0	364.0	386.0	5,747.4
Cooperative Environmental Research											30.0	45.0	45.0	45.0	165.0
Ind. Mineral Development					141.0	141.0									282.0
Permit Simulation					125.0	125.0									250.0
Esker Sampling			15.0												15.0
DNR Geologic Drilling	250.0	250.0	190.0	190.0											880.0
Saline Waters		10.0													10.0
Lithogeochemistry			81.0												81.0
Structure of Duluth Complex		53.0													53.0
Steel Mill Study											20.0				20.0
Total	1000	1063	836	740	1146.1	1518.3	1076.4	971	938	1014.8	758.8	734	720	742	13,258.4
LEG. COMM. ON MINN. RESOURCES (LCMR)															
Aeromagnetic Surveys	347.0	347.0	400.0	400.0	392.0	392.0	315.0	315.0							2,908.0
Kaolin Clay					196.0	196.0									392.0
COREX Direct Smelting				50.0	20.6										70.6
AISI/MN Low-Silica Project							100.0	100.0							200.0
Industrial Minerals							65.0	65.0							130.0
Non-Ferrous Minerals									65.0	65.0					130.0
Acquisition of Private Expl Data							75.0	75.0							150.0
St Louis County Tract Index							40.0	40.0							80.0
Pilot Study of Spectral Radiometry							75.0	75.0							150.0
Poultry Waste and Peat Compost							65.0	65.0							130.0
Glacial Drift Geochemistry					98.0	98.0									196.0
Drill Core Examination and Assay			75.0	75.0											150.0
Greenstone Belts of SW Minnesota									60.0	60.0					120.0
Geochemistry of E-Central MN	75.0	75.0													150.0
Overburden Drilling			100.0	100.0											200.0
Glacial Lake Agassiz Beach Ridges													42.5	42.5	85.0
Total	422	422	575	625	706.6	686	735	735	125	125	0	0	42.5	42.5	5,241.6

TABLE A-2. STATE FUNDING FOR MINERALS RELATED RESEARCH

Trends for the FY1984 to FY1997 Period

July 1, 1983 to June 30, 1997

PROGRAM	ACTUAL EXPENDITURES- M$ FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	TOTAL
IRON RANGE RES. AND REHAB. BOARD															
Development of Plasma Smelting	687.5	687.5	255.0												1,630.0
Iron & Steel Market Studies	70.0	70.0	30.0												170.0
Reclamation Studies				55.0											55.0
Reserve Mining Studies					25.4										25.4
DRI, Iron and Steel Technical Studies					75		2.0	25.0		10.0			160.0		272.0
Ilmenite in Minnesota (Titanium)									20.0	20.0					40.0
AISI/MN Low-Silica Project							25.0	25.0			20.0				70.0
Non-Ferrous Metals Studies											76.5	73.5			150.0
Taconite Processing Studies											48.0				48.0
Manganese Drilling													35.0		35.0
Exploration Incentives														105.5	105.5
Total	757.5	757.5	285	55	100.4	0	27	50	20	30	144.5	73.5	195	105.5	2,600.9
U of M LEGISLATIVE SPECIALS AND ETC.															
Mineral Resources Research Center	780.0	780.0	780.0	780.0	780.0	780.0	780.0	780.0							6,240.0
Natural Resources Research Institute			400.0	421.0	457.0	529.0	484.0	391.0	420.0	396.0	390.0	390.0	390.0	390.0	5,058.0
Other State (GMC/MTI, etc.)			25.0	25.0	22.3	77.5	249.8	218.6	193.0	221.0	200.0	200.0	250.0	250.0	1,932.2
Permanent University Trust Fund											312.8	259.4	388.0	525.0	1,485.2
USBM Mineral Institutes Program	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	116.0	70.0	115.0				1,461.0
Total	925	925	1350	1371	1404.3	1531.5	1658.8	1534.6	729	687	1017.8	849.4	1028	1165	16,176.4
GRAND TOTAL	3,104.5	3,167.5	3,046.0	2,791.0	3,357.4	3,735.8	3,497.2	3,290.6	1,812.0	1,856.8	1,921.1	1,656.9	1,985.5	2,055.0	37,277.3

Appendix B

Coordination of Mineral Research Funding in the FY1998-99 Biennium

Table B-1 is an estimate based on MCC discussions. Actual project selection will depend on actions of committees like the Iron Ore Cooperative Research Committee and the Research Priorities Committee which have been chosen to make project recommendations for individual programs.

Table B-1. Possible Distribution of Minerals Research Funding - FY1998-99.

Possible Distribution of Minerals Research Funding- FY1998-99									
Topic	Possible Funding Sources- $,000								
	Cooperative Research			Mineral Diversification	Diversification Change Level	Permanent University Trust Fund	Minnesota Technology, Inc.	Total	Percent
	Iron Ore	Environmental							
		Base	Change						
Currently Existing Minerals Industries	522			205	125	600	100	1,552	45
Known but Undeveloped Mineral Resources				50	80	150	100	380	11
Potential Mineral Resources				320	140	50		510	15
Land Use and Environmental	100	90	260	175	155	50		830	24
Minerals Basic Research						150		150	4
Total	622	90	260	750	500	1000	200	3,422	100

1. The Change level for Environmental Cooperative Research includes a legislative initiative for $110,000 and a request for a study of mineland hydrology for $160,000.
2. The amount shown for the Permanent University Trust Fund should be about 100 percent of the funds which will be available in the upcoming biennium
3. The Iron Range Resources and Rehabilitation Board has provided significant funding for minerals research and selects project on a case by case basis.

Appendix C

Mineral Diversification Project Results

This appendix is an update of the project section of the 1995 report. The FY1996-97 projects are added and final results from the FY1994-95 projects are updated.

Mineral Diversification Plan Project Descriptions

Since its last biennial report, the FY1994-95 projects have been completed, but the FY96-97 are still ongoing. In general, the projects have progressed successfully. This appendix lists each project approved by the Minerals Coordinating Committee (MCC) since the inception of the Mineral Diversification Program and gives a brief description of each project. The appendix is organized according to the objectives contained in the Mineral Diversification Ten Year Plan. A single description is given where the work extended over more than one biennium.

—OBJECTIVE 1: TO IMPROVE AND EXTEND MINNESOTA'S IRON INDUSTRY

• Pellet Quality and Costs

DIGITAL IMAGE ANALYSIS. Stability, productivity, and product quality in taconite processing require accurate particle size control throughout the concentration process. Accurate and timely particle size information allows equipment operators to do things like adjust cone crusher settings, adjust water additions, make binder and feed adjustments in balling drums, as well as modify blast parameters (such as the size of charge, the spacing of drill holes, etc.). The U. S. Bureau of Mines has been developing software and hardware packages for the operations at Minntac and LTV Steel Mining. Called digital image analysis, this computer-based, particle size monitoring system has undergone testing in both plants. The technique has significant potential for improving the control of particle size during the crushing and grinding process, and improving control of moisture and pellet size in the agglomeration process.

IMPROVED FLUXED PELLETS. Production of fluxed taconite pellets is routine for two Minnesota companies and is being developed by two others. Raw limestone and dolomite are normally used for fluxed pellet production. This project seeks to build on that experience and to reduce costs by replacing the raw flux material with lime/dolomite hydrate.

The work has demonstrated that the substitution of lime/dolomite hydrate for raw flux will reduce the additional energy required for fluxed pellet production by 50 percent. These additional energy savings will help protect equipment and help reduce excessive build-up of slag particulates. Furthermore, bentonite and organic binders can be totally eliminated, and the hydrate does not

increase silica levels in the product, as the bentonite does. The use of the hydrate flux component can be accomplished with relatively minor adjustments to the plants.

Encouraged by the research results, the USX Corporation is considering a proposal to run a full-scale plant test with lime/dolomite hydrate to confirm fuel savings and productivity gains.

PROCESS TEMPERATURE CONTROL. This project was designed to evaluate the effect of water temperature on taconite processing at temperatures ranging from 45 to 120 degrees Fahrenheit, temperatures frequently found in Minnesota plants.

Batch and continuous grinding tests showed an increase of up to 10 percent in fines generation as temperature increased. However, it appears that classification efficiency decreased at the higher temperatures as a smaller percentage of the fines reported to the undersize or overflow. Flotation tests indicated better results as the temperature decreased with the best flotation of silica occurring at 40 degrees Fahrenheit. Optimizing the temperature for various process unit operations should eventually provide economic improvements in taconite plants.

- Improved Classification

PHASE II LOW-SILICA CONCENTRATE. Direct Reduced Iron research covers three areas: concentrate production, energy requirements, and innovative reduction processes. The low-silica concentrate project, which is being done at the Coleraine Minerals Research Laboratory (CMRL), aims to make Minnesota's taconite concentrate comparable with foreign ore.[1]

EFFECT OF PLANT WATER TREATMENT ON FLOTATION AND GREEN BALL QUALITY. The presence of high concentrations of calcium, magnesium, and sulfate ions in plant process water are known to have severe negative effects on flotation and pellet binder consumption. In addition, sulfate ions can contribute to accelerated corrosion. Since most taconite plants use extensive water recycle systems, a progressive build up of ions will result unless specific measures are taken to either prevent such accumulation or remove the ions from the system. Comprehensive water treatment to maintain or improve water quality is expensive, but can be justified if verifiable cost benefits from the treatment program can be demonstrated.

Methods of water treatment that may be applicable to plant water systems include the addition of barium hydroxide, **Ba(OH)2,** to remove sulfate ions combined with **CO2** treatment to control pH, reverse osmosis, soda ash treatment, or ion exchange. These methods could be incorporated into a plant's water system and would be particularly beneficial if placed in a critical process area, thereby reducing the volume of water requiring treatment.

This project quantified the effect that water quality has on two critical process steps—flotation and green balling. Conventional water treatment methodology was used to prepare process water for

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[1]MN DNR Minerals Division, 1994. *Minnesota Steel: A Blueprint for Progress.* September, ix.

bench-scale testing. The test work was based on plant water samples from three different taconite operations which were selected on the basis of preliminary water quality information and the interest of the plant operators. The data helped guide companies in the selection of the type of water treatment suitable for their plants and provide a preliminary cost justification for the capital investment needed to bring water treatment technology on-line.

- Value-added Technology

NOVEL IRON MAKING. The project was targeted specifically at a new iron-making process conceptualized by the Director of the Mineral Resources Research Center. Its purpose was to complete preliminary material and energy balances, as well as operating and capital cost estimates in order to gain some insight into the technical and economic feasibility of the process.

The theoretical material and energy balances indicated that the process did not have any conceptual flaws. However, the work did point out some rather difficult engineering problems which would likely require extensive large-scale test work. The MCC classified the project as speculative research worthy of additional investigation. However, the investigator was not able to secure private funding necessary to continue the project.

COREX. The COREX Process is a commercial success with a 330,000 ton per year plant operating in South Africa, another on order for Korea, and a third may be built in the United States by LTV Steel in Cleveland.

The state, in cooperation with the AISI, sponsored the first successful pilot trial of the COREX process in late 1984. This lead to an attempt by the state to have the first demonstration of the COREX technology built here using a combination of U. S. Department of Energy (USDOE) Clean Coal Technology I funds, state loan guarantees from the Iron Range Resources and Rehabilitation Board (IRRRB), and industry funding. The state's bid for the plant was rejected in place of one from Weirton Steel Company, but in 1987 the state received another opportunity to build the demonstration when Weirton dropped out of the process. At the time, a potential plant operator would have had access to about $82 million of public financing, which would have limited the private investment to less than $25 million. However, no company stepped forward to take the offer, so the federal money was reallocated to other purposes. The project proposal data show that the demonstration plant would have been capable of producing about 400,000 tons of pig iron per year at a cost of about $120 per ton. That price would be very attractive in today's market.

TECHNOLOGY SURVEY. The Minnesota Department of Natural Resources (DNR) tries to keep abreast of iron and/or steel making developments in order to assess whether a particular technology should be pursued. A summary of this effort is maintained by the Division of Minerals. It is a summary which contains the cost estimates of various technologies based on material and energy balances, and estimates of capital costs that have been gathered over the years.

DIRECT REDUCTION RESEARCH. In 1993, the Research Priorities Subcommittee of the Taconite

Enhancement Committee recommended three value-added research projects for funding under the Mineral Diversification and University Trust Fund programs:

- The oxidation/reduction and metallization process concept is somewhat similar to FASTMET except that carbon is not added to the pellets. The goal is to capture the heat from pellet oxidation to improve kinetics of a subsequent reduction reaction, which would take place on a circular hearth. If the work is successful, it could lead to a process that would yield a low-gangue, low-sulfur direct reduced iron (DRI) product which would be competitive with imported products. A patent disclosure on this process has been filed by Dr. Rodney Bleifuss, Director of Coleraine Minerals Research Laboratory (CMRL) of the Natural Resources Research Institute (NRRI).

- Lean Ore Oxidation (LEANOX), i.e. producing a metallized product from low-grade ores, has been looked at several times over the last few decades. Most of the significant work was done in the late 1950s and early 1960s before the taconite industry became firmly established. Metallization of the iron oxides is the easy part, but liberation of the product from the silica matrix has always been the stumbling block. Under conventional grinding methods, the softer iron material tends to smear onto the harder, more brittle silica/silicate material. Consequently, magnetic separation does not yield a clean low-silica product.

- CMRL's research on the production of iron carbide from low-grade materials will be expanded to verify its reaction kinetics, iron oxide conversion, carbon deposition and liberation to achieve a low-silica end product. Lab scale equipment will be used to produce small batches of material for testing.

None of these research projects appeared particularly promising for further development. The work on lean ore indicated that a partially reduced iron product might be separated from the silica matrix, but there has been little or no private interest in a continuation of the effort.

SALT ROASTING OF VANADIUM ORES. Vanadiferous-titaniferous ores are found in northeastern Minnesota. Previous investigations have proven the feasibility of producing pigment-grade synthetic rutile concentrate from the nonmagnetic portion of these ores, but the economics of this process are marginal at this time. The objective of this program is to determine whether a second product (vanadium) could also be extracted, thereby making the entire process more economically attractive.

DIRECT REDUCTION AT NATIONAL STEEL PELLET COMPANY. Several public organizations assisted NSPC in its evaluation of the Svedala, Inc. Grate-Car Process. The objective was to determine the feasibility of replacing the original pelletizing line at National with a DRI line using the existing concentrator lines to provide the raw material. The study showed that it was both technically and economically feasible to install the process. However, National Steel decided to concentrate on increasing NSPC's taconite pelletizing capacity to use the existing excess capacity in the concentrator.

DEVELOPMENT OF A MINNESOTA SPECIFIC DRI PROCESS. Work continues on creation of a process flowsheet which combines elements of existing or new processes which will use fine taconite concentrate and western subbituminous coal in the production of DRI. Technology surveys conducted in prior years have uncovered several possibilities and several potential flowsheets have been constructed. Development of a DRI process which is specific to Minnesota material would yield low-cost DRI, but the development cycle would be costly as both laboratory and continuous pilot scale testing would be necessary.

—OBJECTIVE 2: TO INCREASE THE PROBABILITY OF NONFERROUS METALLIC MINERAL DISCOVERIES

• Geologic Drilling and Mapping

Much of the nonferrous mineral wealth of Canada, South Africa, Australia, and Russia come from Precambrian rocks similar to those in northern and western Minnesota. Geologic mapping of Precambrian rock similar to those in northern and western Minnesota is hampered by a thick cover of Quaternary glacial deposits and the generally inadequate state of geologic mapping here has been an impediment to mineral exploration. A major step to deal with this problem was taken in 1979 when a world-class aeromagnetic survey of Minnesota was authorized and partially funded by the Legislative Commission on Minnesota Resources. Since then, aeromagnetic data have been combined with selective drilling for ground truth to produce credible geologic maps of prospective areas in several parts of the state. The following projects were supported with Mineral Diversification funds.

North-Central Minnesota

1. Geologic mapping in contiguous parts of Koochiching, Itasca, and Beltrami counties ("Koochibel" area), 1988-89 biennium. Mapping revealed hitherto unrecognized fault zones and volcanic rock units in greenstone-belt terrane west of the Vermilion district. The mapping prompted serious exploration for gold and base metals by several companies.

   Publications: Minnesota Geological Survey maps M-67 (1990) and M-68 (1990).

2. Cook-Side Lake area, St. Louis and Itasca counties, 1990-91 biennium. Mapping extended coverage from the western limit of older mapping in the Vermilion district to the eastern boundary of the Koochibel map area described above. In this project also, the mapping revealed previously unknown structures and rock assemblages of consequence to mineral exploration and attracted exploration interest.

   Publications: Minnesota Geological Survey maps M-775 (1991) and M-79 (1993).

Northeastern Minnesota

1. Central Duluth Complex, Lake and St. Louis counties, 1990-91 biennium. Mapping covered a block of ten 7.5 minute quadrangles roughly between Isabella on the northeast and Toimi on the southwest. The work clarified a very complex intrusive history in the unexposed interior of the Duluth Complex and provided a rationale for locating oxide-rich segregations in igneous units that are potential sources for vanadium, titanium, and platinum-group metals.

   Publication: Minnesota Geological Survey Open-File Report 91.4.

2. Duluth Complex, Duluth area, St. Louis County, 1992-93 biennium. Mapping covered several quadrangles in and near metropolitan Duluth. The rationale from the mineral-deposits viewpoint was that much could be learned about mineralizing controls by careful work in this accessible area. The information would transfer to poorly exposed areas elsewhere in the southern part of the Duluth Complex.

Current interest in the Duluth Complex as a probable host for platinum-group-elements (PGE) mineralization has focused attention on peridotitic differentiates and highly evolved oxide-silicate residues. Both of these rock types occur near the city of Duluth where relatively good exposures permit their detailed scientific study.

3. Duluth petrology project, St. Louis County, 1994-95 biennium. This project is an outgrowth and continuation of mapping initiated in the previous biennium. It became evident that more effort was needed to sort out the complex relationships among mineral phases in several rock units near Duluth if the controls on igneous differentiation (and the distribution of platinum-group elements) were to be understood. A program to extend field mapping near Duluth, conduct laboratory work on rock and mineral samples, and compile all data as GIS coverage is now underway. Final map compilations will cover work from the 1992-93 and 1994-95 biennia.

Northwestern Minnesota

1. Bedrock geologic map of northwestern Minnesota, Kittson, Roseau, Marshall, Pennington, Red Lake, Polk, Norman, Mahnomen, Clay, and Becker counties, 1992-93 biennium. Mapping revealed previously unknown relationships among rock units and regional structures in the extensions of three major tectonic subdivisions of the Superior Province of the Canadian Shield. Three poorly known greenstone belts are now known in sufficient detail to attract exploration interest. The Vermilion fault is now known to be a fault zone composed of several strands and to have experienced a complicated movement history. The terrane north of the Vermilion fault is predominantly gneiss and plutonic rocks, not volcanic rocks as formerly thought.

   Publication: Minnesota Geological Survey map M-80 (1994).

East-Central Minnesota

1. Geologic map of an area south of Lake Mille Lacs, west of the Midcontinent rift in several counties, 1994-95 biennium. The principal objective of this project is to produce a bedrock geologic map of a trapezoidal area in east-central Minnesota that is the northwestern half of a quadrilateral bounded by latitudes 45° 07'30"W and 46° 15'00"W. This study area includes some of the least understood Precambrian geology in Minnesota. Much of the bedrock has been interpreted as Penokean granitoid intrusions, but signatures in the gravity and aeromagnetic data imply the presence of diverse rock types and structures. The area is of particular economic significance because it may include rock equivalent to the Penokean metavolcanic rocks of the Wisconsin magmatic terrane that host significant deposits of base-metal sulfides. A reliable geologic map is a necessary for systematic mineral exploration in east-central Minnesota.

Quaternary Mapping

"Koochibel" area, north-central Minnesota, 1992-93 biennium. A geologic map that shows the distribution of glacially deposited surficial materials was prepared as an adjunct to the bedrock geologic map of the same area (see above). The mapping of glacial material was facilitated by the abundant drilling conducted by companies and agencies in the area. It provided the stratigraphic framework for interpreting the occurrence and distribution of "indicator minerals" in the drift that were picked up by glaciers from mineral occurrences in the underlying bedrock. The science of tracing indicator minerals in glacial deposits back to their bedrock source has become an all important element in exploration for gold and diamonds.

Publication: Minnesota Geological Survey map M-76 (1993).

Three Dimensional Mapping of the Duluth Complex in the Allen Quadrangle

The basal zone of the Duluth Complex, just south of the town of Babbitt, contains several large, low-grade copper/nickel deposits. It is an area of known mineralization which has undergone much exploration activity in the last twenty-five years. None of the work conducted thus far has shown any indication of a large high-grade deposit. Recent work in similar geologic terranes in other parts of the world have shown that deeply buried high-grade deposits can exist with lower-grade nearer the surface, i.e. higher in the depositional sequence. This project will use newer mapping techniques to produce a large scale three dimensional map of the basal zone which should yield a better picture of where higher grade deposits might exist.

Geology and Mineralization of Archean and Early Proterozoic Rock in the Virginia Horn

The Virginia Horn is one of the more likely areas in the state for deposits of precious metals, e.g. gold. Past exploration efforts have yielded mineral occurrences, but no one has yet found mineralization zones of sufficient size and grade. Mineral exploration has been hampered by the lack of a sufficiently detailed large-scale geologic map of the area. This project will

assimilate all of the available geological, geochemical, and geophysical data to produce a map which can be used to infer where more exploration should occur.

- Geochemistry

Strategic Minerals

GLACIAL TILL. This project is a continuation of an effort to identify the regional occurrence of gold and other metals in glacial till to stimulate further exploration in northern Minnesota and to assist the Department of Natural Resources in its land management role. Twenty new boreholes in Lake of the Woods County were drilled, sampled, and analyzed. A complete digital data base of results is now available.

Analysis of the drill cores show that the Baudette area contains two distinctive buried landscapes that were unknown prior to this project. These results also immediately aided the development of the U.S. Geological Survey's Roseau bedrock map. In addition, there were many important mineral potential findings. Low levels of gold and five pathfinder elements and minerals were observed in the Rainy till of the eastern portion of the field area in the vicinity of the Baudette fault system. The new observations suggest a secondary kaolin clay deposit may be located in a buried valley near Baudette.

BEDROCK. The primary purpose of this project was to construct a data base of geochemical evaluations of Archean bedrock in fifteen counties. The work brought together all available data from several sources, filled in existing gaps in that data, and made the data available to the minerals industry on a county by county basis. The NRRI constructed a data base of 12,451 complete or partial analyses of drill core and bedrock outcrop samples using published materials, unpublished materials, and data contained within the abandoned lease files of the DNR Minerals Division Hibbing office. The sample locations were also identified on digitized county maps.

GOLD IN EARLY PENOKEAN. Precious metal exploration is primarily confined to northeastern Minnesota. However, precious and base metal potential also exist in the early Proterozoic rocks of the Mille Lacs Group, the Animikie basin rocks, and perhaps in some of the Cuyuna Range rocks. The purpose of this project will be to provide a base from which exploration companies can make decisions on where to begin exploration.

McSwiggen, et al. (1989) indicates the presence of precious metals in these rocks, but a comprehensive lithogeochemical evaluation has never been conducted. As was done for the Archean Bedrock Geochemistry project, this project will digitally georeference all known drill hole and outcrop geochemical samples.

- Mineral Processing

Ilmenite

This work was based on known ilmenite deposits in Minnesota. The work began at the Mineral Resources Research Center, but was completed by the Coleraine Minerals Research Laboratory. The goal was to reproduce or improve upon the concentration work completed earlier by the U. S. Bureau of Mines and Pickands Mather. MRRC was to take the process one step further and test the effectiveness of plasma torches on processing concentrate. That part of the effort was never completed, but CMRL was able to produce a very clean ilmenite concentrate (titaniferous magnetite). Their work became the basis for a major study of the deposit by a private company.

CU, NI, PGM FLOTATION. The Duluth Gabbro is a copper-nickel bearing deposit located in an environmentally sensitive area. At the present time, this deposit is considered to be only marginally economic. A technology, which would allow for the separation of copper-rich and nickel-rich products, maximize PGM recoveries, and minimize the environmental impact of residual sulfides and flotation reagents in tailings, would significantly improve the economics of developing the Duluth Gabbro. Such a technology would also be useful worldwide to solve problems encountered in the processing of complex (copper, lead, and zinc) sulfide ores. This project determined the nature of the electrochemical interactions that occurred during grinding, and integrated and correlated these findings with flotation behaviors. It showed that previous test results may have been biased by iron contamination of the sulfide particle surfaces.

METALLURGICAL EVALUATION OF COPPER/NICKEL ORES. One of the large, low-grade copper/nickel deposits in Minnesota is the Minnamax deposit near the town of Babbitt. In the 1970s AMAX and, subsequently, Kennecott Copper invested a considerable sum of money in mineral processing research in an attempt to find an economical way to mine and concentrate the ore. They were stymied in their efforts due to the complex nature of the ore. They had difficulty producing a clean copper concentrate, and their best results left about 30 percent of the ore value in copper/nickel concentrate that would be difficult for any of the smelters existing at that time. The work did not lead to an active mine and research on the deposit languished for about fifteen years.

Since that time, the state has funded a series of laboratory scale projects to study techniques related to the separation of sulfide bearing materials. One of the more important studies indicated that Kennecott's results may have been influenced by the metallurgy of the grinding media used in their pilot plant. Also, work on flotation itself has generated several promising alternatives, e.g. newer reagents, column flotation, better selective flotation, hydro metallurgy and recovery of platinum group metals, and possibly cobalt. The goal of this project is to evaluate the use of newer mineral processing techniques to create a revised economic basis for a mine on the Minnamax property.

The Minnamax deposit is partially owned by the State and partially by a private company. The whole deposit has been leased to Arimetco, Inc. Arimetco is a participant in the study and will provide a bulk sample from the proposed open pit area of the deposit. They will also provide

matching funds for the mineral processing effort. Other participants include the Iron Range Resources and Rehabilitation Board and Minnesota Technology, Inc. The work will be conducted at the Coleraine Minerals Research Laboratory.

- Data Acquisition and Analysis

DRILL CORE EXAMINATION AND ASSAY. Because of extensive overburden cover, drill core is the premier geologic sample reference regarding Minnesota geology. This project does reconnaissance relogging (describing) and sampling of the Hibbing Drill Core Library materials. The project purposes are: 1) to serve land use planning within the DNR; 2) to encourage private exploration through better data access; and 3) to serve government agency planning of future programs. This project is oriented toward identifying nonferrous metallic mineralization and features permissive of such mineralization. The new sampling and analysis of this project has been done to complement previous work of sample analysis. Results are made available in a digital format to allow for enhanced data handling and interpretation by customers, and GIS usage. Work areas include northern and central Minnesota in several complex geologic terranes. Over 8 years, 898 drill holes have been described (783 logged in digital format) and 2,277 samples have been analyzed. Favorable rock types and anomalous base and precious metal assays indicate a high probability for undiscovered economic mineralization. Mineral leasing has occurred on these lands with active leasing still occurring in portions of the Duluth Complex and the present work area of central Minnesota.

MINERALS DATA BASE. In 1990, the state began to develop a drill core index which would correlate the information available on stored drill core with its location in the Drill Core Library. This relational data base is used daily to access and study material in the Drill Core Library. Since that time, the systems have been expanded to include chemistry, leasing, and other pertinent data. The effort is now concentrated on the development of an overall architecture for minerals data that will allow the coordination of data on a broader basis, and provide the foundation for publication of data in a way that should be useful to exploration geologists worldwide.

- Mineral Deposit Modeling

DULUTH COMPLEX FOOTWALL. Information on footwall mineralization of the Sudbury Complex and the Noril'sk intrusion in Russia indicates some potential for a similar rich copper, nickel, cobalt, gold and/or platinum deposits in the footwall of the Duluth Complex. The objective of this work is to compile existing data from the Duluth Complex and compare it to the ore deposit models developed for the other mining camp regions. The deliverable, if the work is successful, will be an ore deposit model for the footwall of the Duluth Complex.

MINERAL POTENTIAL FOR GOLD AND MASSIVE SULFIDES IN THE ELY TO BIGFORK AREA. The goal of this study is to compare the geological features of five major gold and volcanogenic massive sulfide mining camps (Hemlo, Porcupine, Kirkland Lake, Sturgeon Lake, and Noranda) with the area in Minnesota. The model will be based on an integration of the geological, geochemical,

and geophysical features found in the five mining camps. Geographic Information Systems technology will be used to overlay the data to find similarities and signatures that can be used to identify exploration targets in Minnesota.

- Environmental Research

RECLAMATION RESEARCH. Mine waste characterization and mine waste drainage quality prediction will be among the first environmental impact questions to address when nonferrous mineral development begins in Minnesota. This information will be used to identify water quality controls required to protect the resources of the state.

Ten tailings samples from operating North American gold mines and two titanium tailings samples generated in pilot plant tests were characterized (particle size distribution, chemistry, mineralogy, etc.) and subjected to dissolution testing to determine drainage quality.

Static tests indicated that two of the samples were acid producers and that two others were marginal acid producers. However, acid produced by iron sulfide oxidation was neutralized by dissolution of calcium and magnesium carbonate. Additional dissolution of the same samples may deplete their neutralization potential, however, so they could ultimately produce acidic drainage.

Continuing research seeks to answer questions raised in previous studies on long-term dissolution characteristics of reactive tailings by determining the differences between reactive and non-reactive pyrites. In addition, the project seeks to determine the effect of temperatures and the length of dry cycle on dissolution. Methods of removing arsenic, antimony, and molybdenum from mine drainage will also be surveyed. Much of this work will be conducted at the new Reclamation Research Site in Hibbing using funds from the Environmental Cooperative Research appropriation.

- Mineral Management

Improved Ownership Records

SEVERED MINERALS INTEREST IDENTIFICATION. This project was established to determine the validity of existing state mineral rights ownership claims and to discover previously unknown state claims. Valuable information from a variety of sources other than the official county records was gathered.

Information was gathered from the records of USX Corporation, the mineral claims of Meridian Minerals, and the U. S. Forest Service for the Superior and Chippewa National Forests. Such "non-official" information can make valid state ownership claims for any particular parcel more or less likely. The state also used the official records to examine key title documents for several large minerals rights holders.

The total acreage researched during the FY90-91 totaled 126,000 acres. Diversification funding

provided a 50 percent increase in the number of acres researched. The research results were used to prepare the list of minerals rights to be offered at public lease sales. This work improved the quality of the state mineral rights ownership offered for leasing.

—OBJECTIVE 3: TO ENHANCE MINNESOTA'S INDUSTRIAL MINERALS INDUSTRY

- Aggregate Studies

SAND AND GRAVEL INVENTORY. Minnesota Statute 84.94 mandates that the DNR, in cooperation with the MGS, Minnesota Department of Transportation (MNDOT), and the State Planning Agency, identify and classify potential aggregate resources outside the seven-county metropolitan area. The statute also specifies that the program give priority to those areas of the state where urbanization or other factors may result in a loss of aggregate resources to development.

Mapping of aggregate resources incorporates field work and data, such as high-altitude photographs, geologic and soils maps, published reports, MNDOT test borings, and domestic water well logs.

Final maps are digitized for incorporation into state and county Geographic Information Systems. Maps and accompanying reports provide valuable information to developing areas that wish to protect aggregate resources from future land use conflict. Additionally, the maps may be used for water planning and protection of rare or threatened native animal and/or plant species.

SAND AND GRAVEL RESTORATION. Minnesota ranks sixth nationally in gravel production. Figures for 1990 indicate 34.8 million tons of aggregate production in the state worth $89.4 million. Production was reported in 78 of 87 counties by 205 companies. According to an informal survey conducted by the DNR in 1991, there are about 1,600 active pits in the state. Another 2,500 are either permanently abandoned or only intermittently active. Most sites are mined without the benefit of a reclamation plan, resulting in problems that can include erosion, illegal dumping, safety concerns, and unauthorized activities.

Since 1987, the DNR, MNDOT, local government, and the industry have been working on reclamation techniques. Native prairie grasses seem particularly well suited to gravel pit reclamation. However, the cost and feasibility of the methods must be demonstrated in controlled tests given the fact that there are few examples of successful reclamation in the state.

BUFFALO RIVER STATE PARK. Gravel was mined out many years ago in short strips along an ancient beach ridge of Glacial Lake Agassiz and used in road and railroad construction. Between these strips are areas of undisturbed vegetation that are good quality prairie. The Gravel Pit Reclamation and Prairie Restoration Project is in the process of restoring two former gravel mining areas totaling twenty acres to their original prairie vegetation. The work is confined to the areas disturbed by previous gravel mining. The project area is surrounded by more than 100 acres of prairie and will complement the prairie vista image of the park entrance. Specifically, the project

will:

- Delineate wetlands and identify sensitive wild flower species to be avoided.
- Remove old demolition material.
- Remove invading trees and shrubs on disturbed pit areas.
- Smooth and level 50 year old spoil piles left from gravel mining.
- Replant prairie grasses and wild flowers on the newly landscaped area using locally harvested seed.
- Control invading weeds, as necessary.

This first ever county/state partnership for reclamation and prairie will be a demonstration project. It will complement a recently funded LCMR project to develop and implement a plan to balance gravel production and native prairie restoration in Clay County, scheduled to begin in July 1995.

- Mineral Surveys

Carbonate Resource Assessment

CARBONATE RESOURCE ASSESSMENT. Although it is well-known that all of southeastern Minnesota is covered by layers of carbonate rocks, no one had previously attempted a systematic sampling and analysis of the material. This project vehicle was used to sample over ninety naturally occurring or man-made outcrops in twelve counties. In addition, 14 holes were drilled in areas where channel sampling would have been very difficult. The sample data was correlated with the formations and other data to produce a regional representation of the carbonate rocks. The chemical data was compared to known product specifications to identify development possibilities.

The results have been used by companies and quarry owners in southeast Minnesota to identify new prospects and new uses for materials from existing quarries. One of the more intriguing prospects is the use of material from the Stewartville Formation as flux for fluxed taconite pellet production. The material appears to have the correct chemistry. However, transportation costs may preclude its adoption by the taconite industry. It is expected that the data will become the foundation for much additional work in the future.

CLAY PRODUCT DEVELOPMENT. Although the clay deposits of the Minnesota River Valley have been known for decades, only recently have they been studied intensively to identify high-quality deposits. Today, the kaolin clays of the Valley are used only in the production of cement and bricks. Research conducted by the University will assist industry by locating the best quality clay in the Minnesota River Valley and central Minnesota. Other work is aimed at the production of more valuable products.

Recently completed laboratory scale research to reduce particle size, and silica and iron contents have been successful and could now be pursued in larger scale tests. The resulting product is of a grade fine enough for coating paper or any of the hundreds of other uses for kaolin clay.

Work at the University of Minnesota-Duluth has helped narrow the parameters of exploration by determining the composition of parent rocks associated with the best grade of primary clay deposits. It has also pointed toward extensive secondary deposits which might be even more valuable.

DIMENSION STONE INVENTORY. A reconnaissance-level dimension stone inventory of crystalline rocks was conducted on government-owned and administrated lands in six northern Minnesota counties. Approximately 250 Middle Proterozoic (Keweenawan) and Archean outcroppings were evaluated with respect to joint spacing, color, texture, deleterious minerals, and size of extractable blocks.

Based on industry criteria, field investigations identified eight prospects and two inactive quarries that have potential for dimension stone development. These sites contain rock of a variety of color and texture, some of which is remarkably different from what is currently quarried or available domestically. At the present time two quarries have been opened and one additional site has been leased. Marketing work is being done by one stone fabricator on a unique stone from one of the new Minnesota quarries.

KAOLIN IN CENTRAL MN. The occurrence of kaolin in northern and central Minnesota is documented in drill holes and outcrops. However, very little of this material has been sampled for geochemistry, x-ray diffraction mineralogy, particle size analysis, or firing characteristics. While some kaolin clay samples were collected in central and northern Minnesota during the LCMR-sponsored clay study and the MCC study on the geologic and geochemical controls on the grade and distribution of clays, many new occurrences of kaolin clays have been identified in more recent drilling in the northern part of the state. Since the weathering episode that produced the kaolin clays in the southern part of the state was a statewide event, good grade kaolin and other clays should also exist in the northern regions of Minnesota.

This project collected between thirty and forty samples from drill core and outcrops not sampled in the previous programs. These samples were analyzed for whole rock geochemistry. Particle size analysis, firing tests, and x-ray mineralogy were also conducted for comparison with previously analyzed samples from other areas of the state.

CARBONATE BENEFICIATION. This is a continuation of the original carbonate assessment program. The objective was to select some of the better limestone/dolomite deposits and subject them to standard beneficiation tests which would include stage crushing, high density scrubbing, screening, and hydraulic classification. There is reason to expect that these treatment schemes will reduce the percentage of diluents, primarily silica and alumina associated with intercalated shale and mudstone layers. This will improve the chemical purity of the limestone/dolomite and expand its market potential.

THE ECONOMIC IMPACT OF TRANSPORTATION COSTS IN THE POTENTIAL UTILIZATION OF KITTSON COUNTY BLOATING CLAYS AND THE MINNESOTA RIVER VALLEY KAOLINS. These projects sought to determine the potential of: 1) using the bloating clays found in Kittson County for the production of lightweight concrete aggregate, and 2) using the kaolin found in the

Minnesota River Valley in the papermaking industry. As is the case with other industrial minerals, transportation costs will comprise a significant portion of the delivered price of each of these commodities. This project provided insight into effects transportation costs may have on the development of these resources by developing information on markets and market areas, and modes of transportation such as rail, truck, and possibly barge.

KITTSON COUNTY BLOATING CLAYS. The clays found in Kittson County, Minnesota are a part of the Pleistocene Sherack and Brenna Formations of Glacial Lake Agassiz. The bloating characteristics of the Kittson County clays were first identified during an LCMR-funded clay project. A more thorough evaluation of the bloating characteristics of these clays, based upon small samples, was completed under a GMC-funded project. Clays of this type may have application in the production of lightweight coarse aggregate used in the concrete and construction industry.

The Kittson County clays bloat at the lowest temperature of any of the Minnesota bloating clays. The Brenna Formation clays bloat better and have fewer impurities than the Sherack clays. Both clays outcrop and subcrop over a large area and within a few feet of the surface, making them readily accessible for open pit mining. The actual mining thickness of the clays exceeds 25 feet in most areas. Over 11,000 pounds of the clays were obtained in January 1991 from seven auger holes.

Currently, most lightweight aggregate (trade name: Arkalite) used by the construction industry in Minnesota comes up the Mississippi River by barge from West Memphis, Arkansas. It is possible that lightweight aggregate produced from the deposits found in Kittson County could be competitive with Arkalite provided that the raw material is suitable and the lightweight aggregate produced meets, or exceeds, ASTM standards.

KAOLIN CLAY RESOURCE ASSESSMENT. The occurrence of kaolin clays in the Minnesota River Valley between Redwood Falls and Fairfax has been studied in several MCC projects. This work includes mapping of kaolin occurrences from a point about twenty-five miles east of Redwood Falls northwest through the recently-opened Belview mines, to Granite Falls, MN. Little geologic information was previously available on these clay deposits, their quality, or the controls on grades in the area.

The work concentrated on mapping, sampling, and analysis of kaolin clays and associated bedrock. The samples were analyzed for whole rock geochemistry, particle size, and x-ray mineralogy, and compared to samples from previous studies throughout Minnesota.

Basic Research

The purpose of this portion of the Minerals Diversification Program is to generate mineral research ideas by providing small amounts of money to faculty at degree-granting institutions in Minnesota. The money is then used for preliminary evaluations of promising geologic or mineral processing concepts. Projects funded in FY '90 - '91 included:

* Image processing for gravity and magnetic data.

* Copper-nickel separation using reduced iron powders.

* Flotation of platinum-group minerals from Duluth Complex minerals.

* Identification of diamond-bearing kimberlites in Minnesota.

* Geology and petrogenesis of the Greenwood Lake area in Lake County.

* Optimal production scheduling for nonferrous operations in Minnesota.

This research has had beneficial results. For example, the image processing work has lead to the production of several new maps based on existing data. The U. S. Bureau of Mines became interested in work done on Duluth Complex minerals and sponsored additional work in this area. Finally, the geologic work done in Lake County has substantially increased our knowledge of an area with high mineral potential.