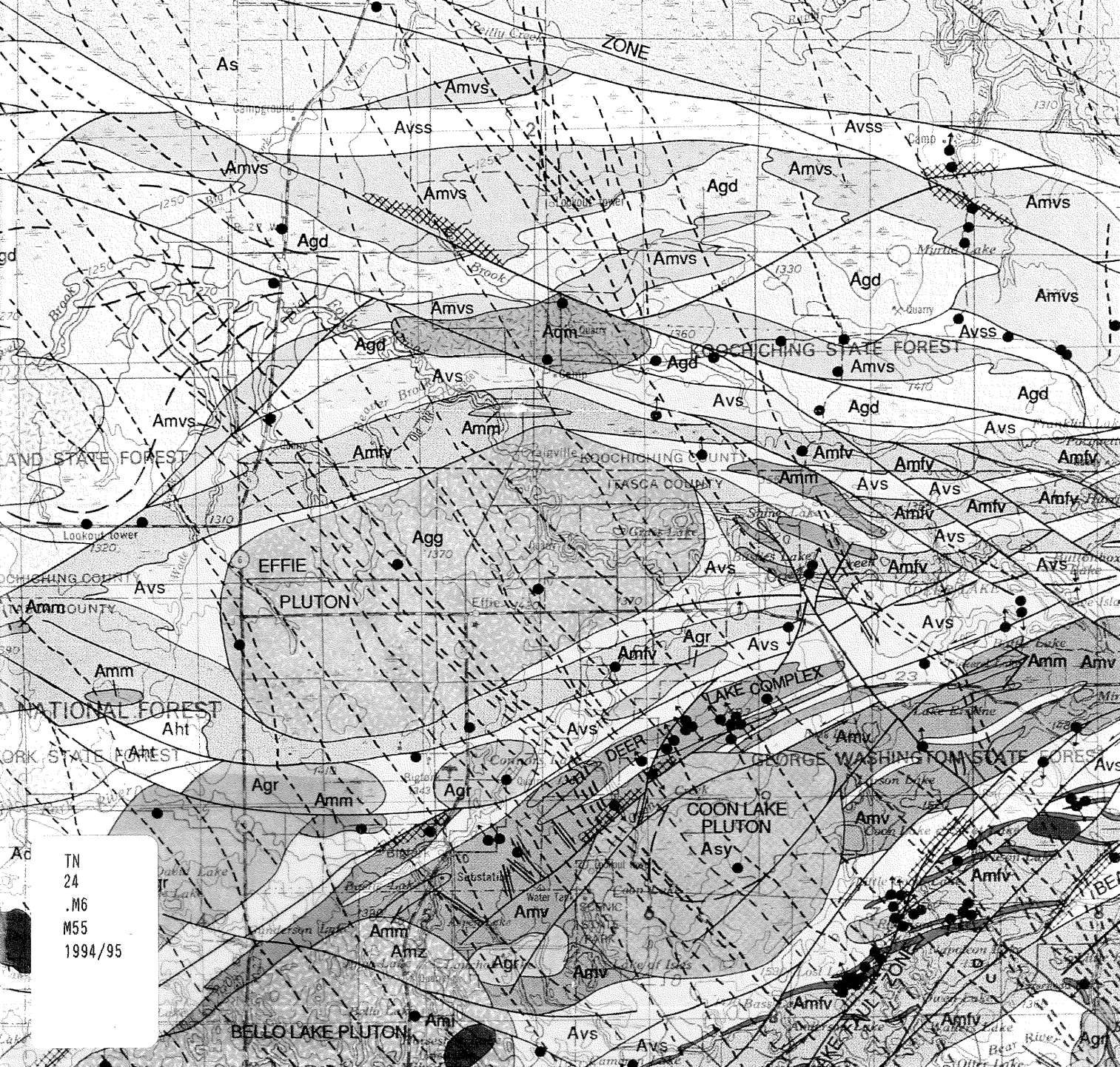




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Minnesota Mineral Diversification: *A Foundation for Economic Growth*



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Minnesota Mineral Diversification: A Foundation for Economic Growth

Writers/Editors:

Don Dinsdorf;

Writer

Phil Pippo, Ron Visness;

DNR Division of Minerals

Graphic Design:

Linda Escher

Adele Smith

DNR Graphic Design Unit

Photography:

Larry Duke, Phil Pippo, Dan Ruda;

DNR Staff

Robert Brandom;

University of Minnesota

Photographs Courtesy of;

Cleveland Cliffs, Inc

Company, JPG Communications,

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Bedrock geologic map of parts of

Koochiching, Itasca, and Beltrami

Counties, North-central Minnesota;

Map M-67 Courtesy of the;

Minnesota Geological Survey



Minnesota DNR
Division of Minerals
500 Lafayette Road
St. Paul, MN 55155-4040
612/296-6157
1-800-766-6000
(MN Toll Free)

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Minnesota Mineral Diversification:

***A Foundation for
Economic Growth***



Executive Summary

The Mineral Diversification Program was created by the Minnesota Legislature in 1987 "To provide for the diversification of the State's mineral economy through long-term support of mineral exploration, development, production, and commercialization" (Minn. Stat. sec. 93.001). The projects conducted under the Minerals Diversification Program are managed and coordinated through the Minerals Coordinating Committee (MCC), which is made up of the directors of the Minerals Division of the Department of Natural Resources, the Minnesota Geological Survey, the Mineral Resources Research Center, and the Natural Resources Research Institute.

The Committee seeks input from the private sector concerning project and funding priorities. Such input takes several forms: from technical contributions of professional groups, to the input of advisory committees made up of persons, groups and agencies with an interest in the progress of mineral diversification.

This report focuses on the accomplishments of the Minerals Diversification Program in the last biennium (FY '90 and '91) and outlines current projects. In keeping with the statutory guidance for the program, the projects fall into one of the three objectives: "to improve and extend Minnesota's iron industry; to encourage exploration and development of non-ferrous metallic minerals; to enhance Minnesota's industrial minerals industry." Additionally, two other charges have been given to the program: "to encourage research that aims at longer term mineral resources development potential in Minnesota; to ensure that mineral development satisfies the highest environmental quality standards."

In each of the project areas, significant progress has been achieved. In the iron ore area, a modified flux material promises to help the taconite industry produce a high-quality product with a 50 percent savings in energy costs for flux calcining. Research on temperature control at different stages of the taconite process also promises greater efficiency and productivity.

In the non-ferrous project area, several new, detailed maps of potential mineral-bearing bedrock have been produced, adding to the geologic database information heretofore unknown, and promising areas for exploration. Chemical analyses of core samples and glacial overburden will also assist exploration of several promising regions. Ownership of severed minerals rights has been identified in a large area, assisting future state leasing, and finally, vital information for the protection of the environment around potential development sites has been gleaned from research on waste materials similar to those likely to be generated in a Minnesota mine.

Mapping of aggregate resources to avoid future land-use conflicts and restoration of sand and gravel pits are two of the industrial minerals projects which showed significant progress in the last biennium. Another project in the industrial minerals area enjoying considerable success is research into uses for Minnesota kaolin clay, which may open new markets. State rules for oil and gas and other industrial minerals leasing were moved forward, with a boost from the Mineral Diversification Program.

Finally, basic research funded by the Mineral Diversification Program continues to add to the geologic knowledge of the state, while keeping the state at the forefront of minerals technology. Several studies have attracted the attention of other organizations such as the U.S. Bureau of Mines, which funded an extension of research on the Duluth Complex minerals group.

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Message from the Chair

As the 10-year Minnesota Mineral Diversification Program approaches the halfway mark, it has clearly born fruit, as shown by its many successes. The State's investment in mineral diversification is important to the state's economy, giving strength to its traditional taconite mining, while providing a foundation for expansion in industrial minerals and precious and strategic metals.

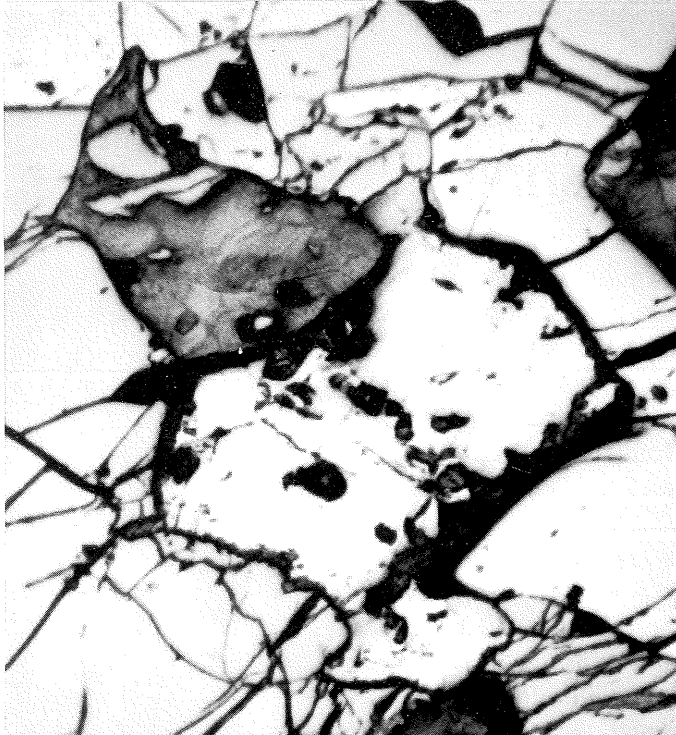
The sponsored projects reflect the statewide benefit of mineral diversification. From sand and gravel to clay, from exploration for gold to taconite processing, virtually every region of the state is enriched by the minerals industry and all share in the use of its products. Of course, a great part of Minnesota's famous quality of life includes environmental health; therefore, the program also gives priority to research that aims to control potentially harmful wastes and enhance post-mining restoration.

The Mineral Diversification program is well managed and highly successful, a tribute to close cooperation between the state, the University of Minnesota, federal agencies, and the minerals industry. The program's innovative approach to technology has helped keep Minnesota iron and taconite competitive. Research and data collection have helped to make Minnesota an attractive place for mineral exploration and has opened the door to new markets. The worth of this program is clear.

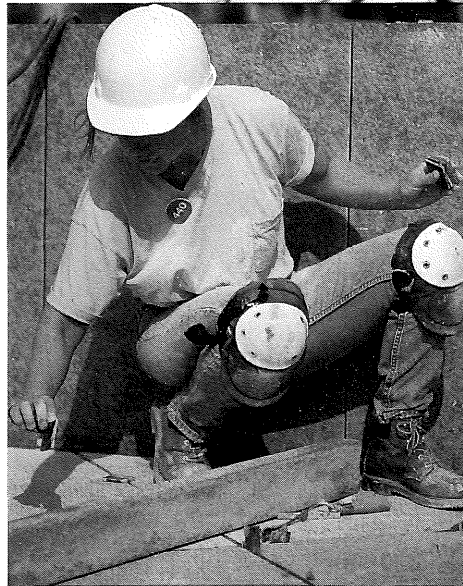
A steady, long-term commitment of the Minnesota Legislature to the Mineral Diversification Program will ensure that it can continue to provide a strong foundation for economic growth through mineral development across the state.

William C. Brice

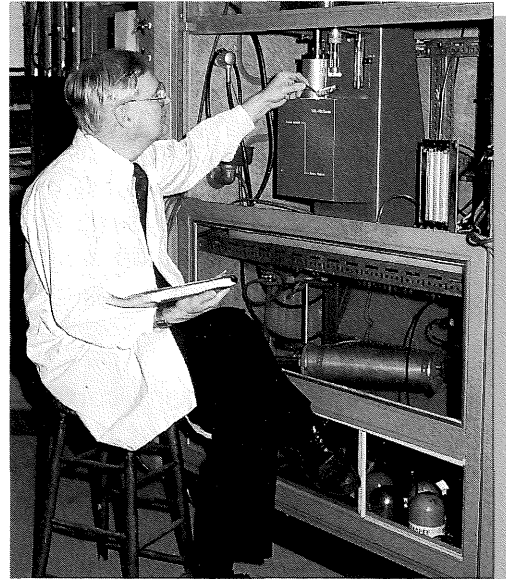




*Non-ferrous mineral:
polished thin section.*



Industrial minerals.



Minerals basic research.



The iron industry.

Accomplishments

Central to the success of Mineral Diversification in Minnesota are projects that help meet the goal. Now entering the third biennium of this ten-year program, the Minerals Coordinating Committee can report solid results.

■ *The Iron Industry*

- ☐ Improving Fluxed Pellets
- ☐ Effect of Water Temperature on Taconite Processing
- ☐ Innovative Iron-Making
- ☐ Current Projects in Taconite Production

■ *Non-Ferrous Minerals*

- ☐ Geologic Drilling and Mapping
- ☐ Archean Geochemistry
- ☐ Drill Core Examination and Assay
- ☐ Severed Mineral Interest Identification
- ☐ Glacial Till Geochemistry
- ☐ Waste Characterization
- ☐ Current Projects in Waste, Mineral Rights etc.

■ *Industrial Minerals*

- ☐ Aggregate Mapping
- ☐ Sand and Gravel Pit Restoration
- ☐ Accelerated Industrial Minerals Leasing
- ☐ Clay Research
- ☐ Current Projects in Mapping, Restoration, etc.

■ *Minerals Basic Research*



The Iron Industry

Keeping Minnesota taconite the raw material of choice for the domestic steel industry is the goal of the iron ore research component of the Mineral Diversification program. Improved product quality and lower production costs are already paying dividends in the state's historic Iron Range.



Iron waste material being loaded by a 33-cubic yard capacity shovel into 170-ton truck.

Improving Fluxed Pellets

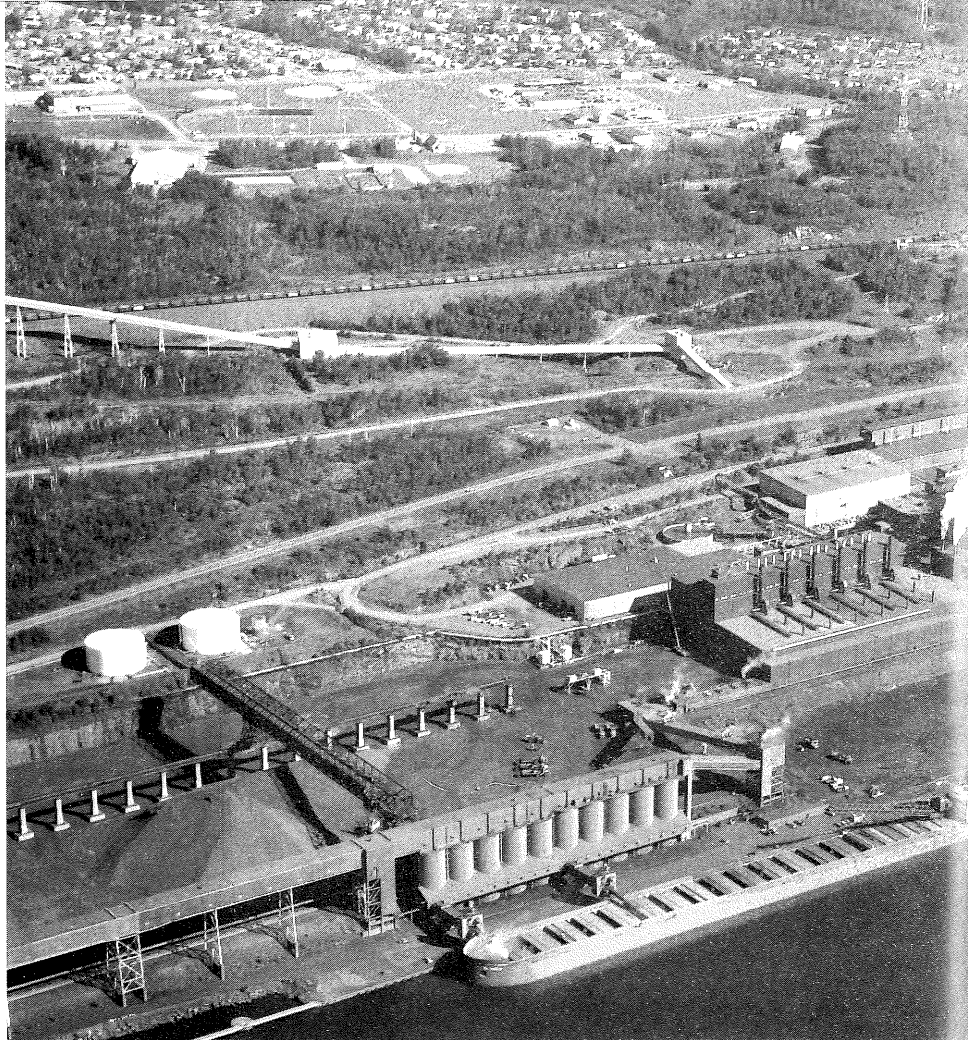
Production of fluxed taconite pellets is routine for two Minnesota companies and is being developed by two others. Raw limestone and dolomite are normally used for fluxed pellet production. This project seeks to build on that experience and to reduce costs by replacing the raw flux material with lime/dolomite 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. Also, 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, USX Corporation is considering a proposal to run a full-scale plant test with lime/dolomite hydrate to confirm fuel savings and productivity gains.



*Aerial scene of Cyprus
North Shore Mining
Corporation in
Silver Bay, Minnesota.*



The Effect of Water Temperature on Taconite Processing

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.

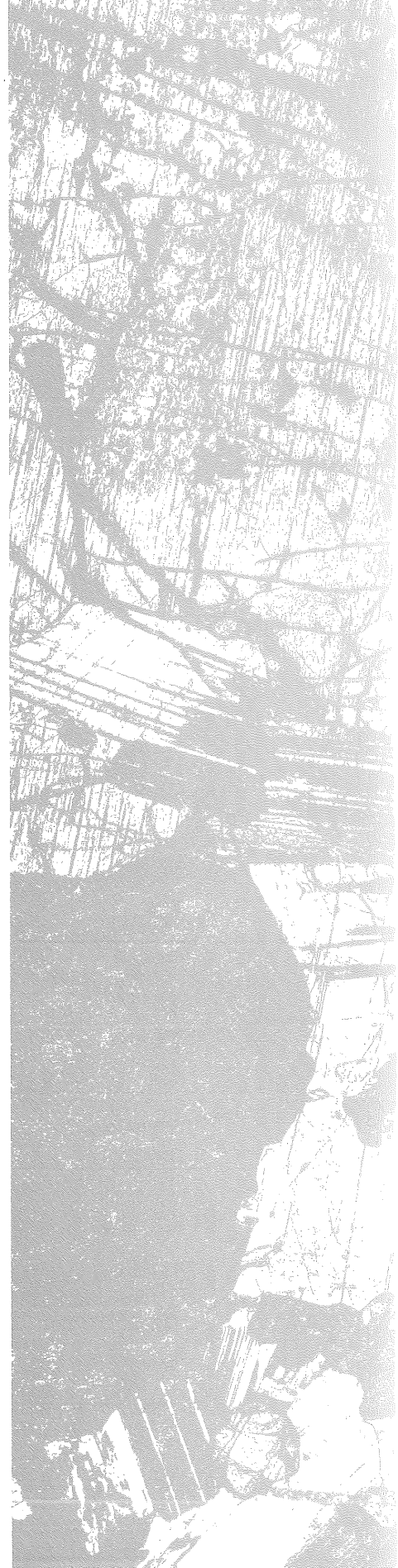
Batch and continuous grinding tests showed an increase of up to 10 percent in fines generation as temperature increased. However, it appears that classification efficiency decreased at the higher temperatures as a smaller percentage of the fines reported to the undersize or overflow. Flotation tests 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.



Innovative Iron-Making

This 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.



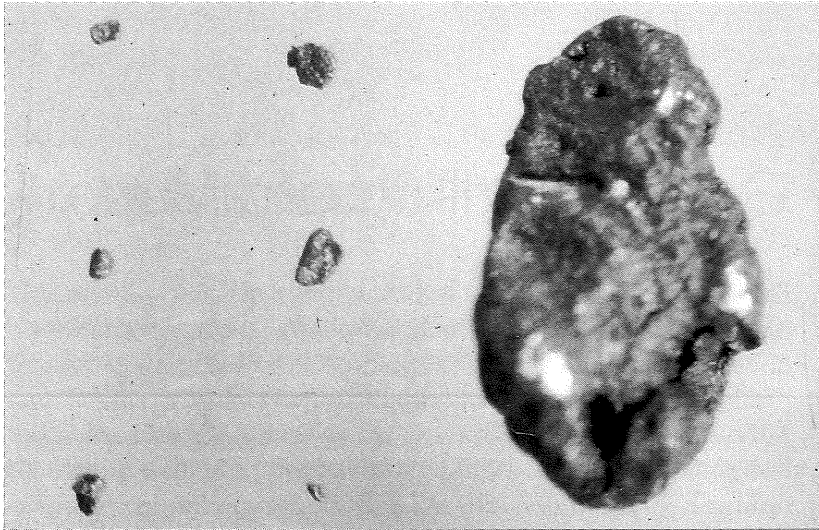
Current Projects

Several projects dealing with problems and possible improvements in taconite-processing technology are currently underway. They include:

- quantifying the effects of improved classification efficiency on grinding.
- research on the production of a low-silica pellet.
- quantifying the effects of water treatment on reducing chemical and pellet binder use.

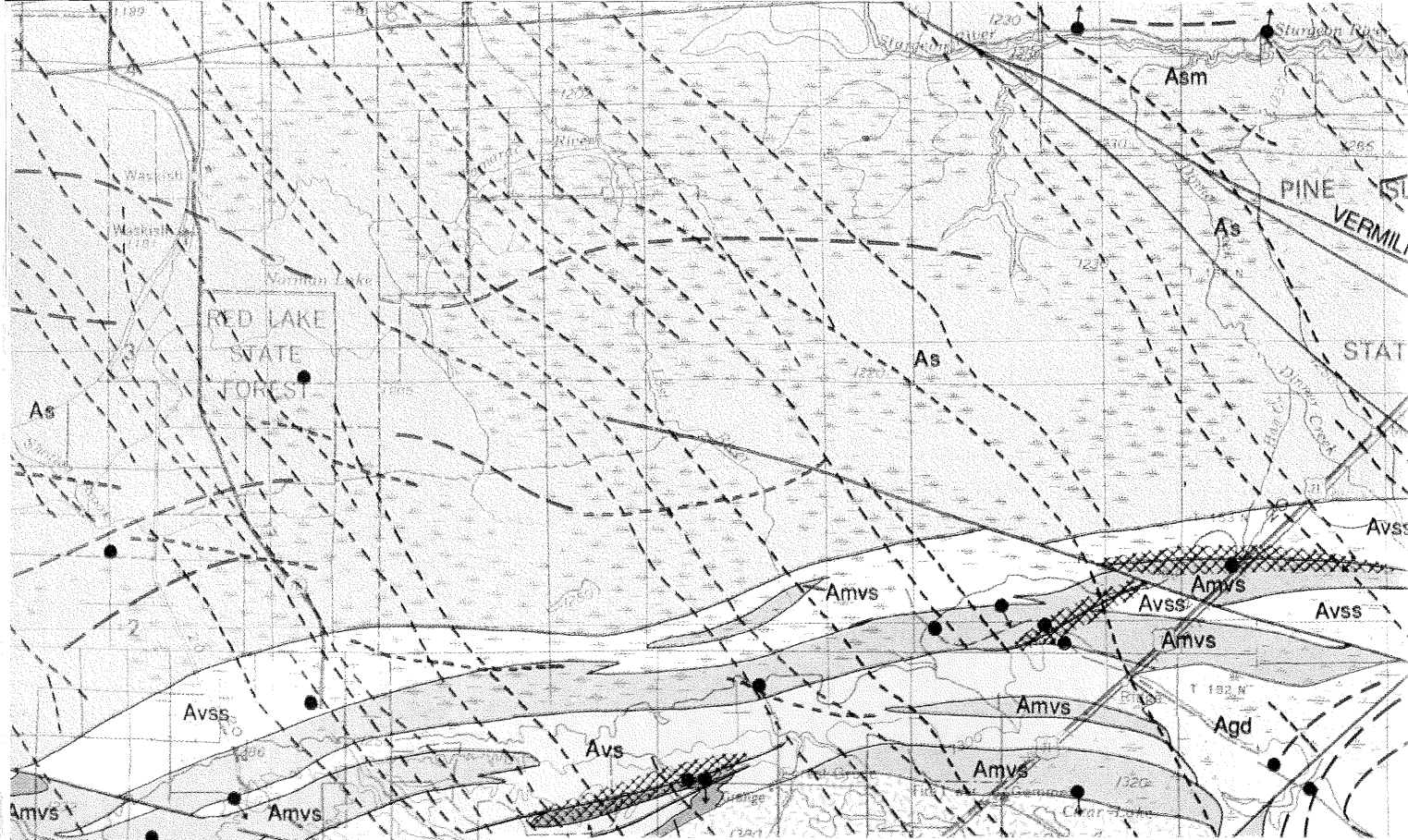
Non-Ferrous Minerals

Minnesota is in global competition for non-ferrous mineral development. Although geologists have known for many years that the state has high potential for the development of non-ferrous metals (gold, platinum, titanium, copper, etc.), development has been hampered by a lack of detailed knowledge of the bedrock geology, particularly in areas covered by thick layers of glacial sand, silt, and gravel. To attract exploration and development, Minnesota must develop geologic and mineral potential data and provide an administrative and economic climate that makes development predictable and attractive, while assuring protection of the environment.



The prime objective: Seven gold grains identified from one sample in Koochiching County. Size of big grain is 625 X 11000 microns.



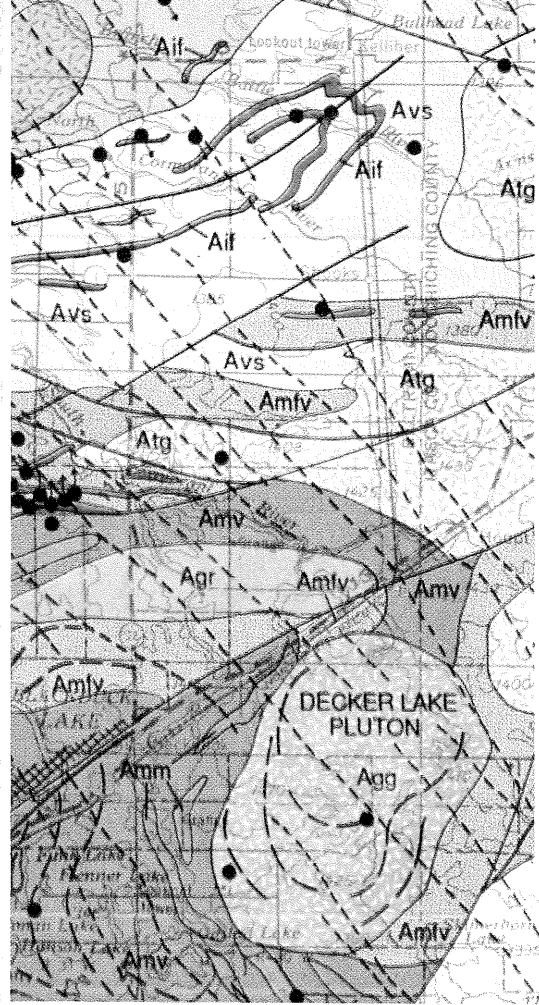


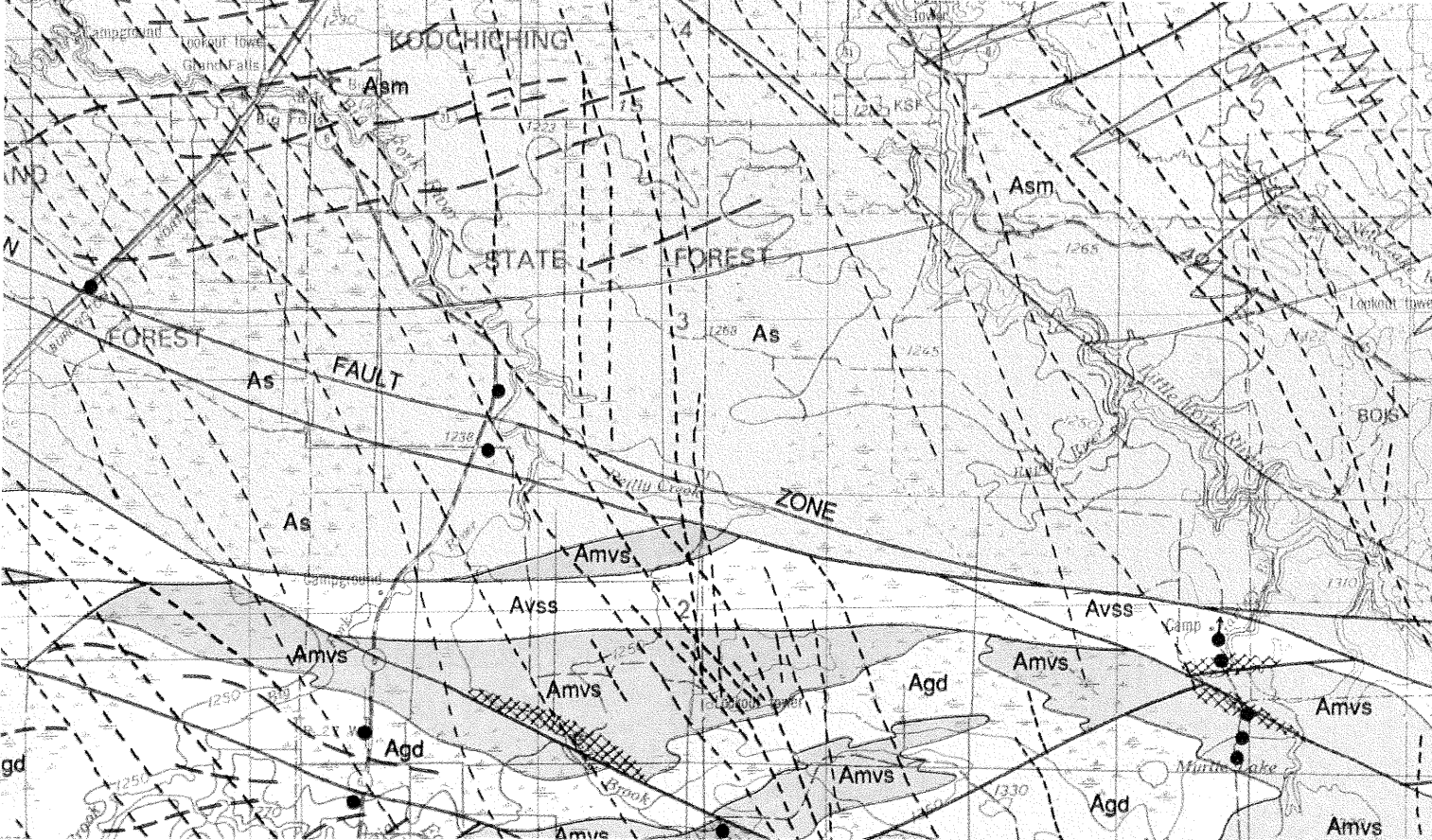
Geologic Drilling and Mapping

Drill-core samples supply the most concrete evidence of bedrock for accurate mapping purposes in glacial drift-covered areas. Geologic maps produced using such data are important guides to Minnesota's mineral potential. The Minnesota Geological Survey, using Diversification funding, has moved ahead in mapping, collecting new data and analyzing information already in hand, to provide a view of Minnesota's buried bedrock that is the most detailed to date.

Four new maps were completed in FY '90 and '91: the Cook area, St. Louis and Itasca Counties; the Cook to Side Lake area, west-central St. Louis County; the central Duluth Complex; and the preliminary map of Archean bedrock in the Soudan-Bigfork area.

The Cook area map revealed previously unknown fault zones and intrusive rock units which may pique interest in further exploration of the area. A collection of about eighty whole rock samples, some from previous projects, were analyzed, providing valuable geochemical information in addition to that used to prepare the maps.

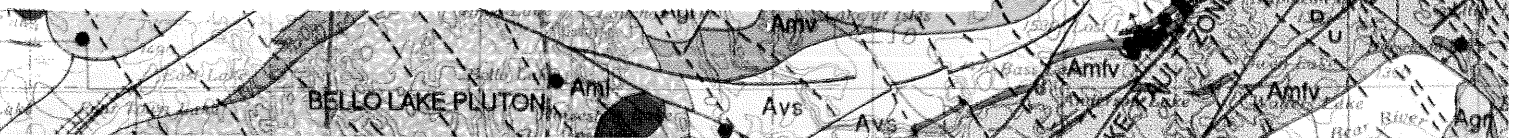




Archean Geochemistry

The primary purpose of this project was to construct a data base of geochemical evaluations of Archean bedrock in 15 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 Natural Resources Research Institute constructed a data base of 12,451 complete or partial analyses of drill core and bedrock outcrop samples, using published and unpublished materials, and data contained within the abandoned lease files of the DNR Minerals Division office in Hibbing. The sample locations were also identified on digitized county maps.

Geology modified from existing maps on the basis of scientific test drilling; interpretation of newly acquired geophysical data; and outcrop mapping. Drilling was funded by the Minnesota State Legislature under the Mineral Diversification Program.





*MN Department of Natural Resources Drill
Core Library, Hibbing, MN.*

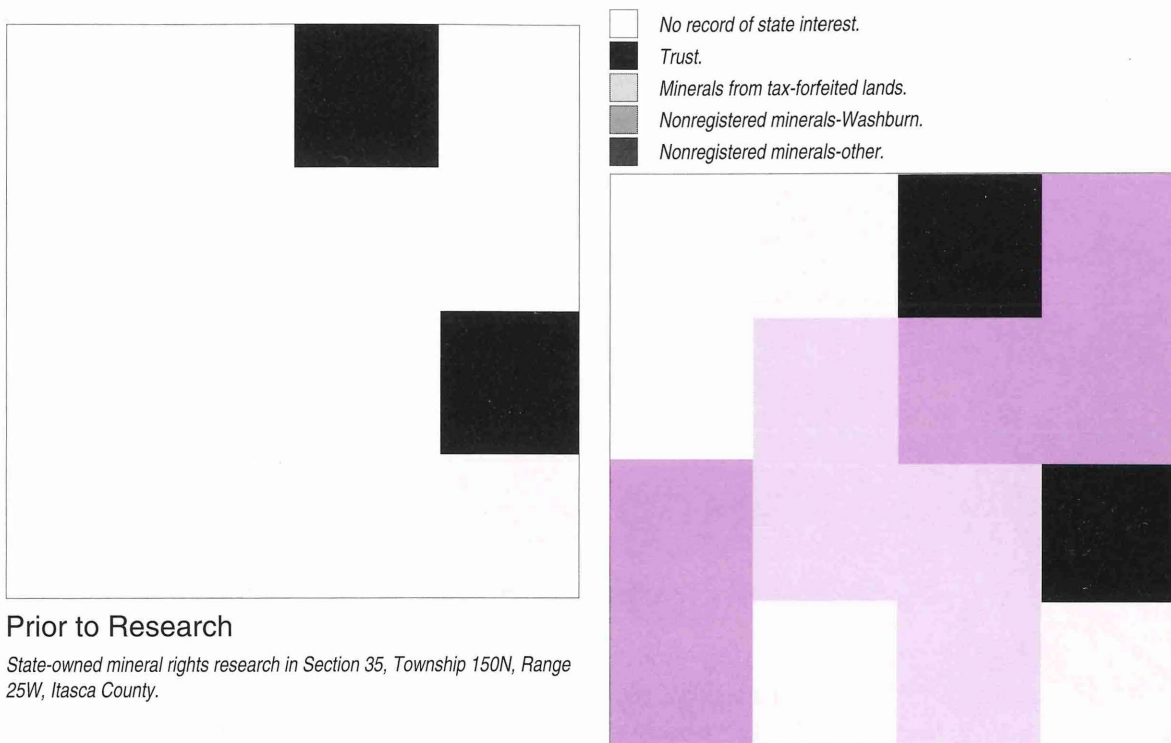


Drill core examination facilities in the new MN Department of Natural Resources Core Building.

Drill Core Examination and Assay

This project consisted of the logging and geochemical sampling of Archean greenstone belt rock cores from a 22-township area in southern Lake of the Woods County. The cores which were drilled from 1969 through 1986 by private companies in their search for base and precious metals are housed in the core library at the DNR Minerals office in Hibbing. A total of 44 cores were logged and analyzed.

The work confirmed elevated levels of gold, copper, zinc, and other metals in the samples, and analyses indicated the nature of the mineralization to provide wider recognition of the rock types favorable for mineralization. The data will increase the level of knowledge of Minnesota's geology and metallic mineral potential and should assist private companies in their exploration work.



Prior to Research

State-owned mineral rights research in Section 35, Township 150N, Range 25W, Itasca County.

Offered After Research

Severed Minerals Interest Identification

The Severed Minerals Interest Identification 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 Fiscal Year (FY) '90-'91 totalled 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 mineral rights to be offered at public lease sales. This work improved the quality of the state mineral rights ownership offered for leasing.

Glacial Till Geochemistry

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 digital database of results is now available.

Analysis of the drill cores shows that the Baudette area contains two distinctive buried landscapes that were unknown prior to this project. These results 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/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 also suggest a secondary kaolin clay deposit may be located in a buried valley near Baudette.

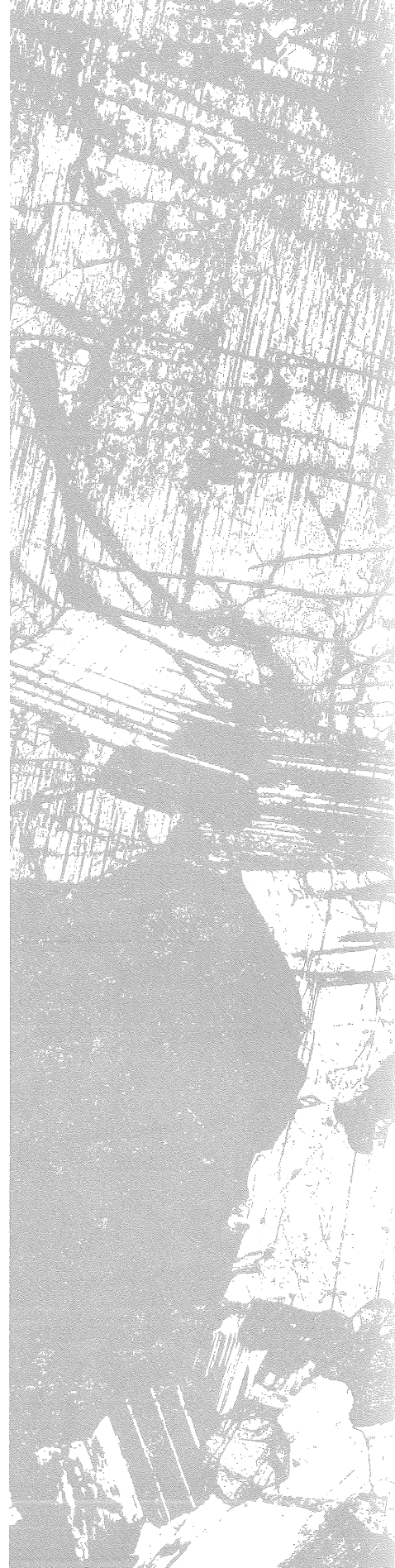
Waste Characterization

Mine waste characterization and mine waste drainage quality prediction will be among the first environmental impact questions to address when non-ferrous 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 (weekly rinsing) 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 associated 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 nonreactive pyrites. In addition, the project seeks to determine the effect of temperatures and the length of dry cycles on dissolution. Methods of removing arsenic, antimony, and molybdenum from mine drainage will also be surveyed.



Current Projects

In addition to continuing projects in waste characterization and severed mineral rights, geologic mapping will move into the state's northwest, the southern Duluth Complex area, and the South Kawishiwi Intrusion. Drill core examination and assay will be done on samples taken in Beltrami County. Portions of Beltrami, Koochiching, and Itasca Counties will be the subjects of glacial till mapping; and the gold, silver, and base metal potential of east-central Minnesota bedrock will be the subject of evaluation. Finally, research will be conducted on a method of preventing the loss of platinum-group metals during flotation, to make Duluth Complex mineral deposits more attractive to private companies.

Industrial Minerals

Industrial minerals commodities produced in Minnesota are valued at over \$135 million annually. Across the state, 450 sites produce gravel and sand, kaolin mines in Brown and Redwood Counties provide material for cement and brick, sixty quarries produce crushed rock, one mine produces silica sand and about a dozen quarries produce dimension stone (granite and limestone). Several companies also market the state's horticultural peat throughout the U.S. Although a mature and stable industry now exists, the Mineral Diversification Program seeks to assist responsible expansion of the industry into new markets and new regions of the state.



Rough-cut granite stacked for further processing.



Map of Aggregate Resources
and Quaternary Geology in
Wright County, Minnesota.

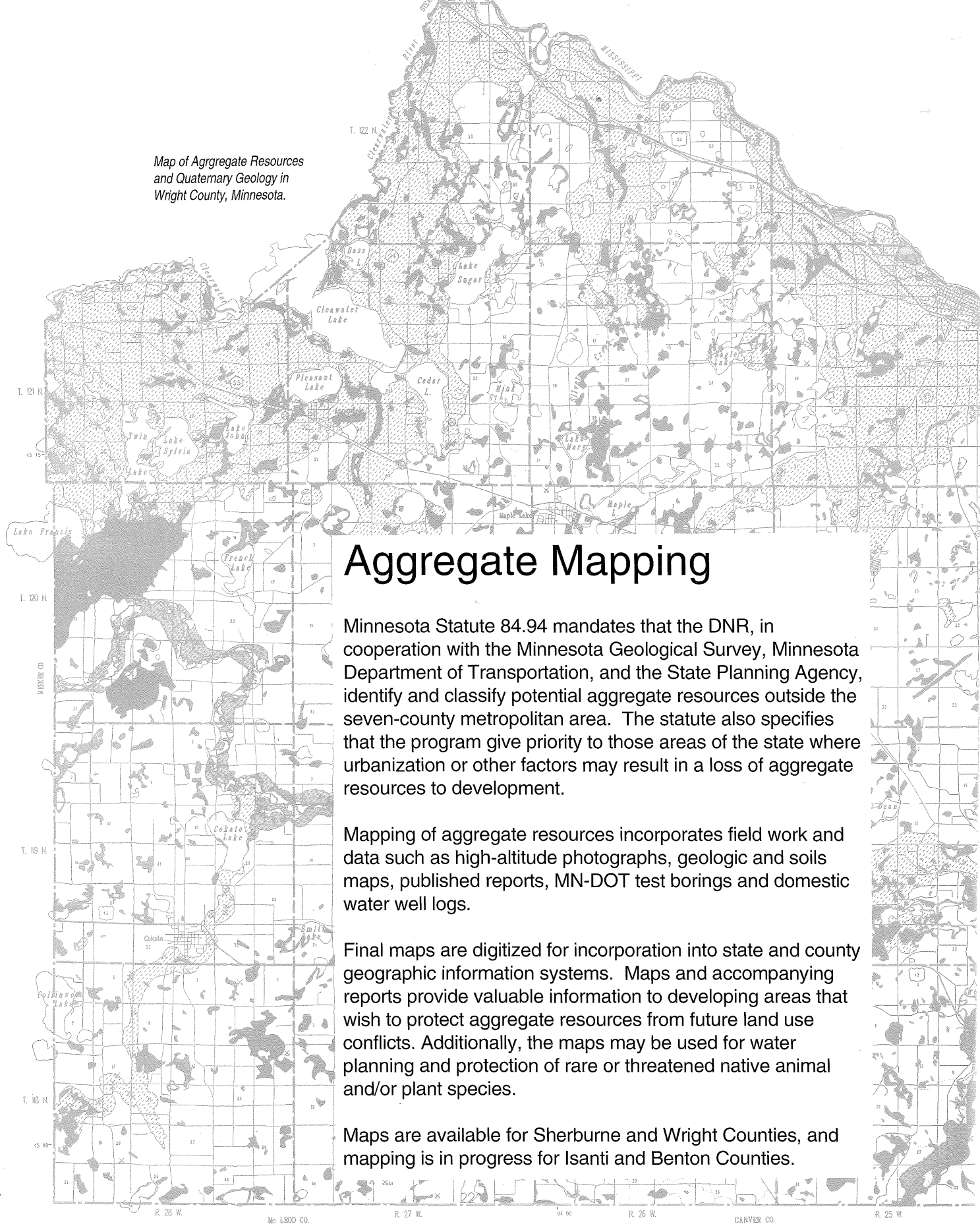
Aggregate Mapping

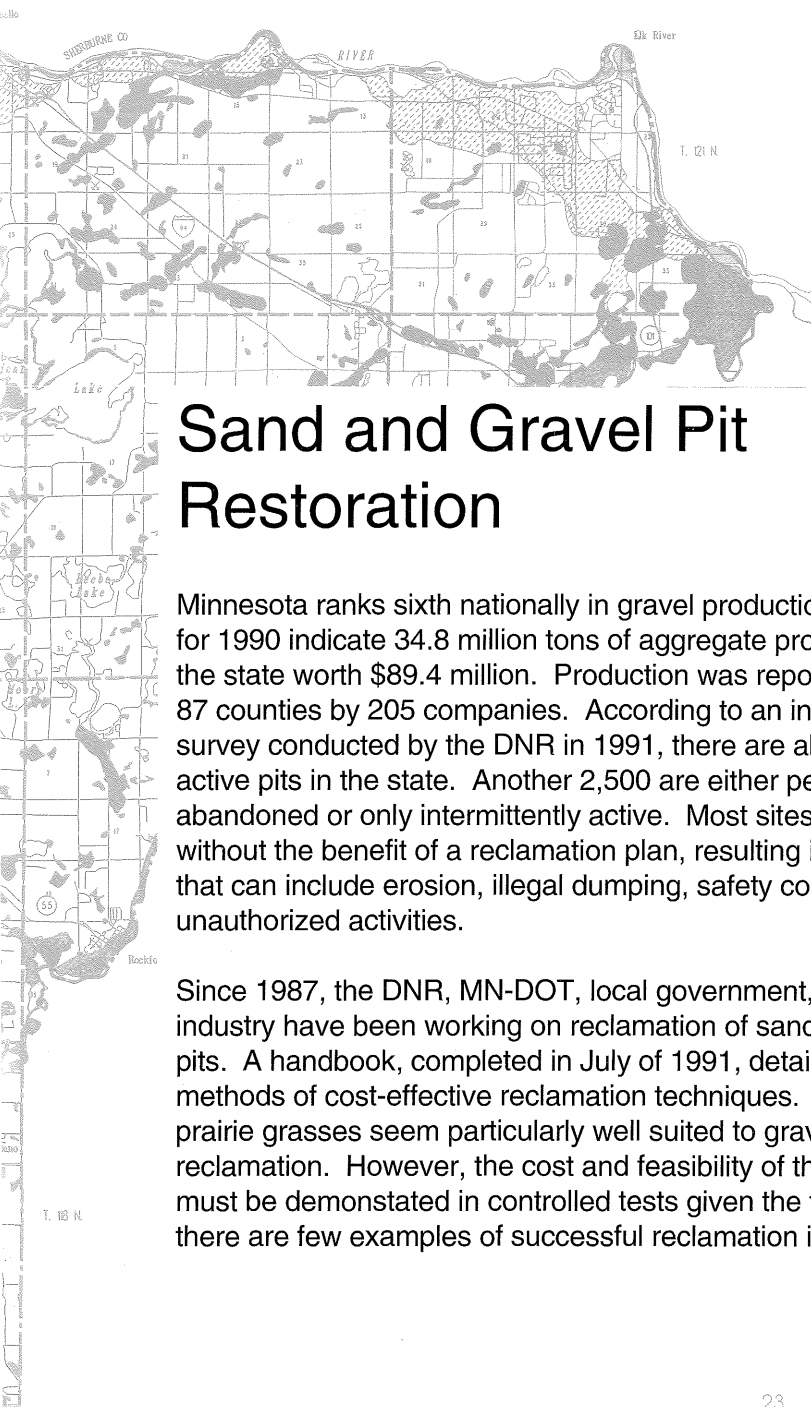
Minnesota Statute 84.94 mandates that the DNR, in cooperation with the Minnesota Geological Survey, Minnesota Department of Transportation, and the State Planning Agency, identify and classify potential aggregate resources outside the seven-county metropolitan area. The statute also specifies that the 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, MN-DOT 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 conflicts. Additionally, the maps may be used for water planning and protection of rare or threatened native animal and/or plant species.

Maps are available for Sherburne and Wright Counties, and mapping is in progress for Isanti and Benton Counties.





Sand and Gravel Pit 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, MN-DOT, local government, and the industry have been working on reclamation of sand and gravel pits. A handbook, completed in July of 1991, details several methods of cost-effective 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.

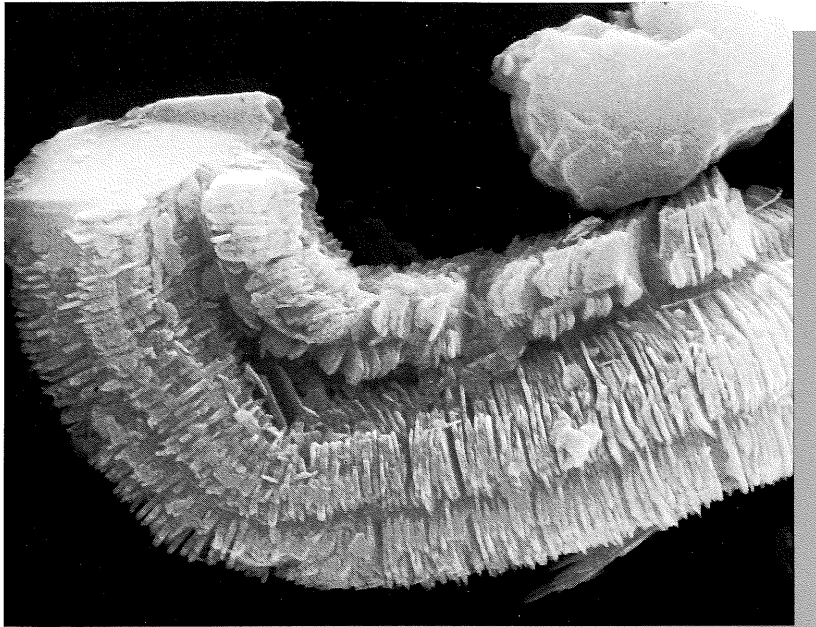
Accelerated Industrial Minerals Leasing

To ensure the orderly development of industrial minerals, the state must promulgate rules which allow such development to move ahead, while protecting the interests of the state and its citizenry. The Mineral Diversification Program has assisted the DNR's Division of Minerals in rules development by making it possible to accelerate the process.

The Division completed a report summarizing the methods used by 37 other states and the federal government in oil and gas leasing. The information contained in the report will be valuable as the state moves ahead with development of its own rules for oil and gas.

Similarly, program funding helped accelerate rules development for industrial minerals such as kaolin clay, granite, industrial diamonds, and gemstones. The ultimate goal is to prepare a basic lease form for industrial minerals, and leasing rules.

The program also funded data gathering on kaolin clay leasing activities in the Minnesota River Valley. The information collected from county records has been used to create a map of the leases in the Valley, to provide a more complete picture of kaolin exploration.



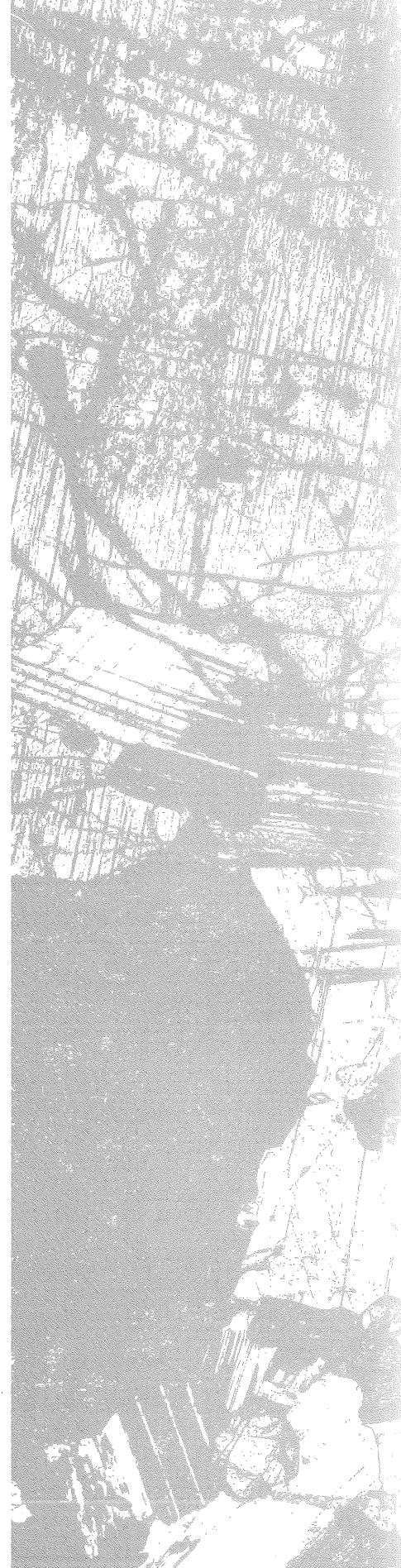
Photomicrograph of kaolin clay.

Clay Research

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 of 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.



Current Projects

Aggregate resource mapping will move into Isanti and Benton Counties, and additional deposits of sand and gravel threatened by urban development will be identified under a separate project. Restoration demonstration projects for sand and gravel pits will continue to move ahead at two sites near Zippel Bay State Park in Lake of the Woods County which were seeded to native grasses in the summer and fall of 1991. Earth moving will begin in another site near Bemidji in the spring of 1992. Data on kaolin clay in central and northern Minnesota will be gathered into a report. In southeastern Minnesota, carbonate resources will be studied for possible use as flux material for the taconite industry. Dimension stone deposits that could be leased as quarry sites will be identified. And finally, the market for industrial minerals will be studied to evaluate current and potential markets for Minnesota minerals.

Minerals

Basic Research

The purpose of this portion of the Mineral 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 used for preliminary evaluations of promising geologic or mineral-processing concepts. Projects funded in FY '90 - '91 included:

- Image processing of 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 non-ferrous 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 has subsequently 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.



Financial Data

SUMMARY BUDGET SHEETS

FY 90-91 (1,000's)	Sources of Funding				Total
	MCC Base	Coop. Res.	LCMR	Other	
The Iron Industry	302.0	627.0	200.0	260.0	1,389.0
Non-Ferrous Minerals	940.3		860.0	87.5	1,887.8
Industrial Minerals	271.0		130.0	244.0	645.0
Minerals Basic Research	111.0				111.0
Total	1,624.3	627.0	1,190.0	591.5	4,032.8
FY 92-93 (1,000's)					
The Iron Industry	264.0	650.0		550.0	1,464.0
Non-Ferrous Minerals	897.4		120.0		1,017.4
Industrial Minerals	320.0				320.0
Minerals Basic Research	100.0				100.0
Unallocated	46.6				46.6
Total	1,628.0	650.0	120.0	550.0	2,948.0

MINERAL DIVERSIFICATION CONTRACTS AND PROJECTS FY 92-93

	<u>Organization</u>	<u>Amount</u>
<u>The Iron Industry</u>		
Improved Classification	NRRI	80,000
Phase II AISI/MN Silica	NRRI/CME	100,000
Water treat./Flotation	NRRI	55,000
Value-added Technology	DNR	20,000
Iron Mining in MN	DNR	9,000
Subtotal		264,000
<u>Non-Ferrous Minerals</u>		
Geo. Drill & Map NW MN	MGS	325,000
Geo. Strat. S. Kawishiwi	NRRI	150,000
Bedrock Map-Duluth Area	MGS	135,000
Drill Core Exam & Assay	DNR	90,000
Quaternary Map NC MN	MGS	95,000
Cu, Ni, & PGM Flotation	CME	3,400
Gold-Early Prot. Panokean	NRRI	25,000
Non-Ferrous Reclamation	DNR	36,000
Geo/Mining Brochure	DNR	18,000
Severed Minerals	DNR	20,000
Subtotal		897,400
<u>Industrial Minerals</u>		
Kaolin in Cent. MN	NRRI	60,000
Sand & Gravel Inventory	DNR	115,000
Carbonate Beneficiation	NRRI	50,000
Dim. Stone Inv.	DNR	40,000
Sand/Gravel Restoration	DNR	20,000
Industrial Minerals Transportation Study	NRRI	10,000
Kittson Bloating Clays	NRRI	25,000
Subtotal		320,000
<u>Basic Research</u>		
	UofM	100,000
Total Mineral Diversification Contracts and Projects		1,581,400
Diversification Appropriation		1,628,000

MINERALS COORDINATING COMMITTEE

MINERAL DIVERSIFICATION BUDGET PROPOSAL FOR FY94-95

Historical Funding Levels

FY88-89 Biennium	1,408.0
FY90-91 Biennium	1,624.2
FY92-93 Biennium (appropriated)	1,628.0
FY92-93 Biennium (after budget cuts)	1,264.0

MINERAL DIVERSIFICATION PROJECTS

Ferrous Projects	FY94-95
Value-added research to support projects selected by the Taconite Enhancement Committee	270.0
Salt roasting of Minnesota vanadium ores	65.0
Creation of artificial wetlands in tailings basins	35.0
High temperature reduction test for pellets	65.0
Sub-total: Ferrous Projects	435.0
Non-ferrous Projects	FY94-95
Geologic drilling and mapping in the Penokean Orogen in east central Minnesota	365.0
Examination and assay of drill core from central Minnesota	115.0
Igneous stratigraphy of the Duluth Complex	135.0
Preparation of geologic index maps for DNR regions 1 and 2 using GIS techniques	36.5
Petrology and metalogenesis of the southern portion of the Duluth Complex	45.5

Non-ferrous projects (cont.)	FY94-95
Use of lithogeochemistry to locate white smokers (lead-zinc mineralization) in the Animike Basin	50.0
Wetland treatment of mine drainage	36.0
Sub-total: Non-ferrous Projects	783.0
Industrial Minerals Projects	FY94-95
Geologic controls on clay grades: Minnesota River Valley west of Redwood Falls	155.0
Aggregate mapping: sand and gravel inventory	40.0
Sand and gravel restoration	30.0
Dimension stone inventory	30.0
Continued development of Kittson County bloating clays	115.0
Industrial minerals inventory	37.0
Sub-total: Industrial Minerals Projects	407.0
TOTAL	1,625.0

Iron Ore Cooperative Research FY92-93

PROJECT TITLE	Project Amount	State Contribution	Matching Funds	Match Contributor
Improved Classification	60,000.00	30,000.00	30,000.00	Cliffs Mining Services
Corrosion of Grate Castings	99,302.00	71,488.00	27,814.00	UofM/Minerals Institute
Dry Cobbing of Rod Mill Feed	40,000.00	20,000.00	20,000.00	USX Corporation
In-Plant Test of PAR-TEC 200	57,000.00	52,500.00	4,500.00	USX Corporation
Oxygen Enrichment - Phase II	80,000.00	40,000.00	40,000.00	Cliffs Mining Services
Column Flotation Optimization	60,000.00	30,000.00	30,000.00	USX Corporation
On-line Moisture Analysis	42,500.00	21,250.00	21,250.00	USX Corporation
Vertimill Grinding System	42,500.00	24,250.00	17,750.00	USX Corporation
Screening Test	25,000.00	12,500.00	12,500.00	USX Corporation
Blast Fragmentation	62,250.00	29,750.00	32,500.00	USX Corporation
Belt Sizer	51,750.00	25,000.00	26,750.00	USX Corporation
Pellet Improvement Series IV	100,000.00	50,000.00	50,000.00	Cliffs Mining Services
Grate Bar - Transpiration	31,300.00	31,300.00	0.00	No Match Provided
Evaluation of CFS Classifier	34,000.00	17,000.00	17,000.00	USX Corporation
Evaluation of Ferrous Wheel	31,000.00	13,000.00	18,000.00	USX Corporation
Ported Grate Kiln Design	18,000.00	9,000.00	9,000.00	Industrial Partners
Liberation of Problem Ores 1	25,000.00	12,500.00	12,500.00	Industrial Partners
Liberation of Problem Ores 2	36,750.00	17,500.00	19,250.00	USX Corp
Inter-Lab Testing	37,125.00	0.00	37,125.00	Industrial Partners
Bentonite Study	7,000.00	0.00	7,000.00	Industrial Partners
HTSM Testing	21,000.00	0.00	21,000.00	Industrial Partners
Totals	961,477.00	507,038.00	453,939.00	

**IRON ORE COOPERATIVE RESEARCH
FY87 THRU FY93**

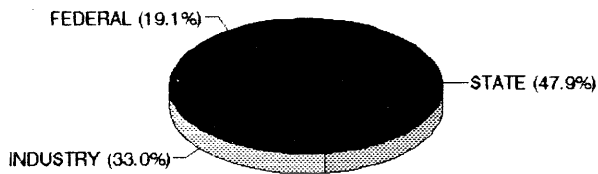


FIGURE 1a.

**CONTRIBUTION SOURCES
TOTAL CONTRIBUTIONS**

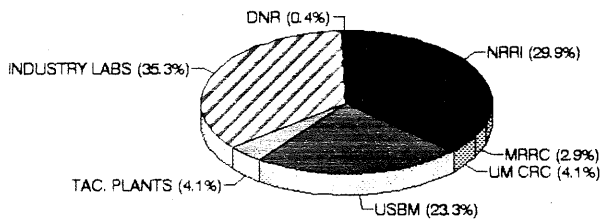


FIGURE 1b.

**FUND DISTRIBUTION
TOTAL
\$3,420,000**

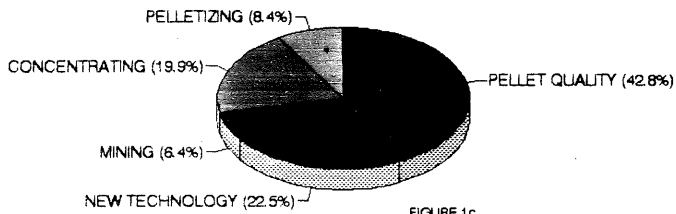


FIGURE 1c.

PROGRAM DISTRIBUTION

