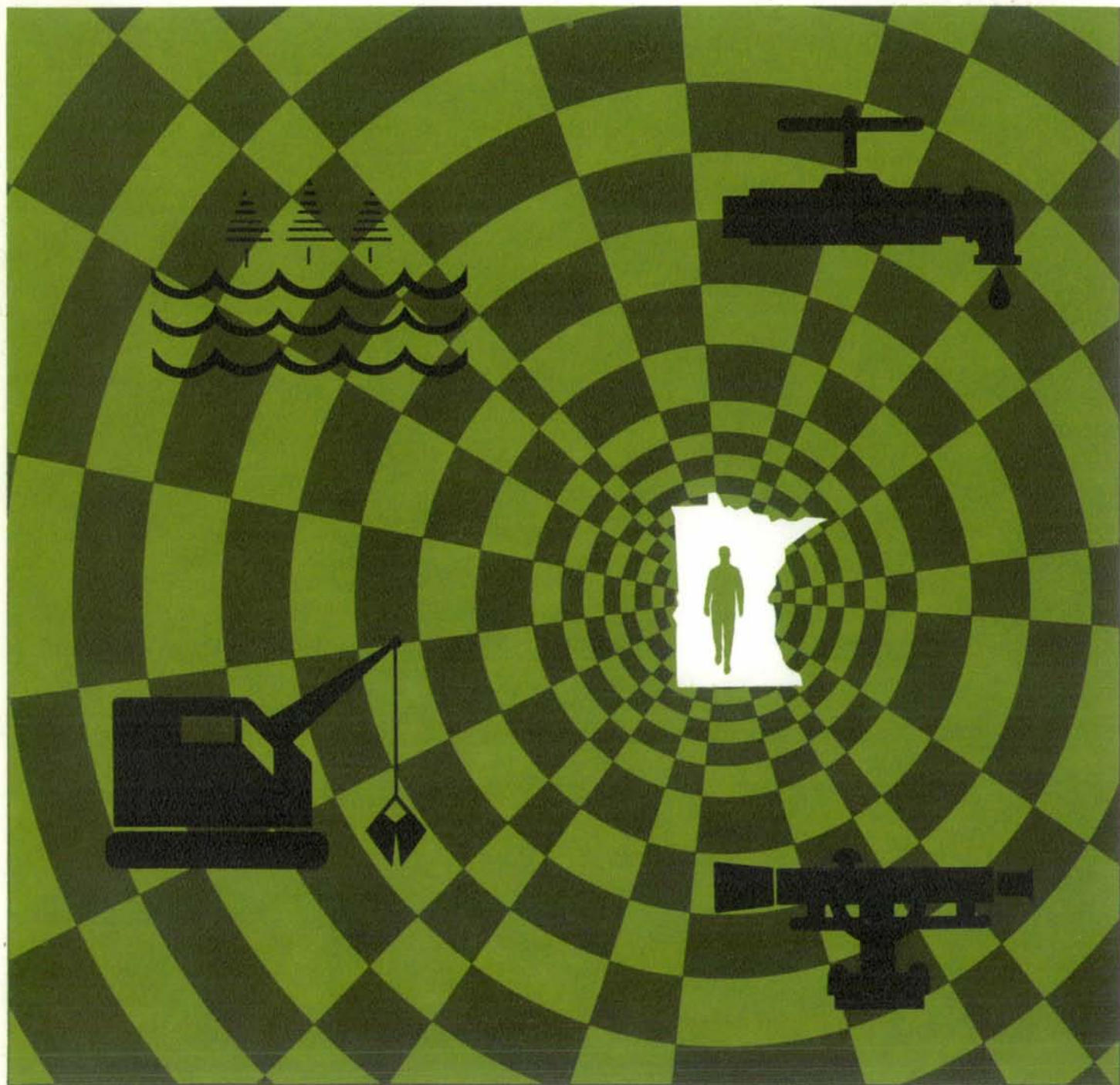


MINNESOTA GEOLOGICAL SURVEY

1968

Newsletter

UNIVERSITY OF MINNESOTA



MINNESOTA GEOLOGICAL SURVEY

Paul K. Sims, Ph.D., *Director*
Rudolph K. Hogberg, M. S., *Assistant to the Director and Geologist*
George S. Austin, M. S., *Geologist*
Rodney J. Ikola, M. S., *Geophysicist*
Glenn B. Morey, Ph. D., *Geologist*
Walter E. Parham, Ph.D., *Geologist*
Eugene C. Perry, Jr., Ph.D., *Geochemist*
Bill Bonnichsen, Ph.D., *Geologist*
Reta Bradley, B.S., *Geologist and Cartographer*

James A. Grant, Ph.D., *Geologist (part-time)*
D. M. Davidson, Jr., Ph.D., *Geologist (part-time)*
J. C. Green, Ph.D., *Geologist (part-time)*
R. W. Ojakangas, Ph.D., *Geologist (part-time)*

Judy Utendorfer, *Secretary*

Additional part-time staff consists of 4 faculty members and 3 graduate students of the Department of Geology and Geophysics, Minneapolis Campus.

Cover: a symbolic design depicting how geology influences man's activities in water management, engineering works, mineral resources, and recreation and aesthetics (see *Environmental Geology*, p. 4).

The Minnesota Geological Survey has the responsibility for conducting investigations of the geology of Minnesota for the benefit of the citizens and industries of the State. It carries out this responsibility by geologic mapping of the rock strata, by research on the occurrence, quality, and usefulness of mineral resources, and by publication of the results.

A list of publications of the Minnesota Geological Survey is available upon request. Book reports include a bulletin series, special publication series, reports of investigations, educational series, information circulars, summary reports, reprint series, and miscellaneous reports. Maps include a State geologic map atlas, geologic map series, miscellaneous map series, and other maps and charts.

The Survey welcomes inquiries concerning any aspect of the geology of the State. Inquiries by mail should be addressed to:

Paul K. Sims, Director
Minnesota Geological Survey
University of Minnesota
Minneapolis, Minnesota 55455

The Survey offices are located in Pillsbury Hall, Minneapolis campus.
Phones 373-3372, 373-4986.

SUMMARY OF ACTIVITIES

The major highlight in geologic activities in the state again was the high level of exploration for copper and nickel deposits in the Duluth Gabbro Complex. The Gabbro continues to be one of the most active exploration areas in the country. Despite some discouraging results, optimism remains high that the state of Minnesota soon will have a copper-nickel industry.

During the past year Survey activity was increased modestly as a result of a somewhat larger appropriation by the 1967 State Legislature. Preparation of a new State Geologic Bedrock Map and studies specifically directed toward aiding the development of new mineral industry continued to receive emphasis. In addition, new efforts were made to contribute to the solution of environmental problems in the State, especially through advising the State Planning Agency on the geologic aspects of water and related land-use planning and by providing geologic data to the Metropolitan Council.

Eight geologic reports and maps were published during the year, and four maps were placed in open-files in order to make the geologic data available to the public at the earliest possible time. The Minnesota Department of Iron Range Resources and Rehabilitation assisted in publishing three geologic and geophysical maps of direct aid to the mining industry.

As an example of our public service activities, the Survey assisted the Yellow Medicine County Historical Society in planning geologic exhibits for its museum in Granite Falls.

Despite the steady increase in the activities of the Minnesota Geological Survey during the past several years, a substantial acceleration still is needed if it is to contribute fully to the growth of the State's mineral industry and to the solution of the manifold problems related to uses of our land and water. Additional efforts are particularly needed in environmental geology. Geologic mapping of the state's glacial deposits is required for the appraisal and efficient use of our underground water supplies, and mapping and engineering studies are needed in the Twin Cities metropolitan area to provide data for planning and construction.

As a result of the expansion of our research staff and of the growth of the teaching faculty in the Department of Geology and Geophysics during the past few years, the Survey and the Department have outgrown their present building — Pillsbury Hall. Except for the administrative office, Survey personnel now are housed in Jones Hall, across the street from Pillsbury. Office, laboratory, library, and storage space are wholly inadequate. Because of the cramped quarters and lack of attractive, comfortable space, the Survey is having increasing difficulties in carrying out its research and its public service functions, and is not in a favorable position to attract top-flight scientists to its staff. A request for a new geology building was submitted to the University administration during the year. Favorable support by the University and by the State Legislature is urgently needed if we are to continue to expand our role in the growth and development of the state.

BUDGET

The Survey program is financed primarily by direct appropriations of the Minnesota State Legislature. Additional support is provided by University Support funds and by grants. The total monies available during fiscal year 1967-68 are listed below:

\$ 80,000 — State Legislative Special
37,513 — University Support funds
70,000 — Natural Resources fund
7,100 — NSF Grant (E. C. Perry, Jr.)
6,600 — Graduate School grants
2,246 — Office of International Programs (W. E. Parham)
3,800 — Water Resources planning (State Planning Agency)
<hr/>
\$207,259

The budget for fiscal year 1968-69 follows:

\$ 80,000 — State Legislative Special
40,413 — University Support funds
70,000 — Natural Resources fund
15,000 — Grants and contracts (estimated)
<hr/>
\$206,413

STAFF NOTES

George S. Austin attended the annual meeting of the Clay Mineral Society in Denver in August, and the North-central region meeting of the Geological Society of America in Iowa City in May.

Bill Bonnicksen began detailed reconnaissance of the geology in the poorly exposed southern part of the Duluth Complex, to aid exploration for copper and nickel deposits.
Donald M. Davidson, Jr., Assistant Professor of Geol-

ogy, University of Minnesota, Duluth, was appointed to the Survey staff during the winter quarter, in addition to the field season.

James A. Grant completed reconnaissance geology of the Precambrian rocks of the Minnesota River Valley for the 1:250,000-scale New Ulm sheet and continued research on the detailed geology and geochronology of the Precambrian rocks in the Sacred Heart-Morton area.

J. C. Green, Associate Professor of Geology, University of Minnesota, Duluth, held an appointment with the Survey during the spring quarter, in addition to the field season. He was one of 20 participants in the AGI International Field Institute in Japan for 6 weeks in the summer of 1967.

R. K. Hogberg was a member of a task force of the State Water Resources Coordinating Committee, and counseled the Minnesota Division of State Parks and the Metropolitan Council on geologic problems related to their mission. In May, he attended the annual meeting of the Association of American State Geologists in Tuscaloosa, Alabama. During the late fall of 1968, he will assume the responsibility as Mineral Resources Planner for the State Planning Agency, and will be employed half-time by the State Planning Agency.

Rodney Ikola attended the annual meeting of the Society of Exploration Geophysicists in Oklahoma City in October and a two-week workshop on digital processing of gravity and magnetic data at the University of Missouri-Rolla in August, 1968.

G. B. Morey completed studies of the Thomson

Formation (with R. W. Ojakangas) and mapping on the Hibbing sheet; in June, he began compilation of the geology of the Duluth sheet, as part of the State Geologic Map program.

R. W. Ojakangas, Assistant Professor of Geology, University of Minnesota, Duluth, was appointed to the Survey staff during the fall quarter, as well as during the field season. During the early part of the summer of 1967 he taught at the CIC Field Camp at Park City, Utah.

W. E. Parham spent one month in Hong Kong and India doing field work on the formation of clay minerals in tropical areas, under sponsorship of the Office of International Programs and the Graduate School, University of Minnesota. Also, he lectured at the University of Hong Kong and at Andhra University in India. In August, he attended the annual meeting of the Clay Mineral Society in Denver.

E. C. Perry, Jr. studied the stable isotope geochemistry of the Biwabik and Soudan Iron-formations, other Precambrian rocks, and of rocks from several metamorphic aureoles.

P. K. Sims attended the dedication of the geology building, University of Texas, in November, the annual meeting of the Geological Society of America at New Orleans in November, and the annual meeting of the American Institute of Mining and Petroleum Engineers in New York in February. He continued as coordinator of the Federal-State cooperative topographic mapping program, financed through the Minnesota Resources Commission.

Lectures and Public Addresses

G. S. Austin —

The sub-drift topography and geology of southern Minnesota:

Minn. Academy of Science, St. Paul, April

Bill Bonnicksen —

Geology of the metamorphosed Biwabik Iron-formation, Dunka River area, Minn.:

Univ. Minn. Mining Symposium, Duluth, January

The Duluth Complex and its copper-nickel deposits:

Mesabi Range Geological Society, Chisholm, April
Metamorphism of the Biwabik Iron-formation, Dunka River area, Minn.:

Inst. Lake Superior Geology, Superior, Wis., May

Don Davidson, Jr. —

Geology of the Perent Lake and Kawishiwi Lake quadrangles, Minn.:

Inst. Lake Superior Geology, Superior, Wis., May

J. C. Green —

The Geology of Japan:

Mesabi Range Geological Society, Chisholm, February

Chemical and physical characteristics of Late Precambrian lavas of northeastern Minnesota:

Amer. Geophysical Union, Washington, D.C., April

Types and structures of flows of the North Shore Volcanic Group, Minn.:

Inst. Lake Superior Geology, Superior, Wis., May

R. K. Hogberg —

Caves of Minnesota:

Geol. Society Minnesota, Minneapolis, January

Glacial geology of the Minneapolis area:

Minn. Chapter Mensa, International, Minneapolis, February

Gravel deposits of Minneapolis quadrangle, Minnesota:
4th Forum on Geology of Industrial Minerals,
Austin, Texas, March

G. B. Morey —

Geosynclines, their origin and geological significance:
Minnesota Geological Society, Minneapolis, March

The sedimentology of the middle Precambrian Thomson formation: (with R. W. Ojakangas)

Inst. Lake Superior Geology, Superior, Wis., May

R. W. Ojakangas –
Sandstone petrology of Great Valley sequences, Sacramento Valley, California: (with 3 others)
Cordilleran section Geol. Society America, Tucson, Ariz., April

Volcanism, sedimentation, and stratigraphy of the western Vermilion district, Minnesota: (with G. B. Morey)
Inst. Lake Superior Geology, Superior, Wisc., May

W. E. Parham –
Clay mineralogy of Minnesota's kaolin clays:
Clay Mineral Society, Denver, August

Clay mineralogy and tropical weathering:
Seminar, Dept. Soil Science, St. Paul, April

P. K. Sims –
Significance of copper-nickel developments in Duluth Gabbro:
American Mining Congress, Denver, September

Status of copper-nickel exploration in Duluth Gabbro:
Twin City Geologists, Minneapolis, October

Geology and mineral potential of the proposed Voyageurs National Park on Kabetogama Peninsula:
Governor's Workshop, Virginia, Minn., November

Minnesota's mineral resources – present and future:
Kiwanis Club of St. Paul, February

The stratigraphic and structural framework of the Vermilion district and adjacent areas, Minnesota:
(with G. B. Morey, R. W. Ojakangas, and W. L. Griffin)
Inst. Lake Superior Geology, Superior, Wis., May

Academic Assignments and other Professional Responsibilities

James A. Grant –
Department of Geology and Geophysics, University of Minnesota: Assistant Professor

R. K. Hogberg –
School of Mineral and Metallurgical Engineering, University of Minnesota: teaching assignment ME 160, Geology and technology of nonmetallic rocks and minerals (with D. H. Yardley)

G. B. Morey –
Department of Geology and Geophysics, University of Minnesota: Assistant Professor

W. E. Parham –
Department of Geology and Geophysics, University of Minnesota: Associate Professor

E. C. Perry, Jr. –
Department of Geology and Geophysics, University of Minnesota: Assistant Professor

P. K. Sims –
Department of Geology and Geophysics, University of Minnesota: Professor; member of Advisory Committee, University's Water Resources Research Center; 1967 teaching assignments, Geology 257, Geology 245; Society of Economic Geologists: Councilor and Chairman of Publications Committee; Economic Geology Publishing Company: Director and member of Executive Committee; North Star Research and Development Institute, Minneapolis: Board of Directors

ENVIRONMENTAL GEOLOGY

Geologic knowledge, which is the base for planning a quality environment has emerged as one of the vital and important sub-disciplines within the field of geology. It is predicted that by 1980, 90 percent of the people of the United States will live in urban centers. This migration to the city in conjunction with man's continual search for knowledge and resources to make his life more comfortable, puts an unprecedented demand on the geologic resources of the urban centers.

In Minnesota the most urgent need for knowledge of the geologic environment is within the Twin Cities Metropolitan area – the 3rd fastest growing metropolitan center in the United States. The Twin Cities Metropolitan area is generally considered to include the 7 counties of Hennepin,

Ramsey, Anoka, Dakota, Scott, Washington, and Carver. Other out-state communities that need environmental studies include Duluth, Rochester, St. Cloud, Mankato, Austin, Moorhead, and Winona. The environmental problems of small towns and rural areas are presently of lesser concern.

Each of the densely populated urban areas has its own unique geologic environment. Knowledge of these geologic parameters is needed. When the background geology is known a systems analyses of the urbanized area can be initiated, the ultimate objective of which is the best use of the existing natural resources.

Minnesota, and particularly the Twin Cities Metropolitan area, is badly lacking in geologic information for the

environmental problems of water management, engineering design, identification of geologic hazards, land use planning, mineral resource evaluation, pollution problems, and preserving the natural recreational resources.

To solve these problems, funds are needed to compile, interpret, and publish the findings of environmental geology studies. Specifically, these studies should include mapping of the glacial deposits and bedrock geology,

mineral resources evaluation, hydrologic research, and engineering studies. These data will aid directly in such widely varied problems as foundation sites for high-rise buildings, ground-water availability, and locating sites for non-polluting sanitary land fills; will promulgate the multiple land use concept into zoning regulations; and will assist in predicting areas susceptible to geologic hazards — floods and landslides — as well as in selecting areas to be set aside for valuable mineral resources.

COPPER-NICKEL EXPLORATION — PROGRESS

For the third successive year exploration for deposits of copper and nickel in the Duluth Gabbro Complex, northeastern Minnesota, remains at a high level. Several major companies have active exploration programs, and Inco is in the final stages of a preliminary development program. Inco has completed a development shaft to a depth of about 1,090 feet and a drift through the mineralized zone at the 1,000 foot level, to obtain bulk samples for metallurgical sampling and to test mining conditions. A decision on the economic feasibility of mining Inco's deposits in the Ely area is expected within the next few months.

Exploration is concentrated in a 65 mile long belt between Duluth and the South Kawishiwi River, southeast of Ely. In addition, significant programs are underway on the north side of the Duluth Gabbro in Cook County.

In general, the drilling has indicated very large tonnages of low-grade copper and nickel-bearing material near the base of the Gabbro. For the most part, specific exploration programs have been encouraging to the respective companies, and optimism remains high. A problem in need of more attention is the extraction of nickel from the mineralized

material. Inco has reported disappointing results in nickel extraction in its metallurgical tests. Both the University Mines Experiment Station and the Minnesota Geological Survey are assisting with this problem by carrying out research on the ore and silicate minerals in the mineralized zone.

To aid in the development of a copper-nickel industry, the Minnesota Geological Survey is continuing geologic mapping, geophysical studies, and research on the ore minerals and associated silicate minerals in the Duluth Gabbro. As noted in the section on publications, a gravity map has been completed for the southern part of the Duluth Complex, in the area of principal interest. A geologic reconnaissance of the same area now is being carried out by Bill Bonnicksen, to determine in so far as possible in this area of sparse exposures the broad geologic features of the intrusive body. An aeromagnetic map of part of this area, prepared by the U.S.G.S. in cooperation with the Minnesota Geological Survey, was placed in open-files in May. Reports on the geology of the Duluth Complex in the Gabbro Lake quadrangle and on compositions of the ore and silicate minerals in the South Kawishiwi area have been completed and will be published soon.

HIGHLIGHTS OF MINNESOTA'S MINERAL INDUSTRY — 1967 (Furnished by Bureau of Mines, U.S. Department of Interior)

In 1967, mineral production in Minnesota was valued at \$518.8 million — a decrease of about 6 percent from that recorded in 1966. The decrease reflected the 6 percent drop in value of iron-ore shipments. Iron ores comprised 90 percent of the State's mineral income in 1967. Taconite pellet shipments increased about 9 percent, to 48 percent of the State's total iron ore shipments — reflecting the expansion at older plants and production from two new plants.

Industrial mineral production increased about 3 percent from 1966. Sand and gravel, which comprised 57.3 percent of the industrial mineral production, rose 4 percent in value due to increases in construction projects. The value of stone production remained about level from last year even though output decreased about 2 percent. Increases over 1966 were reported in quartzite, lime, and peat; decreases were reported in clay and shale, basalt, and marl.

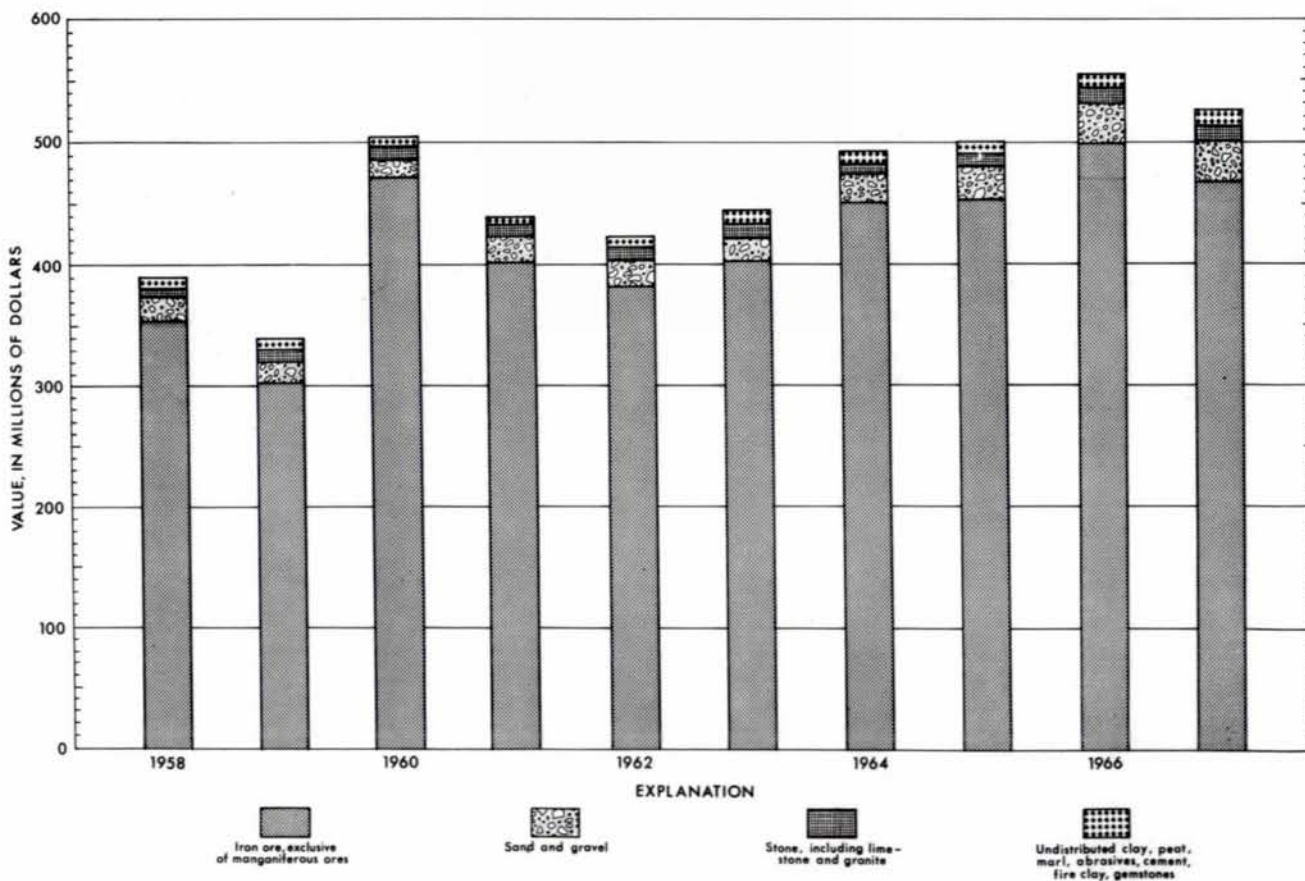
Mineral Production in Minnesota 1966 and 1967*

Mineral	1966		1967	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Clays ^{1/} thousand short tons . . .	224	\$336	228	\$342
Iron ore (usable) thousand long tons, gross weight. . .	55,133	499,388	49,457	468,623
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight. . .	275,581	W	236,753	W
Peat short tons. . .	11,366	197	13,968	257
Sand and gravel. . . thousand short tons . . .	39,331	28,972	41,212	33,132
Stone do	4,901	11,688	4,160	11,442
Value of items that cannot be disclosed: Abrasive stones, cement, fire clay, gem stones, lime and manganiferous ore, and values indicated by symbol W		9,696		9,530
Total		550,277		523,326

W Withheld to avoid disclosing individual company confidential data.

^{1/} Excludes fire clay, value for which is included with "Value of items that cannot be disclosed".

* Information from U. S. Bureau of Mines.



VALUE OF MINERAL PRODUCTION, MINNESOTA, 1958-1967.

PROJECTS

Current Projects

1. DULUTH GABBRO COMPLEX, Lake County W. C. Phinney
(Geologic mapping of Forest Center 15-minute quadrangle, in progress.)
2. GEOLOGY OF PRECAMBRIAN "RED CLASTICS", SOUTHEASTERN
MINNESOTA G. B. Morey
(A stratigraphic and mineralogic study of a deep core recently drilled by
Northern Natural Gas Co. in Rice County. Data will be integrated with
previous information from scattered well cuttings.)
3. MINNESOTA'S CLAY MINERAL RESOURCES W. E. Parham
(Report on Kaolin clay resources completed.)
4. SAND AND GRAVEL RESOURCES, MINNEAPOLIS 15-MINUTE
QUADRANGLE R. K. Hogberg
(Report in preparation.)
5. GEOLOGY AND GEOCHRONOLOGY OF PRECAMBRIAN ROCKS, Minnesota
River Valley J. A. Grant
6. SEDIMENTOLOGY OF PRECAMBRIAN KNIFE LAKE FORMATION R. W. Ojakangas
7. PETROLOGY AND TITANIFEROUS MAGNETITE DEPOSITS OF THE DULUTH
GABBRO COMPLEX, SOUTH LAKE QUADRANGLE AND ADJACENT AREAS,
Cook County H. D. Nathan
(Preliminary geologic maps of Duluth Gabbro in South Lake, Gunflint Lake,
and Hungry Jack Lake 7½-minute quadrangles placed in open-files, June, 1968.)
8. OXYGEN ISOTOPE FRACTIONATION STUDIES E. C. Perry, Jr.
9. GEOLOGIC MAPPING OF TOWER 7½-MINUTE QUADRANGLE, St. Louis County . . R. W. Ojakangas and
(Map and text for report in preparation.) P. K. Sims
10. GRAVITY INVESTIGATIONS IN MINNESOTA R. J. Ikola
(A network of base stations has been established. Gravity coverage will be
obtained for state as part of state geologic map project.)
11. GEOLOGY OF NORTH SHORE VOLCANIC GROUP J. C. Green
(A stratigraphic and petrologic study, in part financed by a grant from the
National Science Foundation.)
12. GEOLOGY OF PERENT LAKE AND ADJACENT QUADRANGLES,
DULUTH GABBRO COMPLEX, Lake and Cook counties D. M. Davidson, Jr.
(Map and text for report in preparation.)
13. GENERAL GEOLOGY OF THE VERMILION DISTRICT AND ADJACENT AREAS . . P. K. Sims
(A geological and geophysical investigation of a 2,000 square mile area lying north of G. B. Morey
the Mesabi range. Preliminary geologic map published in July, 1968.) R. W. Ojakangas
W. L. Griffin
14. ENGINEERING AND GLACIAL GEOLOGY OF MINNEAPOLIS-
ST. PAUL AREA J. E. Stone
(Project recessed temporarily.)

15. SURFICIAL GEOLOGY OF MONTEVIDEO SE QUADRANGLE C. L. Matsch
(Mapping completed; report in preparation.)
16. GEOCHRONOLOGY OF THE MINNESOTA-ONTARIO BORDER REGION S. S. Goldich and
G. N. Hanson
17. SUBSURFACE STRATIGRAPHY OF MINNESOTA G. S. Austin
(An accelerated study of the subsurface stratigraphy of Minnesota's Paleozoic
rocks, to provide data needed for hydrologic investigations.)
18. PARAGENESIS AND COMPOSITIONS OF SULFIDE AND ASSOCIATED
SILICATE MINERALS FROM MINERALIZED ZONE, DULUTH GABBRO
COMPLEX P. W. Weiblen
(Report in preparation.)
19. GEOLOGICAL-GEOPHYSICAL INVESTIGATIONS, SOUTH HALF OF
DULUTH GABBRO COMPLEX Bill Bonnicksen and
R. J. Ikola
(Bouguer gravity map published, June 1968; aeromagnetic map, prepared by
USGS in cooperation with MGS, placed in open-files, May 1968; reconnaissance
geologic mapping in progress.)
20. GEOLOGY OF GRAND PORTAGE AND PIGEON POINT AREAS,
Cook County P. W. Weiblen
(A reconnaissance investigation, to determine the structure and petrology of
the "Logan sills" and the Rove Slate and to evaluate the potential for
mineral deposits.)
21. GEOLOGY AND METAMORPHISM OF THE GUNFLINT IRON-FORMATION G. B. Morey
(Geologic mapping as part of a project being carried out in cooperation
with the U.S. Geological Survey.)
22. REMOTE SENSING – EVALUATION OF RADAR IMAGERY OF
MESABI RANGE AND ADJACENT AREAS Alta Walker
(Carried out in cooperation with USGS and NASA.)
23. STRATIGRAPHY AND SEDIMENTOLOGY OF THE THOMSON FORMATION G. B. Morey and
R. W. Ojakangas
(Report in preparation.)
24. GEOCHRONOLOGY OF MAFIC DIKE ROCKS, NORTHERN MINNESOTA G. N. Hanson
(A cooperative project with field geologists of the MGS; emphasis will be
placed on dating of minerals.)

SPECIAL ACTIVITIES

The Survey conducted two field trips in the northern Minnesota area during the year.

Bill Bonnicksen and W. C. Phinney were co-leaders for a field trip in the Duluth Gabbro Complex near Ely. The trip was given on both May 5 and 8 in conjunction with the Institute on Lake Superior Geology meeting at Superior, Wisconsin. Approximately 200 people attended the field trips, which included stops showing multiple intrusion and

the copper and nickel mineralization associated with the base of the Complex.

G. B. Morey and R. W. Ojakangas conducted a field trip on June 1 in the Vermilion Lake area near Tower-Soudan, in cooperation with the Mesabi Range Geological Society. Twenty participants observed and discussed the structure, stratigraphy, and possible economic potential of the western Vermilion district.

STATE GEOLOGIC MAP ATLAS PROJECT

Preparation of a new state geologic (bedrock) map, which will consist of 11 separate sheets (scale 1:250,000), continued at about the same level during the year. Progress is summarized below and in the accompanying status map:

New Ulm sheet:

Project personnel: G. S. Austin, J. A. Grant
 Progress: 90% completed

Two Harbors sheet:

Project personnel: J.C. Green, W.C. Phinney, Donald Davidson, Jr., H.D. Nathan, Bill Bonnicksen
 Progress: 30% completed

Duluth sheet:

Project personnel: G. B. Morey
 Progress: Mapping begun June, 1968

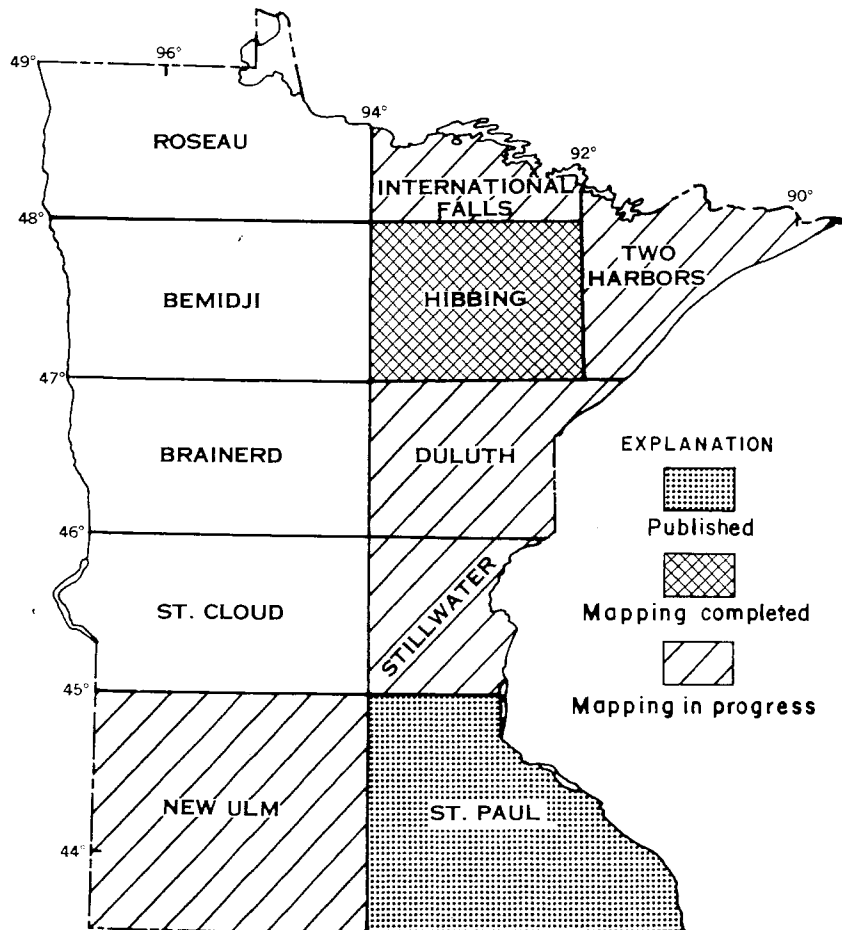
International Falls sheet:

Project personnel: David Southwick, R. W. Ojakangas
 Progress: Mapping begun June, 1968

Stillwater sheet:

Project personnel: G. S. Austin
 Progress: Mapping begun June, 1968

Morris T. Eng of the Division of Waters, Soils, and Minerals, Minnesota Department of Conservation, contributed to the mapping in the Hibbing and International Falls sheets by providing photo-geologic maps of selected areas.



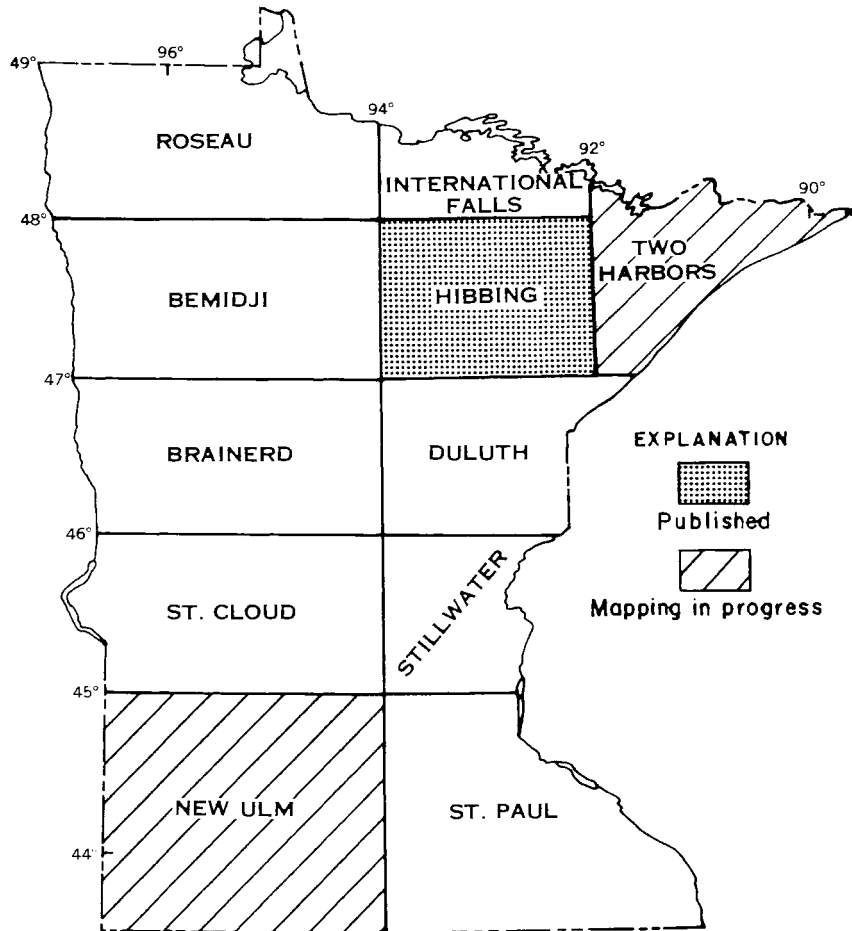
STATUS OF STATE GEOLOGIC MAP ATLAS, JUNE 30, 1968, (SCALE 1:250,000)

STATE GRAVITY MAPPING PROJECT

Gravity surveys are being carried out concurrently with the State Geologic Map Atlas Project, to aid the geologic mapping and to provide basic data on the regional gravity attraction. The data will be published mainly as simple

Bouguer gravity maps. A gravity base-station network has been completed and soon will be published.

The status of the gravity surveying is shown in the accompanying map.



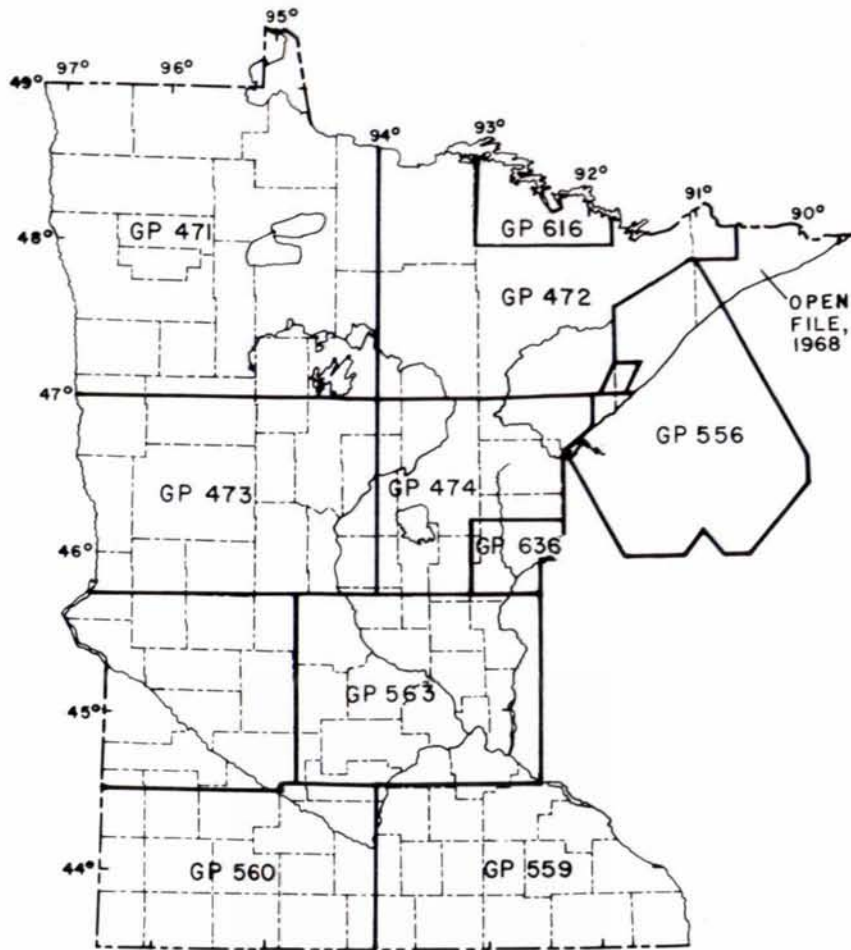
STATUS OF STATE GRAVITY MAP ATLAS, JUNE 30, 1968, (SCALE 1:250,000)

AEROMAGNETIC SURVEYING PROGRAM

Aeromagnetic surveying of the state has been completed, and the last of the maps will be published in the coming year. Support for this program since 1965 was provided by the Minnesota Resources Commission (see MORRC Report No.

7). Aeromagnetic maps are needed for geologic mapping and are basic to exploration for mineral deposits.

The status of aeromagnetic mapping is shown on the map on page following.



STATUS OF STATE AEROMAGNETIC MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, JUNE 30, 1968, (SCALE 1:250,000)

PUBLICATIONS 1967-68

Books and Reports

Bulletins#

Bulletin 45 – Progressive contact metamorphism of the Biwabik Iron-formation, Mesabi range, Minnesota, by Bevan French \$4.50

*Special Publications**

SP-2, 1966, Geology and origin of iron deposits of the Zenith Mine, Ely, Minnesota, by Jerome F. Machamer, 56 p., 3 pls., 11 figs., 4 tbls. \$2.00

SP-5, 1968, Geology of Precambrian rocks, Granite Falls – Montevideo area, southwestern Minnesota, by Glen R. Himmelberg, 33 p., 1 pl., 12 figs. \$2.00

*Reports of Investigations**

RI-7, 1967, Stratigraphy and petrology of the type Fond du Lac Formation, Duluth, Minnesota, by G. B. Morey, 25 p., 1 pl., 3 figs., 5 tbls. \$0.50

RI-8, 1968, K-Ar ages for hornblende from granites and gneisses and for basaltic intrusives in Minnesota, by G. N. Hanson, 20 p., 5 figs., 1 tbl. \$0.50

*Reprint Series**

RS-10 – Stratigraphy and sedimentology of the Middle Precambrian Rove Formation in northeastern Minnesota, by G. B. Morey, (Reprinted from Jour. of Sedimentary Petrology, v. 37, no. 4, 1967). .Gratis

RS-11 – Ages of mafic dikes near Granite Falls, Minnesota, by G. N. Hanson and G. R. Himmelberg, (Reprinted from Geol. Soc. America Bull., v. 28, 1967) Gratis

RS-12 – Copper and nickel developments in Minnesota by P. K. Sims (Reprinted from Mining Congress Journal, v. 54, no. 3, 1968) Gratis

Maps

Miscellaneous map series*

- Map M3**+, 1968, Simple Bouguer gravity map of Minnesota, Hibbing Sheet, (scale 1:250,000), by Rodney J. Ikola \$1.00
- Map M4**+, 1968, Simple Bouguer gravity map of southern part of Duluth Complex and adjacent areas, Minnesota, (scale 1:125,000), by Rodney J. Ikola \$1.00

- Map M5**+, 1968, Preliminary Geologic map of the Vermilion district and adjacent areas, northern Minnesota, (scale 1:125,000), by P. K. Sims, G. B. Morey, R. W. Ojakangas, and W. L. Griffin . . \$1.00

Order from University of Minnesota Press.
* Order from Minnesota Geological Survey
+ Published in cooperation with the Department of Iron Range Resources and Rehabilitation.

Manuscripts Submitted for Publication

1. Geology of the Isaac Lake quadrangle, St. Louis Co., Minn., by W. L. Griffin and G. B. Morey
2. Geology of the Cloquet quadrangle, Carlton Co., Minn., by H. E. Wright, Jr., L. Mattson, and J. A. Thomas.
3. Clay Mineralogy and geology of Minnesota's kaolin clays, by Walter E. Parham

Open-file Maps

- Kangas Bay 7½-minute quadrangle (scale 1:24,000), by W. C. Phinney
- South Lake 7½-minute quadrangle (scale 1:24,000), by H. D. Nathan
- Hungry Jack Lake 7½-minute quadrangle (scale 1:24,000), by H. D. Nathan
- Gunflint Lake 7½-minute quadrangle (scale 1:24,000), by H. D. Nathan

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- Hanson, G. N. and Himmelberg, G. R., 1968, Ages of mafic dikes near Granite Falls, Minnesota: Geol. Soc. Am. Bull., v. 78, p. 1429-1432.
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- Morey, G. B. (with E. P. Pflieger and R. L. Bleifuss), 1968, Mesabi deep drilling project, Progress Rept. No. 1, 29th Ann. Mtg. Mining Symposium, Univ. Minnesota (in press).
- Ojakangas, R. W., 1967 (with A. O. Beall, Jr.), Mineralogy of an Upper Cambrian K-bentonite from Missouri: Jour. Sed. Petrology, v. 37, p. 952-956.
- Perry, E. C. Jr., 1967, The oxygen isotope chemistry of ancient cherts: Earth and Planetary Science Letters, v. 3, p. 62-66.
- Sims, P. K., 1968, Copper and nickel developments in Minnesota: Mining Congress Journal, v. 54, no. 3, p. 29-34.

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- Goldich, S. S., Lidiak, E. G., Hedge, C. E., and Walthall, F. G., 1966, Northern area, in Geochronology of the midcontinent region, United States: Jour. Geoph. Review, v. 71, p. 5389-5408.
- Muehlberger, W. R., Denison, R. E., and Lidiak, E. G., 1967, Basement rocks in continental interior of United States: Am. Assoc. Petrol. Geol., v. 51, p. 2351-2380.
- U. S. G. S., 1968, Aeromagnetic map of the Kabetogema-Grassy Lake area, Minnesota: U. S. Geol. Survey Map GP-616.
- U. S. G. S., (in press) Aeromagnetic map of central Pine County, Minnesota, and adjacent parts of Wisconsin: U. S. Geol. Survey Map GP-636.
- Zablocki, C. J., 1966, Electrical properties of some iron-formations and adjacent rocks in the Lake Superior region, in Mining Geophysics, v. 1, Case histories: Tulsa, Oklahoma, Soc. Explor. Geophysicists, p. 465-492.

NOTEWORTHY RESULTS

Stratigraphic Framework of the Western Part of the Vermilion District and Adjacent Areas

It has been concluded from recently-completed geologic mapping in the Vermilion district and adjacent areas that the sequence of Ely Greenstone, Knife Lake Group, and associated Keewatin iron-formations constitutes a volcanic pile accumulation, which is remarkably similar to that in other greenstone belts of the Superior Province. In general, mafic volcanism was followed by felsic volcanism, accompanied by deposition of fragmental and clastic deposits. Marginal to the volcanic pile clastic sediments were deposited, and these strata intertongue laterally with the volcanic materials.

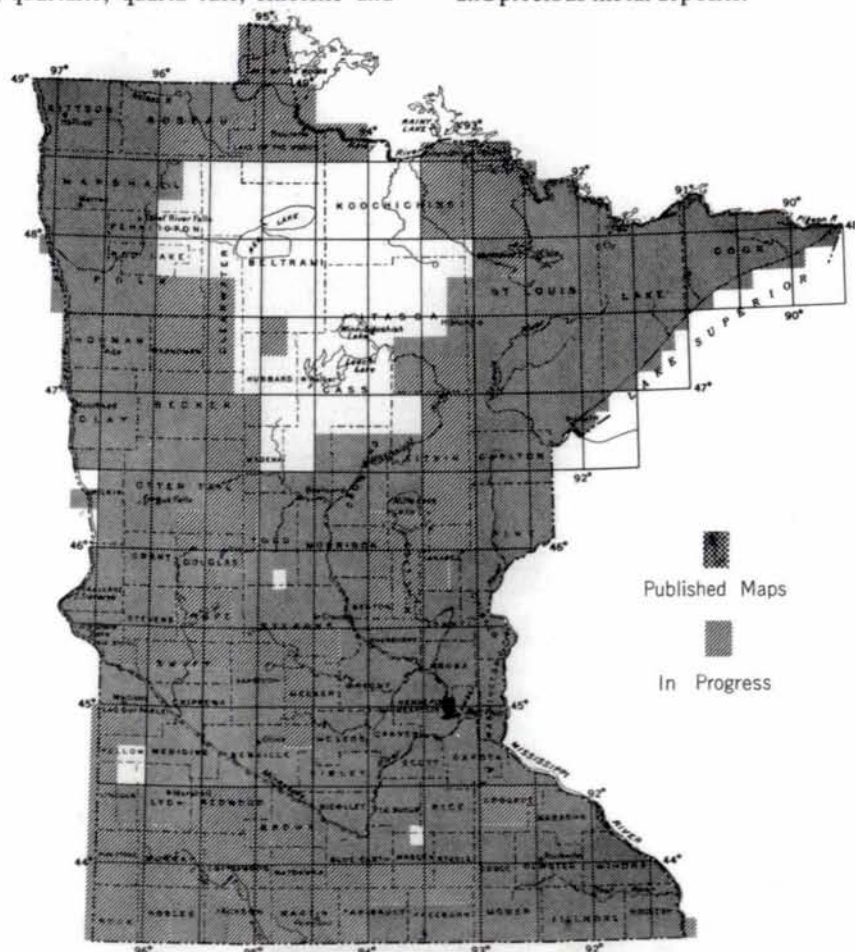
In the Tower-Ely area, the mafic volcanic rocks that constitute the Ely Greenstone of Clements (1903) consist dominantly of pillowed basalts, massive (?) basalts, diabase, and lesser mafic sediments. Iron-formations of Soudan-type occur as lenses at various stratigraphic positions in the volcanic pile. The largest and most continuous iron-formation, the Soudan, extends from Soudan hill to a point south of Ely.

In the vicinity of Soudan, a variety of rock types stratigraphically overlie the mafic volcanic rocks (Ely Greenstone). From south to north, the Soudan Iron-formation, which lies directly on the mafic volcanics, is overlain by a succession of mixed clastic and volcanic rocks — mainly conglomerate, quartzite, quartz tuff, chloritic and

biotitic graywacke, and, locally, iron-formation. This mixed unit, in turn, is overlain by (1) either another mixed unit — consisting of pillowed basalts, breccia, agglomerate, and sericite schist — or by (2) a unit that consists of interbedded pillowed basalts and chloritic graywacke. Unit 2 is well exposed on Pine Island. Westward, these rocks intertongue with biotitic graywacke. In the vicinity of Cook, to the west of Tower, two layers of pillowed basalt and associated mafic rocks are intercalated with biotitic graywacke. Similar intercalations of the pillowed basalts and graywacke occur at places on the north side of the outcrop belt of the Animikie Biwabik Iron-formation.

It is concluded from the mapping that pillowed basalts definitely are intercalated stratigraphically with both volcanoclastic and clastic sediments well above the main masses of pillow basalt and associated rocks. Accordingly, it is no longer permissible to designate just any pillow lava in the sequence as Ely Greenstone. This conclusion raises problems with respect to usage of the formal nomenclature of the region, and has implications regarding the Coutchiching problem.

Because of the similarity of the volcanic sequence in the Vermilion district to greenstone belts in Canada that contain valuable ore deposits, the Vermilion district warrants attention as a potential source of commercial massive sulfide and precious-metal deposits.



STATUS OF TOPOGRAPHIC MAPPING BY U. S. GEOLOGICAL SURVEY,
TOPOGRAPHIC DIVISION, JUNE 30, 1968, (SCALE 1:24,000).

TOPOGRAPHIC MAPPING PROGRAM

Minnesota's progressive topographic mapping program is nearly on schedule. The goal is to complete topographic mapping of the state by 1975. The 1967 State Legislature appropriated \$1 million for this biennium, which is matched by Federal (U.S.G.S.) funds. Credit for the current accelerated program is due the Minnesota Resources Commission (see MORRC Rept. No. 7) and the State Legislature, who recognized the value to the state of such a

program. It should be noted that the Iron Range Resources and Rehabilitation Commission supported topographic mapping in northern Minnesota during the preceding 15 years; as a result of this support, the mining and recreational areas of northeastern Minnesota are completely mapped topographically.

The current status of the topographic mapping program as of 1968 is shown on the map on the opposite page.

GEORGE MELVIN SCHWARTZ GEOLOGICAL SURVEY FUND

Several alumni and friends of Professor Emeritus George Schwartz contributed to the Geological Survey Fund during the year. It appears probable from the present trend that our goal of publishing the volume on "The Geology of Minnesota"

with these funds will be reached. You can help us reach our goal by contributing to the Fund.

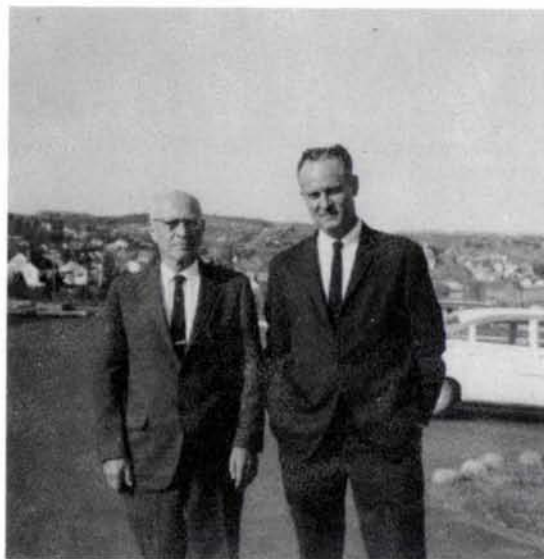
The following contributed during the year:

Aldrich, Henry R.
Applebaum, William
Bennett, T. W.
Callaway, Richard J.
Cram, Ira H.
Davies, F. A.
Doe, Bruce R.
Erdahl, W. M.
Ffolliott, John H.

Frellsen, Sidney A.
Fried, Marlin G.
Gibson, George R.
Goldich, S. S.
Grogan, Robert M.
Hadley, Richard F.
Hoeft, David R.
Hoppin, Richard A.
Kohls, Donald W.

Kraft, John C.
Maher, Louis J., Jr.
Mathisrud, Gordon C.
Neily, J. E.
Nelson, Clarence W.
Pickering, Warren Y.
Rapp, George R., Jr.
Riley, Charles M.
Stetson, Harland J.

Sumner, John S.
Sundeen, Stanley W.
Thiel, George A.
Thompson, Willis H., Jr.
Watkins, Vernon L.
Wheeler, James D.
Whelan, James A.
Wilcox, Stanley W.



Professor Emeritus George Schwartz and Paul Sims at the Superior, Wisconsin meeting of the Lake Superior Institute of Geology, May, 1968.

IN MEMORIUM, RAYMOND D. NOLAN

Raymond D. Nolan, former director of the State Conservation's Department of Lands and Minerals for 30 years, died on April 5, 1968. While director he was responsible for leasing and managing the iron mines on

state-owned lands. He was a key figure in the State's recent leasing of state tracts for copper-nickel exploration and mining.

OTHER GEOLOGIC ACTIVITIES IN THE STATE

Limnological Research Center, University of Minnesota

The Limnological Research Center continues projects related to Minnesota geology. Apart from fossil studies of lake sediments by H. E. Wright, Jr., E. J. Cushing, and associates to determine late-glacial and post-glacial environmental history, much effort has been placed on a survey of lake-water chemistry, which shows a tremendous range from the conifer forest region of the southeast to the prairie potholes of the southwest. Eville Gorham and R. C. Bright have completed separate studies

of these variations; the latter was concerned primarily with determining habitats for diatoms and mollusks, but in the process evaluated much of the published hydrologic and groundwater data to explain the regional water-chemistry. Also of implication to Minnesota geology and natural resources are the studies of R. O. Megard on the carbonate cycle and the formation of marl in lakes, and the studies on the ecology and history of the peatlands north of Red Lake and elsewhere in northern Minnesota.

U. S. Geological Survey

Water Resources Division

Water resources investigations in Minnesota were continued by the U. S. Geological Survey during 1968 fiscal year in cooperation with the following State agencies: Department of Conservation, Division of Waters, Soils and Minerals; Department of Highways; Department of Iron Range Resources and Rehabilitation; and Minnesota Geological Survey. Some of the State matching funds were contributed by municipalities, counties, and iron mining companies. Funds totaling \$252,035 from cooperating State agencies were matched equally by U. S. Geological Survey funds. An additional \$19,350 of State funds were unmatched. Other programs were financed entirely by the U. S. Geological Survey or by the St. Paul District Corps of Engineers, Federal Water Pollution Control Administration, Bureau of Sport Fisheries and Wildlife, and Department of State.

Water data collection programs included statewide networks of stations at which ground-water levels, stream flow, water quality, and sediment loads were measured. Water levels and artesian pressures were measured continuously at 44 observation wells and periodically at 50 wells during the year. In addition, water level data were collected from 20 wells in the several project areas. Well logs and lake inventories in the files of the Department of Conservation, Division of Waters, Soils and Minerals were prepared for automatic data processing.

Daily streamflow data were obtained at 121 stations and miscellaneous or periodic measurements of discharge were made at about 57 sites. Lake and reservoir stage records were collected at 41 sites. A network of 140 stations on small drainage basins throughout the State were maintained to determine the annual peak discharge of these streams. Samples were collected daily at 1 station and monthly or periodically at 59 stations for chemical analysis of the surface water. The sediment discharge of streams was measured daily at two stations and periodically at 17 stations. The records of

streamflow and water quality for the 1966 water year was published in the annual report series "Water Resources Data for Minnesota."

The appraisal of the water resources of the 39 major watersheds in Minnesota was continued. During 1968 fiscal year, Hydrologic Investigations Atlas HA-241 for the Roseau River and HA-269 for the Lac qui Parle River watersheds were published. Four were published previously. Atlases for the Mustinka-Bois de Sioux (HA-272), Mississippi Headwaters (HA-278), Chippewa (HA-286), Otter Tail (HA-296), Buffalo (HA-307), and Yellow Medicine (HA-320) watersheds were released to the open file and were in press at the end of the fiscal year. Field work and office compilation were in process for the Wild Rice, Red Lake, Crow Wing, Kettle, Snake, St. Croix, Cottonwood, Redwood, Rum, Mississippi-Sauk and Minnesota-Hawk Creek watersheds.

These atlases describe the general availability, variability, and water quality of the surface and ground waters in the watersheds. They include an analysis of the streamflow records for flood frequencies, flow duration, and low flow and storage requirements. The potential for ground-water supplies, the extent and thickness of the glacial drift, and the general configuration of the underlying bedrock are given. The water table and regional movement of ground water are shown.

As a part of the water resources appraisal of watersheds in the Minnesota River basin, a deep test hole was drilled near Tyler, Minnesota and cores of the Cretaceous materials were obtained to give a better definition of the water-bearing formations and geology of the area.

For the lake eutrophication studies of the FWPCA, the U. S. Geological Survey continued to measure the surface water inflow and outflow of Shagawa Lake at Ely which will be used to determine the water budget of the lake. A similar study on the St. Clair-Muskrat-Sallie chain of lakes near Detroit Lakes, Minnesota was begun. It will include the

measurement of the surface water inflow and outflow, and determination of the local ground-water flow patterns which are important in estimating ground-water contribution to the lake.

The Minnesota District participated in a pilot Federal project to determine the most practical methods for outlining, on topographic maps, those areas subject to occasional flooding. Twenty-two quadrangles were completed and released to the open file.

Intensive studies to determine the availability of ground water for irrigation in the vicinity of Wadena, Broton, and Perham are being made. The extent, thickness, and water-yielding characteristics of the water-table aquifers are defined by power augering, analog modeling, and test pumping. Reports on the Wadena and Broton areas are near completion and will be published in the Water-Supply Paper series. Augering and installation of observation wells are

continuing in the Perham area.

The flow characteristics, the water quality, and the geologic and hydrologic environment of selected streams in Minnesota are being evaluated in regard to the recreational aspects of the waters. Reports on the Big Fork, Little Fork, Kettle, and St. Louis Rivers are near completion and will be published as Hydrologic Atlases.

A regional study of the geology and water-bearing characteristics of glacial deposits in northeastern Minnesota was begun this year. A large volume of data on the geology, hydraulic properties and mineralogy of the glacial drift in the Mesabi Iron Range are available and are being prepared for computer analysis and correlation.

Extensive augering and installation of observation wells for use during a pumping test were completed near St. James, Minnesota to define the extent, thickness and water yield of a glacial outwash sand and gravel aquifer.

Department of Conservation, State of Minnesota Division of Waters, Soils and Minerals

Reorganization of the Department of Conservation according to Laws 1967, Chapter 905 became effective July 1, 1967. The former Division of Waters and the Minerals Section of the former Division of Lands and Minerals were consolidated into a new Division of Waters, Soils and Minerals. The administration of state lands, formerly a function of the Division of Lands and Minerals was transferred to the new Division of Lands and Forestry.

Collection of Basic Hydrologic Data:

The collection of basic data continues under a cooperative agreement between the division and the U.S. Geological Survey. The program includes 65 steam gaging stations, 38 lake stage stations and about 80 observation wells. Samples of surface water are taken periodically at 37 locations for analysis for chemical constituents, and suspended sediment measurements were made at 12 locations. A considerable number of water samples were taken for chemical analysis from both ground and surface water sources in connection with the preparation of water resources reports on various watershed units.

Data from several thousand well logs which are now filed in the office of the Division and in the district office of the U.S. Geological Survey are now being punched on cards and will soon be available for sorting, display and analysis by electronic data processing methods. All streamflow records have also been prepared for data processing, and flow duration data are available for all steam gaging stations in the state which have substantial periods of record.

Permits:

Applications for 1336 permits for appropriation of

water or for operations in the beds of public waters were received by the division during calendar year 1967. Most notable of these was an application of the Minneapolis Gas Company for a permit to displace underground waters by the storage of natural gas under the Waseca-Waterville area. Because of the many unknown factors involved in such operations and because of the possible hazards to the public, considerable investigative work was done on this proposal by the division staff and a consultant.

Watershed Districts:

Establishment of the Upper Minnesota Watershed District by the Water Resources Board brought to 18 the number of such districts now operating in Minnesota. Approval of a petition for establishment of the Buffalo Creek Watershed District was pending before the board at the end of the fiscal year.

Appropriations:

State funds available to the Waters Section of the Division of Waters, Soils and Minerals for the fiscal year ending June 30, 1968 were as follows:

From General Revenue Fund:

Salaries	\$242,061
Supplies and Expense	20,635
Hydrologic Studies	60,000
	<u>\$322,696</u>

From Natural Resources Fund:

Hydrologic Studies and Research	75,000
Red River Basin Studies	35,000
Aerial Photographs	25,000
	<u>\$135,000</u>



