

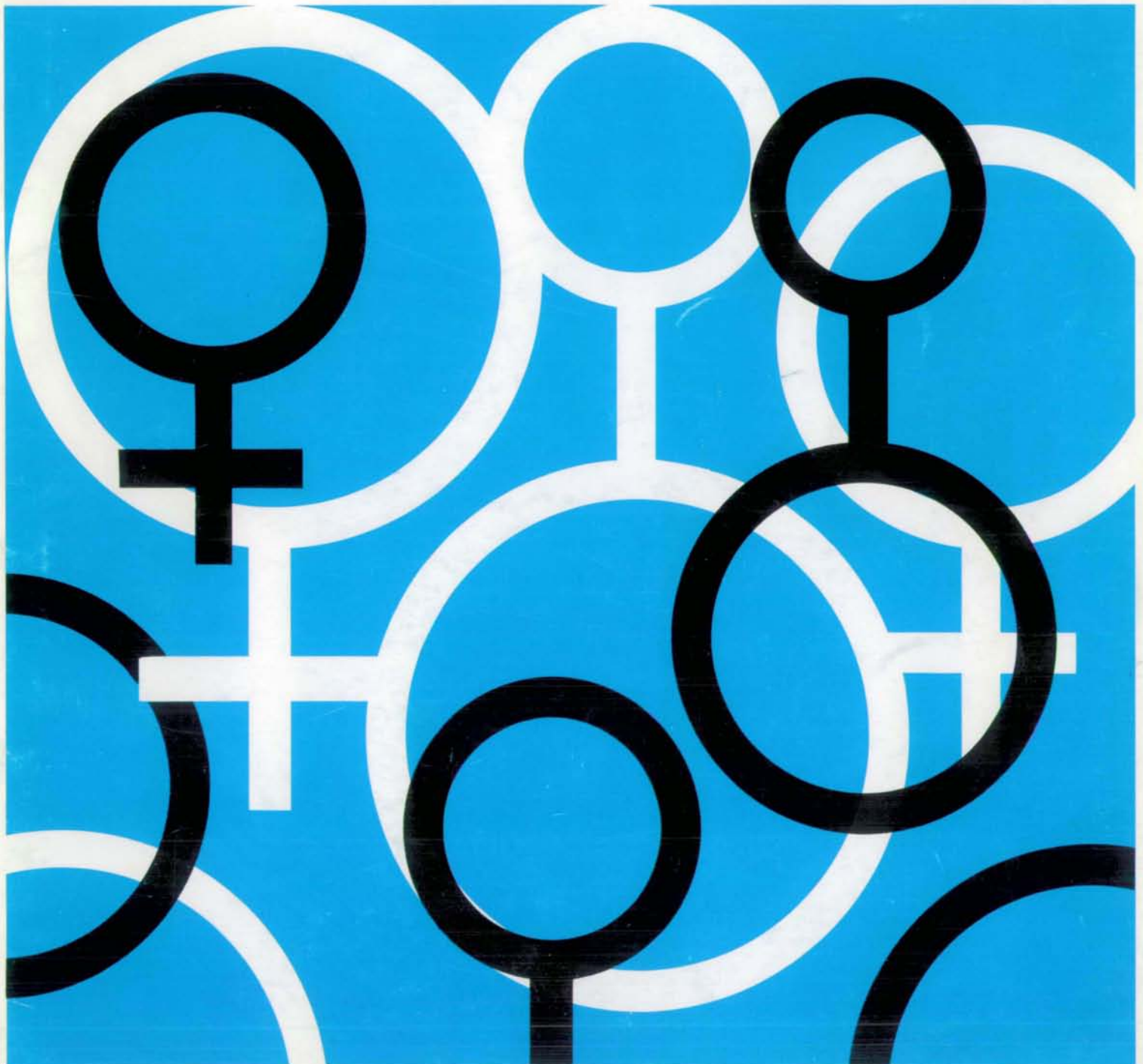
MINNESOTA GEOLOGICAL SURVEY

1966

Minnesota Geological Survey
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Newsletter

UNIVERSITY OF MINNESOTA



MINNESOTA GEOLOGICAL SURVEY

Paul K. Sims, Ph.D., *Director*
Rudolph K. Hogberg, M.S., *Assistant to the Director and Geologist*
Rodney J. Ikola, M.S., *Geophysicist*
Glenn B. Morey, Ph.D., *Geologist*
Walter E. Parham, Ph.D., *Geologist*
John E. Stone, Ph.D., *Geologist*
Sarah Tufford, A.B., *Geologist*

Robert C. Bright, Ph.D., *Paleontologist (part-time)*
James A. Grant, Ph.D., *Geologist (part-time)*
George Austin, M.S., *Geologist (part-time)*

Peter Stupnitsky, *Cartographer*
Judy Sorum, *Secretary*
Sandra Stephenson, *Account Clerk (part-time)*

Additional part-time staff consists of 3 faculty members and 5 students of the Department of Geology and Geophysics, Minneapolis, campus, and 3 faculty members of the Department of Geology, Duluth campus, who are employed during the summer.

Cover: The alchemical symbols for copper (♀) and nickel (♁) illustrate the theme of this year's newsletter—the renewal of base metal exploration in Minnesota in 1966.

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, miscellaneous reports, and reprints. Maps include a State geologic map atlas, geologic map series, and miscellaneous maps.

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 past year was a period of marked growth for the Survey. Through funds available from the Omnibus Natural Resources Act passed by the 1965 State Legislature, two new programs and a new publication series for educational and recreational purposes were initiated, to supplement the general program of research and public service.

The major new effort was the start of a systematic program of State-wide geologic mapping. The objective of this program is to complete in a 10-year period a geologic map atlas of the State at a scale of 1:250,000. A modern geologic map of the State is urgently needed to provide the basis for a comprehensive evaluation of our mineral resources and to aid in locating and evaluating our ground water supplies. The maps will assist in stimulating exploration by private mining companies and in appraising use of the land for industrial and recreational purposes. With completion of the aeromagnetic mapping in the State during the forthcoming biennium, it is anticipated that the funds formerly used for this purpose will be made available for geologic mapping.

The second new program funded by the Natural Resources Act is state-wide paleontologic studies. Emphasis in this research is given to vertebrate fossil remains, and particularly to preparation of exhibits for display in the Minnesota Museum of Natural History on the Minneapolis campus of the University.

The regular program of the Survey followed the pattern of the previous year, and again emphasized research and geologic mapping intended to aid in the development of new mineral resources. Research on the State's clay deposits and accumulation of data on our other industrial mineral resources were continued. Although interest in the kaolin clay deposits of the Minnesota River Valley remains high, no plant for commercial operation has as yet been built. Geologic mapping recently completed in the Gabbro Lake area, east of Ely along the St. Louis-Lake County border, has assisted in stimulating renewed explora-

tion for copper-nickel deposits along and near the base of the Duluth Gabbro Complex. To further aid in the search for commercial deposits of copper and nickel, a comprehensive study of the copper-nickel mineralization was begun during the year. This study will be accelerated as funds become available.

Public service activities again increased over the past year. In addition to oral and written requests from the public and from State and Federal agencies, the Survey aided several commercial firms in engineering and resource problems. It is noteworthy that there was a marked increase in requests for educational materials. The Survey participated with other University and State officials in the State's unsuccessful attempt to obtain a 200 Bev accelerator, to be built somewhere within the United States by the United States Atomic Energy Commission, at a site near Rosemount, Minnesota.

Eleven geologic reports and maps were published during the year, three were completed and will be published when funds become available, and several others were being prepared for publication. A few of the publications deserve special mention because of their economic importance. Two maps, the "Bedrock geologic map of Minneapolis, St. Paul and vicinity" (Map M-1) and the "Surficial geologic map of the New Brighton quadrangle" (Map GM-2), are being widely used by municipalities and by private companies and individuals to assist in solving engineering and resource problems. The former map provides much-needed basic data required for water problems. An outstanding addition to our publication series was the publication of three pamphlets in the Educational Series. These pamphlets are written in understandable language for the general reader, and will include geologic topics of general interest.

Funds available for the forthcoming year are approximately the same as for the current year. Accordingly, there will be no major shift or change in emphasis in the Survey program.

BUDGET

The general Survey program is supported by State Special and University Support funds. Special appropriations from the State's Natural Resources Account are earmarked specifically for two projects – (1) preparation of a State Geologic Map and (2) paleontologic studies.

The budget for the fiscal year 1966-1967 follows:

\$ 60,357	—Special item, University budget
34,731	—University Support funds
50,000	—Mapping program, 1956 Omnibus Natural Resources Act (Transferred to MGS from Department of Administration, State of Minnesota)
7,000	—Paleontology program, 1965 Omnibus Natural Resources Act
<hr/>	
\$152,088	—Total

STAFF NOTES

Dr. R. C. Bright was appointed as paleontologist (part-time) in the Minnesota Geological Survey and Curator of Paleontology, Minnesota Natural History Museum on October 1, 1965. He was awarded the Ph.D. degree in geology by the Department of Geology and Geophysics, University of Minnesota in June, 1963. During the year he curated available vertebrate and mollusk collections at the Museum. In April, he presented a paper "Fossil mollusks, a paleoecologic tool" at the Minnesota Academy of Science meetings at Macalester College.

In addition to his administrative duties, *R. K. Hogberg* continued studies and collection of data on the non-metallic mineral industry. He has begun a comprehensive investigation of the sand and gravel resources within the Minneapolis 15-minute quadrangle. During the spring quarter he again collaborated with *Dr. D. H. Yardley* in teaching a course on non-metallic minerals and rocks in the School of Mineral and Metallurgical Engineering. He attended the Midwest Forum on non-metallic minerals at the University of Indiana in April.

Rodney J. Ikola conducted gravity and magnetic investigations in the Hibbing 1:250,000-scale sheet, as part of the State geologic map project. In addition, he completed work on a manuscript concerning a detailed geophysical investigation of Carlton County.

During the past year *Dr. G. B. Morey* did reconnaissance mapping in the Hibbing 1:250,000-scale sheet and studied a deep core from the Red Clastics in east-central Minnesota. He presented a paper, "Stratigraphy and origin of the type Fond du Lac Formation (Late Keweenaw) Duluth, Minnesota" at the Minnesota Academy of Science Meetings at Macalester College, April 16, 1966.

Dr. W. E. Parham continued research on (1) kaolin clay resources of the Minnesota River valley, (2) clays of the Austin area, and (3) clay mineralogy of the Decorah and Glenwood Shales of Southeastern Minnesota. He submitted a paper, "Lateral variations of clay mineral assemblages in modern and ancient sediments" for publication in the Proceedings of the International Clay Conference, 1966, held in Jerusalem, Israel.

During the field season *Dr. P. K. Sims* supervised Survey field parties in northern Minnesota and continued geologic mapping in the Hibbing two-degree sheet. In March, he received a citation from the Minnesota Outdoor Recreation Resources Commission for his contributions to the program of the Commission. He and *R. K. Hogberg* attended the dedication of the new Geology and Geological Survey building at the University of North Dakota in October, 1965. He served as adviser to three Ph.D. candidates in the Department of Geology during the year. For the year 1966-67 he is Councilor and national program chairman of the Society of Economic Geologists.

Dr. J. E. Stone continued investigations of the geology of the Twin Cities area, with special emphasis on the application of geology to engineering, mineral and water resources, and planning problems. During the year, he prepared a report on the geology of the Rosemount area, which was incorporated in the State's site proposal for AEC's proposed 200 BeV accelerator. He again served as an advisor to the Metropolitan Planning Commission.

Sarah P. Tufford compiled data on the subsurface of the Twin Cities artesian basin and assisted with editing of technical reports. She is preparing an educational booklet on the geology of the Minneapolis-

COPPER-NICKEL EXPLORATION RESUMED IN MINNESOTA

The national need for copper and nickel has stimulated renewed interest in the mineral deposits in the Duluth Gabbro Complex in northeastern Minnesota. During the past year, at least three major mining companies and several individuals have indicated an active interest in the deposits. The major new development has been the leasing of 4,894 acres in the Superior National Forest by International Nickel Company, and the statement by the Chairman of the Board that INCO hopes to develop a copper-nickel mine within a few years.

In contrast to the State's iron deposits, the copper-nickel deposits have been known only a relatively short time. Following discovery in 1948 on the Kawishiwi River near State highway 1, the deposits were explored by private mining interests and by the U. S. Bureau of Mines. Only one company, International Nickel Company, was successful in blocking out a potential commercial ore body. Exploration in the area ceased in 1959-60.

The renewal of interest can be attributed to several factors. Improved technology as well as a favorable metal market undoubtedly are the major factors. Passage of the Taconite Amendment assisted, in that it indicated a more favorable tax climate in the State. Also, Rules and Regulations covering mining leases for copper, nickel, and associated minerals on State lands were drawn up by the Minnesota Department of Conservation and now are scheduled for a public hearing on July 15.

The Minnesota Geological Survey, as part of its responsibility to stimulate development of the State's mineral resources, has been carrying out studies of the copper-nickel deposits since their discovery. A report published in 1952 in Mining Engineering (Schwartz and Davidson) called attention to the nature of the deposits, and pointed out the environment most

favorable for the occurrence of commercial ore bodies. In 1955, a thesis prepared under Survey guidance discussed all available data on the relation of the copper-nickel sulfides to the Duluth Gabbro Complex. In 1961, detailed geologic mapping was started in the Gabbro Lake 15-minute quadrangle, which contains the principal known occurrences of the ore minerals. This map, prepared by W. C. Phinney, J. C. Green, and P. W. Weiblen, was placed in open-files in 1965, and perhaps more than any other study by non-company personnel stimulated interest in potential target areas for exploration. The map has been submitted to the printer, and will be available by September, 1966 (see list of publications). Geologic mapping and research by Bill Bonnicksen in the Dunka River area (Babbitt NE 7 1/2-minute quadrangle), which has been underway since 1965, will provide industry and governmental agencies with additional information on an area contiguous to the Gabbro Lake quadrangle. Research on beneficiation and recovery of metals from the ore are being carried out through the cooperation of the Mines Experiment Station of the University of Minnesota.

The ultimate potential of the Duluth Gabbro Complex as a source of copper and nickel is promising. If a mine is brought into production by INCO — as seems likely from statements by company officials — it can be expected that other exploration and development will be greatly accelerated. An area 75 miles in length, extending from the vicinity of Gabbro Lake to near Duluth, is favorable for exploration, but will require sophisticated techniques for geologic and geophysical study. To aid in the development of the total area and in full evaluation of its potential, the Minnesota Geological Survey will continue its studies of the region. Additional funds will be requested from the next Legislature to accelerate our geologic work.

TACONITE DRILLING PROGRAM

A drilling project intended to determine the feasibility of mining taconite from the Biwabik Iron-formation at depths of about 1000 feet will be started this year through a grant approved by the Minnesota Iron Range Resources and Rehabilitation Commission. The project will include geologic, mining, and milling research to be carried out respectively by the Minnesota Geological Survey, School of Mineral and Metal-

lurgical Engineering, and the Mines Experiment Station, all of the University of Minnesota. The principal investigator is Professor E. P. Pfeleider of the School of Mineral and Metallurgical Engineering. The Geological Survey has the responsibility of determining the geology and mineralogy of the iron-formation.

HIGHLIGHTS OF MINNESOTA MINERAL INDUSTRY - - 1965

(Furnished by Bureau of Mines, U. S. Department of The Interior)

Minnesota mineral production in 1965 was valued at \$507.8 million, a 2-percent increase over 1964. Iron ore shipments continued to furnish the bulk of the State total value, comprising 91 percent in 1965. Non-metallic mineral production represented 9 percent of the total value. Total values of non-metallic pro-

duction were increased for fire clay, grinding pebbles, lime, sand and gravel, and tube mill liners.

Shipments of taconite concentrates were 18.9 million tons, which comprised 37 percent of the total iron-ore shipments from the State.

TABLE 1. --Mineral production in Minnesota, 1965*

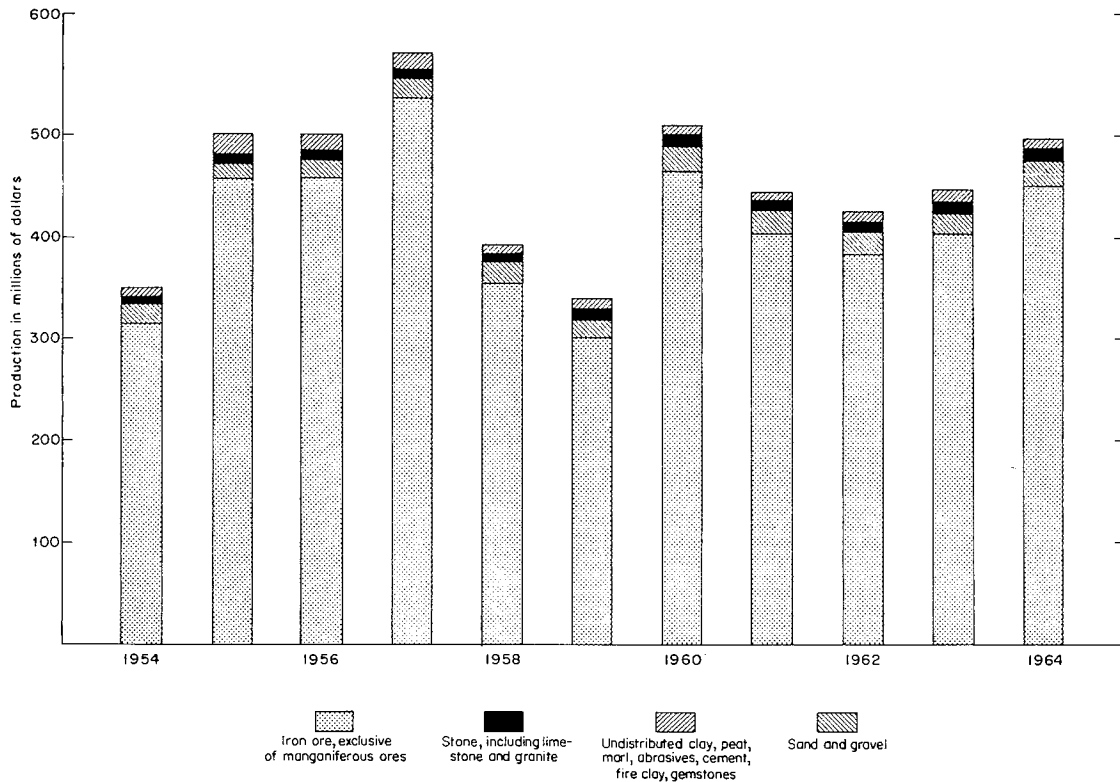
Mineral	1965 (estimated)	
	Quantity	Value (thousands)
Clays ^{1/} thousand short tons ..	207	311
Iron ore (usable) thousand long tons, gross weight..	50,873	459,290
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight..	280,706	W
Peat short tons..	7,346	123
Sand and gravel . . . thousand short tons ..	37,545	27,296
Stone do..	4,371	11,680
Value of items that cannot be disclosed: Abrasive stones, cement, fire clay, gem stones, lime, manganiferous ore, and values indicated by symbol W.....	XX	9,060
Total	XX	507,760

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.

During the year, Minnesota observed the tenth anniversary of the start of its commercial taconite industry. Existing plants at Silver Bay (Reserve Mining Co.) and Hoyt Lakes (Erie Mining Co.) were being expanded in 1965, and four new taconite plants were in construction or were completed during the year. When presently operating plants are expanded

and new ones are completed, Minnesota will have 33.5 tons of annual pellet capacity.

The Mines Experiment Station (University of Minnesota) and the Federal Bureau of Mines carried out research on the beneficiation of non-magnetic taconites and semi-taconites.



Value of mineral production, Minnesota, 1954-1964.

SPECIAL ACTIVITIES

Seminar on Geology and Urban Growth Planned

A seminar on geology and urban growth, sponsored jointly by the Minnesota Geological Survey and the Minnesota section of the American Institute of Professional Geologists, will be held in the Twin Cities on October 19, 1966. The purpose of the meeting is to outline the kinds of information that geologists

can provide to city administrators, planners, and engineers, and explore ways and means of obtaining the data and making it most useful to the users. Dr. John R. Borchert of the University of Minnesota will be the luncheon speaker.

Field Conference Held September 10 - 11, 1965

Twenty-five geologists from mining companies, state agencies, and the University of Minnesota attended a field conference conducted by the Survey at the conclusion of the 1965 field season. Two areas in northeastern Minnesota recently mapped by Survey personnel were visited. Especial interest was shown

in the Duluth Gabbro Complex, an area currently being investigated by several mining companies as a potential source of copper and nickel ores. Field conferences of this type provide the Survey with an opportunity to discuss new geologic data with interested geologists from private enterprise.



Geologists examining an outcrop of the Duluth Gabbro Complex during the field conference.

Publication of Educational Series Begun

To meet the needs for educational and recreational material on the geology and scenery of the State, a new publication series was initiated during the year. The series will consist of illustrated booklets on various geologic subjects. The series will supplement the book, "Minnesota's Rocks and Waters," published as Bulletin 37, which is now widely used both as a

school text and as a reference book for the general reader. The following have been published:

Guide to Fossil Collecting in Minnesota

Guide to Mineral Collecting in Minnesota

Geologic sketch of the Tower-Soudan State Park

The booklets can be ordered from the Minnesota Geological Survey. Postage is prepaid.

Geology Workshop Held

During the spring of 1966, Survey personnel conducted a geology workshop for junior high school teachers in St. Paul. Seven one and one-half hour classroom lectures were held at Como Park Junior

High School. R. K. Hogberg, Dr. W. E. Parham, Dr. J. E. Stone, and Sarah Tufford presented the lectures. In addition the group was guided on two local field trips.

PROJECTS

Current Projects

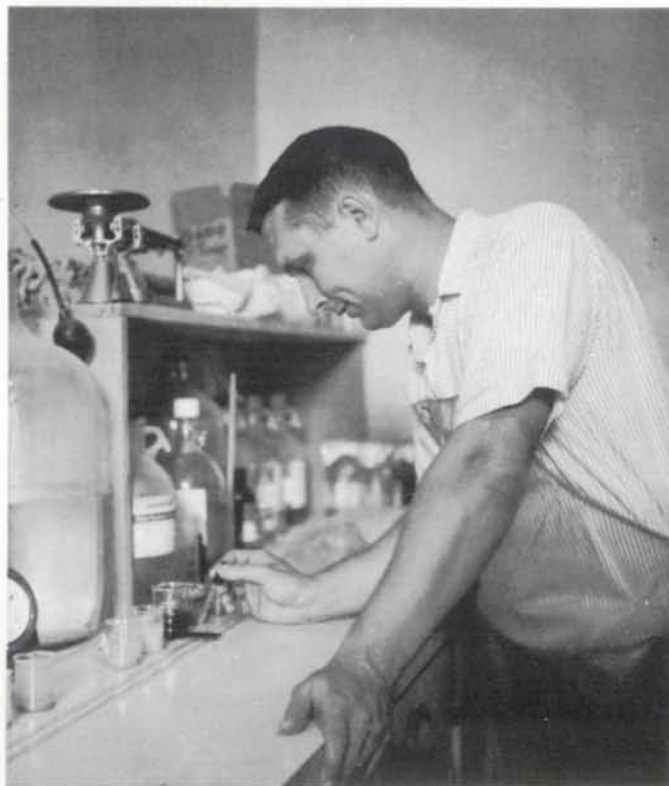
1. DULUTH GABBRO COMPLEX, Lake County Dr. W. C. Phinney
2. ENGINEERING AND GLACIAL GEOLOGY OF MINNEAPOLIS-ST. PAUL
METROPOLITAN AREA Dr. J. E. Stone
3. MINNESOTA'S CLAY MINERAL RESOURCES Dr. W. E. Parham
4. SAND AND GRAVEL RESOURCES, MINNEAPOLIS 15-MINUTE QUADRANGLE..... R. K. Hogberg
5. MINNESOTA'S INDUSTRIAL MINERAL RESOURCES..... R. K. Hogberg
6. PETROLOGY AND METAMORPHISM OF PRECAMBRIAN ROCKS, EMBARRASS-
BABBITT AREA, ST. LOUIS COUNTY W. L. Griffin
7. STUDY OF PLATTEVILLE FORMATION..... Ghassan Rassam
8. COPPER-NICKEL MINERALIZATION, Duluth Gabbro Complex Bill Bonnichsen
9. GEOLOGY AND GEOCHRONOLOGY OF PRECAMBRIAN ROCKS,
Minnesota River Valley Dr. J. A. Grant
10. SEDIMENTOLOGY OF PRECAMBRIAN KNIFE LAKE FORMATION Dr. R. W. Ojakangas
11. MINERALOGY OF THE BIWABIK IRON-FORMATION Dr. G. R. Rapp, Jr.
12. GEOLOGICAL AND GEOPHYSICAL INVESTIGATION OF MID-CONTINENT
GRAVITY HIGH Dr. J. C. Craddock
(Project now financed entirely by other funds. Includes seismic studies by Dr. H. M.
Mooney and students).
13. STUDIES OF PATTERNED WETLANDS NORTH OF THE RED LAKES Dr. H. E. Wright, Jr.
(Project now financed entirely by other funds).

New Projects

1. GEOLOGY OF PRECAMBRIAN "RED CLASTICS" SOUTHEASTERN MINNESOTA..... Dr. 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).
2. SURFICIAL GEOLOGY OF MONTEVIDEO SE QUADRANGLE C. L. Matsch
(Mapping and study of glacial deposits, as a first step toward a comprehensive geomorphic investi-
gation of the entire Minnesota River Valley).

Projects Completed

1. GRAVITY MAP OF MINNESOTA Dr. J. C. Craddock
(Map is being compiled for publication at a scale of 1:1,000,000)
2. RECONNAISSANCE GLACIAL GEOLOGY IN PARTS OF PINE AND KANABEC
COUNTIES Dr. E. J. Cushing
3. GROUNDWATER CONTRIBUTION TO STREAM FLOW AND ITS RELATION TO
BASIN CHARACTERISTICS IN MINNESOTA Earl A. Ackroyd



Dr. Walter E. Parham preparing a clay-mineral slide for X-Ray diffraction.

STATE GEOLOGIC MAP PROJECT

The St. Paul sheet, which consists of the St. Paul and parts of the Mason City, Eau Claire, and LaCrosse 1:250,000 maps, has been published. The map sheet is the first of the 11 sheets that will comprise the new bedrock geologic map of the State (see index map). It is available, folded in an envelope, at a price of \$2.00.

The status of other map sheets, now in preparation, follows:

Hibbing sheet:

Project personnel: P. K. Sims, G. B. Morey, R. W. Ojakangas, Rodney Ikola

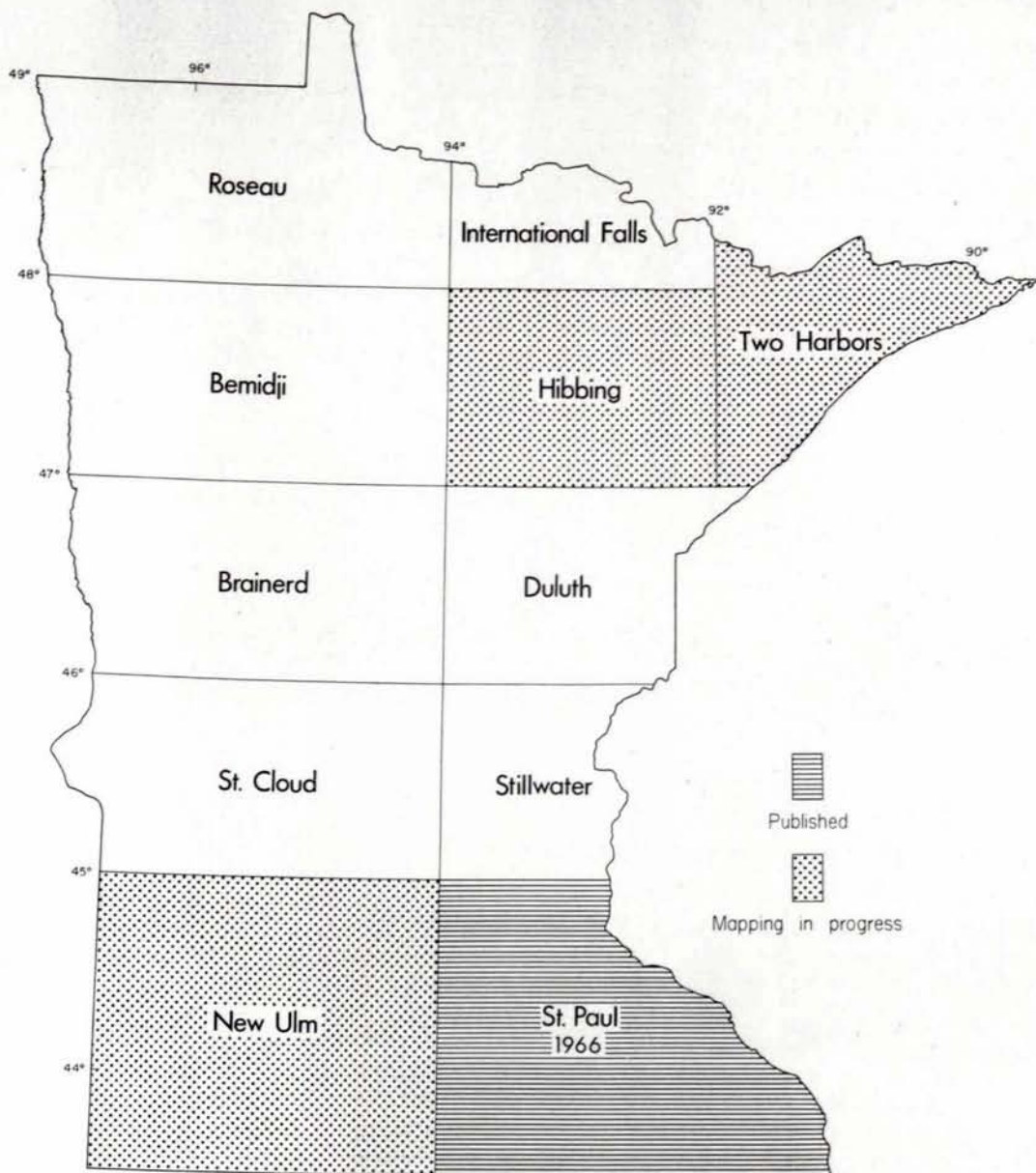
Progress: 50% completed.

New Ulm sheet:

Project personnel: G. S. Austin, J. A. Grant
Progress: Southern part (Fairmont sheet) completed. Reconnaissance of remainder begun this summer.

Two Harbors sheet:

Project personnel: J. C. Green, W. C. Phinney, Donald Davidson, Jr.
Progress: Compilation started; reconnaissance field work begun this summer.



Status of state geologic map atlas project.

PUBLICATIONS 1965 - 1966

Book Reports

Special Publication Series*

SP-3, 1965, Ostracoda of the Dubuque and Maquoketa Formations of Minnesota and northern Iowa, by J. H. Burr, Jr. and F. M. Swain (40 p., 6 pls.) \$1.50

(Twelve genera and seventeen species, four of which are new, are described and illustrated. The ostracode assemblages provide data on the stratigraphic correlation with other Middle and Upper Ordovician rocks in the Mississippi Valley).

SP-4, 1966, The Middle and Upper Ordovician conodont faunas of Minnesota, by G. F. Webers (123 p., 15 pls.) \$2.00

(Describes 33 form species or groups of form species and discusses nomenclatural problems. On the basis of conodonts, the Middle and Upper Ordovician strata of Minnesota can be subdivided into 10 biostratigraphic zones).

*Educational Series**

ES-1, 1965, Guide to fossil collecting in Minnesota, by Sarah Tufford and R. K. Hogberg (30 p.) \$0.25

(A well-illustrated booklet written for the general reader. Drawings of common fossils are an aid to identifying fossils and the strata that contain them).

ES-2, 1966, Guide to mineral collecting in Minnesota, by G. R. Rapp, Jr. and D. T. Wallace (42 p.) \$0.50

(This booklet is written for the general reader. It describes and illustrates the minerals that are found in Minnesota, and lists many collecting localities. Excellent drawings are given of many of the common minerals).

ES-3, 1966, Geologic sketch of the Tower-Soudan State Park, by P. K. Sims and G. B. Morey (29 p.) \$0.50

(An up-to-date description of the Soudan mine and the adjoining region, intended primarily to add to the enjoyment of visitors to the Tower-Soudan State Park. The booklet is well-illustrated, and includes a section on the geologic history of northeastern Minnesota).

*Information Circulars**

IC-2, 1965, Chemical analyses of igneous rocks in Minnesota, by A. P. Routsala and Sarah P. Tufford (87 p.) \$0.50

IC-4, 1966, Directory of Minnesota mineral producers, 1964 (49 p.) Gratis

(Lists, by counties, all producers of clays, industrial silica, iron ore, marl, peat, sand and gravel, and stone; locations of mines, pits, and quarries are given).

Maps

*State Geologic Map**

St. Paul sheet, bedrock geology, compiled by R. E. Sloan and G. S. Austin (1966) \$2.00

(This is the first map sheet to be completed. The colored map covers all of southeastern Minnesota east of Longitude 94 degrees 00' W. and south of Latitude 45 degrees 00' N. It includes most of the Paleozoic rocks of Minnesota.)

(The map shows the distribution of Paleozoic rock units in the metropolitan area, and covers the area from St. Louis Park and Golden Valley on the west to St. Paul on the east and from New Brighton on the north to Wold-Chamberlain International Airport on the south. The map can be of practical use to engineers, water well drillers, and planners).

Geologic Map Series#

GM-2, 1966, Surficial geology of the New Brighton quadrangle, Minnesota, by J. E. Stone (39 p., 3 pls.) \$1.75

(This report consists of a text and map in book form; it includes a colored surficial geologic map, geologic sections, and a map of the bedrock topography, all at a scale of 1:24,000. Several new formal stratigraphic names are proposed in the text. Data on the engineering properties of the surficial units are given to facilitate use of the map for engineering projects).

M-2, 1966, Geologic map of Gabbro Lake quadrangle, Minnesota, by J. C. Green, W. C. Phinney, and P. W. Weiblen \$2.00
(colored geologic map at scale of 1:31,680; in press)

(This map covers an area actively being explored for copper-nickel deposits. It includes part of the Precambrian Duluth Gabbro Complex and areas underlain by intrusive rocks of the Ely Greenstone and Knife Lake Group).

*Other Maps and Charts**

Map of Mineral resources of Minnesota, 1966
(Map is updated from the 1956 edition) Gratis

*Miscellaneous Map Series**

M-1, 1965, Bedrock geologic map of Minneapolis, St. Paul and vicinity, by C. M. Payne (colored geologic map at scale of 1:24,000) \$2.00

*Available from the Survey
#Available from the University Press

Manuscripts Completed, Ready for Publication

- Bull. 45, Progressive contact metamorphism of the Biwabik Iron-formation, Mesabi range, Minnesota, by Bevan M. French.
- SP-2, Geology and origin of the iron ore deposits of the Zenith mine, Vermilion district, Minn-

esota, by J. F. Machamer.

- (USGS) Geophysical Map, GP563, Aeromagnetic and inferred Precambrian paleogeologic map of east-central Minnesota (in press), by P. K. Sims and Isidore Zietz.

Publications by Staff in Scientific Journals

- Cushing, E. J., 1965, Problems in the Quaternary phytogeography of the Great Lakes region: in *The Quaternary of the United States*, eds. H. E. Wright, Jr. and D. G. Frey, Princeton University Press, p. 403-416.
- Hogberg, R. K., 1966, Development of Minnesota's mineral resources: *Minnesota Technologist*, v. 46, no. 5, p. 12-14.
- Parham, W. E., 1966, Lateral variations of clay mineral assemblages in modern and ancient sediments: in *Proceedings of the International Clay*

Conference, 1966, Jerusalem, Israel.

- Wright, H. E., Jr., 1965, Glaciations of Minnesota and Iowa: in *The Quaternary of the United States*, eds. H. E. Wright, Jr., and D. G. Frey, Princeton University Press, p. 29-42.

- Wright, H. E., Jr. Stone, J. E. Cushing, E. J., and Matsch, C. L., 1965, Guidebook for Field Conference C, Upper Mississippi Valley, VII Congress International Assoc. for Quaternary Research.

Publications Resulting From MGS Cooperative Program With U. S. Geological Survey (Administered by Minnesota Department of Administration)

- Bath and Schwartz, 1965, Aeromagnetic and geologic map of northeastern Minnesota: U. S. Geol. Survey Geophysical Invs., Map GP-472.
- _____, 1965, Aeromagnetic and geologic map of west-central Minnesota: U. S. Geol. Survey Geophysical Invs., Map GP-473.
- Jahren, C. E., 1965, Magnetization of Keweenaw rocks near Duluth, Minnesota: *Geophysics*, V.

30, no. 5, p. 858-874.

- Philbin, P. W. and Gilbert, F. P., 1966, Aeromagnetic map of southeastern Minnesota: U. S. Geol. Survey Geophysical Invs., Map GP-559.

- _____, 1966, Aeromagnetic map of southwestern Minnesota: U. S. Geol. Survey Geophysical Invs., Map GP-560.

Other Publications on Minnesota Geology

- Blake, R. L., 1965, Iron phyllosilicates of the Cuyuna district in Minnesota: *Am. Mineralogist*, v. 50, p. 148-169.
- Case, G. R., 1965, An occurrence of the sawfish, *Anchopristis dunkli*, in the Upper Cretaceous of Minnesota: *Jour. Minn. Acad. Science*, v. 32, no. 3, p. 183.

- Cloud, P. E., Jr., 1965, Significance of the Gunflint (Precambrian) microflora: *Science*, v. 148, no. 3666, p. 26-35.

- Cloud, P. E., Jr., Gruner, J. W., and Hagen Hannelore, 1965, Carbonaceous rocks of the Soudan Iron-formation (Early Precambrian): *Science*, v. 148, no. 3678, p. 1713-16.

Cotter, R. D., and others, 1965, Ground and surface water in the Mesabi and Vermilion iron range area, northeastern Minnesota: U. S. Geol. Survey Water Supply Paper 1759-A, 35 p.

_____, 1965, Water resources in the vicinity of municipalities on the Western Mesabi iron range, northeastern Minn: U. S. Geol. Survey Water-Supply Paper 1759-B, 24 p.

_____, 1965, Water resources in the vicinity of municipalities on the west-central Mesabi iron range, northeastern Minn: U. S. Geol. Survey Water-Supply Paper 1759-C, 21 p.

_____, 1965, Water resources in the vicinity of municipalities on the Central Mesabi iron range,

northeastern Minn: U. S. Geol. Survey Water-Supply Paper 1759-D, 20 p.

_____, 1965, Water resources in the vicinity of municipalities on the East-central Mesabi iron range, northeastern Minn: U. S. Geol. Survey Water-Supply Paper 1759-E, 23 p.

_____, 1965, Water resources in the vicinity of municipalities on the Eastern Mesabi iron range and the Vermilion iron range, northeastern Minn: U. S. Geol. Survey Water-Supply Paper 1759-F, 27 p.

Thompson, G. L., 1965, Hydrology of melt-water channels in southwestern Minnesota: U. S. Geol. Survey Water-Supply Paper 1809-K, 11 p.

THESES ON MINNESOTA GEOLOGY, 1961-1966 (Available in Winchell Library of Geology)

Anderson, Daniel H.

Uranium-thorium-lead ages of zircons and model lead ages of feldspars from the Saganaga, Snowbank and Giants Range granites of northeastern Minnesota, Ph.D., 1965.

Baker, Richard G.

Late-Wisconsin geology and vegetation history of the Alborn area, St. Louis County, Minnesota. M.S., 1964.

Bayer, Thomas N.

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Bleifuss, Rodney L.

The origin of the iron ores of southeastern Minnesota. Ph.D., 1966.

Cushing, Edward J.

Late-Wisconsin pollen stratigraphy in east-central Minnesota. Ph.D., 1963.

Hanson, Gilbert N.

The contact metamorphic effect of the Duluth Gabbro upon the Rb-Sr age of the biotites of the Snowbank stock. M.S., 1962.

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The effect of contact metamorphism on mineral ages in the Snowbank Lake area, Minnesota, and in the Beartooth Mountains, Wyoming. Ph.D., 1964.

Himmelberg, Glen R.

Precambrian geology of the Granite Falls-Monte-video area, Minnesota. Ph.D., 1964.

Ikola, Rodney J.

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Jones, Norris W.

The relationships between the Duluth Gabbro and the dikes and sills in the vicinity of Hovland, Minnesota. M.S., 1963.

Kirwin, Peter H.

Subsurface stratigraphy of the Upper Keweenaw red beds in southeastern Minnesota. M.S., 1963.

Matsch, Charles L.

Pleistocene geology of the St. Paul Park and Prescott quadrangles. M.S., 1962.

Morey, Glenn B.

The sedimentology of the Precambrian Rove Formation in northeastern Minnesota. Ph.D., 1965.

Paulsen, Gerald W.

Preservation and stratigraphical distribution of pigments in Minnesota lake sediments. M.S., 1962.

Rogers, Marion Alan

Carbohydrates in plants and sediments from two Minnesota lakes. M.S., 1962.

Sutton, Thomas C.

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Veith, Karl F.

A geophysical study of a portion of the Midcontinent Gravity High. M.S., 1966.

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A study of the Middle and Upper Ordovician con-

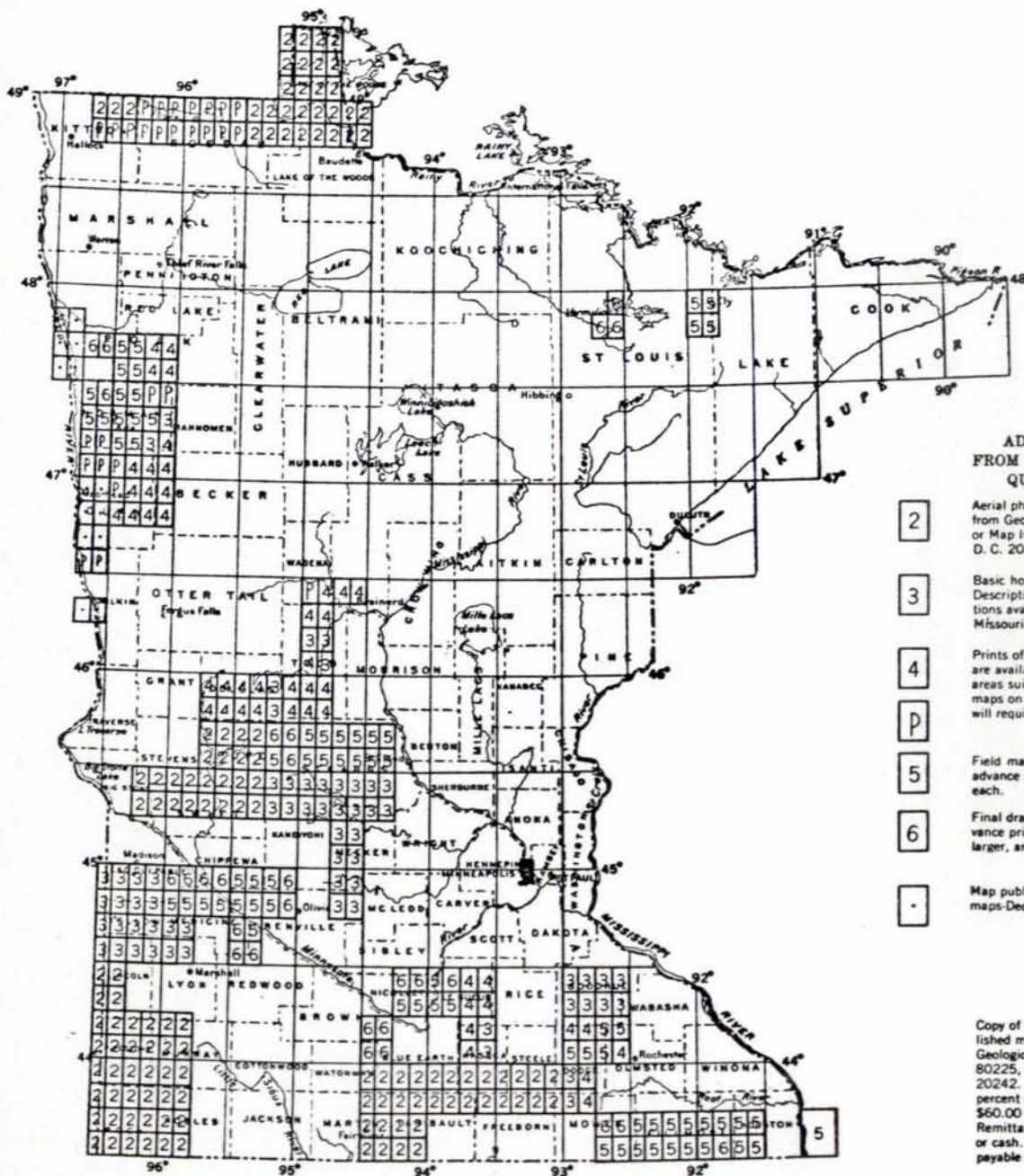
odont faunas of Minnesota. Ph.D., 1964.

Weiblen, Paul W.

A preliminary study of the metamorphism of the Thomson Formation. M.S., 1964.

Weiblen, Paul W.

A funnel-shaped, gabbro-troctolite intrusion in the Duluth Complex, Lake County, Minnesota. Ph.D., 1965.



ADVANCE MATERIAL AVAILABLE FROM CURRENT TOPOGRAPHIC MAPPING QUARTERLY EDITION JULY 1966

- 2 Aerial photography completed. Information available from Geological Survey, Box 133, Rolla, Missouri 65401, or Map Information Office, Geological Survey, Washington, D. C. 20242.
- 3 Basic horizontal and vertical control surveys completed. Descriptions and unadjusted coordinates and/or elevations available from Geological Survey, Box 133, Rolla, Missouri 65401.
- 4 Prints of manuscripts compiled from aerial photographs are available at 50 cents each. Contours are shown in areas suitable for stereoplotting. Letter "P" indicates maps on which contouring is not complete and which will require field work to complete the contouring.
- P Field mapping and checking completed. One-color advance prints (without names) available for 50 cents each.
- 5 Final drafting completed. Partially-edited one-color advance prints (with names) at publication scale, or slightly larger, are available for 50 cents each.
- 6 Map published since latest edition of index to published maps-Dec. 1965. See published map statement below.

PUBLISHED MAPS

Copy of State Index available free. Copies of published maps available at a price of 30 cents each from Geological Survey, Federal Center, Denver, Colorado 80225, or from Geological Survey, Washington, D. C. 20242. On orders amounting to \$10.00 or more a 20 percent discount is allowed; on orders amounting to \$50.00 or more a 40 percent discount is allowed. Remittance may be made by check, money order, or cash. Checks or money orders should be made payable to the Geological Survey

Status of advanced material from topographic mapping, July, 1966.

TOPOGRAPHIC MAPPING PROGRAM

The State topographic mapping program was greatly accelerated last year by appropriation from the 1965 Omnibus Natural Resources Bill of \$940,000, matched by Federal funds, for the biennium beginning July 1, 1965 and ending June 30, 1967. The cooperative mapping program is administered by the Minnesota Department of Administration.

The status of current topographic mapping in Minnesota as of June 30, 1966 is shown on the map on the opposite page. The summary data below, are for the period ending December 31, 1965.

Scale of published maps	<i>Land area</i>	
	Square miles	Percent coverage
1:24,000 (7 1/2-minute series)	17,072	21.3
1:62,500 (15-minute series) not covered by 7 1/2-minute series . .	<u>25,400</u>	<u>31.8</u>
Total	42,472	53.1

1:62,500 (15-minute series) also covered by 7 1/2-minute series . . 3,702 4.6

During the previous fiscal year, approximate expenditures for topographic surveys and mapping in Minnesota were:

State funds	\$187,900
Federal funds (direct appropriations to the U. S. Geological Survey) . .	<u>489,100</u>
Total	\$677,000

OTHER GEOLOGIC ACTIVITIES IN THE STATE

Department of Conservation, State of Minnesota Division of Waters

Preparation and publication of reports on the water resources and water needs of several of the 39 watershed units in the state are continuing as in previous years. The reports are prepared in part by the staff of the Division of Waters and in part by the staff of the district office of the U.S. Geological Survey, Water Resources Division, under a cooperative 50-50 matching agreement.

The division has published the following bulletins:

Bull. 23, Chemical quality of ground water in the Minneapolis-St. Paul area.

Bull. 24, The Lake Superior watershed unit.

An inventory of Minnesota lakes, which will be published as Bulletin 25, is in final editing. Field work has been started on a hydrologic report on the Cannon River watershed.

The division participated in the planning activities of the Red River Basin Planning Committee, composed of members from Minnesota and North Dakota, in studies of pollution of Rainy River and Red River conducted by advisory boards appointed by the Inter-

national Joint Commission, and in the work of the Upper Mississippi Comprehensive Basin Study.

Collection and compilation of data by the division on all water appropriations in the state, except that for domestic use serving less than 25 persons, is progressing as required by Chapter 797, Laws 1965.

Surveys and field investigations were made by the division throughout the year. These were concerned with the protection of lakes from encroachment or drainage, with inspection of operations under permit, and with proposals for lake and stream improvement.

Director's reports were made, as required by law, on plans for proposed public drainage projects. Reports were also made to the Water Resources Board on petitions for establishment of watershed districts under the Minnesota Watershed Act, M.S. Chapter 112, and on overall plans for development of water resources prepared by the Boards of Managers of watershed districts.

State appropriations available to the Division of Waters for the fiscal year were as follows:

From General Revenue Fund:	
Salaries	\$195,382
Supplies & Expense	17,880
Hydrologic Studies	50,795

Thief River snag removal	12,000
Minnesota River channel improvement	40,000
Water Control Study, Swan Lake, Nicollet County	2,500
Water Level Control, Emily Lake, Pope County	25,000
	<hr/>
	\$343,557
From Natural Resources Fund:	
Red River Basin Studies	\$ 35,000
Hydrologic Studies and Research	75,000
	<hr/>
	\$110,000

U.S. Geological Survey
Water Resources Division

Cooperative programs for water resources investigations were continued by the U. S. Geological Survey, Water Resources Division with the Minnesota Department of Conservation, Department of Highways, and Department of Iron Range Resources & Rehabilitation during the year ending June 30, 1966. Some of the State matching funds were contributed by municipalities and iron mining companies. Funds totaling \$211,691 from cooperating agencies were matched by Federal funds. The total funds expended in the State by the Division during 1966 total \$532,146.

Water data were collected at network stations throughout the State. Water levels and artesian pressures were measured continuously in 40 observation wells and were measured at monthly intervals in 51 additional wells. Observations of water levels were discontinued during the year in 24 observation wells, and 31 observation wells were added to the networks. Records of gage height and discharge were obtained from 53 full time gaging stations. Miscellaneous discharge measurements were made at 7 sites and stage records were collected at 37 lakes and 2 river sites. Stream discharge and stages of reservoirs and streams were collected at 61 additional sites in programs other than the cooperative program and were made available to the State. Peak discharge data from small drainage areas were computed at 141 crest stage sites maintained in the cooperative program of the Department of Highways. Baseflow measurements were made at about 75 partial records sites during the year. Samples of surface water were collected for chemical analyses at 31 stations. Samples of ground water were collected from wells at 43 sites as part of a network sampling program. An additional 200 samples were

collected and analyzed from ground and surface water sources as a part of the watershed study projects. A hydrologic bench mark station, which is designed to measure the hydrologic variability resulting from natural changes alone, was constructed in the Kawishiwi River basin. Assistance will be rendered by the U. S. Forest Service in collection of data in this basin.

The major part of the interpretive programs of the Survey was devoted to watershed studies. During fiscal year 1966, the Big Stone Lake unit of the Minnesota River basin was published as Hydrologic Atlas 213. The Pomme de Terre unit and the Lac qui Parle unit of the Minnesota River basin and the two Rivers unit and Roseau unit of the Red River basin were in press at the end of the fiscal year. Office compilation is underway on the Chippewa unit of the Minnesota basin, the Mustinka and Ottertail units of the Red River basin and the Mississippi Headwaters and Crow Wing units of the Mississippi River Basin. Field studies are currently underway in the Yellow Medicine unit of the Minnesota River basin, the Buffalo, Wild Rice, and Red Lake River units of the Red River basin, and the Kettle unit of the Mississippi River basin. The published watershed reports show availability of surface and ground water and the approximate total water yield of the basin. In addition, all current studies show the thickness of the glacial drift and the altitude in configuration of the underlying bedrock. Records of approximately 5,000 wells were collected during the fiscal year. In the Red River basin, approximately 9,500 feet of test holes were augered and an additional 2,500 feet of test holes were augered in the Minnesota River basin during the fiscal year. A detailed low flow investigation was completed in the Lac qui Parle watershed.

The Twin City metropolitan area study during the year emphasized the collection and analysis of data required to construct an analog model of a hydrologic system in the Twin Cities metropolitan area. Contour maps constructed on the water table as developed in the 1885 period prior to significant ground water pumpage and in 1949, 1959, and 1965 were constructed. Maps showing the residual drawdown during non-pumping periods were constructed from these basic maps. Information on pumpage was collected from numerous State, municipal, and industrial sources in order to obtain an estimate of the total quantity of water pumped during the period from 1885 to the present. A prototype analog model was completed in Phoenix and was tested during the fiscal year. Modifications made to this model will result in construction of a more complex and accurate, larger scale model which will then be probed for construction of

various maps based on schemes of development in the metropolitan area.

Studies made as part of the cooperative project with St. James, Minnesota and Hibbing, Minnesota resulted in completion of reports for those specific areas.

MINNESOTA GEOLOGICAL SURVEY

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