

**MINNESOTA
GEOLOGICAL
SURVEY**

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**1964
NEWSLETTER**



UNIVERSITY OF MINNESOTA

MINNESOTA GEOLOGICAL SURVEY

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Edward J. Cushing, Ph.D., *Geologist*

Walter E. Parham, Ph.D., *Geologist*

John E. Stone, Ph.D., *Geologist*

George Austin, M.S., *Geologist (temporary)*

C. Marshall Payne, B.S., *Geologist (temporary)*

Peter Stupnitsky, *Cartographer*

Judy Holmes, *Secretary*

Part-time staff consists of 4 faculty members and 10 students of the Department of Geology and Geophysics, employed during the summer.

Cover: Part of topographic map of the buried bedrock surface in the Minnesota-St. Paul metropolitan area. compiled by C. Marshall Payne.

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. The publications include a bulletin series, geologic map series, reports of investigations, special publication series, information circulars, summary reports, reprints, miscellaneous reports, and miscellaneous maps.

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

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The Survey offices are located in Pillsbury Hall, Minneapolis campus.
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ACTIVITIES

Continuing the trend begun in 1961, the scope and breadth of Survey activities again were increased during the year. A major highlight in our program of resource studies was the beginning of research on the State's non-metallic mineral deposits. Also, a significantly greater number of requests for geologic information were answered, several manuscripts were published or readied for publication, and progress was made in public-education service.

There is an urgent need in the State for an assessment of our non-metallic mineral resources. As our population increases and the trend toward urbanization continues, the raw material requirements for buildings, highways, and industries accelerate proportionally. If supplies of these raw materials can be found within the boundaries of the State, new jobs and income can be created. As a first step toward evaluating our industrial minerals and rocks, and locating potential new sources, intensive studies were begun during the year on our clay mineral resources. Clays have sustained a modest, stable mineral industry in the State during the past century. It is timely now to investigate all known deposits and determine insofar as possible potential new uses for our clays. Because of private commercial interest and the potential importance of the kaolin clays of the Minnesota River valley, these clays were selected first for study, and a preliminary report suggesting possible uses for them has been prepared. In addition to the clay research, special studies also have been started on the State's dimension stone and sand and gravel resources. These studies will be intensified this year.

Geologic mapping continued at about the same pace during the year. A new project was started at one locality—the Dunka River area in the eastern part of the Mesabi range—to determine the stratigraphy, mineralogy, and structure of the metamorphosed Biwabik Iron-formation. This study should

assist private enterprise in developing the new taconite mine now being opened at Dunka River.

The release to open-files during the year of geologic maps of a part of the Twin Cities metropolitan area stimulated an increase in requests for reliable information concerning the geology, engineering properties, and mineral and water resources of the rocks and surface materials of the area. Efforts will be made to accelerate the present rate of mapping and the engineering and resources studies to better meet these needs.

Four new publication series were established during the year: (1) Geologic Map Series, (2) Reports of Investigations, (3) Special Publications, and (4) Information Circulars. The Geologic Map series will be issued through the University of Minnesota Press, who publishes the Bulletin Series, whereas the other series will be issued by the Survey. The new series will provide means for publishing preliminary results of longer investigations, information on short-range studies, and data of immediate economic or scientific interest.

In response to the demand for geologic educational materials, work was begun on the first two pamphlets of an Educational Series. Drs. Tibor Zoltai and W. C. Phinney of the Department of Geology and Geophysics started the writing of a revised booklet on *Minerals and Rocks of Minnesota*. This is being written for general use as well as for possible use as a text or reference in the secondary schools of the State. The other pamphlet, *The Caves of Minnesota*, was begun by R. K. Hogberg in cooperation with members of a speleological group in the State.

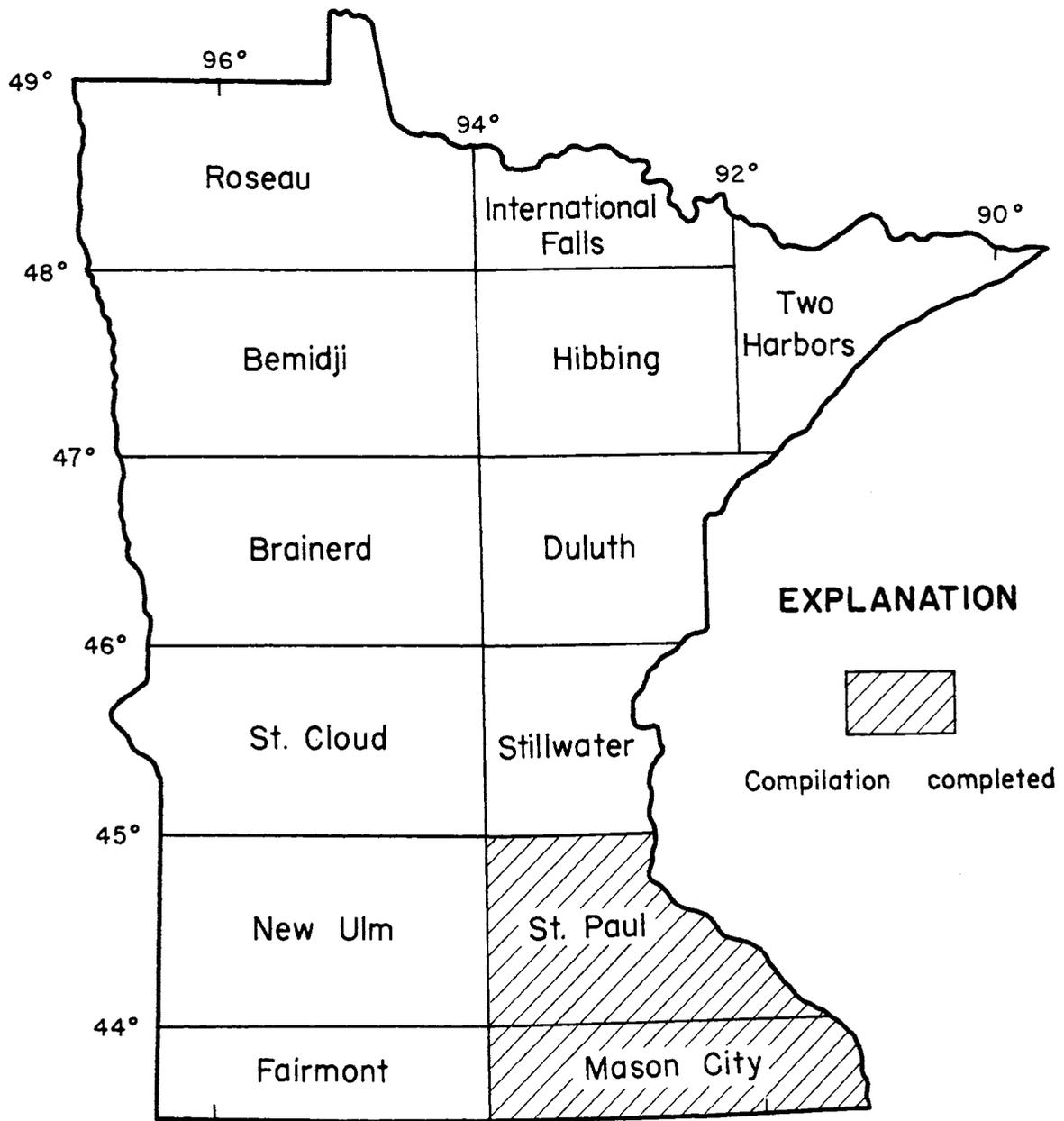
The 15th annual field conference of the Midwest Friends of the Pleistocene was sponsored by the Survey. It was held in east-central Minnesota on May 16-17. Leaders for the conference were Dr. H. E. Wright, Jr., Dr. E. J. Cushing, R. J. Baker, and Dr. J. E. Stone.

FISCAL STATEMENT

The Survey's activities are financed by money appropriated by the State Legislature to the University. During the fiscal year 1963-64, ending June 30, 1964, \$55,000 was appropriated directly to the Survey as a special item and \$27,752 was received from University support funds. In addition, special allotments totalling \$20,750 were made from Regent's Reserve funds for publication purposes.

The appropriation for fiscal year 1964-65 follows:

\$60,000—Special appropriation
29,348—University support funds
<hr/>
\$89,348—Total



Plan for proposed geologic mapping at a scale of 1:250,000

STAFF NOTES

Dr. Walter E. Parham was appointed to the regular Survey staff in September 1963, to begin a comprehensive study of the State's clay and shale resources. Parham was Assistant Geologist in the Clay Mineralogy Section of the Illinois State Geological Survey from 1958 to 1963.

Edward J. Cushing was awarded the Ph.D. degree in geology by the Department of Geology and Geophysics, University of Minnesota in December, 1963. He will leave the staff temporarily on September 15.

C. Marshall Payne has again joined the staff from June 1 to September 1. He is attending the University of Arizona as a graduate student in geology.

The following staff members of the Department of Geology and Geophysics have part-time appointments with the Survey during the summer: Dr. J. C. Craddock, Dr. W. C. Phinney, and Dr. R. E. Sloan. Also, Dr. J. C. Green of the Geology Department, University of Minnesota, Duluth, again has been appointed for work during the summer.

PROPOSAL FOR GEOLOGIC MAP ATLASES OF MINNESOTA

The Survey has proposed a state-wide geologic mapping program as part of a 10-year mapping plan submitted to the Minnesota Outdoor Recreation Resources Commission, a legislative body created by the Omnibus Natural Resources and Recreation Act of 1963. The proposed program consists of (1) regional geologic mapping of both the bedrock and surficial materials, (2) completion of aeromagnetic surveying of the State, and (3) detailed geologic mapping in cooperation with the U. S. Geological Survey. The total estimated cost to the State of the 10-year geologic program is less than 1.8 million dollars.

The proposed regional geologic mapping would be done at a scale of 1:250,000, using the Army Map Service topographic maps as bases. Atlases would be prepared for both the bedrock geology and the surficial geology; these would provide modern maps needed for regional planning, development, and evaluation of the State's natural resources. Compilation of two sheets (St. Paul and Mason City) has been com-

pleted, as shown by the accompanying index map on page 3. These sheets will be published when funds become available.

About 72,000 square miles, or 85 percent of the State, has been flown with the airborne magnetometer on page 5. The magnetometer surveys that have been completed in the State have disclosed concentrations of magnetic iron and have been an aid to the geologist in unravelling geologic problems. Completion of the magnetic surveying is needed to assist in the preparation of the regional bedrock geologic maps.

The proposed detailed geologic mapping, to be done in cooperation with the U. S. Geological Survey, would consist of quadrangle mapping in certain areas in the northeastern and southeastern parts of the State. Mapping would be done on standard topographic maps at scales of 1:62,500 and 1:24,000. Geologic maps at these scales are needed in critical areas to evaluate mineral and water resources.

PUBLICATIONS

Issued by the University Press

Bulletin Series

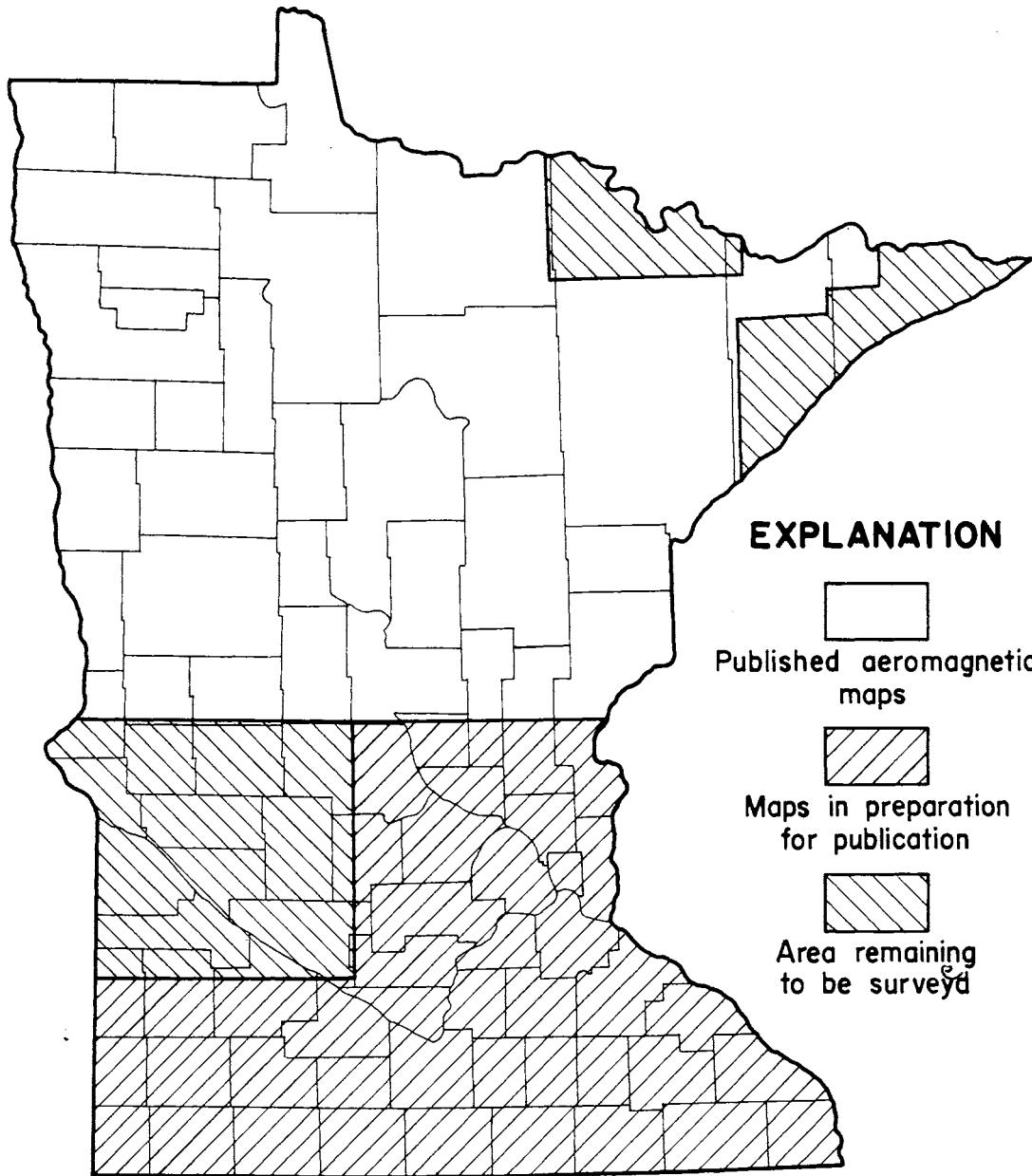
Bull. 37 (revised edition), **MINNESOTA'S ROCKS AND WATERS**, by G. M. Schwartz and G. A. Thiel, 1963 (366 p., 161 illus.)\$4.00

Written in popular style and well illustrated, this book tells the story behind the geological features to be found in Minnesota today. It consists of two parts: (1) the story of the rocks, and (2) geological excursions through Minnesota. The revision was in response to the needs of science students and teachers, rock-hounds, and general readers for an understandable geological description of the State.

Bull. 44, **GEOLOGY OF THE DULUTH GABBRO COMPLEX NEAR DULUTH, MINNESOTA**, by Richard B. Taylor, 1964 (63 p., 18 figs., colored geologic map)\$4.50

This report is a major contribution to our knowledge of the Duluth Gabbro Complex. It deals mainly with the petrology and structure of the complex and delineates multiple intrusions.

At Duluth, the oldest rock, a coarse-grained anorthositic gabbro that was intruded into the Keweenawan flows, makes up the upper part of the complex. It was intruded by basaltic magma of a second period of magmatic activity which formed rocks called the layered series. The layered series constitutes the lower two-thirds of the complex and is about 15,000 feet thick.



Status of aeromagnetic surveying

The Duluth Gabbro Complex is compared and contrasted with the Skaergaard Intrusion and the Stillwater Complex.

Geologic Map Series

GM-1, BEDROCK GEOLOGY OF DULUTH AND VICINITY, ST. LOUIS COUNTY, MINNE-

SOTA, by Richard B. Taylor, 1963 (12 p. text plus colored geologic map)\$1.75

This is the first of a new publication series that will be issued by the University Press. It describes the general geology of the Duluth area, which is dominated by the Duluth Gabbro Complex and associated mafic volcanic rocks, and lists the principal mineral products.

Issued by the Survey

Report of Investigations Series

RI-1, GEOLOGIC INTERPRETATION OF MAGNETIC MAP OF McLEOD COUNTY, MINNESOTA, by P. K. Sims and G. S. Austin, 1963 (7 p., 2 plates)\$0.25

Three structural blocks are delineated in the buried Precambrian basement rocks. A horseshoe-shaped magnetic anomaly in the northwestern part of the county may reflect an iron-formation of the Cuyuna-type. The report contains a magnetic map of the county (scale: approximately one inch represents one mile) and a more detailed magnetic map of the northwestern part.

RI-2, GEOLOGY OF CLAY DEPOSITS, RED WING AREA, GOODHUE AND WABASHA COUNTIES, MINNESOTA, by G. S. Austin, 1963 (23 p., black and white geologic map)\$0.50

This report describes the clay deposits in the Cretaceous Windrow Formation and in a Pleistocene lake bed that are used in local industry. Reserves of clay appear to be adequate for future local needs. The geologic map (scale: one inch equals approximately two miles) covers about 340 square miles and shows the distribution of Cretaceous and Paleozoic sedimentary rocks and localities containing clay deposits.

RI-3, KAOLIN CLAY RESOURCES OF THE MINNESOTA RIVER VALLEY IN BROWN, REDWOOD, AND RENVILLE COUNTIES, A PRELIMINARY REPORT, by W. E. Parham and R. K. Hogberg, 1964 (43 p., includes a map showing sample localities)\$0.50

Kaolinitic clay deposits of potential commercial interest as paper clays and as refractories occur in a thick regolith formed by weathering of Precambrian crystalline rocks and in overlying Cretaceous sedimentary rocks. Data are presented on the mineralogy and preliminary physical tests; tests for specific commercial uses are suggested.

Special Publication Series

SP-1, HISTORY OF THE MINNESOTA GEOLOGICAL SURVEY, by G. M. Schwartz, 1964 (39 p., includes a chapter on the present period by P. K. Sims)Free upon request

Information Circular Series

IC-1, DIRECTORY OF MINNESOTA MINERAL PRODUCERS, 1962, compiled by R. K. Hogberg, 1964Free upon request

Open-file Maps

Pending publication, the following two maps are available on open-file. They can be consulted in the Survey office or copies can be reproduced at cost.

1. "Geologic map of the New Brighton quadrangle, Minnesota—surficial geology," by J. E. Stone (scale=1:24,000).

Twelve lithologic units and artificial fill are delineated as map units. The materials are Wisconsin in age.

2. "Preliminary bedrock geologic map of Minneapolis, St. Paul and vicinity," by C. Marshall Payne (scale=1:24,000).

This map is a detailed revision of the bedrock map published in Bulletin 27, prepared by G. M. Schwartz in the mid-1930's. It shows the position and depth of the numerous buried valleys cut in the bedrock as well as the geology of the bedrock surface.

Manuscripts in Preparation for Publication

1. "The Cretaceous System of Minnesota (ca. 60 typed p., 13 illus.)," by R. E. Sloan.

2. "Ostracoda of the Dubuque and Maquoketa Formations of Minnesota and northern Iowa (ca. 50 typed p., 5 fossil plates)," by J. H. Burr and F. M. Swain.

3. "Geology and origin of the iron ore deposits of the Zenith mine, Ely, Minnesota (ca. 100 typed p., several figs.)," by Jerome F. Machamer.

Publications by Survey Personnel in Scientific Journals

Craddock, J. C., Thiel, Edward, and Gross, Barton, 1963, A gravity investigation of the Precambrian of southeastern Minnesota and western Wisconsin: Jour. Geophysical Res., v. 68, no. 21, p. 6015-6032.

Farnham, R. S., McAndrews, J. H., and Wright, H. E., 1964, A late-Wisconsin buried soil near Aitkin, Minnesota, and its paleobotanical setting: American Jour. Science, v. 262, p. 393-412.

Papers by Survey Personnel Presented at Scientific Meetings

1. "Correlation between field relations and microprobe analyses in the Duluth Gabbro Complex," by W. C. Phinney and P. W. Weiblen (given at annual meeting of the Geological Society of America, New York, November, 1963).

2. "Current investigations of the Precambrian Ely Greenstone in northern Minnesota," by J. C. Green (presented at the 10th Annual Institute on Lake Superior Geology, Ishpeming, Michigan, May, 1964).

3. "Clay-mineral facies of certain Pennsylvanian underclays," by Walter E. Parham (presented at an-

nual meeting of the Geological Society of America, New York, November, 1963).

4. "Drainage patterns controlled by systematic joints in glacial drift," by J. E. Stone (presented at annual meeting of the Geological Society of America, New York, November, 1963).

5. "Origin of pseudostratification and interlayering in glacial tills," by E. J. Cushing (presented at annual meeting of the Geological Society of America, New York, November, 1963).

Other Publications on Minnesota Geology

Foster, R. L., 1963, Mineralization in Cook County, Minnesota: Econ. Geology, v. 58, p. 796-803.

Frischknecht, F. C. and Ekren, E. B., 1963, Evaluation of magnetic anomalies by electromagnetic measurements: Art. 90 in U. S. Geol. Survey Prof. Paper 475-C, p. C117-C120.

Jones, J. R., Akin, P. D., and Schneider, Robert, 1963, Geology and ground-water conditions in the southern part of the Camp Ripley Military Reservation, Morrison County, Minnesota: U. S. Geol. Survey Water-Supply Paper 1669-A, p. A1-A32.

Norvitch, R. F., Schneider, Robert, and Godfrey, R. G., 1963, Geology and hydrology of the Elk River, Minnesota, nuclear-reactor site: U. S. Geol. Survey Bull. 1133-C, p. C1-C25.

Oakes, E. L., 1964, Bedrock topography of the eastern and central Mesabi range, northeastern Minnesota: U. S. Geol. Survey Misc. Geologic Inv., Map I-389 (4 map sheets).

Rodis, H. F., 1963, Geology and occurrence of ground-water in Lyon County, Minnesota: U. S. Geol. Survey Water-Supply paper 1619-N, 41 p.

Schiner, G. R., 1963, Ground-water exploration and test pumping in the Halma-Lake Bronson area, Kittson County, Minnesota: U. S. Geol. Survey Water-Supply Paper 1619-BB, 38 p.

Swain, F. M., Venteris, Gunta, and Ting, Francis, 1964, Relative abundance and order of stability of amino acids in some aquatic plants and associated fresh-water sediments: Jour. of Sed. Petrology, v. 34, p. 25-45.

Winter, T. C., 1962, Pollen sequence at Kirchner Marsh, Minnesota: Science, v. 138, no. 3539, p. 526-528.

Wright, H. E., Winter, T. C., and Patten, H. L., 1963, Two pollen diagrams from southeastern Minnesota: problems in the regional late-glacial and post-glacial vegetational history: Geol. Soc. America Bull., v. 74, p. 1371-1396.

Zietz, Isidore, 1964, A magnetic anomaly of possible economic significance in southeastern Minnesota: U. S. Geol. Survey Circular 489, 5 p.

CURRENT PROJECTS

1. DULUTH GABBRO COMPLEX, LAKE COUNTY

Project chief—Dr. W. C. Phinney, assisted by P. W. Weiblen

Geologic mapping of Duluth Gabbro Complex in the Gabbro Lake 15-minute quadrangle and adjacent quadrangles (to south and east), in the central part of the body; studies of the petrology, structure, titaniferous magnetite deposits, copper-nickel deposits, and origin. Mapping of the Gabbro Lake quadrangle will be completed this year. Silicate minerals are being studied by using microprobe analysis. Project is supported in part by National Science Foundation funds.

2. GRANITE FALLS-MONTEVIDEO AREA, MINNESOTA RIVER VALLEY, MEDICINE AND CHIPPEWA COUNTIES

Project chief—Glen R. Himmelberg; Supervisor—Dr. W. C. Phinney

Geologic mapping, petrology, and structure of Precambrian rocks in a part of the Minnesota River valley, with emphasis on phase equilibria studies. Mapping has been completed. Project is supported in part by National Science Foundation funds. Project will be completed this year.

3. BROWN IRON ORES, FILLMORE COUNTY

Project chief—R. L. Bleifuss; Supervisor—Dr. H. L. James

A study of the occurrence, distribution, and origin of the iron ores. Study has been completed and the final manuscript is nearing completion.

4. PRE-KEWEENAWAN ROCKS, GABBRO LAKE QUADRANGLE, LAKE COUNTY

Project chief—Dr. J. C. Green

Geologic mapping of the pre-Keweenawan metamorphic and igneous rocks that lie northwest of the Duluth Gabbro Complex in the quadrangle. First phase of an intensive study of the pre-Keweenawan rocks of northeastern Minnesota.

5. CONODANT ZONATION, UPPER ORDOVICIAN ROCKS, SOUTHEASTERN MINNESOTA

Project chief—G. F. Webers; Supervisor—Dr. R. E. Sloan

A paleontologic investigation to determine conodont zonation in Upper Ordovician rocks as an aid in subsurface correlation. Final manuscript is nearing completion.

6A. ENGINEERING AND GLACIAL GEOLOGY OF THE MINNEAPOLIS-ST. PAUL METROPOLITAN AREA

Project chief—Dr. J. E. Stone

A long-range comprehensive restudy of the surficial deposits. The study is intended to result in a new geologic map of the area and a comprehensive summation of the engineering properties of its

rocks and soils as related especially to urban development. A reconnaissance geomorphic map has been completed of fifteen 7½-minute quadrangles. A map of the New Brighton quadrangle was open-filed this year; it will be published as a colored geologic map, hopefully next winter. Maps of the Centerville, White Bear Lake West, and Hugo 7½-minute quadrangles will be completed during the year.

6B. SUBSURFACE GEOLOGY OF THE MINNEAPOLIS-ST. PAUL METROPOLITAN AREA

Project chief—C. Marshall Payne

A revision and up-dating of all available subsurface data in the metropolitan area. Well cuttings are being collected and studied and available well logs are being assembled. A map of the metropolitan area showing the topography and geology of the bedrock surface (scale—1:24,000) has been placed in open-files, and is available for examination; or reproduction at cost. Upon completion of work during the summer, the map will be submitted for publication as a colored geologic map. The project is supported in part by the Division of Waters, State Department of Conservation.

7. CLAY MINERAL RESOURCES OF THE MINNESOTA RIVER VALLEY

Project chief—Dr. Walter E. Parham; assisted by R. K. Hogberg

A detailed study of geologic occurrence, mineralogy, and physical properties of kaolinitic clays in Brown, Redwood, and Renville counties, in the Minnesota River valley. A preliminary report has been prepared for publication as Report of Investigations 3. This is the first phase of a long-range detailed investigation and evaluation of clay and shale resources in Minnesota. The studies are being done in cooperation with the Mines Experiment Station, University of Minnesota.

8. STRATIGRAPHY OF THE (ANIMIKIAN) ROVE FORMATION

Project chief—G. B. Morey; Supervisor—Dr. F. M. Swain

Regional study of outcrops between South Lake on the west and Pigeon Point on the east, in Cook County. The first phase of the study was geologic mapping of the formation in the South Lake 7½-minute quadrangle. Report is nearing completion.

9. INDUSTRIAL MINERAL RESOURCES

Project chief—R. K. Hogberg

A long-range investigation of the State's known and potential industrial minerals and rocks. This study, begun in 1963, is intended to result in an inventory of the non-metallic mineral deposits and a comprehensive summary of the controlling geologic factors of the deposits.

10. PALEONTOLOGY OF DECORAH SHALE, SOUTHEASTERN MINNESOTA

Project chief—Olgerts L. Karklins; Supervisor—Dr. F. M. Swain

A study of Ordovician cryptostome bifoliate Ectoprocta, as an aid in subsurface correlation. Field study has been completed and manuscript is nearing completion.

11. RECONNAISSANCE GLACIAL GEOLOGY IN PARTS OF PINE AND KANABEC COUNTIES

Project chief—Dr. E. J. Cushing

Geology and palynology of surficial deposits of Superior lobe and Grantsburg sublobe of late Wisconsin age. Part of current re-study of the glacial geology of the State, intended to provide a basis for reclassification of the Pleistocene materials and investigations of the resources and engineering properties of the surficial deposits. Area was site of the 15th annual field conference of the Midwest Friends of the Pleistocene on May 16-17, 1964.

12. PALEOZOIC ROCKS OF SOUTHEASTERN MINNESOTA

Project chief—Dr. R. E. Sloan; assisted by G. S. Austin

Compilation of bedrock geologic maps for the St. Paul, Mason City, La Crosse, and Eau Claire 1:250,000 AMS topographic sheets. Maps are completed and will be published as part of a geologic atlas for Minnesota, a revision of the state geologic map issued in 1932.

13. GEOLOGY AND GRAVITY INVESTIGATIONS OF MID-CONTINENT GRAVITY HIGH

Project chief—Dr. J. C. Craddock; assisted by Bruce Hemingway

An investigation of the positive gravity anomaly in eastern Minnesota. An interpretative paper on gravity investigation was published during the year; gravity and geologic studies will continue this year.

14. AEROMAGNETIC MAP OF EAST-CENTRAL MINNESOTA

(Cooperative project with U. S. Geological Survey—Isidore Zietz, U.S.G.S.; P. K. Sims, M.G.S.)

Geophysical and geologic interpretation of magnetic anomalies above the Keweenaw basin of eastern Minnesota and adjacent pre-Keweenaw rocks. Report will be published by U. S. Geological Survey in the Geophysical Map series.

15. GEOLOGY OF THE METAMORPHOSED BIWABIK IRON-FORMATION, DUNKA RIVER AREA, ST. LOUIS COUNTY

Project chief—Bill Bonnicksen; Supervisors—Dr. H. L. James and Dr. P. K. Sims

A detailed study of the mineralogy, petrology, and structure of the iron-formation; geologic mapping at a scale of 1:4,800. Area is being stripped by Erie Mining Company, preliminary to the opening of a new taconite pit to provide raw materials for the pelletizing plant at Hoyt Lakes, Minnesota. Iron-formation is adjacent to and intruded by the Duluth Gabbro Complex.

16. PETROLOGY, AGE, AND ORIGIN OF HIGH-GRADE METAMORPHIC ROCKS, EMBARRASS-BABBITT AREA, EASTERN ST. LOUIS COUNTY

Project chief—W. L. Griffin; Supervisors—Dr. P. K. Sims and Dr. W. C. Phinney

An investigation of the amphibolite facies gneisses that previously were mapped as a part of the Giants Range batholith. Knowledge of the age and origin of the gneisses is needed to determine the early geologic history of the area between the eastern end of the Mesabi range and the Vermilion range. Project is expected to have a duration of two years.

17. GEOCHEMICAL STUDY OF PEAT DEPOSITS IN NORTHERN MINNESOTA

Project chief—Dr. F. M. Swain

Two peat deposits will be sampled, the types of peat will be classified, and the organic geochemistry will be studied. Purpose is to determine relationships between type of peat and kind and amounts of humic acids, hydrocarbons, waxes, carbohydrates, amino compounds and other substances in the peat. Project is scheduled to be completed this year.

18. GEOCHEMICAL STUDY OF CARBONATE MINERALS, PLATTEVILLE AND GALENA FORMATIONS

Project chief—Ghassan Rassam; Supervisors—Dr. F. M. Swain and Dr. K. S. Deffeyes

Mineralogic and chemical study of carbonate rocks, to determine environment and origin of different facies. Will aid in economic evaluation of carbonate rocks of State. Project is expected to have a duration of two years.

NOTEWORTHY RESULTS OF CURRENT PROJECTS

Clay Resources

Preliminary studies of kaolin clays in the thick fossil regolith of the Minnesota River valley, in Brown, Redwood, and Renville counties, by W. E. Parham and R. K. Hogberg, indicate that they are promising as potential sources of filler and coating clays in the paper industry and as refractory clays. Ball clays, previously unknown in Minnesota, and a few thin bentonite beds occur in overlying rocks of late Cretaceous age. These bentonites are of the non-swelling variety of montmorillonite. Some specific re-

commendations for further testing are given in a preliminary report (Report of Investigations 3).

Dunka River Area, Mesabi Range

Detailed geologic mapping and study of the Biwabik Iron-formation in the Dunka River area at the east end of the Mesabi range, by Bill Bonnicksen, is defining the stratigraphy and structure of the taconite beds. The study will aid in the mining and concentration of the taconite now being developed in the area.

Ely Greenstone

Mapping and study of the pre-Keweenaw rocks in the 15-minute Gabbro Lake quadrangle just east of Ely by John C. Green has shown that the Ely Greenstone, the oldest formation in the area, consists dominantly of pillowed metabasalt, intruded by abundant diabasic sills. The formation is estimated to be 10,000 feet thick; the base is not exposed. Thin stringers of banded chert-hematite-magnetite iron-formation occur at several horizons. Conglomerates and some graywacke occur sporadically in the greenstone; those in the upper part of the formation contain pebbles of the Laurentian dacite porphyry that elsewhere in the area intrudes the formation. Mappable stratigraphic units are rare, but a dacite flow or tuff, stringers of iron-formation, and a spherulitic pillowed basalt can each be traced for a few miles. Deformation occurred mostly during the Algonian orogeny, and probably took place at shallow depths; the rocks have deformed mainly by local shearing and some brecciation, and the metamorphic grade is mostly low. The strata are nearly vertical throughout the area. Some major faulting followed intrusion of the Giants Range batholith. Between shear zones, minor structures are well preserved in much of the rock. The Ely Greenstone is overlain, perhaps entirely by fault contact, by the younger but pre-Algonian Knife Lake group.

Rove Formation

Geologic mapping of the Animikian Rove Formation in the South Lake 7½-minute quadrangle, Cook County and detailed reconnaissance eastward along the International Boundary to Pigeon Point by Glenn B. Morey indicates that the formation consists of two lithic units, a lower argillite member, approximately 400 feet thick, and an upper member about 1,400 feet thick of interbedded graywacke and argillite. The top of the formation is not exposed. Estimates of the thickness are approximate, for the Rove Formation contains many sills and dikes of Keweenaw mafic intrusive rocks and generally is poorly exposed. The Rove sediments contain quartz, sodic plagioclase (An_{5-35}), muscovite, chlorite, pyrite, pyrrhotite, carbonaceous matter, and rock fragments. Structures that are characteristic of turbidite deposits are common. These structures together with heavy mineral data are interpreted to indicate that the sediments were derived from the north.

Magnetic Surveys

Ground magnetometer surveys in south-central Minnesota have indicated a magnetic anomaly of possible economic significance. This anomaly, north of Hutchinson in McLeod County, was described in Report of Investigations 1.

MAGNETIC ANOMALY IN FILLMORE COUNTY DRILLED

The 4,000-gamma air magnetic anomaly near Lanesboro, Minnesota, in Fillmore County, reported in U. S. Geological Survey Circular 489 (see list of publications on Minnesota geology), was drilled by the New Jersey Zinc Company in 1962. The company reported at the annual meeting of the Institute

on Lake Superior Geology, held in Ishpeming, Michigan on May 6-7, that gabbro containing titaniferous magnetite was intersected in one drill hole at depths from 724 to 1124 feet. The magnetite in the core is not considered to be of commercial interest under present economic conditions.

MINNESOTA MINERAL INDUSTRY—1963

According to preliminary figures released by the United States Bureau of Mines, the value of Minnesota's mineral production in 1963 was \$451.5 million, a 5 percent increase over 1962. The principal reason for the gain was a 3 percent increase in iron ore shipments. Greater output of manganiferous ore also contributed to the rise. Other value gains were re-

corded for portland and masonry cements, lime, stone, and tube-mill liners. Value decreases were indicated for clays, grinding pebbles, peat, and sand and gravel. Iron-bearing ores (including manganiferous ores) continued to furnish the bulk of the State total value, comprising approximately 91 percent of the 1963 total.

SURVEY EXHIBITS

In the summer of 1963 the Survey presented a display on the *Rocks and Minerals of Minnesota* in the State Exhibits Building at the Minnesota State Fair. The Fair, the largest of its kind in the United States, gives the Survey an opportunity to inform a State-wide audience of its services. Also in September, 1963, photographs, maps, and rocks that il-

lustrated the current projects of the Survey were exhibited at the University's Annual Legislators', Editors', and Broadcasters' day.

Clay and shale resources and industries of Minnesota will be the theme of the Survey display at the 1964 Minnesota State Fair.

GEOLOGIC STUDIES OF THE MESABI RANGE BY THE MINNESOTA GEOLOGICAL SURVEY

Geologic studies on the Mesabi Range by the Minnesota Geological Survey have contributed substantially to the development and utilization of these iron ores, which have been so important to Minnesota's economy. The early work in the late 1900's by Survey geologists N. H. Winchell, H. V. Winchell, and J. E. Spurr, provided the first descriptions of the geology and iron ore deposits of the district. These studies together with those by C. K. Leith and C. R. Van Hise of the U. S. Geological Survey called attention to the very great economic significance of the range and furnished industry with data essential to exploration and development.

About the time of World War I Frank F. Grout and T. M. Broderick mapped the eastern end of the Mesabi range, using the stratigraphic nomenclature of Fred Wolff, published in the AIME Transactions for 1917. This work became the foundation for subsequent research and exploration that led to the discovery of large tonnages of concentratable taconite. It also indicated the extent and nature of the taconite in the eastern part of the range, and its potential as a future source of iron ore.

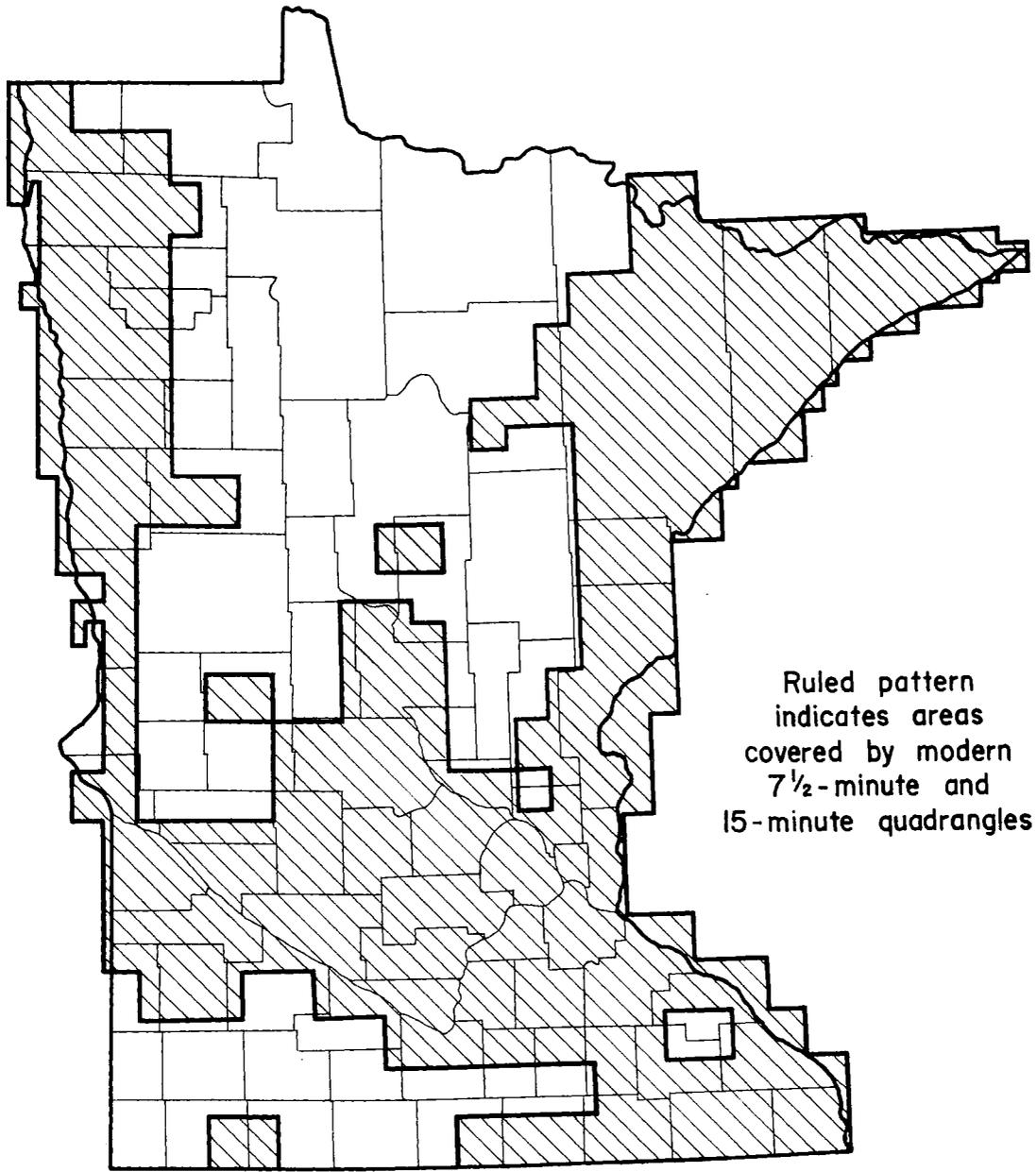
Beginning in the early 1920's, John W. Gruner mapped the taconite from Allan Junction westward to the vicinity of Grand Rapids, in the central and western parts of the range. He distinguished the magnetic taconites from the worthless gangue, and showed that about one-fourth or one-third of the Biwabik Iron-formation could be classed as probable or possible ore which could be concentrated by some magnetic process. His recognition of abundant iron-silicate minerals in the taconite clarified discrepancies be-

tween the total recoverable iron and the total soluble iron determined by analysis.

Two more recent studies supplemented the earlier work of Gruner. A study by David A. White in the early 1950's contributed to a better understanding of the stratigraphy and structure of the iron-formation throughout the entire length of the range, which proved helpful in later development of the iron ores. Research by James Novotny Gundersen and George Schwartz in the late 1950's provided a basis for detailed recognition of the layering in the metamorphosed iron-formation of the Eastern Mesabi District. This work has aided the operating companies on the Eastern Mesabi in planning mining operations and in maintaining a uniform feed for their taconite processing plants.

Currently, research is continuing in the Eastern Mesabi District. A project in the Dunka River area, being carried out by Bill Bonnicksen, is intended to provide detailed knowledge of the stratigraphy, mineralogy, and structure in an area where the iron-formation is intruded and intensely metamorphosed by the Duluth Gabbro.

As utilization of the taconite resources of the range increases, the need for geologic data increases. On the one hand, precise knowledge of the vertical and lateral variations in mineralogy is needed for an understanding of the beneficiation characteristics of the magnetic taconites, and, on the other hand, knowledge of the stratigraphy and structure of the taconite beds is needed for planning and development of mine workings. The latter will be particularly important if underground mining of taconite is some day to become a reality.



Ruled pattern
indicates areas
covered by modern
7½-minute and
15-minute quadrangles

Status of topographic mapping

OTHER GEOLOGIC ACTIVITIES IN THE STATE

Division of Waters State Department of Conservation

The Division of Waters, Department of Conservation, issued a report entitled, "Quality of waters, Minnesota, a compilation, 1955-62 (Bull. 21)" during the past fiscal year. The report has 104 pages of chemical analyses of both surface and ground water. Five reports are in the process of completion: (1) Basic geologic and ground water data for Kittson and parts of Marshall and Roseau Counties, Minnesota, 102 pages (Bull. 19) copy ready for photo offset; (2) Water resources of the St. Louis River watershed unit; (3) Water resources of the Lake Superior watershed unit; (4) Availability and appraisal of water resources in the Middle River watershed unit; and (5) Report on Big Stone Lake watershed unit.

A project involving the inventorying of Minnesota lakes, size 10 acres or larger, has been in progress in the Division for several years. This project is scheduled to be completed during fiscal year 1964.

During the past fiscal year 49 topographic quadrangle maps in Minnesota were published by the U. S. Geological Survey. To date about one-half of the State is covered by modern, published topographic maps as shown on the index map on page 12. Appropriations of \$25,000 from the General Revenue Fund and of \$163,000 from the Natural Resources Fund were made available by the State for topographic mapping; these funds were matched by an equal amount of Federal funds. Additional topographic mapping in the State was supported entirely by Federal funds.

A part of the funds available under the Omnibus Natural Resources and Recreation Act of 1963 has been allocated for research to determine the feasibility of augmenting the ground water in the Twin City area by artificial recharge of the underlying aquifers. Initial plans were discussed at a meeting in March 1964 attended by representatives of the City of Minneapolis, Minneapolis Park Board, Hennepin County Highway Department, State Health Department, State Highway Department, State Conservation Department (Division of Waters), and U. S. Geological Survey (Ground Water Branch).

Additional funds were appropriated under this act for a hydrologic study of the Red River basin, for

hydrologic studies in other parts of the State, and for the collection of basic data (surface water, ground water, quality of water) over the entire State. These funds, together with moneys from other sources, were assigned to the cooperative agreement with the Water Resources Division of the U. S. Geological Survey.

The Division of Waters continued work by its regular staff on the preparation of reports on watershed units, and assigned part of this work to the U. S. Geological Survey under the cooperative agreement.

For fiscal year 1964, a total of \$199,993 was appropriated to the Division of Waters for its regular activities. Additional funds appropriated to the Division from the Natural Resources fund were \$75,000 for hydrologic studies and research, and \$35,000 for the Red River basin study. An additional \$70,000 was appropriated to the Division for special projects such as reconstruction of lake dams and channel improvements on the Minnesota River and the Thief River.

Ground Water Branch U. S. Geological Survey

Cooperative programs for water resources investigations in the State by the U. S. Geological Survey were continued by the Department of Conservation, the Department of Iron Range Resources and Rehabilitation, the Department of Highways, and Hennepin County during the year ending June 30, 1964. Funds totaling \$146,190 from cooperating agencies were matched by Federal funds.

Current cooperative projects include watershed studies on the first four watersheds to be undertaken by the Geological Survey in cooperation with the Division of Waters. These watershed studies include the Middle River unit and the Two Rivers unit in the Red River basin, and the Big Stone unit and the Pomme de Terre unit in the Minnesota basin. Other data collected pertains to water levels and artesian pressures in 69 observation wells, records of streamflow at 105 sites and chemical quality of water in streams at 16 sites; peak discharges on small drainage areas were collected at 137 sites and chemical quality analyses were made of water from the principal aquifers.

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Return Requested