

# Minnesota Geological Survey NEWSLETTER



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MINNESOTA GEOLOGICAL SURVEY, UNIVERSITY OF MINNESOTA  
2642 UNIVERSITY AVENUE, SAINT PAUL, MINNESOTA 55114-1057, (612) 627-4780

## PRISCILLA C. GREW, NEW DIRECTOR

On November 1, 1986, Priscilla C. Grew became the new Director of the Minnesota Geological Survey and Professor in the Department of Geology and Geophysics, University of Minnesota, Twin Cities.

From 1981 to 1986, Dr. Grew was a Commissioner of the California Public Utilities Commission. She served as Director of the Department of Conservation in California from 1977 to 1981. The Department includes both the state geological survey, called the Division of Mines and Geology, and the regulatory Division of Oil and Gas. Dr. Grew also chaired the California State Mining and Geology Board, which is responsible for mined land reclamation policy.

Dr. Grew received her B.A. in Geology from Bryn Mawr College and her Ph.D. in

Geology from the University of California at Berkeley. She has taught geology and environmental studies at Boston College, the University of California at Davis, and U.C.L.A. She serves on the U.S. National Committee on Geology and the National Research Council Board on Mineral and Energy Resources. She is a Fellow of the Geological Society of America and the American Association for the Advancement of Science, and chairs the Committee on Public Affairs of the American Geophysical Union.

She is married to Edward S. Grew, who is Associate Research Professor of Geology at the University of Maine at Orono. His research concerns Precambrian studies in East Antarctica and petrology of granulite facies metamorphic rocks.



## DIRECTOR'S COLUMN

"I understand Minneapolis offers a broad cultural world, and of course the wilderness is not far away." That is how a friend in Irvine, California, reacted to the news of my move to the Twin Cities. From San Antonio, Texas, came the question, "What are you going to dig up in Minnesota? Recalling my sophomore year in geography class, I believe that area is one big glacial moraine." From Vienna, Virginia: "I have wondered from time to time where you would land." A letter from Moscow, USSR, read: "Your new position is related with studies of the Precambrian and in particular such ancient sequences as the Morton Gneiss."

Matt Walton, his predecessor Paul Sims, and the MGS staff have all helped to ease my abrupt transition from California regulation to Minnesota geology. It is indeed an honor to join MGS, for Matt's legacy is the scientific renaissance he has inspired in MGS studies of the geologic framework of Minnesota. With the far-sighted funding by the Legisla-

tive Commission on Minnesota Resources (LCMR), MGS embarked on its nationally acclaimed aeromagnetic survey of the state, and began a drilling program to provide bedrock ground truth.

My first week on the job fortuitously coincided with the inception of the University of Minnesota's comprehensive new planning process, which President Kenneth H. Keller calls "A Strategy for Focus." As MGS looks to the future in the Focus plan, a fundamental premise is our relocation to a new building, which will once again house us with the Department of Geology and Geophysics.

Emerging state and local needs for geological information relevant to the maintenance of ground-water quality clearly indicate that hydrogeology must be a priority activity for MGS in coming years. The recently endowed Gibson Chair in Hydrogeology will enrich the Department in this discipline that is critical to the mission of MGS. The complexity of Minnesota's glacial stratigraphy revealed by MGS drilling will require us to focus on Quaternary stratigraphy and sedimentology as they relate to hydrogeologic problems.

Rigorous characterization of Minnesota's bedrock geology, regolith, and glacial

stratigraphy is critical to the future diversification of the state's mineral economy. Our corresponding focus will be the development of a cross-disciplinary program incorporating reflection and refraction profiling of Quaternary, Paleozoic, and Precambrian structures; drilling and core characterization, including geochronology; and data interpretation using advanced computer techniques.

MGS staff are actively participating in the geological interpretation of deep seismic reflection profiling across the Keweenaw Rift, which was recently conducted by the U.S. Geological Survey and the Geological Survey of Canada. We are seeking to attract the national consortia of COCORP and DOSECC to conduct crustal profiling and drilling projects in Minnesota. These activities continue the MGS tradition of coupling basic research at the scientific frontier with translation of the information for societal use at the state and local level.

Yes, MGS is in the metropolis not far from the wilderness beneath our feet. Our mission is indeed related to studies of the Precambrian. We have more than one big glacial moraine up here. There are some things I can dig up, now that I have finally landed in Minnesota.

*Priscilla Grew*

# COMPUTERIZED GEOLOGIC DATA BASE

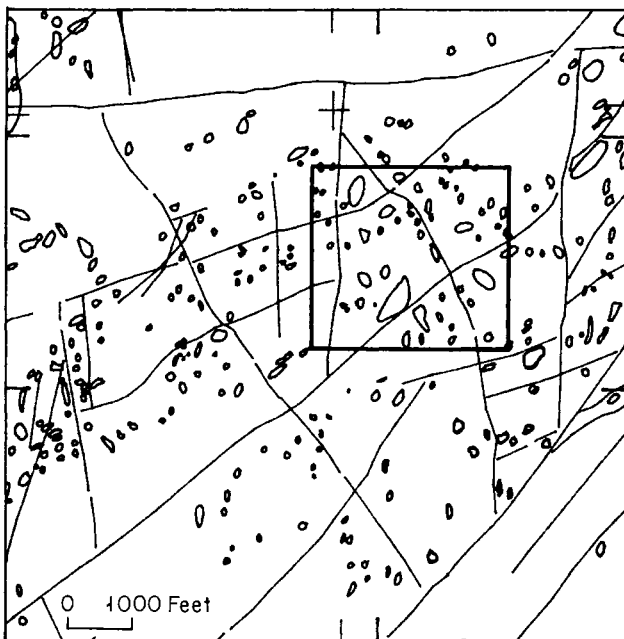
The Minnesota Geological Survey, with the cooperation of the Minnesota Department of Natural Resources, has developed a system to computerize mapped geologic data. To test the system, the Duluth Complex, a body of mafic igneous rocks of Middle Proterozoic age in northeastern Minnesota, was selected for the pilot study area on the basis of its abundance of available data, well-defined geologic boundaries, and economic potential. Much of the data on the Duluth Complex available through 1984 have been put into the data base. These include the following types of geologic features:

1. Point features—drill-hole locations, sample sites, small outcrops
2. Two-dimensional linear features—faults, lineaments
3. Three-dimensional linear features—fold axes, lineations
4. Planar features—bedding planes, igneous layering, foliation

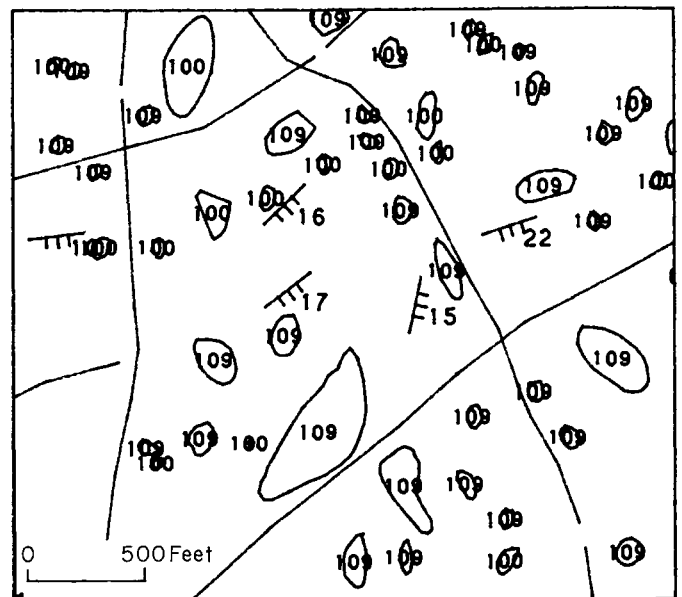
5. Polygonal features—rock outcrop areas, mapped geologic units

Features are digitized from geologic maps by entering their exact geographic locations and labeling them. An index is maintained that cross references all data points to their original source maps. With the aid of a plotter, maps can be generated from the digitized data by choosing the geographic extent of the mapped area, the scale of the map, and what geologic features will be indicated and how they will be labeled. The generated data base can be used to compare and contrast the known geology of an area at any scale, to easily and continuously update maps, and to assess areas in need of additional study. The system's greatest potential rests on the capability it provides to manipulate and present data in diverse ways and to eliminate the need for replotting existing data.

Mary Jo Kuhns



General geologic map of the Harris Lake area, St. Louis County, showing geologic structure and outcrops.



Detailed structure and rock types of outlined area at left.

## In Memoriam

Two distinguished Minnesota earth scientists died in 1986. In early August, Harold M. Mooney, professor of geophysics at the University of Minnesota, died after a long illness. Dr. Mooney, who retired in June, was a gifted teacher and researcher. Included in his research activities was the setting up of a network of earthquake detection stations in the state. He was the author or co-author of several MGS publications, one of which was an earthquake history of Minnesota.

In early November, Ralph W. Marsden died while attending the annual meeting of the Geological Society of America in San Antonio. Dr. Marsden, a renowned authority on iron-formations and deposits, had held in the course of his long career positions in both industry and academia. He spent 17 years with U.S. Steel Corporation (now USX) and headed the Department of Geology at the University of Minnesota, Duluth, for 7 years. He published numerous papers and reports on the iron-formations in the State of Minnesota.

## Moon Lake Rising

Moon Lake, near the town of Brandon in west-central Minnesota, is rising and has flooded several lakeshore cabins. Other landlocked lakes in the state have also risen in recent years, creating similar problems for property owners; one of the most notorious is Lake Pulaski. A monitor well just a few feet from Moon Lake records the water table at about 30 feet below the lake surface. A nearby lake—also rising—is very near a dry gravel pit that has been excavated well below the elevation of the lake surface. What's happening?

A tentative solution for these related puzzles may be found in the glacial history of the area. Moon Lake is in the Alexandria moraine, which was deposited by the Wadena lobe and overridden by the Des Moines lobe before the ice trapped in the moraine had completely melted. When the ice did melt out, ice-block lakes formed that were lined with clayey Des Moines lobe till. The clayey till would act as a hydrologic barrier between Moon Lake and the underlying sand and gravel.

# PROJECT UPDATES

## QUATERNARY GEOLOGY

Gary Meyer completed reconnaissance field mapping this summer of the glacial deposits of Lake of the Woods County and parts of western Koochiching and eastern Roseau Counties. The mapping was done in conjunction with MGS's drilling in the area (see Precambrian Geology for an update on the MGS drilling program). The entire region falls within the boundaries of Glacial Lake Agassiz; all surficial features formed at the bottom or edges of the fluctuating lake. There are significant differences in the carbonate and shale content of drift from north to south, reflecting the flow lines of the last ice advance out of the Winnipeg lowland. Nothing older than late Wisconsinan sediment was found below the lake sediment, leaving analysis of earlier glacial history dependent on the evidence gathered from drilling by MGS and the Department of Natural Resources, Division of Minerals.

This year's drilling has shown that the northeastern source Rainy lobe drift (late Wisconsinan) underlies the northwestern source Des Moines lobe drift and overlies bedrock throughout much of the eastern part of the study area. However, in the Beltrami Island vicinity of central Lake of the Woods County, the drift sequence becomes thicker and more complicated. Rainy lobe sediments are more discontinuous below Des Moines lobe sediments, but deposits from older advances—primarily from the northwest—are preserved. Regolith formed in Precambrian bedrock also becomes thicker and more widespread to the west.

While mapping surficial geology in Olmsted County this last summer, Howard Hobbs recognized paleosols and possible paleosols. These ancient soils may provide insight into the erosional history of the county following retreat of the last (pre-late Wisconsinan) glacier. Two exposures of till containing abundant fragments of wood were also discovered, but the wood is probably beyond the reach of radiocarbon dating.

Clues to the more recent history of Olmsted County may be found in numerous ventifacts and contorted sediments, evidence of wind erosion and frost action in the soil. These may be the effects of a permafrost climate during the late Wisconsinan (roughly 25,000 to 10,000 years ago). The late Wisconsinan ice stopped to the west near the border of Steele and Dodge Counties, but the glacial climate did not. Evidence of permafrost soil flow includes fossil ice wedges and a large contorted gabbro boulder, now completely disintegrated by weathering (grus).

Rich Lively continues to study uranium-series (U-series) disequilibrium dating of calcite from cemented gravels in southeastern Minnesota. Such dating from several sites in

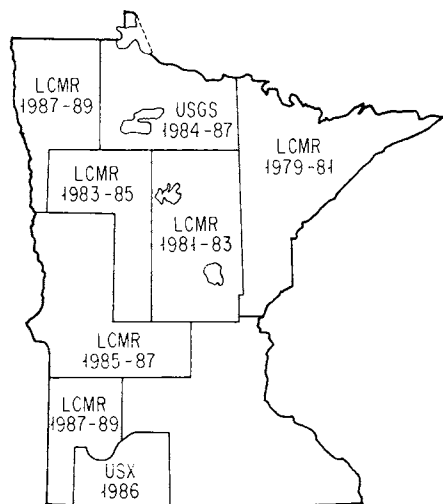
Olmsted County has provided Howard Hobbs with minimum ages for the overlying glacial till. He is also continuing with U-series disequilibrium dating of speleothems from the Bahamas in an attempt to correlate sea level changes recorded by speleothem growth on San Salvador Island with glacial/interglacial intervals identified from dates in southeastern Minnesota and adjacent areas of the Upper Midwest.

## STRATIGRAPHIC GEOLOGY

The Cretaceous rocks of southwestern Minnesota reflect a transition from marine deposits in the Dakotas to nonmarine deposits east of the Cretaceous sea. Dale Setterholm established a preliminary stratigraphy unique to the area from drill holes, geophysical logs, and geochemical analyses. Two of his stratigraphic units contain beds anomalously high in manganese. The project was supported by the U. S. Geological Survey as part of its Midcontinent Strategic and Critical Minerals Project.

John Mossler is revising the nomenclature used by MGS for Paleozoic rocks in Minnesota. The Galena Formation is being raised to group status, and some important nomenclatural revisions are being introduced in the Devonian part of the column. We hope to have it in print for the GSA meeting at the end of April.

## GEOPHYSICS



*Status of state aeromagnetic mapping—planned, in progress, or completed. The latest MGS survey in west-central Minnesota, sponsored by the Legislative Commission on Minnesota Resources, is complete, and the data are publicly available. MGS has also received the USX (formerly U.S. Steel) data for southwestern Minnesota and will eventually receive the USGS north-central Minnesota data.*

Seismic reflection profiles that were recently given to MGS have been used to constrain gravity and magnetic interpretations of the deep structure of the Midcontinent rift. The volcanic rocks with interflow sedimentary units frequently yielded excellent reflection data, which suggest that some sequences may be more than 9 miles thick. Parts of the rift are somewhat asymmetric in cross section and may have formed as half grabens. One profile in east-central Minnesota delineates a pronounced angular unconformity in the flow sequence at a depth of 3 to 4.3 miles. The seismic sections also indicate that listric thrust faults may locally bound the St. Croix horst. In southeastern Minnesota, a line reveals that Keweenaw sedimentary rocks atop the St. Croix horst are 2.5 miles thick, with the flanking sedimentary basins having possibly the same thickness.

## ENGINEERING AND ENVIRONMENTAL GEOLOGY

As part of the work for the Olmsted County atlas, the City of Rochester and the Olmsted County Board of Commissioners are funding a study of ground water in the two major county aquifers. E. Calvin Alexander, Jr., of the Department of Geology and Geophysics is working with MGS to determine, by radiocarbon dating, the length of time that water remains in the aquifers. This "residence" time can vary from a few days to thousands of years and can be used to predict the effects of aquifer contamination. A local study group and MGS are preparing maps of Oronoco Township to demonstrate the possibilities of interpretive maps at this level of detail. The atlas for Olmsted County should be printed by mid-1988.

Fieldwork for the Hennepin County atlas will begin in 1987 and is expected to take 2 years to complete. James Piegat, a hydrogeologist with the Hennepin County Soil and Water Conservation District, will be working with MGS staff on the atlas.

The second and final long-term test cycle of the aquifer thermal energy storage (ATES) project began October 2, 1986. The first long-term test demonstrated that just over 60% of the heat stored in the Franconia-Ironton-Galesville aquifer could be recovered after injection and storage periods. The second test is needed to confirm the consistency of these results, proof needed before any applied system could be constructed.

A third round of investigations of ground-water contamination in communities southwest of the Twin Cities Army Ammunition Plant includes drilling 30 new test holes outside the arsenal property. The Minnesota Pollution Control Agency (MPCA) is in charge of drilling. Both the MGS and the Land Management Information Center of the State Planning Agency have access to all the information from the new drilling, water wells, and soil borings in an already existing

computer data base. Water chemistry for specific wells can be obtained from the MPCA; some chemical differences result from the surficial and bedrock geology. Bruce Bloomgren and Gary Meyer are using the new data to revise the geologic maps of the New Brighton 7.5-minute quadrangle published in 1966.

## HYDROGEOLOGY

Barb Palen compared about 50 ground-water resource studies from states with climates analogous to climates projected for Minnesota in the Greenhouse scenarios. Some differences in the mechanisms of recharge are pertinent. First, recharge to fine or compact surficial deposits, such as silt and clay till versus recharge to outwash and alluvial sands, declines from a ratio of about 1:3 in the eastern prairie states to 1:10 in the drier states of the High Plains. Indiana has shallow water tables, as does Minnesota, while water tables are deep on the plains uplands. A drier climate in Minnesota has a relatively greater impact on recharge to hilly areas, such as end moraines and the slopes of incised river valleys, than on recharge to outwash and alluvial floodplains. Second, the proportion of precipitation that becomes recharge in summer increases significantly with irrigation, because increased soil moisture mitigates the effects of a drier climate. Third, drier states depend relatively more on infrequent summer storms for surficial recharge, in contrast to the dependable spring recharge from snowmelt in the Midwest.

The Iron Range Resources and Rehabilitation Board and MGS are cooperating on the development of a water-well data base for the Mesabi range. A study area located between the cities of Hibbing and Virginia was selected, and a field crew verified the locations of about 2,000 water wells for which MGS had records. This information will be used to evaluate the amount of additional study required to produce a comprehensive understanding of the ground-water resources of the study area.

## PRECAMBRIAN GEOLOGY

Twenty-one test holes were drilled in Lake of the Woods, Roseau, Beltrami, and westernmost Koochiching Counties as part of the 1986 drilling project, and core samples are being studied petrographically and geochemically. Cores, overburden samples, and geophysical logs may be examined at MGS. The drilling was planned and managed by Dave Southwick, in cooperation with Warren Day and Klaus Schulz of the USGS. Site geologists were Sarah Mills, Gary Meyer, Doug Bergstrom, and Bruce Bloomgren.



*Mapping on the North Shore. From left to right: Holm, Reichhoff, Early, Miller, Steve Shank, John Green, Boerboom.*

Field mapping of quadrangles along the North Shore continued as part of the U.S. Geological Survey COGEMAP (Cooperative Geologic Mapping) program, for which G.B. Morey is the principal investigator. Jim Miller and four graduate students—Terry Boerboom, Daniel Holm, and Colin Reichhoff from UMD and Dusty Early from the Twin Cities campus—finished mapping in the Silver Bay 7.5-minute quadrangle (scale 1:24,000 or 1 inch = 2,000 feet) and much of the adjacent Illgen City quadrangle. A bedrock geologic map of the Silver Bay and Split Rock Point NE quadrangles is in prepa-

ration, as well as a report presenting petrographic and chemical data.

Mark Jirsa continued field mapping in northeastern Itasca County. More field work is needed in five of the six quadrangles to be published as a single map at the scale of 1:48,000. Ongoing geochemical studies, by Steve Hauck of the Natural Resources Research Institute at UMD, are aimed at characterizing the Archean volcanic and plutonic suites in the Itasca greenstone belt.

Peter McSwiggen is preparing a geologic map of the Denham-Atkinson area of Carlton and Pine Counties. The map when completed will include an outcrop inventory, drill hole locations, rock types, and minor structural data, as well as the distribution of magnetic and electromagnetic anomalies. The units of the Thomson Formation are being redefined.

Doug Bergstrom is measuring the natural remanent magnetization of the Sioux Quartzite in hopes of using paleomagnetic analysis to clarify the stratigraphy and structure of the Sioux, the temporal equivalence of four depobasins that have been recognized, and the correlation of the Sioux with other Baraboo-type strata.

## STAFF NEWS

*Val Chandler, Priscilla Crew, Rich Lively, Jim Miller, Bruce Olsen, and John Spletstoesser* attended the annual meeting of the Geological Society of America in San Antonio on November 10-13. Val Chandler presented two papers: (with Peter McSwiggen and G.B. Morey) "Reinterpretation of the Midcontinent rift system in Minnesota and Wisconsin using gravity, magnetic and seismic data," and (with Kelley Carlson) "A combined analysis of gravity and magnetic anomalies in east-central Minnesota." Rich Lively co-chaired the symposium "Quaternary evolution of the Mississippi valley" and presented a paper (with Bruce Olsen) on "Buried valleys and U/Th ages in the Upper Mississippi valley, Minnesota."

*Marc Hoyer* presented a paper on "Aquifer thermal energy storage experiments at the University of Minnesota, St. Paul, Minnesota, U.S.A." at the 21st Intersociety Energy Conversion Engineering Conference in San Diego, August 25-29.

*John Spletstoesser* was co-organizer of the 20th annual meeting of the Association of Earth Science Editors, held in Duluth on October 5-8.

*Roman Kanivetsky* presented a paper on "Ground-water data systems for water and land-use planning in Minnesota" at the spring meeting of the American Institute of Hydrology, Washington, D.C., October 15-17.

*John Mossler* attended the 16th annual field conference of the Great Lakes Section of the Society of Economic Paleontologists and Mineralogists, held in Superior, Wisconsin, September 19-21. The theme of the conference was the petroleum potential of the Precambrian Midcontinent rift system.

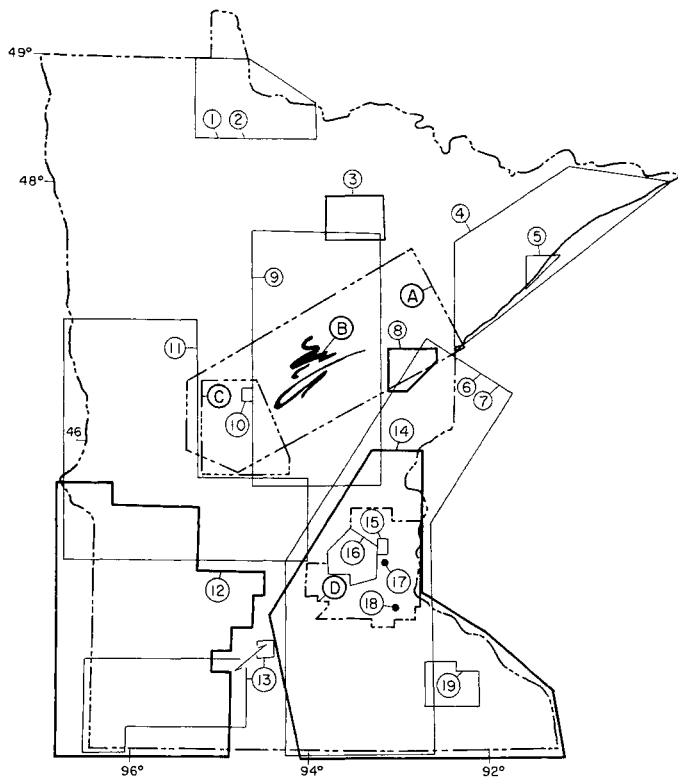
*Sarah Mills* attended two field conferences on platinum group minerals (PGM) last summer. The first, held in June near Marathon, Ontario, focused on the PGM prospect held by Fleck Resources in the Coldwell alkaline complex. Then in July she attended a 4-day field conference, based in Hibbing, that included 2 days of discussion on the Duluth Complex and PGM. Dr. Eugen Stumpf of the Mining University in Loeben, Austria, lectured on worldwide occurrences of PGM.

*Dave Southwick* represented MGS at the U.S. Geological Survey's regional cluster meeting in Lawrence, Kansas, on September 15-17, where he took part in a panel discussion on various approaches to geologic mapping.

*Mark Jirsa* attended the Ontario Geological Survey's 1986 Geoscience Research Seminar and Open House, December 3-4 in Toronto. Nearly all the presentations were related to minerals potential, with emphasis on Archean greenstone terranes, platinum group minerals, engineering and terrane geology, and geophysical, geochemical, and computer applications.

*Pete Moody* outlasted all opponents to become the winner of the first annual MGS tennis tournament. Doubles teams will have to wait until next year, however, as the doubles tournament was cancelled due to snow!

# SUMMARY OF RESEARCH AREAS



Approximate areas of work in progress or recently published

1. 1986 drilling project/Southwick, Mills, Meyer
2. Quaternary geology field mapping/Meyer
3. "Itasca greenstone belt" mapping/Jirsa
4. Duluth Complex digitizing/Kuhns, Wahl
5. Silver Bay area mapping/Miller, Morey
6. Seismic profiling across the Midcontinent rift/Chandler

7. Gravity and magnetic modeling of Midcontinent rift/McSwiggen, Chandler, Morey
8. Denham-Atkinson area of Carlton and Pine Counties, geologic mapping/ McSwiggen
9. Werner deconvolution of aeromagnetic data/Ferderer
10. Metasedimentary rocks in Philbrook area, Todd County/Boerboom
11. Aeromagnetic surveying/Chandler
12. Cretaceous rocks and manganese potential/Setterholm, Morey, Southwick
13. Sioux Quartzite, magnetic polarity study/Bergstrom, Chandler
14. Stratigraphic and sedimentologic studies
  - Paleozoic lithostratigraphy/Mossler
  - sedimentology of Dresbachian rocks/Mossler
  - sedimentology of Shakopee Formation/Mossler
  - U-series dating of calcite from cemented gravels/Lively
15. New Brighton mapping project/Bloomgren, Meyer
16. Hennepin County atlas/Olsen, Bloomgren
17. Aquifer thermal energy storage, St. Paul/Hoyer, Walton, Splettstoesser
18. Ooids in the Solor Church Formation/Kuhns
19. Olmsted County atlas/Hobbs, Olsen, Lively

#### Studies Covering Entire State (Areas Not Shown)

20. Regional hydrogeochemical maps/Kanivetsky
21. Greenhouse study, climate changes on aquifer recharge rates/Palen
22. Statewide summary file of water-well records (INDEX)/Olsen, Kanivetsky, Bloomgren

#### Recent MGS Publications

- A. Scientific core drilling/Southwick, Meyer, Mills
- B. Distribution of iron-formations, Cuyuna range/Morey, Morey
- C. Subsurface till stratigraphy, Todd County/Meyer
- D. Bedrock geologic and topographic maps, Twin Cities/Jirsa, Olsen, Bloomgren

Mark Jirsa

## ★ Meetings

The third annual **Minerals Activities Forum** was held in Hibbing on October 21. The forum, which is sponsored by the Minnesota Department of Natural Resources, Division of Minerals, MGS, the Mineral Resources Research Center, and the Natural Resources Research Institute, is designed to give legislators, exploration and mining companies, state agencies, and the public the opportunity to view posters detailing ongoing research related to mineral resources.

MGS staff members Doug Bergstrom, Val Chandler, Bob Ferderer, Mark Jirsa, Mary Jo Kuhns, Peter McSwiggen, Jim Miller, G.B. Morey, Dale Setterholm, Dave Southwick, and Tim Wahl attended the meeting or had posters presented.

MGS was host to the **International Energy Agency's meeting** on "Energy Conservation through Energy Storage," held at the Radisson University Hotel near the Minneapolis campus on October 14-15. About 45

## ★ NEWS NOTES ★

individuals attended the meeting, and nearly 20 presentations were made of projects in the U.S. (Minnesota and Alabama) and Europe (Sweden, Denmark, Switzerland, Netherlands, West Germany). Results of the Minnesota ATEs project were presented by Matt Walton, Marc Hoyer, Steven Eisenreich, and Robert Miller.

The annual meeting of the **Geological Society of America North-Central Section** will be held in St. Paul, April 30-May 1, with field trips on April 29 and May 2-3. Contact the meeting organizers Peter Hudleston or Robert Sloan, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455, for further information on the meeting and program. For information on the field trips, contact Dave Southwick of MGS. The guidebooks for the field trips will be published by MGS in its Guidebook Series and will be available at the meeting.

## Weaton Collection

George F. Weaton, former director of the Minnesota Office of Ore Estimation, has donated his collection of rock and mineral specimens to the MGS. The specimens from mineral deposits and mines across North America reflect Mr. Weaton's interests during his long and distinguished career. It will be displayed on a rotating basis with the rest of our permanent rock and mineral collection, which is open to the public.

## New Phone Numbers

- |                |  |
|----------------|--|
| (612) 627-4780 | Main Office                                  |
| 627-4784       | Water-well Records,<br>Other Subsurface Data |
| 627-4782       | Maps and Publications<br>Sales               |

# RECENT THESES ON MINNESOTA GEOLOGY

- Carlson, K.E., 1985, A combined analysis of gravity and magnetic anomalies in east-central Minnesota. M.S., University of Minnesota, Minneapolis, 138 p.
- Fenelon, J.M., 1986, Glacial geology of the Cramer quadrangle, northeastern Minnesota. M.S., University of Wisconsin, Milwaukee, 76 p.
- Goldstein, B.S., 1985, Stratigraphy, sedimentology, and late Quaternary history of the Wadena drumlin region, central Minnesota. Ph.D., University of Minnesota, Minneapolis, 219 p.
- Grow, S.R., 1986, Water quality in the Forestville Creek karst basin of southeastern Minnesota. M.S., University of Minnesota, Minneapolis, 229 p.
- Miller, J.D., Jr., 1986, The geology and petrology of anorthositic rocks in the Duluth Complex, Snowbank Lake quadrangle, northeastern Minnesota. Ph.D., University of Minnesota, Minneapolis, 2 v., 525 p.
- Samson, S.D., 1986, Chemistry, mineralogy, and correlation of Ordovician bentonites. M.S., University of Minnesota, Minneapolis, 128 p.
- Sansome, C.J., 1986, Origin and configuration of the present-day land surface, Goodhue County, Minnesota. Ph.D., Oregon State University, Corvallis, 2 v., 144 p.

# RECENT SURVEY PUBLICATIONS

- Scientific core drilling in central Minnesota: Summary of lithologic and geochemical results, by D.L. Southwick, G.N. Meyer, and S.J. Mills. 1986. 186 p. (Information Circular 23) \$8.00.
- Bedrock geologic and topographic maps of the seven-county Twin Cities Metropolitan Area, Minnesota, by M.A. Jirsa, B.M. Olsen, and B.A. Bloomgren. 1986. 2 sheets, scale 1:125,000. (Miscellaneous Map Series M-55) \$8.00.
- Distribution of iron-formations in the main Cuyuna range, east-central Minnesota, by G.B. Morey and D.D. Morey. 1986. Scale 1:48,000. (Miscellaneous Map Series M-60) \$6.00.
- Subsurface till stratigraphy of the Todd County area, central Minnesota, by G.N. Meyer. 1986. 40 p. (Report of Investigations 34) \$5.00.

Mail orders must be accompanied by payment (check or money order made out to the University of Minnesota). There is a \$1.00 postage and handling fee, and Minnesota residents must include 6% sales tax (excluding the postage and handling fee). A list of publications is available on request. Please direct inquiries and orders to Maps and Publications Sales (612) 627-4782.

## SINKHOLES

Sinkholes are common in the karst region of southeastern Minnesota. They are characterized by depressions in the land surface and are formed when unconsolidated deposits, such as sand, are washed into cavities in limestone and dolomite.

Karst regions, with their patterns of underground drainage and caverns, are very susceptible to ground-water pollution, and sinkholes provide a pathway for surface contamination to reach ground-water supplies.

In the accompanying photograph, glacial geologist Howard Hobbs examines a sinkhole, located at the top of a quarry, where the sediment has washed out.



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