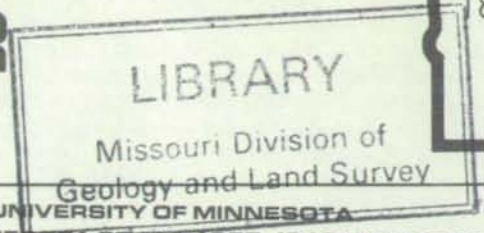


After - - July ⊕ - still
Sally Jones

Minnesota Geological Survey NEWSLETTER

VOLUME 3, NUMBER 1 SPRING 1987



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

PALEONTOLOGY REVISITED

The Minnesota Geological Survey has published a report that makes available in one volume the major advances in Ordovician biostratigraphy and lithostratigraphy of the Upper Mississippi region that have been made in the last three decades. Parts of the report not immediately concerned with Minnesota geology are important to the study of Minnesota, because the fossils are the same no matter from which state they were collected.

In addition to chapters on major groups of fossils, stratigraphy, and nomenclature, a major extinction event is documented. Beds of altered volcanic ash (K-bentonite) extend across wide areas of the eastern United States in rocks of Ordovician age. Because individual beds can now be identified by their unique chemical signatures, they can be traced across their extent. All the organisms in the eastern half of the United States were killed by the fall of 80 cubic miles of ash from the eruption of an andesitic volcano near what is now Birmingham, Alabama, 454 million years ago. This ash is the Deicke K-bentonite (formerly known as the Carimona bentonite) near the top of the Platteville Formation. The region was repopulated from outside during at least the next half a million years. All of the echinoderm species, 90% of the trilobite, 80% of the gastropod, 39% of the brachiopod, and 10% of the conodont species that were present in the region before the eruption disappeared forever.

The title of the new report is "Middle and Late Ordovician lithostratigraphy and biostratigraphy of the Upper Mississippi valley" (MGS Report of Investigations 35). It was edited by Robert E. Sloan of the Department of Geology and Geophysics at the University and published in conjunction with the Ordovician field trips and symposia of the North Central sectional meeting of the Geological Society of America.



MN
G.S.
11/13/11

Courtesy of William F. Rice.

Standing on the Glenwood Formation, examining the Platteville Formation at Shadow Falls where Summit Avenue ends at the Mississippi River in St. Paul. Although not visible in the picture, both the Deicke and Millbrig K-bentonites can be seen at this locality.

CRETACEOUS ROCKS

A sequence of Cretaceous rocks overlying the gneiss terrane and lapping onto the flanks of the Sioux Quartzite ridge has long been recognized in southwestern Minnesota. Due to the thickness and extent of glacial deposits overlying these rocks, relatively little was known of their rock types, age, and depositional history. The potential for manganese deposits in the Cretaceous rocks, recently suggested by the U.S. Geological Survey (USGS), has led to economic interest and investigations, co-funded by MGS and USGS, which are intended to provide a regional geologic framework to support more detailed manganese exploration.



Cretaceous rock occurrences (patterned), southwestern Minnesota. The unpatterned areas represent Precambrian terranes, either gneissic or Sioux Quartzite.

Maps of the configuration of the pre- and post-Cretaceous bedrock surfaces were generated by interpreting water-well logs in light of a smaller number of reliable scientific data points. Seismic reflection data were generated to supplement sparse well data in some areas. These maps were then used to map the distribution and thickness of the Cretaceous rocks. The thickness of the glacial cover was also mapped.

The Cretaceous rock sequence was divided into mappable lithologic units representing distinct depositional environments. Toward this end, available core, cuttings, and well logs were examined and two new test holes drilled. Downhole geophysical well logs were also examined, including several new logs generated for this study. The geophysical logs, especially gamma logs, were useful in distinguishing subtle but important lithologic characteristics often undetected in older well-log records. This work led to the development of a seven-unit stratigraphic division of the local Cretaceous section and the recognition of marine and nonmarine rock units in a transgressive succession. Available paleontologic data were incorporated into this stratigraphy allow-

Cretaceous Continued on next page.

DIRECTOR'S COLUMN

Did you really know what you would be in for when you hired somebody from California to be Director of MGS? Warm winters, yes, but earthquakes, too? And maybe a gold mine in Minnesota's future?

People warned me that Minnesota has two seasons: winter and road construction, especially winter. But in 1987 I didn't get much use out of the cross-country skis that my staff at the California Public Utilities Commission gave me as a going-away present. "We've put on a special transition season for you," said my Minnesota friends, as day after mild, snowless day of what Garrison Keillor called "that dry, odd, brown winter" progressed.

With the springtime came a surprise letter from Washington appointing me to the National Research Council Committee on Earthquake Research. I thought, "Oh, they must think there's still some action in our Precambrian basement." Sure enough, by June 11 I found myself discussing the intricacies of seismic accelerations with the plant manager of the Northern States Power Company Prairie Island nuclear facility, where the alarms had been set off by the magnitude 5 Lawrenceville, Illinois, earthquake the previous evening, which made front-page headlines in the Twin Cities newspapers. Unhappily, like the gentleman in St. Paul who wrote us that he "was facing southeast, watching 'Wheel of Fortune' and didn't feel a thing," I didn't even notice the shaking of the earthquake. Val Chandler, our one and only MGS geophysicist, has officially designated this phenomenon the "Vanna White effect." My Minnesota earthquake-hazard-mitigation role was limited to being media consultant for Val's interview on KSTP-TV: I recommended using 3M yellow Post-It-Notes to highlight the epicenters of historic Minnesota earthquakes on the Legislative Commission on Minnesota Resources (LCMR)-funded aeromagnetic map for his background visuals.

In California, the legislators used to ask me, "Priscilla, how come we always get an earthquake the week before your budget comes up in committee?" As an out-of-state newcomer fresh to the Minnesota political scene, I had been pretty apprehensive about my first testimony in St. Paul, but I felt much more at home being able to appear in the hearing room on June 17 armed with the aeromagnetic maps, each sporting a gold star locating the 1975 Morris earthquake on a lineament of the Great Lakes Tectonic Zone. The Legislative Commission on Minnesota Resources promptly granted us our full request for the 1987-1989 biennium, less a two-percent reduction imposed equally on all projects. With this funding of \$784,000, we will be able to complete the aeromagnetic survey in northwestern and southwestern Minnesota, and we will intensify our efforts to merge the data already flown by the U.S. Geological Survey and USX Corporation with our coverage, so that only the south-central and southeastern portions of the state will remain for the final biennium in 1989-1991.

In other budget developments affecting MGS, the Legislature approved the Governor's recommendation for our State Special appropriation, which will amount to \$951,900 in fiscal 1987-1988. At this level, but without the \$50,000 budget increase the University had requested, we will continue to depend heavily on external contracts and grants, which supported fully 30% of MGS salaries in fiscal 1986-1987. MGS program planning will continue to be intensely influenced by the tasks required by the external contracts we manage to secure during the biennium.

The bad news for us this year was that the Legislature turned down the University's request for planning funds for the new Earth Sciences Building. We plan to work closely with the Department of Geology and Geophysics and the Institute of Technology to present the strongest possible case for our new building in the 1988 legislative consideration of capital requests.

The good news was that the Legislature endorsed a Mineral Diversification initiative in the Rural Development Bill. Minnesota has ranked fifth among states in nonfuel mineral production and has traditionally been the nation's leading producer of iron ore. The minerals policy signed into law by Governor Perpich in June 1987 is unprecedented for Minnesota: it promises a commitment "to diversify the state's mineral economy through long-term support of mineral exploration, evaluation, development, production, and commercialization." This dramatic legislative support for nonferrous mineral

diversification, with substantial new state funding of \$500,000 per year, comes at a time when Minnesota presents a most exciting frontier for mineral exploration and basic earth sciences research. As the international geological community turns its attention increasingly to understanding the evolution and dynamics of continental interiors, Minnesota will be a focal point for industrial and academic investigations of the complex mineralization in Archean and Proterozoic terranes. The gold-bearing shear zones in Archean greenstones and the platinum-group element distribution in intrusive complexes of the intraplate rifts are current topics of intense interest in Minnesota and other Precambrian settings around the world. Modern computerized geophysics and sophisticated geochemistry, detailed geologic mapping, and overburden drilling are at last making Minnesota's rich diversity of geological environments attractive and accessible to today's cost-conscious mineral exploration companies.

My great-grandfather couldn't find the gold when he scratched around in the Mesozoic greenstones of the California Foothills in 1850. I expect much more success from the Minnesota argonauts of the late 1980s, as they unravel the mysteries of our intricate Archean geology, armed with the latest aeromagnetic and gravity surveys, innovative models of coeval shear deformation and alteration, and new interpretations of the igneous, structural, and metamorphic processes that formed the Archean gold we know must be there.

Priscilla Grew

Indo-U.S. Workshop

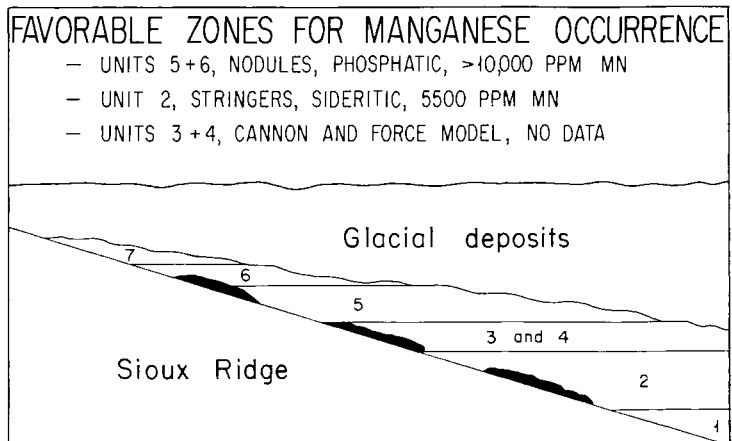
MGS geophysicist Val Chandler attended a workshop sponsored by the National Science Foundation in Bangalore, India, in April. The title of the workshop was "Regional Geophysical Lineaments and Their Tectonic and Economic Significance." One of the workshop goals was to assess the state of the art in lineament studies.

The Precambrian geology in Minnesota is strikingly similar in rock types and ages to that of peninsular India. India provides dramatic examples of geophysical lineaments coinciding with fundamental structures in the continental lithosphere that have been reactivated throughout geologic time. The recent discovery of post-Cretaceous offset along prominent geophysical lineaments in Minnesota will encourage further lineament studies in our state.

Cretaceous Continued from front cover.

ing tentative correlation with the standard Cretaceous nomenclature of the Western Interior. Geochemical characterizations were done for the stratigraphic units. The results of these studies are available as an MGS open-file report (\$20.00, plus \$4.00 for postage and handling; Minnesota residents must pay an additional 6% sales tax or \$1.20).

Further investigations have been proposed to create a geologic map of the seven Cretaceous units and further define their characteristics. More paleontologic control is necessary, and we also hope to investigate the local effects of the Sioux ridge on Cretaceous sedimentation and manganese distribution.



Dale Setterholm

PROJECT UPDATES

Olmsted County Atlas

More time has been shaved off the scheduled publication date. Expect the atlas to be in print by the end of March 1988. Hydrogeologic mapping is in progress. Mapping of both glacial and bedrock geology is nearly finished, and automated data base systems have been established with the Olmsted County Department of Health and Consolidated Planning.

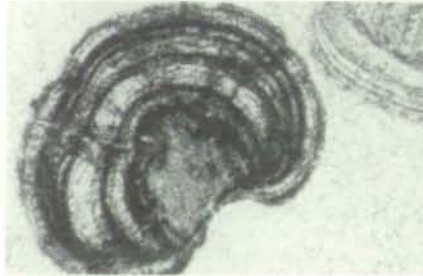
Information collected for the atlas is already being put to good use:

- The Olmsted County Board of Commissioners has requested that MGS prepare maps for several townships describing the sensitivity of different geologic conditions to the movement of surface contaminants into the ground water. These maps will be used to evaluate how proposed changes in land use will affect ground-water quality.
- The City of Rochester and the U.S. Geological Survey, Water Resources Division, are jointly preparing a computer model of the Prairie du Chien-Jordan aquifer, which is the upper bedrock aquifer in about a third of Olmsted County. Much of the information used to construct the model was obtained for the Olmsted County geologic atlas.
- The Minnesota Departments of Agriculture and Health have used atlas information to select water wells for sampling to determine whether agricultural pesticides are contaminating ground water in geologically sensitive areas. The results show that although pesticides are present in the karsted aquifers in at least parts of Olmsted County, the concentrations are below the level permitted by the standards of the Minnesota Department of Health.
- Dr. E. Calvin Alexander, Jr., of the Department of Geology and Geophysics at the University, worked with MGS to sample water wells for carbon-14 dating of aquifer waters. Funding for these analyses was provided by the Olmsted County Board of Commissioners and the water utility for the City of Rochester. Results show that most county residents drink water that entered the ground-water system less than 30 years ago—a clear indication that care should be taken to prevent surface contamination from entering ground-water supplies. In contrast, age dates from other aquifers in the state, such as the Mt. Simon aquifer of the Twin Cities area, ranged from at least 5,000 years, to more than 35,000 years.

Contact Bruce Olsen for further information on the county atlas program.

Solor Church Formation

Mary Jo Kuhns has been studying the origin of ooids in the Solor Church Formation of southeastern Minnesota. The sediments of the Solor Church were laid down under predominantly fluvial conditions during late Precambrian time. Ooids are found in thin carbonate units within the formation and consist of very small (less than a millimeter), roundish grains formed by successive layering of calcite, hematite, or chamosite around a nucleus. This layering occurs either through inorganic precipitation (to form oolites) or organically through accretion by blue-green algae (to form oncolites).



Petrographic study of the ooids in the Solor Church revealed erratic, asymmetrical banding, highly disrupted layering, preferred growth directions, and the presence of grapestone clusters—all possible indications of algal activity. Scanning electron microscopy reveals the presence of light elements, presumably organic carbon, as well as phosphorus, which is also presumably of biogenic origin. Their presence suggests that these ooids are of organic origin and therefore true oncolites.

Glacial Geology

Howard Hobbs finished the glacial mapping for the Olmsted County atlas this spring. The most striking finding of his investigations was that the bedrock floor of most valleys is far below the present level of the streams. The intervening deposits are largely sand and gravel rather than till and appear to be relatively young and unweathered. He interprets these deposits as debris washed from the uplands during the last glaciation. Ice from the most recent glaciation did not reach Olmsted County, but its proximity turned the climate cold, dry, and windy, and therefore enhanced erosion from the uplands and filled in the valleys.

Gary Meyer was busy with several projects during the winter and spring. He completed a generalized surficial map of the International Falls 2° sheet at the request of the U.S. Geological Survey. The map includes available data on drift thickness and glacial stratigraphy. He reviewed the glacial geology of the Hibbing-Virginia area for the Iron Range Resources and Rehabilitation Board as part of a work plan and budget for a geologic atlas of the Mesabi range. He also began work in northern Hennepin County in May for a geologic atlas of that county.

Philbrook Area, Todd County

Terry Boerboom is preparing a Report of Investigations on a sequence of tourmaline-rich metasedimentary rocks and a nearby mafic to ultramafic, zoned, dioritic intrusion in northeastern Todd County. The intrusion is rich in apatite, magnetite, and ilmenite and contains some unusual rock types, such as nelsonite and hornblende.

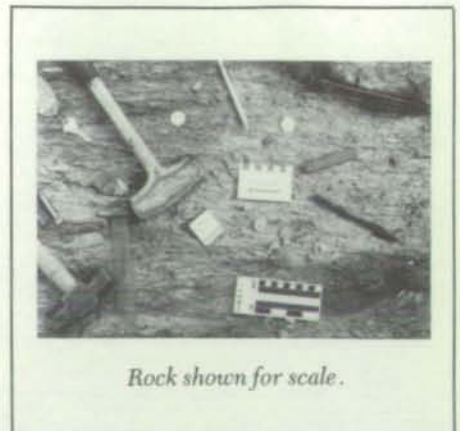
Aquifer Recharge

Barb Palen has evaluated the simple linear regression model of static water-level rise versus available precipitation. Although this model is adequate for moderate to shallow water-table levels in sand aquifers, a multiple regression model using known precipitation of the past one or two years as a second-predictor variable results in a better fit for both shallow water tables subject to waterlogging and for water tables deeper than 30 feet. A log transformation of the static water-level rise may improve recharge estimates for fluctuating water tables in fine-grained sediments.

Geophysics

The aeromagnetic program under the direction of Val Chandler and funded by the Legislative Commission on Minnesota Resources continues with plans now being laid for surveys over northwestern and southwestern Minnesota during the 1987-1989 biennium. The U.S. Geological Survey has completed its aeromagnetic surveying over north-central Minnesota, and these data are expected to be released to MGS sometime this year.

Other geophysical projects last winter and spring include a detailed gravity study in the Little Fork and Cook areas, which was prepared for the Minnesota Department of Natural Resources, and Bob Ferderer's work on inverse magnetic modeling using Werner deconvolution. Numerous structures have been delineated in the drift-covered Penokean foldbelt in east-central Minnesota.



Rock shown for scale.

MGS Staff

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 G. B. Morey, *Associate Director and Chief Geologist*
 David L. Southwick, *Associate Chief Geologist*

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 Lynn M. Swanson, *Librarian*
 Timothy E. Wahl, *Analyst/Programmer*
 Matt Walton, *Professor Emeritus*

A State Special appropriation from the Minnesota Legislature provides operating funds (salaries, benefits, supplies, travel, etc.) for the Survey. These appropriations are made by the Legislature on a biennial (24-month) schedule. State appropriations for the second year of the biennium ending June 30, 1987, was \$899,700. For fiscal year 1987 the total funds from all sources were about \$1.9 million. The contracts and grants listed below were active in the fiscal year ending June 30, 1987, and many will carry over into the next fiscal year and longer.

Federal Contracts and Grants

Midcontinent Strategic Minerals Mapping—U.S. Geological Survey.
COGEO MAP—U.S. Geological Survey.
Aquifer Thermal Energy Storage—Battelle Pacific Northwest Laboratories.
A Structural-Metamorphic Transect of the Vermilion Granitic Complex, NE Minnesota—National Science Foundation (in cooperation with the University of Minnesota, Department of Geology and Geophysics).

State and Other Contracts, Grants, and Appropriations

Surficial and Subsurface Geology of the New Brighton 7.5-Minute Quadrangle, Minnesota—Minnesota Pollution Control Agency.
Public Sample Analysis Program—Minnesota Department of Natural Resources.
Bedrock Drilling in West-Central Minnesota—Minnesota Department of Natural Resources.
Ground-Water Data Automation—Minnesota Department of Natural Resources.
Hydrogeologic Study of the Mesabi Iron Range—Iron Range Resources and Rehabilitation Board.
Olmsted County Geologic Atlas, Phases II and II—Olmsted County, Minnesota.
Hennepin County Geologic Atlas—Hennepin County, Minnesota.
Age, Residence Times, and Recharge Rates of Groundwater—Legislative Commission on Minnesota Resources.
Lanesboro Watershed Management Techniques—Legislative Commission on Minnesota Resources.
Aeromagnetic Mapping—Legislative Commission on Minnesota Resources.

UPLIFTING MOMENTS IN THE FIELD



What some geologists won't do to get a good picture.

These guys may look like rejects from Barnum & Bailey's Greatest Show on Earth, but they're not. This outcrop of an Archean volcanic breccia, seen during a field trip in May at the Institute on Lake Superior Geology meeting in Wawa, Ontario, contained rare clasts as large as 10 feet in diameter. Getting a good photo required a bit of stunt work by MGS geo-acrobats Doug Bergstrom (shaking top) and Mark ("My knees will never be the same") Jirsa.



"Well, I guess we didn't need quite so much powder!"

All Doug Bergstrom wanted was some rhyolite cobbles from a conglomerate quartzite in Pipestone County. He knew he'd have to soften up the outcrop with a bit of blasting to get enough. A few calls, maybe. A week later, and after an average of three calls each to the county highway engineer and sheriff, the county and state fire marshalls, construction contractors, the Bureau of Criminal Apprehension, various explosives, quarry, and natural gas companies, University insurance, and an experienced blaster, his efforts culminated in the spectacle above. Result: about 40 pounds of rhyolite recovered for dating.

AQUIFER THERMAL ENERGY STORAGE

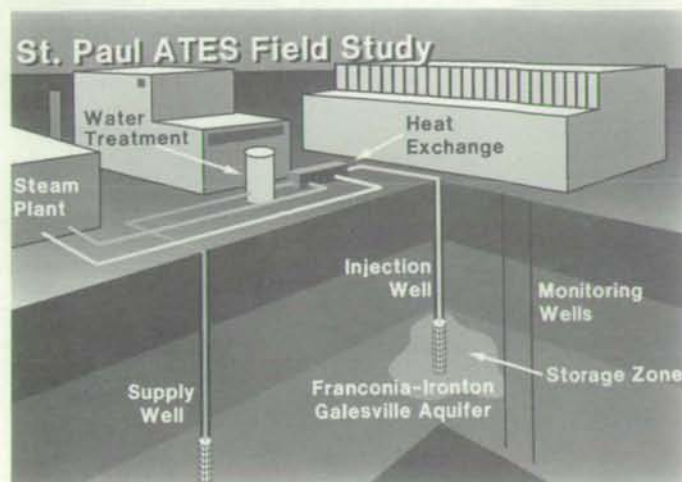
A project studying the feasibility of storing and retrieving heated (more than 212°F) water from a confined aquifer is nearing completion on the St. Paul campus of the University of Minnesota. MGS, along with the University of Minnesota Physical Plant, the U.S. Geological Survey, and personnel from the University's Environmental Engineering Laboratory, have been working on this project—currently the deepest, largest, and hottest such in the world—since May 1980. What has been learned in this experiment will have substantial impact upon use or adoption of this technology for large-scale district heating or cooling systems.

The first phase of the project included designing and constructing the ATEs facility, obtaining detailed information about the aquifer and its confining beds to allow modeling of the system, and acquiring the necessary permits and variances to build and operate ground-water injection wells. To this end, core holes were drilled at the storage and source well sites, which were used in pumping tests and geophysical logging.

The aquifer chosen, the Franconia-Ironton-Galesville (FIG) confined aquifer, is little used as a water source in the St. Paul campus area. The storage site itself is near the center of the Twin Cities artesian basin; the ground-water flow in the FIG aquifer at the site is very slow, less than four feet in a year.

The second phase of the project included ambient-temperature tests and four short-term ATEs cycles—planned as eight days each of injection, storage, and recovery of the heated water. A precipitator had to be used on the naturally hard FIG ground water to collect the scale that threatened to clog the well system under the high temperatures used in the test. About 58%-62% of the heat energy was recovered in those cycles that ran close to the planned storage period.

In the third phase of the project, two long-term test cycles were run to simulate seasonal storage. These cycles were planned to include 60 days each of heated-water injection, storage, and recovery. An ion-



Courtesy of Pacific Northwest Laboratories.

exchange water softener was installed to prevent scaling during the long-term cycles. Approximately 60% of the heat energy was recovered in each of the long-term cycles.

The recently begun final phase of the project involves post-test monitoring and pumpout—to include pumping the heated water from the aquifer, monitoring water levels and temperatures at the site for at least one year, and quarterly sampling of the ground water—and site restoration.

The project is part of the Underground Energy Storage Program of the U.S. Department of Energy administered by Battelle Pacific Northwest Laboratories.

Marc Hoyer

STAFF NEWS

Dave Southwick and **Dale Setterholm** attended the U.S. Geological Survey-sponsored V.E. McKelvey Forum on Mineral and Energy Resources held in Denver in early February.

Two MGS staffers taught classes in the Department of Geology and Geophysics this spring quarter. **Val Chandler** shared in the teaching of a course on electrical exploration, while **Peter McSwiggen** taught a graduate-level course on metamorphic petrology.

Mark Jirsa attended the Prospectors and Developers Association of Canada annual meeting in Toronto, Ontario, March 8-10. He was part of a Minnesota contingent promoting minerals development in our state.

Roman Kanivetsky attended the spring meeting of the American Institute of Hydrology, March 26-27, in San Francisco. While there he presented the paper "Field Determination of Vertical Hydraulic Conductivity of a Confining Bed."

Suzanne Bakke was recently hired as a secretary to replace **Denise Fletcher**. Suzanne's most recent job before coming to MGS was with the City of St. Paul Department of Fire and Safety Services.

The 33rd Annual Meeting of the Institute on Lake Superior Geology was held in Wawa, Ontario, in mid-May. MGS staff members who presented papers or posters while there include **Val Chandler** and **Bob Ferderer** (Werner deconvolution and geomagnetic mapping), **Mark Jirsa** (Itasca County metavolcanic belt), **Mary Jo Kuhns** (Solor Church Formation modeling), and **Jim Miller** (North Shore Volcanic Group).

MGS staff members were busy this spring even before the Lake Superior meeting preparing for the North Central sectional meeting of the Geological Society of America. **Doug Bergstrom**, **Bob Ferderer**, **Howard Hobbs**, **Marc Hoyer**, **Mark Jirsa**, **Roman Kanivetsky**, **Mary Jo Kuhns**, **Rich Lively**, **Gary Meyer**, **Jim Miller**, **John Mossler**, **Dale Setterholm**, and **Dave Southwick** all presented papers or posters. **Howard Hobbs**, **Jim Miller**, and **John Mossler** led field trips. Co-chairs of special symposia included **Rich Lively**, **Jim Miller**, **Dale Setterholm**, and **Dave Southwick**. **Priscilla Grew** was the featured speaker at the sectional meeting banquet. The title of her talk was "The Pork Barrel, the Bandwagon, and the Ivory Tower."

Twin Cities Geologists

The organization Twin Cities Geologists (TCG) recently celebrated its 30th birthday with a hog-roast picnic. TCG was started in 1957 by Don Lindgren (president), George Thiel (vice president), and Fred Swain (secretary/treasurer), and its first meeting was held in Fred Swain's office at the University. MGS has occasionally sponsored and currently sponsors the organization and schedules monthly meetings and speakers at area restaurants. The activity and membership have fluctuated through the years, but interest in the group persists, with membership now near 100. Annual dues are nominal, the atmosphere is informal, and the intent is to bring together geoscience professionals for informal interaction and discussion. If you would like to join, or just want further information, please contact Doug Bergstrom or Bruce Bloomgren at MGS.

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We are seeking information from anyone who felt the earthquake on Wednesday, June 10, 1987, at 6:49 p.m. Minnesota has always been regarded as a seismically stable area. Since 1860, there have been only nine well-documented earthquakes with epicenters inside the state border. Occasionally, larger earthquakes centered *outside* the state are felt in Minnesota. The epicenter of the June 10 earthquake was near Lawrenceville, Illinois. MGS collects historical information from people who feel these earthquakes. We use their reports to map zones affected by earthquakes and their relative intensity. That way we can compare the effects of different earthquakes in the state.

If you felt the earthquake on June 10, send a card or letter to MGS. We would like to know where you were, what kind of structure you were in and on which floor, how long the shaking lasted, and any other observations. Reports from areas outside the Twin Cities will be especially useful.

Quantitative geophysicist and scientists seeking personal reports
EARTHQUAKE TALES

GSA NORTH-CENTRAL MEETING

The 21st Annual Meeting of the Geological Society of America (GSA) North-Central Section, held April 28 to May 3, brought 744 people to downtown St. Paul—near record-breaking numbers for this section. Major symposia were Ordovician stratigraphy and paleontology, hydrogeology of glacial terranes, tectonics of Precambrian terrane boundaries, the eastern side of the Cretaceous seaway, Upper Mississippi valley karst, Keweenawan rocks, and Quaternary paleoecology and glacial geology—this last in honor of Herbert E. Wright, Jr.

The meeting was organized by Peter J. Hudleston, Section chairman, and Robert E. Sloan, vice chairman and program chair, both of the Department of Geology and Geophysics at the University. David L. Southwick of MGS organized the field trips. Most of the students, staff, and faculty of the School of Earth Sciences, together with many from other colleges, were involved in some aspect of the meeting's planning or activities. In conjunction with the meeting, MGS published three guidebooks and a Report of Investigations.

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RECENT MGS PUBLICATIONS

- Bibliography of Minnesota geology, 1981-1985**, compiled by L. Swanson, N. H. Balaban, and G. B. Morey. 1987. 107 p. \$10.00. (Bulletin 47) *Includes index.*
- Minnesota Geological Survey Newsletter**, v. 2, no. 2, Fall 1986; v. 3, no. 1, Spring 1987 (this issue). *Free over the counter at MGS Maps and Publications Sales; requests by mail must be accompanied by \$1.00 to cover postage and handling.*
- Field trip guidebook for the Upper Mississippi valley, Minnesota, Iowa, and Wisconsin**, edited by N. H. Balaban. 1987. 185 p. \$10.00. (Guidebook Series 15) *Trips are Karst hydrogeology of southeastern Minnesota; Geology of the St. Croix River valley; Middle Ordovician fossils of the Twin Cities, Minnesota; Middle and Late Ordovician strata and fossils of southeastern Minnesota and Iowa; Rock Elm disturbance, Pierce County, Wisconsin; and Quaternary geology of southeastern Minnesota.*
- Field trip guidebook for Quaternary and Cretaceous geology of west-central Minnesota and adjoining South Dakota**, edited by N. H. Balaban. 1987. 84 p. \$10.00. (Guidebook Series 16) *Trips are Geomorphology and Pleistocene glacial geology of central Minnesota; and Cretaceous rocks on the eastern margin of the Western Interior Seaway, western Minnesota and eastern South Dakota.*
- Field trip guidebook for selected areas in Precambrian geology of northeastern Minnesota**, edited by N. H. Balaban. 1987. 70 p. \$10.00. (Guidebook Series 17) *Trips are Structural geology of the boundary between Archean terranes of low-grade and high-grade rocks, northern Minnesota; and Geology of the Keweenawan (Upper Precambrian) Beaver Bay Complex in the vicinity of Silver Bay, Minnesota.*
- Simple Bouguer gravity map of Minnesota, International Falls sheet**, by V. W. Chandler, S. J. Mills, and R. J. Ferderer. 1987. Scale 1:250,000. \$4.00. (Miscellaneous Map M-62)
- Middle and Late Ordovician lithostratigraphy and biostratigraphy of the Upper Mississippi valley**, edited by R. E. Sloan. 1987. 232 p., 75 figs., 15 tables, 30 pls. \$25.00. (Report of Investigations 35)

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

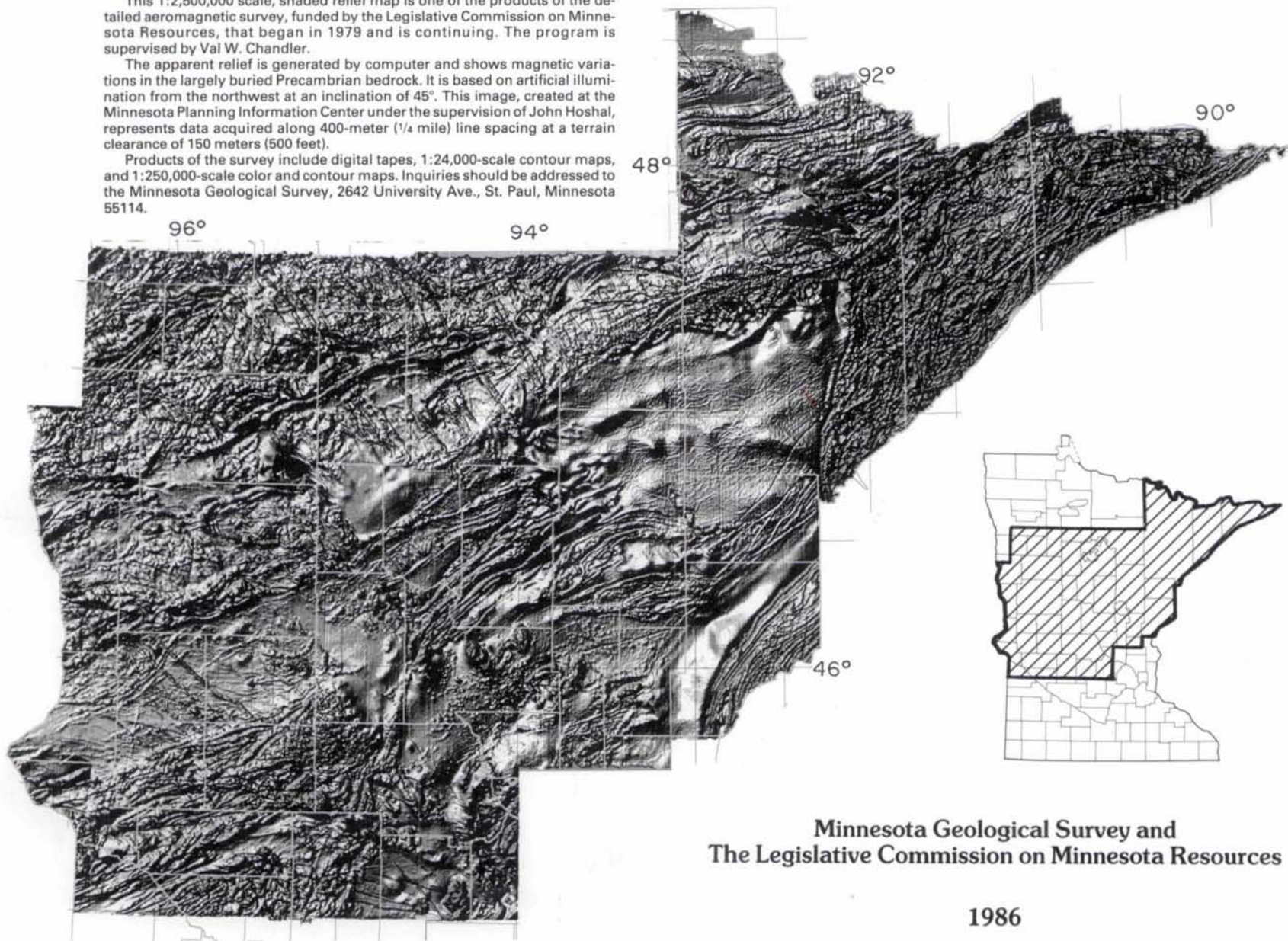
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SHADED-RELIEF AEROMAGNETIC MAP OF CENTRAL AND NORTHEASTERN MINNESOTA

This 1:2,500,000 scale, shaded relief map is one of the products of the detailed aeromagnetic survey, funded by the Legislative Commission on Minnesota Resources, that began in 1979 and is continuing. The program is supervised by Val W. Chandler.

The apparent relief is generated by computer and shows magnetic variations in the largely buried Precambrian bedrock. It is based on artificial illumination from the northwest at an inclination of 45°. This image, created at the Minnesota Planning Information Center under the supervision of John Hoshal, represents data acquired along 400-meter (1/4 mile) line spacing at a terrain clearance of 150 meters (500 feet).

Products of the survey include digital tapes, 1:24,000-scale contour maps, and 1:250,000-scale color and contour maps. Inquiries should be addressed to the Minnesota Geological Survey, 2642 University Ave., St. Paul, Minnesota 55114.



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