

July 1, 1993

LCMR Final Status Report - Summary - Research

I. Subsurface Greenstone Belts in Southwestern Minnesota - Minerals 1

Program Manager: D.L. Southwick
Minnesota Geological Survey
2642 University Avenue
St. Paul, MN 55114-1057
612-627-4780

A. M.L. 1991, Chapter 254, Art. 1, Sec. 14, Subd. 11(a) Appropriation: \$120,000
Balance: \$00.00

This appropriation is to the University of Minnesota, Minnesota Geological Survey, to apply aeromagnetic interpretation techniques and test drilling to determine greenstone and associated mineral potential in southwestern Minnesota.

B. Compatible Data: During the biennium ending June 30, 1993, the data collected by projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the Information Policy Office. In addition, the data must be provided to and integrated with the Minnesota Land Management Information Center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

C. Match - N/A

II. Narrative

The recently completed aeromagnetic survey of southwestern Minnesota has identified several anomalies mainly in Nobles, Murray, and Lincoln Counties that may be indicative of greenstone-type metavolcanic sequences. Greenstone sequences are the host for many important mining districts in Canada and elsewhere in the world. Because the rocks responsible for the greenstone-like aeromagnetic anomalies in southwestern Minnesota are covered by younger materials, they must be evaluated by geophysical methods and selective drilling. If greenstone sequences are in fact present in southwestern Minnesota, they could be the habitat for deposits of gold, copper, lead, zinc, and other

metals. This potential would attract mineral exploration interest to a sector of the state that has never been systematically explored.

III. Objectives

A. To establish, through a combination of geophysical and geological techniques, the geological attributes of rocks that cause greenstone-like aeromagnetic anomalies in southwestern Minnesota, and assess their viability as mineral exploration targets.

A.1. Narrative: Although the characteristics of aeromagnetic anomalies in parts of southwestern Minnesota are strongly suggestive of greenstone-belt sources, other sources are possible. The only way to be certain about the subsurface geologic origin of the observed geophysical patterns is to acquire direct samples of the buried Precambrian rock where the geophysical anomalies occur.

A.2. Procedures: The work will involve (a) computer-assisted analysis and interpretation of aeromagnetic and gravity data; (b) ground-based magnetic and gravity surveys to assist with optimal siting of shallow drill holes; (c) geological analysis of previous drilling data from all available sources; (d) confirmatory drilling of 7-9 test holes; (e) follow-up laboratory studies (petrography; X-ray mineralogy; chemical analysis) to determine the mineral composition, geologic structure, and chemical attributes of recovered core samples. Each test hole will pass through the unconsolidated overburden material and extend 10-20 feet into the underlying crystalline bedrock. Samples of the unconsolidated overburden will be collected systematically as drilling progresses; the bedrock will be sampled by diamond coring. Every test hole will be logged by down-hole geophysical methods (natural gamma, self-potential, others) and abandoned to code.

A.3. Budget:	LCMR Funds	Matching Funds
a. Amount Budgeted	\$120,000	-0-
b. Balance	\$00.00	-0-

A.4. Timeline for Products/Tasks

July 91	Jan 92	June 92	Jan 93	June 93
a.	b.	c.	d.	e.

- a. Acquisition and analysis of geophysical and geological data pertinent to drill-site selection, late summer and fall, 1991
- b. Drill sites selected, late fall 1991

- c. Drilling program (7-9 holes), spring and summer 1992
- d. Follow-up geophysical studies, analysis of drill materials, fall and winter 1992-93
- e. Synthesis and report writing, spring 1993

A.5. Status:

This project has confirmed the presence of greenstone belt rock assemblages in the subsurface of southwestern Minnesota. Because greenstone belts are a geological environment in which many significant deposits of gold, silver, copper, and zinc have been found, as, for example, in South Africa, Australia, Russia, and Canada, the confirmation of greenstone belts in specific places beneath the agricultural land of southwestern Minnesota provides a rationale for eventual mineral exploration in the area. This does not mean that a mineral boom is likely in the near term. At the present time there are many technical and economic deterrents to mineral exploration activity, including the extensive cover of glacially deposited debris that masks the rocks of prime interest and makes the exploration process difficult and costly. Nevertheless, as exploration technology evolves and business conditions change in the future, a mineral industry could develop in southwestern Minnesota that would diversify and stimulate the local economy.

Perhaps of greater significance than the mineral favorability confirmed by this study were discoveries made with respect to ground water resources. Several of the test holes drilled to acquire bedrock information on mineral-related geophysical targets provided valuable and unexpected data on deep sand and gravel aquifers within the glacial section. The aquifers found along the north side of the buried bedrock high known as Sioux Ridge have the physical potential for high yields of ground water. Although pumping tests and water-quality analyses are required to assess fully their viability as sustained sources of water, the water-bearing deep sands and gravels encountered as a side benefit of this minerals project appear to offer a local alternative to continued use of near-surface, environmentally vulnerable aquifers. They also may be an alternative to importing water from outside the region. Further hydrogeologic research aimed specifically at evaluating this potential ground water resource is clearly warranted.

The full technical results of this project will be published by the Minnesota Geological Survey as Information Circular 39 in July or August 1993. In addition, certain of the results will be incorporated in the Regional Hydrogeologic Assessment of Southwestern Minnesota that is now being prepared jointly by the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Further funding will be sought for

B) Dale R. Setterholm
Geologist
Minnesota Geological Survey, University of Minnesota

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Mr. Setterholm's specialties are the stratigraphy and sedimentology of Cretaceous rocks in Minnesota, the geology of clay deposits, and applied down-hole geophysical logging. He has much practical experience with Minnesota drilling projects. He has published several papers, reports, and abstracts on Cretaceous strata and clay deposits, and is working on a major synthesis of the Cretaceous geology of southwestern Minnesota. Mr. Setterholm will be in charge of lithologic and geophysical logging at the drill sites, and will supervise junior staff in the field.

Selected publications:

Setterholm, D.R., Morey, G.B., Boerboom, T.J., and Lamons, R.C., 1989, Minnesota kaolin clay deposits: A subsurface study in selected areas of southwestern and east-central Minnesota: Minnesota Geological Survey Information Circular 27, 99 p.

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VII. Reporting

Semiannual status reports will be submitted not later than Jan. 1, 1992, July 1, 1992, Jan. 1, 1993, and a final status report by June 30, 1993. A technical summary of all findings will be published by MGS shortly after the project concludes.

1991 RESEARCH PROJECT ABSTRACT
FOR THE PERIOD ENDING JUNE 30, 1993

This project was supported by MN Future Resources Fund

TITLE: Subsurface Greenstone Belts in Southwestern Minnesota
PROGRAM MANAGER: Dr. David L. Southwick
ORGANIZATION: MN Geological Survey
LEGAL CITATION: M.L. 91, Ch. 254, Art. 1, Sec. 14, Subd. 11(a)
APPROP. AMOUNT: \$120,000

STATEMENT OF OBJECTIVES

To establish, through a combination of geophysical and geological techniques, the geological attributes of rocks that cause greenstone-like aeromagnetic anomalies in southwestern Minnesota, and assess their viability as mineral exploration targets.

OVERALL PROJECT RESULTS

This project has confirmed greenstone-belt rock assemblages in the subsurface of southwestern Minnesota through geophysical analysis and test drilling. Because greenstone belts are a geological environment in which many significant deposits of gold, silver, copper, and zinc have been found, as, for example, in South Africa, Australia, Russia, and Canada, the confirmation of greenstone belts in specific places beneath the agricultural land of southwestern Minnesota provides a rationale for eventual mineral exploration in the area by private companies. Particularly intriguing as a speculative exploration target is a belt in Yellow Medicine County that contains diverse mafic and ultramafic rocks spatially associated with a regional shear zone.

Perhaps of greater significance than the indications of mineral favorability were discoveries made with respect to groundwater resources. Several of the test holes encountered deep, well protected sand and gravel aquifers within the glacial section. Deep aquifers along the north side of the Sioux Ridge have the physical potential for high groundwater yields, although pumping tests and water-quality analyses are required to assess them as sustained sources of water. These water-bearing deep sands and gravels may offer a local alternative to the use of environmentally vulnerable near-surface aquifers.

PROJECT RESULTS USE AND DISSEMINATION

The full technical results of this project will be published by the Minnesota Geological Survey (MGS) as Information Circular 39 in July or August 1993. Some of the results will be incorporated in the Regional Hydrogeologic Assessment of Southwestern Minnesota that is now being prepared jointly by the MGS and the Minnesota Department of Natural Resources. Specific elements of the work have been shared with local watershed districts and school classes. Additional presentations at technical and public forums are planned.

July 1, 1993

LCMR Final Status Report - Detailed for Peer Review - Research

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- c. Drilling program (7-9 holes), spring and summer 1992
- d. Follow-up geophysical studies, analysis of drill materials, fall and winter 1992-93
- e. Synthesis and report writing, spring 1993

A.5. Status:

The project has been completed essentially as planned.

Eleven geological test holes were drilled on geophysical targets to determine whether or not greenstone-belt assemblages of metamorphosed supracrustal rock occur upon or within the Archean gneiss terrane of southwestern Minnesota. Relatively low-grade metamorphic rocks of the greenstone-belt lithic association were intersected at five drill sites; the rock types recovered were metadiabase, meta-andesite, picritic or komatiitic metabasalt, metagabbro, and serpentized peridotite. Drilling at five other sites encountered a variety of rock types including mesocratic quartz diorite gneiss, granodiorite gneiss, Sioux Quartzite (unexpected at the places found), and skarn. The skarn discovery is a "first" in Minnesota, and both the geological setting and the significance of this rather uncommon rock type remain to be worked out. The eleventh drill hole did not reach basement because of poor drilling conditions in the overlying Quaternary section.

An east-west belt of moderately metamorphosed mafic rocks in the subsurface of southern Yellow Medicine County is spatially associated with and perhaps related to a regional shear zone at the boundary between two tectonic blocks of cratonic gneiss. This association with shearing raises several possibilities for the tectogenesis of the greenstone assemblage, and suggests several strategies for mineral exploration (gold, base-metal massive sulfide deposits) in the belt. Although much additional geologic and geophysical work will be needed to establish its mineral potential, the belt definitely is a reasonable target for future exploration activity. The present drilling project has documented a diverse suite of rocks in the belt and provided a valuable sample set on which to base future research.

Despite the geological favorability of the subsurface Yellow Medicine County greenstone belt as a mineral exploration target, a near-term boom in exploration is unlikely. At the present time the economic and political disincentives to domestic mineral exploration and mining outweigh the incentives of favorable geological targets, and until that picture changes there is little probability of private investment in the speculative potential of southwestern Minnesota.

Perhaps of greater significance than the mineral favorability confirmed by this study were discoveries made with respect to ground water resources. Several of the test holes drilled to acquire bedrock information on mineral-related geophysical targets provided valuable and unexpected data on deep sand and gravel aquifers within the glacial section. The aquifers found along the north side of the buried bedrock high known as Sioux Ridge have the physical potential for high yields of ground water. Although pumping tests and water-quality analyses are required to assess fully their viability as sustained sources of water, the water-bearing deep sands and gravels encountered as a side benefit of this minerals project appear to offer a local alternative to continued use of near-surface, environmentally vulnerable aquifers. They also may be an alternative to importing water from outside the region. Further hydrogeologic research aimed specifically at evaluating this potential ground water resource is clearly warranted.

The full technical results of this project will be published by the Minnesota Geological Survey as Information Circular 39 in July or August 1993. In addition, certain of the results will be incorporated in the Regional Hydrogeologic Assessment of Southwestern Minnesota that is now being prepared jointly by the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Further funding will be sought for topical, academic research on some bedrock cores of special geological significance that were obtained from this drilling project, and also for the applied hydrogeological research (aquifer evaluation) mentioned above. The latter may be proposed as a project for the LCMR to consider for the next biennium.

A.6. Benefits: If this project demonstrates the existence of greenstone-belt metavolcanic sequences in the subsurface of southwestern Minnesota, it will open the area to the short-term economic benefits of mineral exploration by private-sector firms. Successful exploration could ultimately result in the economic benefits of mining, but such an outcome cannot be reasonably predicted at this time. In addition, the data obtained on the composition and stratigraphy of the overburden materials will be useful to ground water research and management activities, and may be significant in the context of nonmetallic mineral resources (e.g. sand, gravel, clay). Such data will be reported to appropriate agencies and individuals on a continuing basis.

IV. Evaluation

The short-term success of this program will be judged on whether or not rock successions are found that have mineral potential. If they are found, economic benefits should follow. Viewed from a broader perspective, however, the project cannot fail because the

data developed, whatever they turn out to be, will be completely new and potentially of value to a variety of users.

V. Context

- A. Available information is very sparse on the composition, structure, and significance (both scientific and economic) of the subsurface rocks of Minnesota southwest of the Minnesota River. The aeromagnetic survey suggests the existence of a varied and complex geology about which very little is known in detail. Present data are totally inadequate for meaningful mineral resource evaluation.
- B. The proposed project is a logical outgrowth from and application of the LCMR-funded aeromagnetic survey. Previous MGS projects in other parts of Minnesota that were a similar combination of regional geophysics and confirmatory test-drilling have produced data and concepts that are of value to both applied and academic fields in of the earth sciences. Although the principal thrust of the project is mineral-resources related, we anticipate that the results will be of interest to ground-water specialists and academic geologists as well as mineral exploration firms. We further anticipate that this work may lead to further scientific drilling in the area.
- C. There have been no previous systematic studies of the bedrock southwest of the Minnesota River by any public or private entity, so far as we know. The area has not been explored for minerals, and, until recently, there was no impetus to investigate deep ground-water resources because shallow ground water of acceptable quality was in adequate supply. Previous LCMR work in the region includes the aeromagnetic survey flown in 1987-88 (MGS Aeromagnetic Map A-8 and supplemental materials) and a small drilling project in an area north and northeast of the proposed study (summarized in MGS Information Circular 31).
- D. Related program, 1990-91 Biennium:
Aeromagnetic Surveying Program in Minnesota: Budget: \$630,000 (M.L.89, Ch.355, Sec.29, APID-62200-01-13)

VI. Qualifications

1. Program Manager:

Dr. David L. Southwick
Assistant Director

Minnesota Geological Survey, University of Minnesota

Ph.D. Geology, Johns Hopkins University, 1962

The program manager has conducted geological research investigations in Minnesota since 1968. His studies have focused primarily on the structural geology and petrology of the Precambrian basement rocks of northeastern and southwestern Minnesota, and have included considerable integration of geophysical and geological techniques. He has managed the Scientific Shallow Drilling Program of the MGS since its inception in 1980. He has published about 50 refereed journal articles and geologic maps, about 50 abstracts, and numerous agency reports on various aspects of Minnesota geology. The program manager will coordinate all aspects of the proposed project and take primary responsibility for siting drill holes and interpreting the basement rocks recovered.

Selected publications:

- Southwick, D.L., Morey, G.B., and McSwiggen, P.L., 1988, Geologic map (scale 1:250,000) of the Penokean orogen, central Minnesota, and accompanying text: Minnesota Geological Survey Report of Investigations 37, 25 p. + map.
- Southwick, D.L., Morey, G.B., and Mossler, J.H., 1986, Fluvial origin of the Lower Proterozoic Sioux Quartzite, southwestern Minnesota: Geological Society of America Bulletin, v. 97, p.1432-1441.
- Southwick, D.L., Setterholm, D.R., and Boerboom, T.J., 1990, Scientific test drilling in west-central Minnesota: Summary of lithologic and stratigraphic results, 1987-88, and some preliminary geological conclusions: Minnesota Geological Survey Information Circular 31, 98 p.

2. Major Cooperators:

- A) Dr. Val W. Chandler
Senior Scientist (Geophysicist)
Minnesota Geological Survey, University of Minnesota

Ph.D. Geophysics, Purdue University, 1977
M.S. Geophysics, Purdue University, 1973

Dr. Chandler's specialty is potential field geophysics, primarily the measurement, enhancement, and geologic interpretation of small variations in the earth's magnetic and gravity fields. He has directed the LCMR aeromagnetic program since its beginning in 1979, and has published numerous papers, maps, and abstracts based on the aeromagnetic survey. In addition, he has supervised the research of several graduate students in geophysics who have worked on Minnesota projects. He has collaborated with the Program Manager and graduate students on various regional geophysics-geology projects in southwestern Minnesota. Dr. Chandler will coordinate the geophysical components of the project, which will include analysis and enhancement of the aeromagnetic data and existing gravity data, ground magnetic and gravity surveys, and rock-property measurements.

Selected publications:

Chandler, V.W., 1989, Aeromagnetic map of Minnesota, southwestern region: Minnesota Geological Survey Aeromagnetic Map A-8, scale 1:250,000.

Chandler, V.W., and Ferderer, R.J., 1989, Copper-nickel mineralization of the Duluth Complex, Minnesota--a gravity and magnetic perspective: *Economic Geology*, v. 84, p. 1690-1696.

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