Compilation of Mineral Resources Digital Information for the Minnesota River Valley Corridor

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Contents

Plates

Digital files available on CDROM and on the Department of Natural Resources website, www.dnr.state.mn.us on the Division of Lands and Minerals page.

Introduction and Purpose

The Minnesota River Valley contains hundreds of miles of geological outcrops, or exposures of layers of geological materials, that are otherwise uncommon in their diversity and extent in the remainder of Minnesota. It is not surprising that the economic value of some of these geological materials was recognized more than a hundred years ago. Mining has occurred continuously since then for granite, limestone, clay, silica sand, quartzite, and/or sand and gravel. There will be continued future demand for mineral resources for our society as our population and economy grows. Will that future demand be served from mines in this region?

There are many direct and indirect benefits from mining for the local economy. Direct benefits include the creation of wealth through jobs, royalty payments to the land owners, and profits for the business. Indirect benefits include contributions to the local economy for suppliers to the mine, and through local tax revenue. Another example of indirect benefits from local availability of construction aggregates is that the cost to transport such a bulk commodity is reduced significantly. Since governments purchase approximately half of the construction aggregates on a regional basis, there can be significant cost savings to governments if local aggregates are available. The Twin Cities Metropolitan Council estimated that if local aggregates are not available for them, there could be an increase of $430 million (or about 25%) in their 20 year plan that calls for $1.7 billion in the transportation capital improvement program. Another indirect benefit is that when local aggregates are available, the trucks that haul them make shorter trips. These shorter hauls do not cause as much traffic congestion on the main roads, nor do they cause as much wear and tear on the roadways as longer hauls. This is most noticeable near regional market centers such as Mankato, where significant tonnages are hauled each year. In general, for any of these bulk mineral commodities, the ultimate consumer cost will be lower when commodity haul costs are lower.

Land use zoning is an important factor influencing whether mineral commodities will be available locally in the future. This compilation places mineral resource information in the hands of local decision makers, and is intended to support their long-range planning and zoning work. This information, compiled and distributed in digital format, has not been readily available publicly before.

Two main results are presented here. The first is the location of existing industrial mineral mines. This shows where mining is or has occurred recently. The second is a general regional-scale interpretation of the available geological information to predict areas where the geology is favorable for potential mineral resources.

In this report, the term Minnesota River Valley Corridor is used. This area (Plate 1) encompasses the length of the Minnesota River and a width of approximately two townships on each side of the river. Major landforms within the Minnesota River Valley are shown. The study area contains the majority of natural geological outcrops, mines, and potential mineral resources in the region.

To improve the report's readability, terminology for many different types of mineral resources is simplified into five general commodity types (Table 1). Common industrial terms are used here in place of geological terms. Hence, mining of the rock type "gneiss" is lumped into the granite commodity type.

Table 1. Description of commodity terminology used in this report.

Commodity Term Used :	Refers to a Class of Industrial Mineral Commodities:
Granite	Produced from any fresh (unweathered) Precambrian crystalline bedrock type in the Minnesota River Valley, such as granite, gneiss, monzonite, gabbro, amphibolite, basalt, or peridotite, for various end uses.
Quartzite	Produced from a Precambrian crystalline bedrock formation composed of quartz sand grains cemented together with silica to form a very hard, durable rock, for various end uses.
Limestone	Produced from carbonate bedrock formations of variable composition, including limestone and dolomite, for various end uses.
Silica Sand	Produced from sandstone bedrock formations - not from common sand found in sand and gravel pits - to make high value, high purity, highly rounded grains of quartz sand, for various end uses.
Industrial Clay	Produced from various types, grades, and colors of kaolin clays, ball clays, Cretaceous shales, and Cretaceous sediments for various end uses.
Sand and Gravel	Produced from glacial deposits composed of crushed bedrock such as granite, basalt, limestone, and shale from many distant sources for various end uses in construction.

The mineral commodities included in this report are granite, quartzite, limestone, silica sand, industrial clay, and sand and gravel. Each has many end uses. Some **granite** quarried locally for dimensional stone is marketed worldwide. Other local granite is crushed for landscape rock, railroad ballast, and high quality construction aggregate for markets across Minnesota and a number of other states. Crushed **quartzite** has many applications, such as railroad ballast, high quality construction aggregate, landscape rock, poultry grit, and traction grit for markets in Minnesota and nearby states. **Limestone** is quarried for dimensional stone and crushed for construction aggregate, landscape rock, and agricultural lime soil amendment. The dimensional limestone is marketed worldwide, and the other limestone products are marketed across Minnesota. **Silica sand** produced here is sold worldwide as a raw material used to pump down into petroleum wells for improved petroleum recovery, and also as a raw material to make glass. The silica sand here ranks with the highest quality in the world, due to its spherical shape and high purity. **Industrial clay** is mined for use as the main raw material in brick making (such as in the only brick factory in Minnesota at Springfield), as a raw material in production of cement in Iowa, livestock feed filler, specialty ceramics, and for modeling clay. **Sand and gravel** are mined for local use as construction materials for roads, bridges, trails, schools, houses, farms, commercial and retail buildings, and government buildings. The average sand and gravel consumption in Minnesota can be expressed as 10 to 12 tons per person per year in recent years.

Brief Geological History

During a 2,000 year timespan, from approximately 11,000 to 9,000 years ago, a very large river called Glacial River Warren occupied what we now call the Minnesota River Valley. At some stages, it occupied the entire width of the valley, with water levels near the top of the valley. That river was fed by Glacial Lake Agassiz, a very large lake created by the meltwaters of the last glacier, and a lake that no longer exists in Minnesota. The erosion caused by Glacial River Warren was the primary factor in the creation of the Minnesota River Valley. Erosion caused by Glacial River Warren cut down through glacial drift and soft rock formations. These unconsolidated materials were washed downstream to the ancestral Mississippi River and beyond. In the western portion of the valley, erosion cut all the way down to the hard and resistant Precambrian crystalline bedrock formations. These actions created the Minnesota River Valley, which is more than five miles wide near Le Sueur and more than 200 feet deep nearby at St. Peter. The current Minnesota River is very small in comparison to the Glacial River Warren.

If the geologic materials are summarized in a simplified form as a stack of layers, then they can be described as follows from top to bottom.

1) The top of the stack has many layers of unconsolidated (not cemented together to form bedrock) glacial drift and is composed of various amounts of boulders, cobbles, gravel, sand, silt, and clay. The glacial drift is up to a few hundred feet thick. When these materials have been washed by the action of moving water, gravel and sand deposits are formed. For example, the Glacial River Warren created many sand and gravel deposits within the valley, but water from the melting glacier created temporary rivers that also created sand and gravel deposits in many places outside the valley (see gravel pits, Plate 2).

2) The next major geologic unit in the stack does not occur everywhere. In some places, beneath the glacial drift materials are layers of shale or clay-bearing materials with a thickness of 10 to 50 feet, deposited at the bottom of a shallow sea during part of the Cretaceous period. Also during the Cretaceous, but after the sea left the area, a semi-tropical climate caused the weathering of bedrock that created clay-bearing materials. Some of these deposits contain a high content of kaolin clay that is marketable.

3) The third major geologic unit in the stack would be the limestone and sandstone formations, that occur throughout southeastern Minnesota as layers up to 100 feet thick or more, along the valley from approximately Mankato to the Mississippi River. These materials accumulated in different environments related to a sea that encroached on the area during the Cambrian and Ordovician geologic time periods. Specific layers within this unit are marketable as limestone products or silica sand products.

4) The fourth major geologic unit at the bottom of the stack would be the Precambrian bedrock formations, here including the commodities granite and quartzite.

Methods

The majority of information cited in the results section was developed through a series of Department of Natural Resources (DNR) contracts with the Minnesota Geological Survey and the Natural Resources Research Institute. The contracts (see listing, Table 2) were funded through a grant from the State of Minnesota Minerals Diversification Fund for a proposal by the DNR. The objective of the contracts was to develop in Arcview digital format the most up-to-date information on as many commodities as possible in the study area.

The method used for the overburden thickness estimate involved interpretations of data from water wells, outcrops, and land surface elevation (Setterholm, 1998). Bedrock elevation was determined from water well logs after the field locations of the wells were verified. These bedrock elevation data and outcrop elevation data were plotted, contoured, and gridded to create a "top of bedrock" elevation model. That top of bedrock elevation model was subtracted from a gridded land surface elevation model from the U.S. Geological Survey, to create a depth to bedrock grid. That grid was contoured at 50 foot intervals to obtain the 50 foot depth to bedrock portrayed here.

The method used here to describe where potential mineral resources are likely to occur is straightforward. The location of geological units known at this time to be likely to contain each mineral commodity is combined with a best estimate of the overburden thickness no greater than is considered feasible for mining. For quartzite, granite, silica sand, and limestone (Plate 3), this is 50 feet. For industrial clay resources (Plate 4), a 100 foot thickness of overburden is applied. Industrial clay deposits typically occur, and are mined, along the valley slopes, where overburden thickness may be up to100 feet to the main surface of the surrounding land. These are primarily geological factors, without regard to specific economic and other criteria, and are deemed appropriate to this regional scale review over a long time period. For example, the occurrence of granite within 50 feet of the surface is identified as potential granite mineral resource, without regard to mineral quality, extent, quantity, or suitability of any specific granite product. There is no attempt here to evaluate suitability of specific sites, economic factors, zoning, permitting, ownership, or other criteria. The prediction of these factors 10 or 20 years into the future is simply not feasible. It is predicted, for example, that when a granite commodity permit is requested within the study area, it is very likely to occur within the identified mineral potential zone.

Table 2. Summary of contract information developed for this project. See the complete citations in the reference section of the report.

Subject [Specifically for this Minnesota River Valley Corridor and report.]	Purpose	Author & Agency Performing the Contract
Pit and Quarry Locations	Identify all visible pits and quarries on 1991 air photos.	Sara Gran, Minnesota Geological Survey
Precambrian Bedrock Outcropping Map Project	Develop the Precambrian bedrock geology map information created by Grant in 1966, primarily outcrop locations and rock types, into a digital format. This is specific to the area between Redwood Falls and Fairfax.	Julie Oreskovich, Natural Resources Research Institute
Industrial Clay Project	Develop a new classification of clay mineral potential from Fairfax to Granite Falls. Compile existing information relative to clay mineral potential in the remainder of the Minnesota River Valley.	Larry Zanko and John Heine, Natural Resources Research Institute
Bedrock Topography & Depth- to- Bedrock Interpretation	Identify the areas near bedrock outcrops that have shallow overburden that might mean mining of the bedrock is considered.	Dale Setterholm, Minnesota Geological Survey
Water Well Locations & Data Developed for the County Well Index (CWI)	For portions of 6 counties, field locate water wells, compile data & enter into County Well Index.	Dale Setterholm, Minnesota Geological Survey

Source Material for this Digital Information Compilation

Diverse geological information was taken from the primary report sources (see Table 2) to create an overall interpretation. The original reports are available upon request. These include a digital version of a bedrock geology map (Oreskovich, 1998) for a part of the area, a digital glacial drift thickness and bedrock topography map (Setterholm, 1998; scale 1:100,000) and a compilation report with digital maps regarding clay resource information (Zanko, 1998). Details pertinent to each report cited in this compilation can be found in the documentation for the original report.

A summary of which source material was used to develop the digital files is as follows:

- The landform map units on Plate 1 are available for download on the DNR Data Deli (see Geomorphology of Minnesota at deli.dnr.state.mn.us).
- The pits and quarries on Plate 2 are from Gran (1997).
- The limestone map units on Plate 3 are from Ellingson (1999 for Blue Earth County; 2000, for Nicollet County; in progress for Le Sueur County) and from Southwick et al., (2000) for the seven counties of the Twin Cities Metropolitan Area. The silica sand-bearing bedrock map units on Plate 3 is from Balaban and McSwiggen (1982) for Scott County, and from Ellingson (1999 for Blue Earth County; 2000 for Nicollet County; in progress for Le Sueur County).
- The granite (excluding the quartzite) Precambrian bedrock outcrop areas in Renville, Redwood, Brown, and Nicollet Counties on Plate 3 are from Oreskovich (1998, derived from work by Grant, 1966). The granite Precambrian bedrock outcrop areas in Big Stone, Swift, Lac Qui Parle, Chippewa, and Yellow Medicine counties are from Setterholm (1998). The Precambrian bedrock quartzite map unit in Nicollet county is taken from Ellingson (2000).
- The industrial clay map units on Plate 4 are modified from Zanko et al., (1998).

Sand and Gravel Resources

While sand and gravel mines that were visible on 1991 air photos are identified, mapped, and included in this study, potential sand and gravel resources are treated differently than the other commodities in this report. No prediction of potential resources is provided here, for two reasons. One is that sand and gravel distribution is not confined to the main portion of the Minnesota River Valley as are the other commodities (see the existing pits, Plate 2). The second reason is that prediction of potential sand and gravel resource sites requires much more detailed information than is currently available. The sand and gravel resources are so widely distributed in the glacial drift--in contrast to the confined distribution of other commodities in the main deep valley -- that we cannot do an adequate job at this time. However, sand and gravel resource information for construction aggregates in some parts of the Minnesota River Valley Corridor have been mapped previously and are available in some detail for 6 pertinent counties--Hennepin, Carver, Dakota, and Scott from Southwick, et al. (2000), and Blue Earth and Nicollet from Ellingson (1999 and 2000). To obtain the maps and datasets, see the Division of Lands and Minerals page on the Department of Natural Resources website, www.dnr.state.mn.us. Similar mapping in Le Sueur County is in progress at this time.

Results

The primary products of this work are map plates (in both PDF and postscript formats) and data (in Arcview shapefile format) on a compact disc or the DNR website. There is more information on the compact disk or website than is presented here in summary form on the plates. The map plates, created using digital information and Arcview version 3.2a software, are intended for the general audience to view the entire study area. The digital information permits flexibility for the user to examine in more detail a particular geographic area, such as a county, or one commodity, while providing an efficient means to provide many layers of information for distribution for this large study area. It also provides the means to integrate many layers of commodity information onto one geographic area, such as a county. The set of map plates was created to summarize the information.

- The major landforms of the Minnesota River Valley (Plate 1) include the floodplain area, which is designated here generally by the *wetlands*, *alluvium sediments*, and *bedrock outcrops* in the river bottoms, the *slope walls* of the main valley and secondary valleys near where they enter the main valley, and *terraces* within the main valley, which are relatively flat benches created during past (more than 9,000 years ago) high water flood events. Note the relatively flat plain surrounding the main valley.
- Known mineral resources (Plate 2) are indicated by the outline of pits and quarries that were visible on 1991 air photos, and limited data that summarizes commodities using six color codes. Note the distribution of one active quartzite quarry near New Ulm, numerous industrial clay pits in the west-central area, numerous granite quarries in the west-central area, the silica sand quarry operations near Kasota, and numerous limestone quarries in the eastern area.
- Plates 3 and 4 show where likely exploration for potential mines for granite, quartzite, limestone, silica sand and industrial clays will occur.

Mineral commodities in the Minnesota River Valley Corridor fall into one of three different categories of *geological information* for the purposes of this report: fairly complete, incomplete, and so incomplete that a prediction cannot be made. The geological data presented here is fairly complete for granite, quartzite, silica sand, and limestone, because we have a good idea where these rock formations occur. However, for **industrial clay** the information we have is incomplete, since we do not know all the places where it occurs buried just under the surface. For **sand and gravel**, our information is so incomplete that we cannot provide the second component here-- where potential resources are located. Thus, we have compiled the mineral resource information as we know it at this time. It is likely that our information will grow in the future, and the picture will change.

Resource Information: Uses and Limitations

There are limitations to the data, primarily expressed by the scale for each set of information. Each data set has a scale at which it is appropriate to display and use the information. For example, the limited number of data points --primarily water wells down to bedrock and bedrock outcrops -- available to compile the glacial drift thickness information was a constraint that led that author to develop a 1:100,000 scale product. It is not appropriate, therefore, to apply this data to scales larger than this. To determine the appropriate scale for a given data set, check the documentation (metadata) in the original reference for that data set.

The viability of any particular mine is influenced by its site, mineral quality and volume, overburden thickness, location, ownership, market preference, distance to market and transportation costs, permit requirements, environmental conditions, specific commodity price, and related economics. While society's demands for mineral resource raw materials continue to grow, the specifications for the raw materials are generally becoming more stringent and market conditions are changing over shorter time frames. These factors make it very difficult to predict future needs from current economic conditions. Therefore this compilation does not attempt to evaluate and predict the details of the changing economic markets applied to any mineral commodity. Rather, this work looks at the geological conditions of the area, which are likely to remain stable over long timeframes. Hence, predictions for specific sites or specific commodity end uses are not made. Areas that have favorable geologic map units are identified, and labeled for potential mineral resources over the long term. History shows us that these are, in general terms, the likely areas where future exploration and development evaluations for mining will be proposed.

Discussion

The Minnesota River Valley Corridor has many layers of geological materials exposed at the surface that are buried elsewhere in the state. This circumstance has led to the development of mines for six commodities. The mines for each commodity except gravel tend to be geographically confined, first, to the main valley and second, to the limited distribution of a particular geologic unit–such as the limestone exposed in the area roughly east of Mankato. These are the reasons that regional mineral potential areas can be identified by the geological factors. The distribution for the mineral commodities can be summarized in the most general way:

- **limestone** and **silica sand** occur from Mankato eastward and northward to Shakopee (Plate 3);
- **quartzite** is only known to occur in one place, in regard to this study area, near New Ulm (Plate 3);
- **granite** occurs from Ortonville eastward nearly to New Ulm (Plate 3);
- **industrial clay** occurs in a small area near Granite Falls and a larger zone from Redwood Falls to Mankato, with smaller areas of lower potential west of New Ulm and west of Mankato (Plate 4);
- **sand and gravel** pits occur dispersed within and outside the main valley of the Minnesota River, and dispersed along the entire study area (Plate 2).

Almost all of the mineral resources currently mined in the region are owned by private landowners. There are no active state-owned industrial mineral leases in this study area, except for sand and gravel. For a general discussion about mineral ownership and leasing, refer to "Leasing State Owned Mineral Rights for Selected Industrial Minerals in Minnesota" (Minnesota Department of Natural Resources, Division of Minerals, Mineral Leasing and Mineral Rights Management Section, 1997).

The thickness of overburden (or mine waste material) above the mineral commodity layer is one important limiting factor for mining. The cost of removing the overburden, such as glacial drift, to get access to the mineral resource below it is one economic factor that influences the decision for mineral development. There is no general overburden thickness guideline that can be applied to every site, because that factor is tied to economic criteria. Industrial mineral mines commonly remove10 to 50 feet of overburden. History shows that as mineral commodities become more valuable, thicker overburden can economically be removed. We chose an overburden thickness of 50 feet for long range planning purposes for four commodities on Plate 3 and 100 feet for one commodity on Plate 4 because they seem most appropriate at this time. Furthermore, the limited amount of subsurface information (such as water well records and drill cores) available to create overburden estimates limits these estimates reliability to fairly coarse levels. Thus, the 50 foot contour *interval* (0, 50,100 foot contour lines) is appropriate to the scale of the information we have. These overburden thickness limitations should be viewed as guidelines, not absolute limits. For example, industrial clay mining typically occurs by working into the clay outcrops in the valley slopes, eventually removing significant thicknesses of overburden. Three local industrial clay mines have removed more than 80 feet of overburden. In these special cases, the "overburden" was successfully marketed as fill material or aggregate to nearby construction projects, thus changing the economics of removing the overburden.

The potential for industrial clay in the region should include the possibility of sale to the papermaking industry in Minnesota and the upper Midwest. Currently, kaolin used to make high quality glossy paper such as that produced in Grand Rapids, Minnesota, is transported by rail from Georgia. The significant transportation costs from Georgia create an opportunity, should a company be able to economically produce a high quality kaolin product from local resources.

Additional historical information on past pits and quarries is available in "Industrial Minerals, Inventory of Industrial Minerals Pits and Quarries in Minnesota" (Nelson et al., 1990).

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