UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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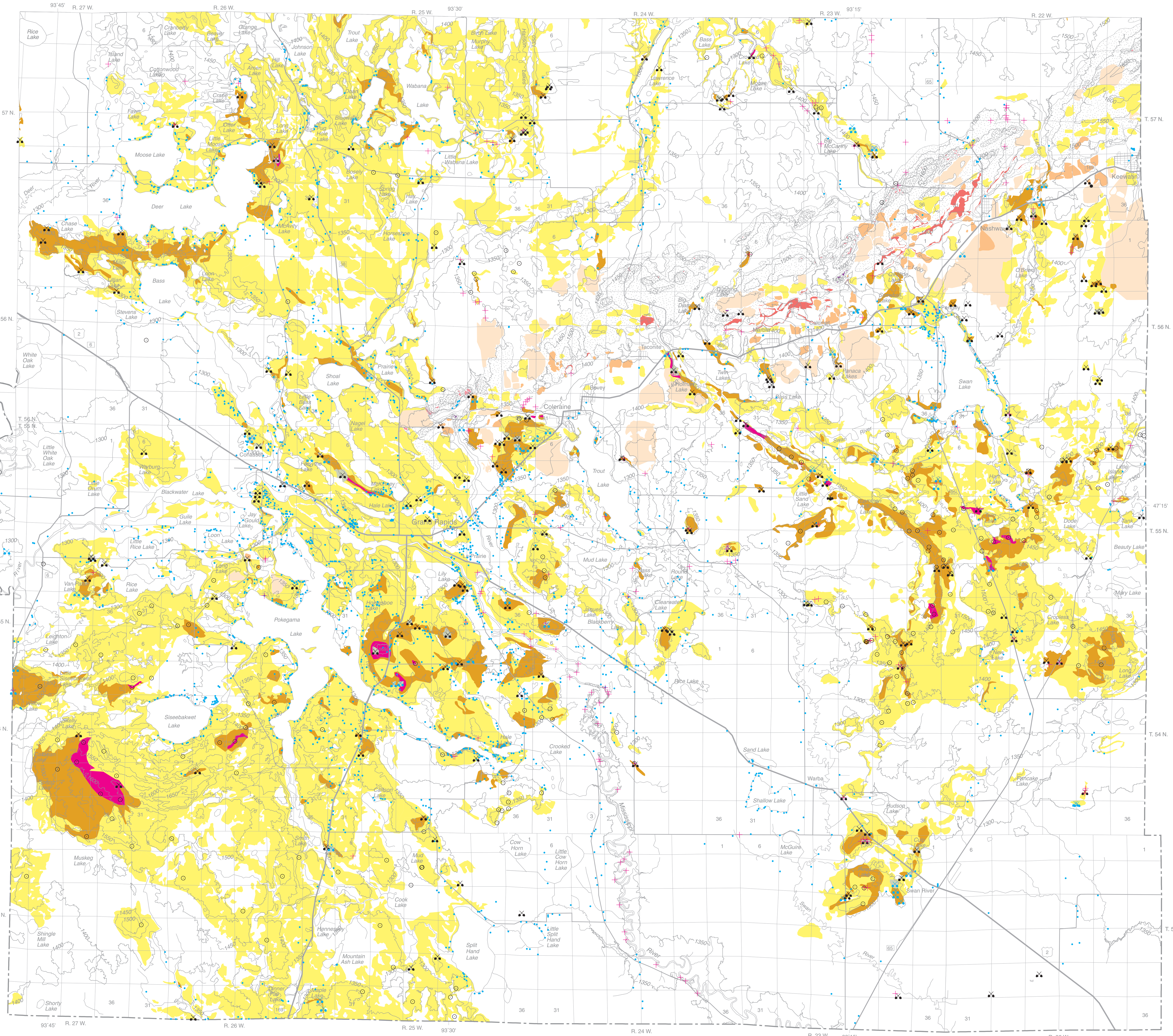
AGGREGATE ENDOWMENT OF SOUTHEAST ITASCA COUNTY

By

Gary N. Meyer and Mark A. Jirsa

2005



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

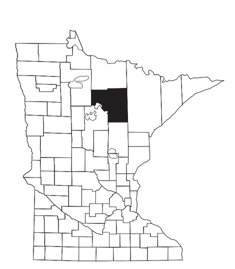
Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

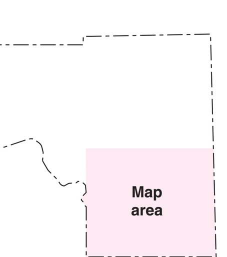
GIS compilation and cartography by Joyce Meints and R.S. Lively
Edited by Lori Robinson

SCALE 1:100 000

CONTOUR INTERVAL 50 FEET



LOCATION DIAGRAM



ITASCA COUNTY

Table 1. The potential for sand and gravel resources in southeast Itasca County.

	Highly desirable	Moderately desirable		Less desirable	
sand and gravel thickness (feet)	20–50 or greater	0–40 or greater		0–20 or greater	
overburden thickness (feet)	less than 5	less than 10		less than 20	
retained on #4 sieve	greater than 20%	greater than 15%		less than 15%	
probability	very high to high	high to moderate		high to moderately low	
total spall[1]	<1.5%	<1.5%	<5%	<1.5%	<5%
quality	very good to good	very good to good	good to moderate	very good to good	good to moderate

[1]Spall materials are rock particles that will cause a pop-out in hardened concrete or bituminous pavement. Maximum permissible spall materials allowed by the MN/DOT in coarse aggregate for concrete used in highway construction, by weight percent of total sample, are: shale, 0.7 percent; soft iron oxide particles, 0.3 percent; total spall materials (shale and iron oxide, plus unsound chert, coal, and clayey limestone), no more than 1.5 percent. Maximum permissible total spall materials in bituminous pavement is 5.0 percent.

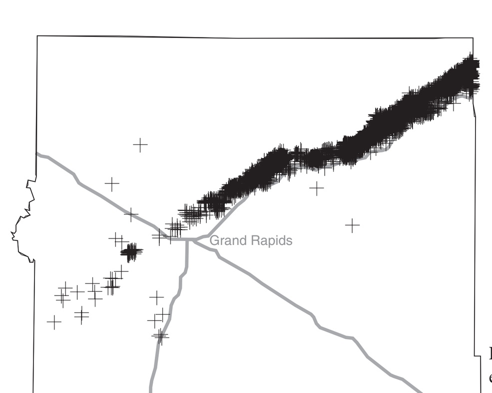


Figure 2. Distribution of mineral exploration borings across southeast Itasca County.

INTRODUCTION

For the purpose of this study, aggregate endowment refers to geologic map units within which there is a reasonable probability of discovering and developing economically viable aggregate deposits. The endowment of sand and gravel in southeast Itasca County is subdivided into three categories of relative deposit potential on the basis of geologic attributes and physical properties of the mapped materials. Bedrock formations in the area are generally suitable for crushing for aggregate where overburden is thin.

The judgment of potential deposit quality is based predominantly on reconnaissance-level geologic information and interpretation. This study does not identify specific aggregate resources, which are defined in part on economic and societal criteria and concerns. Furthermore, this assessment does not mean that economic aggregate deposits exist everywhere within a given map unit; rather, the materials represented by each map unit were created by geologic processes that could have produced aggregate deposits at specific sites within the unit as mapped. Geologic endowment, although imprecisely measured, is fixed; whereas, economic criteria and environmental regulations vary across time and place. Important site-specific factors such as land ownership, zoning, protected waters and wetland designations, environmental impact, required permits, distance to markets, royalties, and site access, all contribute to the final "potential" of a specific parcel. These factors are outside the scope of this study.

DESCRIPTION OF MAP UNITS

POTENTIAL SAND AND GRAVEL SOURCES—These units exhibit geologic characteristics that typically produce sand and gravel deposits. Existing gravel pits and aggregate sources used by the Minnesota Department of Transportation within these units are "identified" or "known" resources. Geologic units that have the best potential for sand and gravel include delta and ice-contact sediments (eskers, kames, and fans); they typically contain sorted sand and gravel with little silt and clay. The map units are classified by the thickness of sand and gravel, thickness of overlying deposits, percentage of material retained on the number 4 sieve (4.76-millimeter pore space), and percentage of spall materials[1] (Table 1). Very good to good quality deposits generally contain less than 1.5 percent total spall materials. Good to moderate quality deposits generally contain less than 5 percent total spall materials. Gravel in moderate to poor quality deposits generally contains more than 5 percent total spall materials.

Highly desirable sand and gravel deposits—Highly desirable deposits are defined as having a sand and gravel thickness of 20 to more than 50 feet (6 to 15 meters); generally less than 5 feet (1.5 meters) of overburden; on average more than 20 percent of material retained on the number 4 sieve; and are of very good to good quality. The probability that a sand and gravel deposit exists within this unit is very high to high.

Moderately desirable sand and gravel deposits—Moderately desirable deposits have a sand and gravel thickness ranging from near zero to more than 40 feet (12 meters); less than 10 feet (3 meters) of overburden; generally more than 15 percent material retained on the number 4 sieve; and are of very good to moderate quality. The probability that a sand and gravel deposit exists within this unit is high to moderate.

Less desirable sand and gravel deposits—Less desirable deposits consist primarily of sand and gravelly sand (less than 15 percent retained on the number 4 sieve) ranging from near zero to greater than 20 feet (6 meters) thick, with overburden no more than 20 feet (6 meters) thick, and are of very good to moderate quality. The probability that a sand and gravel deposit exists within this unit is high to moderately low.

POTENTIAL CRUSHED STONE SOURCES—The following subdivision of potential crushed stone resources into three major categories of apparent desirability is based largely on the proximity of crystalline bedrock to the land surface, and to a lesser extent on known and speculated characteristics of the various materials created by iron mining. These characteristics are inferred from fieldwork, topographic trends, soil survey maps, drill hole records, and published bedrock topographic, depth to bedrock, and historic topographic maps (Jirsa and others, 2002; Lively and others, 2002). In general, there is a coincident relation of these units with the level of confidence or "probability." That is, the probability is great that rock is at and very near the surface in areas of outcrop (the "highly desirable" category); however, the probability for rock at the depths indicated generally decreases with increasing distance from the outcrop (the "moderately" and "less desirable" categories). Despite obvious differences in the physical characteristics of the various rock types, these are not considered here because some parts of all rock types have the potential to yield suitable crushed stone. Because of extreme lithologic diversity and a large number of variables locally affecting aggregate quality, sight-specific evaluation of all bedrock types is required to properly assess aggregate potential. Therefore, the use of the term "desirable" on the crushed stone potential map is both relative and approximate. Figure 1 describes the attributes of each major rock type as they relate to the assessment of crushed stone potential.

Highly desirable potential crushed stone resource—Bedrock outcrop (excludes iron-formation); includes large areas of continuous outcrop, together with clusters of closely spaced, small rock exposures separated by thin soil cover. Many outcrop areas are a composite of multiple rock types; color indicates the dominant rock type in each unit. Two rock types are subdivided:

Granitic gneiss and foliated granite—Typically shades of light gray and pink.

Quartzite—Pale tan to pink.

Moderately desirable potential crushed stone resource—Includes three categories of material:

Crystalline bedrock inferred to be overlain by less than 20 feet (6 meters) of unconsolidated sediment—Refer to Figure 1 for general rock type. Because the cover of sediment thickens abruptly adjacent to outcrops in mine pits, areas of rock less than 20 feet (6 meters) from the surface are too narrow to be depicted as separate units at this scale.

Mounds of coarse- and medium-grained mine waste-rock and stockpiles—Typically reddish brown, broken, iron-bearing rock. Coarse-grained material ranges from about one inch to 3 feet (3 centimeters to 1 meter) in diameter; medium-grained material ranges in size from coarse sand to about 2 inches (5 centimeters). Refer to the surficial geologic map for the location of individual material types.

Iron-formation outcrop—Color varies from deep red to dark gray.

Less desirable potential crushed stone resource—Includes two categories of material:

Crystalline bedrock inferred to be buried 20 to 50 feet (6 to 15 meters) beneath unconsolidated sediment—The position of these units is considerably more speculative than those above because of limited depth-to-bedrock data. For the same reason, unmapped areas of rock within 50 feet (15 meters) of the land surface are likely to exist. Refer to Figure 1 for general rock type. Unit is locally overlain by mine waste materials of varied thickness—refer to the surficial geologic map for locations.

Mounds of unknown content, overburden, coarse-grained waste-rock and overburden, or raised plains of fine-grained tailings—Dump mounds that contain a variety of material stripped from iron mines. These mounds may locally contain significant amounts of sand and gravel or crushed stone. Fine-grained tailings materials consist of iron-poor rock, crushed to fine to coarse sand size, and slurried into tailings basins. Tailings materials vary from deep red to medium reddish gray. The basins typically are enclosed within containment dikes of coarser-grained rock. Refer to the surficial geologic map for the location of individual material types.

LIMITED POTENTIAL FOR AGGREGATE SOURCES—The map shows that the remainder of southeast Itasca County is underlain by geologic units that have little or no potential for significant aggregate resources, or about which little is known. This area may include aggregate deposits that are too small to map or were unrecognized. Disturbed land (unit Qd on the surficial geology map) is mapped as having limited potential for aggregate, although it likely includes gravel or crushed stone in places. The possibility also exists for the presence of scattered areas of bedrock outcrop in and north of the mining district.

IDENTIFIED AGGREGATE RESOURCES—Areas where aggregate resources have been mined or are currently being mined. Pit locations have been gathered from aerial photographs, topographic maps, the county soil survey (Nyberg, 1987), the Minnesota Department of Transportation (2004a), and fieldwork for this study. No distinction is made on the map between active, inactive, depleted, and reclaimed pits.

Large gravel pit, or an area of more than one gravel pit or gravel-pit operation—The areas of larger pits shown on the map were primarily determined using aerial photographs from 1991, so some pit areas are probably more extensive than portrayed. Aggregate resources may remain within some pits. Smaller pits are indicated only by the pit symbol.

Gravel pit listed in the Aggregate Source Information System data base of the Minnesota Department of Transportation—May include test-hole logs, sieve data, test data on aggregate quality, and information drawn from U.S. Geological Survey 7.5-minute topographic quadrangles.

MAP SYMBOLS

Field observation—Exposure of Quaternary sediment for which data are available; includes streamcuts, roadcuts, iron-mine exposures, and construction sites.

Soil borings—Includes 185 auger holes drilled by the Itasca County Highway Department and the Minnesota Geological Survey for this study. Locations of Minnesota Department of Transportation foundation borings used in this study can be accessed at <http://www.mrrapps.dot.state.mn.us/website/index.htm#> (Minnesota Department of Transportation, 2004b).

Record of water-well construction from the County Well Index (CWI) data base—Note that records of mineral exploration borings from the CWI data base are too abundant and closely spaced to be shown on this image. Refer instead to Figure 2.

Rotary-sonic drill hole location—Drill core from a deep test hole, housed in the Minnesota Department of Natural Resources core library in Hibbing, Minnesota.

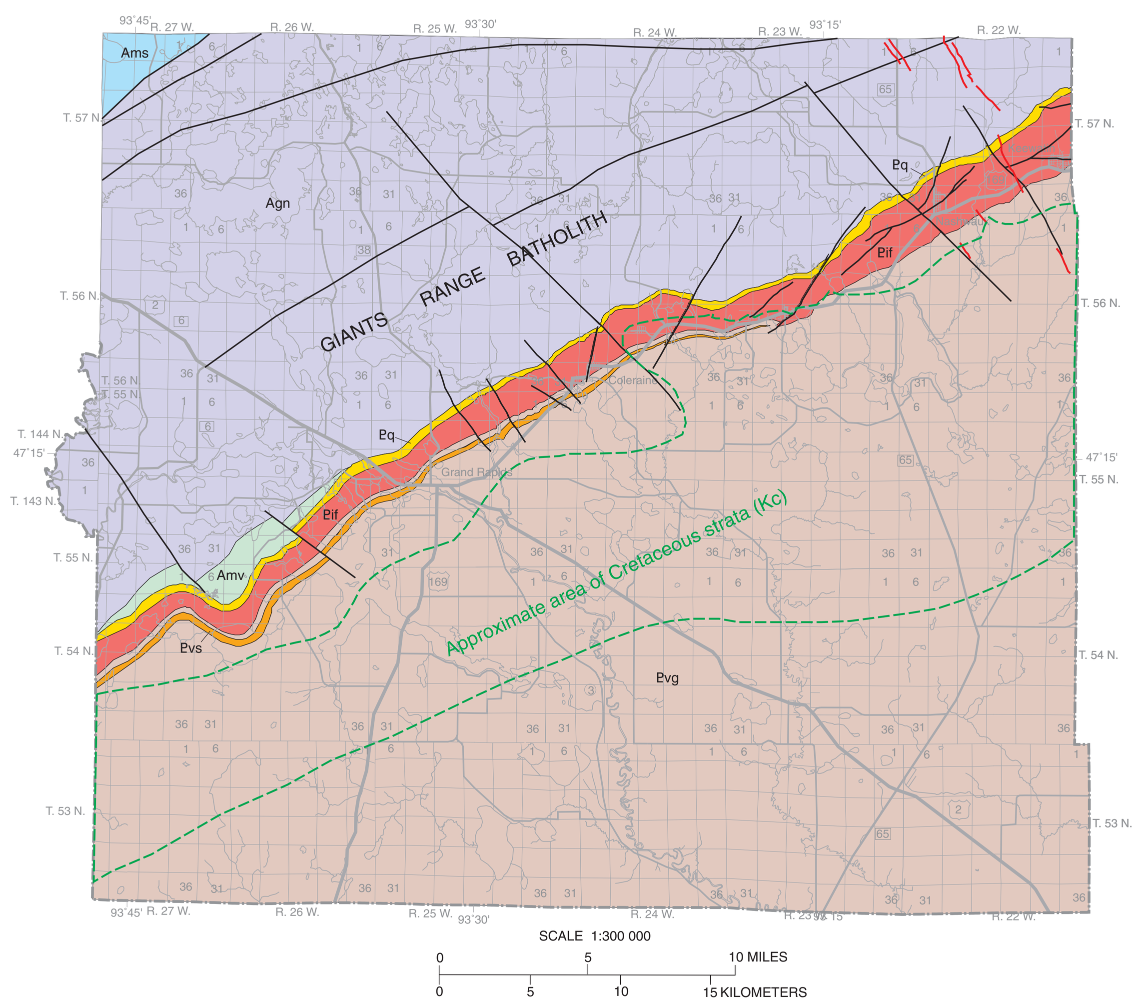


FIGURE 1. Bedrock geology and implications for crushed stone potential

DESCRIPTION OF BEDROCK GEOLOGIC MAP UNITS

CRETACEOUS ROCKS (approximately 93 million years old)

Kc **Coleraine Formation**—Consists of a basal conglomerate containing clasts of iron-formation, locally overlain by poorly consolidated sandstone and mudstone. Varies from a few feet to as much as 100 feet (30 meters) thick. Locally fossiliferous; lignite layers have been reported in some locations. Distribution is poorly constrained by mine exposures and drill holes; thus, the unit is shown by a dashed outline.

PALEOPROTEROZOIC ROCKS (approximately 2.1 to 1.85 billion years old)—The Virginia Formation, Biwabik Iron Formation, and Pokegama Quartzite form a gently southward dipping sedimentary rock sequence deposited unconformably on the older Neoarchean crust.

Pvg **Virginia Formation**—Graywacke and slate. Dark gray, fine-grained rocks consisting of interbedded slate, siltstone, and graywacke (poorly sorted gray sandstone that has an altered clayey matrix). No natural outcrops and few dump mounds of this material exist, so its consideration for aggregate is unlikely.

Pvs **Virginia Formation**—A cherty siderite (iron carbonate) layer identified from drill core.

Pif **Biwabik Iron Formation**—Consists of interbedded layers of iron-rich granular chert (quartz), iron-bearing slate and siltstone, iron-carbonate, and various layers and irregular zones of their oxidized equivalents. Oxidized rocks contain hematite, goethite, and limonite, together with unoxidized relict components. The resulting red coloration makes aggregate use of both the bedrock and the various dump mounds containing this rock somewhat limited. Parts of the iron-formation that are less oxidized, including taconite, are intuitively more desirable. However, some components of taconite may oxidize over time, and this together with the abundance of silica, make the rock poorly suited for use in concrete.

Pq **Pokegama Quartzite**—Quartzite, siliceous siltstone, and local basal conglomerate. Tan to pinkish to light gray. Typically hard and well-indurated, having a specific gravity between about 2.5 and 2.7. Used locally for rip-rap.

Pd **Diabase dike**—Northwest-trending tabular units noted by a line symbol. Dikes contain fine-grained diabase along the nearly vertical contacts that coarsens to central zones composed of medium- to coarse-grained gabbro. Dikes vary in map width from a few feet to 350 feet (107 meters)—most are within the range of 100 to 200 feet (30 to 61 meters) wide and extend deep into the crust. Diabase and gabbro consist of variably altered plagioclase feldspar, pyroxene and its alteration products, amphiboles, and iron (pyrite and pyrrhotite) and titanium (ilmenite) oxides. Diabase typically is dense, having a specific gravity between 2.8 and 3.1. Sulfide mineral content typically is less than 1 percent. Composition within dikes and from one dike to another is very consistent. Rocks are massive (unfoliated); joints are blocky, orthogonal, and tend to be widely spaced. Finer-grained parts of the dikes and narrower dikes have grain size and composition much like traprock.

NEOARCHEAN ROCKS (approximately 2.7 billion years old)

Agn **Granitic gneiss and foliated granitic intrusions**—Medium- to coarse-grained, colors in shades of gray to pinkish; variably layered and foliated. Rock types include granite, granodiorite, and tonalite that collectively are part of the Giants Range batholith. Minor amounts of more mafic (dark colored), biotite- and hornblende-bearing quartz diorite, diorite, and hornblendite occur. Inclusions of metamorphosed country rocks (metavolcanic and metasedimentary) are present locally. Specific gravity values range from 2.5 to 2.9. Fractures are varied in orientation and abundance, but those parallel to the rock fabric are more abundant. Sulfide minerals (pyrite and pyrrhotite) are rarely present.

Ams **Metasedimentary rock**—Fine- to medium-grained, varies in color from dark to light gray; protoliths include graywacke, slate, and minor, light colored volcaniclastic rocks, all metamorphosed to lower and medial greenschist facies. Contains mineralogic mixtures of quartz and feldspar, with a small percentage of mafic minerals including biotite, hornblende, and chlorite. Specific gravity varies from about 2.6 to 2.7. Sulfide minerals occur locally in small amounts. Fractures tend to be closely spaced and those parallel to bedding are most pronounced. This unit is not exposed in southeast Itasca County—attributes are inferred from exposures elsewhere and from drill cores.

Amv **Metavolcanic rock**—Very fine- to medium-grained, varies in color from dark gray to greenish gray; dense rocks derived from mafic to intermediate volcanic, volcaniclastic, and intrusive rocks are now metamorphosed to amphibolite facies. Rocks contain a mixture of amphiboles (most notably hornblende and actinolite) and plagioclase feldspar, with minor amounts of micas and iron oxide minerals. Tightly annealed schistose fabric is most common. Lighter colored rocks contain greater percentages of feldspar and quartz. Rock fabric varies from dense, massive, and traprock-like, to schistose. Specific gravity varies from 2.7 to 3.1. Sulfide minerals are extremely variable in abundance and irregular in distribution, but most of the rock contains less than 1 percent. Fractures are varied in spacing and orientation; however, those parallel to the rock fabric (northeast-trending) are most common and pronounced. This unit is not exposed in southeast Itasca County—attributes are inferred from exposures elsewhere and from drill cores.

MAP SYMBOLS

Geologic contact

Fault—Faulting occurred at several times during deformation of the Neoarchean terrane. Most faults dip vertically in the near-surface crust, and are marked locally by the presence of disaggregated, sheared, and variably altered rocks known as mylonite, phyllite, and schist. The anastomosing planar fabric of such fault-rock typically precludes its use for crushed stone. Faulting during and after deposition of the Paleoproterozoic sedimentary rocks (the Virginia Formation, Biwabik Iron Formation, and Pokegama Quartzite) resulted in largely vertical zones of variably crushed and oxidized rock and localized removal of silica by leaching adjacent to faults. The latter process also facilitated oxidation by fluids that penetrated both faults and the adjacent bedding planes. Thus, most of the near-fault rock is not suitable for most aggregate uses.

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AGGREGATE RESOURCE POTENTIAL OF ITASCA COUNTY, MINNESOTA