UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

SUPPORTED IN PART BY THE MINERALS DIVERSIFICATION PROGRAM AS ADMINISTERED BY THE MINERALS COORDINATING COMMITTEE FOR THE MINNESOTA LEGISLATURE, THE ITASCA COUNTY BOARD OF COMMISSIONERS, AND THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF LANDS AND MINERALS

MISCELLANEOUS MAP SERIES
MAP M-131
Plate 4—Aggregate Endowment, Northeast

AGGREGATE ENDOWMENT OF NORTHEAST ITASCA COUNTY

By

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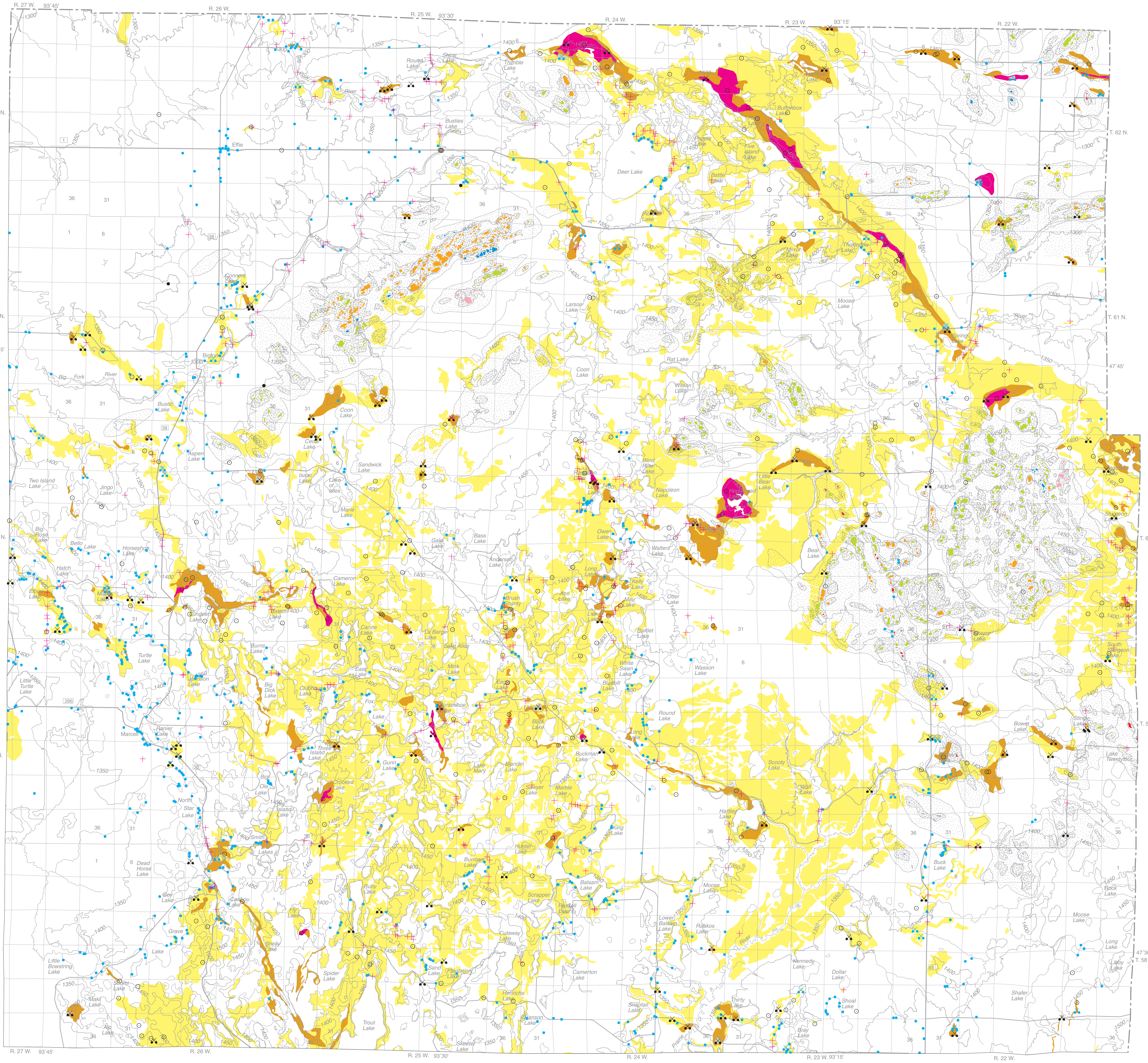
2005



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

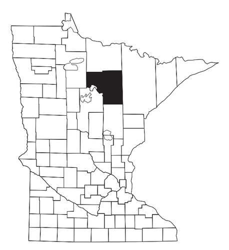
SCALE 1:100 000

1 0 1 2 3 4 5 MILES

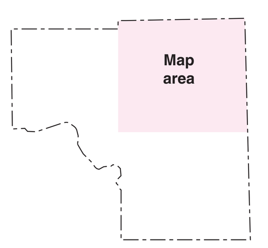
1 0 1 2 3 4 5 6 7 8 KILOMETERS

CONTOUR INTERVAL 50 FEET

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



LOCATION DIAGRAM



ITASCA COUNTY

Table 1. The potential for sand and gravel resources in northeast 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.

MAP SYMBOLS

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

Soil boring—Includes about 200 auger holes drilled by the Itasca County Highway Department and the Minnesota Geological Survey for this study.

Record of water-well construction from the County Well Index (CWI) data base.

Rotary-sonic drill hole location—Drill core from a deep test hole (Martin and others, 1989), housed in the Minnesota Department of Natural Resources core library in Hibbing, Minnesota.

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 northeast 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 judgement 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 categories is based largely on the proximity of crystalline bedrock to the land surface, as inferred from fieldwork, topographic trends, and scant drill hole records. Because of a scarcity of drill hole information, 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 decreases with increasing distance from the outcrop (the "moderately" and "less desirable" categories). Despite obvious differences in the 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. 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; 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.

Diabasic dikes ranging from 100 to 200 feet (30 to 61 meters) wide

Granitic rock

Gneissic rock

Variably metamorphosed intrusive rock of mafic composition

Metasedimentary rock

Metavolcanic rock

Moderately desirable potential crushed stone resource—Bedrock inferred to be overlain by less than 20 feet (6 meters) of unconsolidated sediment. Refer to nearby outcrops and Figure 1 for general rock type.

Less desirable potential crushed stone resource—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 nearby outcrops and Figure 1 for rock type.

LIMITED POTENTIAL FOR AGGREGATE SOURCES—The map shows that the remainder of northeast Itasca County is underlain by geologic units that have little or no potential for significant aggregate resources. This area may include aggregate deposits that are too small to map.

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), 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; 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.

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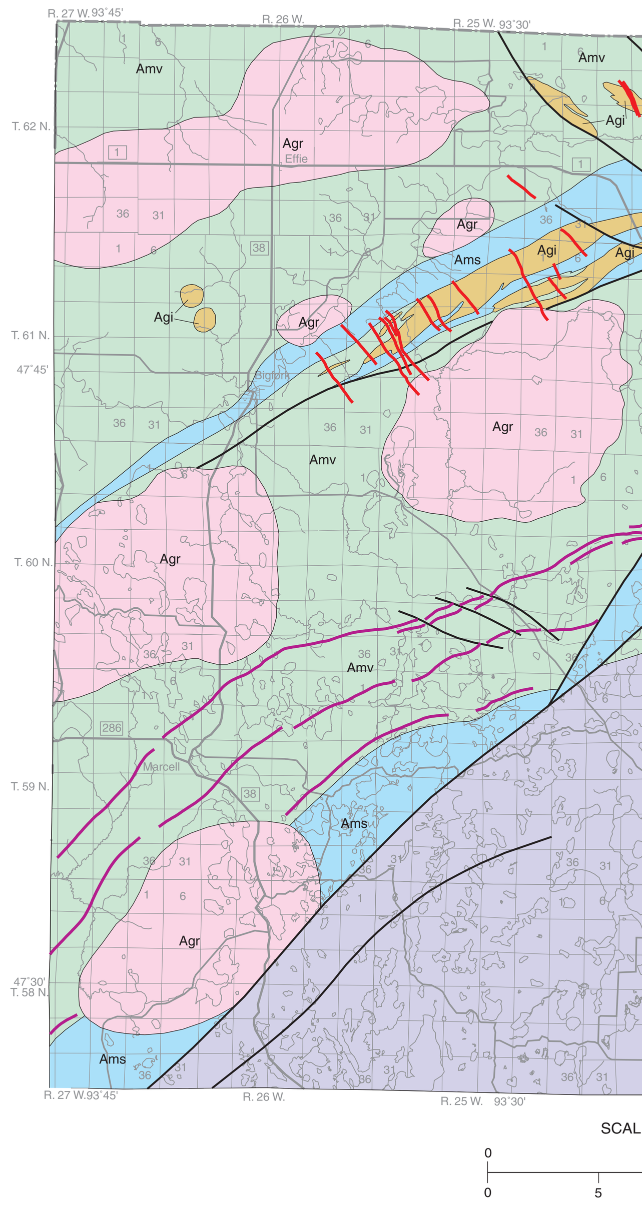

FIGURE 1. Bedrock geology and implications for crushed stone potential

Much of the bedrock of northeast Itasca County consists of Neoarchean (~2.7 billion years old) "greenstone" and granite. The term greenstone can be applied to metamorphosed volcanic rocks and closely allied intrusions, and the detritus shed from volcanic edifices, including various tuffs and breccias, iron-formation, and large wedges of the sedimentary rock known as graywacke—a mixture of sand and muds. These volcanic and volcaniclastic sequences were deformed during crustal movement, creating distinct, northeast-trending structural and lithologic units that dip nearly vertically; thus, the thickness of any derived aggregate unit is nearly infinite. During this process, the rocks were buried and metamorphosed to grades ranging from greenschist (low grade) to amphibolite (high grade). Rocks metamorphosed to greenschist-grade commonly contain chlorite and actinolite; whereas, those metamorphosed to amphibolite-grade typically are tightly annealed schists containing various proportions of hornblende and other amphibole minerals. The lower-grade rocks may be a less desirable aggregate source, as chlorite reduces overall hardness.

At various times in their evolution, the greenstone sequences were intruded by magmas that vary in composition from light-colored, quartz-bearing felsic (granitic) rocks to dark-colored, quartz-poor mafic (gabbroic) rocks. Both are comparatively coarse-grained rocks; in some cases, so coarse that crushing may result in undesirable breakage along grain boundaries. Some of the intrusions contain evidence for metamorphism that occurred about 2.68 billion years ago, others do not. For example, granitic gneiss in the southern part of the map area was metamorphosed locally. By contrast, the northwest-trending diabasic dikes, shown here as line symbols, were emplaced during Paleoproterozoic time (approximately 2.1 billion years ago), and therefore lack evidence for significant metamorphism. The dikes vary in width from a few feet to 350 feet (107 meters)—most range from 100 to 200 feet (30 to 61 meters) wide and extend deep into the crust. Because of their comparative resistance to erosion, the dikes are one of the major features controlling topography of the bedrock surface, and thus, the distribution of outcrops and areas of near-surface bedrock.

Faulting occurred at several times during deformation of this 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 potential for 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 crushed rock potential. Therefore, the use of the term "desirable" on the crushed stone potential map is both relative and approximate.

DESCRIPTION OF BEDROCK GEOLOGIC MAP UNITS

PALEOPROTEROZOIC ROCKS (approximately 2.1 billion years old)

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. Consists of variably altered plagioclase feldspar, pyroxene and its alteration products, amphiboles, iron sulfides (pyrite, pyrrhotite), iron oxides (magnetite and hematite), and titanium oxides (ilmenite). Diabase typically is dense, having a specific gravity between 2.8 and 3.1. Sulfide minerals are typically less than 1 percent. Composition within dikes and from one dike to another is very consistent. Rocks are massive (unfoliated); joints are blocky and tend to be widely spaced. Diabase is used locally and intermittently for a variety of dimension-stone applications. Finer-grained parts of the dikes are much like traprock.

NEOARCHEAN ROCKS (approximately 2.7 billion years old)

Agr **Granitic rock**—Includes granite, monzonite, granodiorite, monzodiorite, and syenite; typically massive, medium- to coarse-grained; shades of red, pink, or gray in color; contains potassium and sodic feldspars and quartz, together with accessory biotite, hornblende, and rarely pyroxene. Specific gravity typically is about 2.5 to 2.7. Locally contains preferred orientation of larger mineral grains (trachytoid foliation), but rarely contains a truly planar foliation. Fractures are typically blocky and widely spaced. Sulfide minerals are rarely present. Many of the granitic intrusions shown would make suitable aggregate or have phases within them that could be used. Some of the larger intrusive bodies contain central zones that are probably too coarse-grained to be suitable for aggregate.

Agn **Gneissic rock**—Medium- to coarse-grained; colors range in shades of gray; variably layered and foliated; typically irregularly layered mixtures of granitic rock types including granite, granodiorite, and tonalite, with minor amounts of more mafic (dark colored), biotite- and hornblende-bearing quartz diorite, diorite, and hornblendite. Inclusions of metamorphosed country rocks (metavolcanic and metasedimentary) are present in small amounts 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.

Agi **Gabbroic intrusion**—Typically dark greenish gray, coarse- to medium-grained; composed of various combinations of calcic plagioclase, ferromagnesian minerals (hornblende, pyroxene, biotite), and iron oxides. Specific gravity is between 2.8 and 3.1. Sulfide minerals are typically less than 1 percent, but exceed 3 percent locally. Fractures tend to be blocky (orthogonal) and widely spaced. Use of this rock type as an aggregate source is not favored, due to potentially deleterious contents of sulfide and ferromagnesian minerals.

Ai **Iron-formation**—Extremely diverse layered rocks composed of chert, siliceous tuffaceous sedimentary rock, slate, iron oxides including magnetite and hematite, and iron sulfides including pyrite and pyrrhotite. Typically interbedded on all scales with metavolcanic and metasedimentary rock types. Marked by closely spaced fractures. Unit position is inferred locally from aeromagnetic maps, represented on the map by a line symbol. Although siliceous content may make parts of the rock suitable for certain aggregate applications, the extreme variability requires site-specific evaluation and may preclude its use.

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.

Amv **Metavolcanic rock**—Very fine- to medium-grained; varies in color from dark gray to greenish gray; protoliths include mafic to intermediate volcanic, volcaniclastic, and associated hypabyssal intrusive rocks, now metamorphosed to amphibolite and greenschist facies. Rocks of higher metamorphic grade occur largely in the southern part of the area. They contain dense mixtures of amphiboles (most notably hornblende) and plagioclase feldspar, with minor amounts of micas and iron oxides. Tightly annealed schistose fabric is most common in the higher-grade rocks. Rocks of lower metamorphic grade contain altered plagioclase feldspar, chlorite, and actinolite, a mineral assemblage that typically is softer than the higher-grade varieties. Lighter colored rocks contain a greater percentage of feldspar and quartz. Rock fabric varies with composition and size of unit; thick packages of volcanic rock typically lack schistosity and are much like traprock; thinner units contain well developed schistosity that locally produces a fissile rock. In addition to well developed rock fabric, the abundance of chlorite and local presence of calcium, iron carbonate, and sulfide minerals tends to make much (though not all) of the lower-grade rock less durable. Specific gravity ranges from 2.7 to 3.1. Sulfide distribution is extremely variable, 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.

MAP SYMBOLS

Geologic contact

Fault

AGGREGATE RESOURCE POTENTIAL OF ITASCA COUNTY, MINNESOTA